Road Infrastructure and Rural Poverty in Ethiopia

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Abstract

In the face of high population growth and declining natural resource base, tackling rural poverty necessitates an increase in overall factor productivity or a rise in the market rate of return of assets possessed by the poor. Towards achieving these objectives, the role of spatial integration of markets and the efficiency with which these markets operate are considerably important, as these factors shape the structure of incentives and the level of opportunities open to the rural poor. As a result, factors that hinder the spatial integration of markets and their efficient operation will have significant impact on rural poverty. In Ethiopia markets are often segmented mainly due to high transport cost associated with poor road infrastructure. The existing poor quality and low road density are expected to contribute to rural poverty through limiting the size of the market, increasing market risk (price volatility), widening the spatial prices gaps, reducing the market return to land and labour, inflating the profitability of new technologies and reducing the incentive to produce for market. This research endeavours to empirically substantiate if there is a robust link between farm income and the quality of road infrastructure farm households have access to as well as the pathways through which the effects of road on rural income are felt. The empirical result consistently showed that improving rural road access will have significant impact on rural income in general and the income of the poor in particular. The mechanisms by which road boosts rural income and reduce poverty are also found to work through narrowing down spatial price gaps, promoting technology adoption, boosting resource allocation efficiency and raising the market return to land and labour. The result also showed that the rural poor benefits from road induced income growth.

Key Words: *Rural, Income, Wage, Poor, Road, Prices, Efficiency, Village Household*, Ethiopia

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List of Acronyms

EGTE: *Ethiopian Grade Trade Enterprise*
ERA: *Ethiopian Road Authority*
MoFED: *Ethiopian Ministry of Finance and Economic Development*
UNDP: *United Nation Development Program*
CSA: *Central Statistical Authority*
SNNPR: *Southern Nations and Nationalities Peoples Region*

Chapter 1 Introduction and Background

1.1 Introduction

In terms of economic development, Ethiopia is one of the least developed countries, and also one of the poorest. Currently, it is estimated that about 47.5% of the population is below the national poverty line; if the international poverty line of a dollar per person per day is used, 90% of the population would fall under the poverty line (Tafesse, 2003). In the human development index, Ethiopia ranks 169 out of 177 (UNDP, 2007).

For such poor social and economic indicators, the major factors are civil war, border conflict, political experimentation, economic mismanagement and natural shocks (Geda and Degefe, 2002). Among these factors, the development policy and strategy pursued in the 1970s and 1980s is mainly to blame. It was biased towards industrial development, neglecting the agriculture sector, which the comparative advantage of the country mainly relies on (MoFED, 2002b). Driven by communist ideology, government support to the agriculture sector was biased to state and collective farms, which were only contributing 2% of the agricultural output, while marginalizing the small private farms that contribute 95% of the agricultural output (ibid). Extension of agricultural credit, allocation of foreign exchange, supply of fertilizer, and improved seeds were deliberately biased towards state farms, although all available studies indicated that productivity of state farms had been consistently lower than the productivity of smallholder agriculture (MoFED, 2002a). This marginalization, coupled with misguided taxation, exchange rate, grain pricing, and marketing policies left the peasant agriculture with both low and declining productivity (Degefe and Nega, 2000).

In addition, given that 98% of farming in Ethiopia is rain-fed, which contributes 52% of the GDP, 85% of the rural income, and 90% of the export earning, the vagaries of nature, specifically the timely and adequate availability of rainfall, also have a share of the responsibility for the poor performance of the overall economy (Geda and Degefe, 2002). Besides domestic factors, given that over two-thirds of the export earnings of the country mainly derive from a single export crop (coffee), adverse external economic environments have also contributed to the low economic growth. Since a substantial share of government revenue comes from the foreign trade tax, where the bulk of it comes from agricultural export, the adverse growth effect of natural and external market conditions have also been felt through their influence on the fiscal stance of the government.

Furthermore, in view of the fact that the agriculture sector is dominated by small scale traditional farmers, the way these farmer respond to various technical and economic opportunities has also been an important factor that contributed to the poor growth performance of the economy (Geda and Degefe, 2002). War and security-related risks have also been other important adverse factors that have contributed to poor performance of the economy.

After assuming power in 1991, the current government put in place a sustainable development and poverty reduction strategy (MoFED, 2002). Given that 88% of the poor live in rural areas, and the bulk of GDP is contributed by agriculture sector, market driven agriculture sector growth is stipulated as the prime mover of the overall economic growth. Unlike the previous regime, the role of the government is restricted to areas where the market is inefficient or fails to provide a socially optimal outcome (MoFED, 2002). Fiscal policy instruments have been employed to promote growth and to narrow income disparities between the urban and rural areas, as well as regions. Consistent with the rural centred growth and poverty reduction strategy of the government, the government has significantly raised expenditure on education, health, roads, agricultural research, water harvesting, and the development of small scale irrigation[1] (MoFED, 2002a). To enhance overall efficiency, the government has implemented major political and economic decentralization policies that have shifted decision-making closer to the grass-roots population. Coupled with this, to create an environment that promotes private sector growth, the government also has been implementing various measures that would improve governance (ibid).

In order to achieve the desired agricultural led growth, due to the limited prospects for crop area expansion, agricultural intensification and expansion in irrigation infrastructure are identified as the main potential sources of growth (Demeke, et al., 1997). Although Ethiopia has good potential to develop irrigation, its technical and financial requirements are unlikely to be met in the short to medium term (Yao, 1996). Therefore, in the short to medium term, increasing farm productivity through agricultural intensification remains the only realistic option in achieving the desired agriculture sector growth and reduction in rural poverty (Demeke, et al., 1997; Yao, 1996).

[1] Accordingly regions that are relatively underdeveloped and remote received higher per-capita federal government transfer (MoFED).

As over 90% of the agricultural output comes from smallholder peasant farming, increased agricultural productivity should also occur in small scale peasant agriculture. A shift in resource allocation and increased application of modern technologies were identified as the main source of productivity growth of the sector (Demeke, et al, 1997). Accordingly, since the 1990s, recognizing that enhancing commercialization of the peasant agriculture is critical in altering the resource allocation and technology uptake behaviour of the farm households, the government has been implementing various institutional and economic policy measures. Among the measures taken, dismantling of producer quota schemes, allowing producer prices to be market determined, lifting the restrictions on interregional grain trade, the introduction of government-sponsored extension programs, and operationalization of a fertilizer credit scheme are the main ones (Dercon, 1995). These measures, through improving the level of incentives, were meant to enhance smallholders' market participation, technology adoption, and promote a shift in cropping pattern that reflects the comparative advantages of each agro-zone (Shousha and Pautsch, 1997)

Despite such concerted effort, the result however is not promising. The observed meager farm sector growth in the 1990's was rather more due to good weather and reclamation of marginal lands than productivity improvement (Degefe and Nega, 2000). The rate of modern technology adoption has been at low level and currently only 33% of the peasant households has been using fertilizers (Dercon and Christiaensen, 2007; CSA, 1996). Moreover, even those that have used fertilizers, their average use was around 10.8 kg/hectare, which is far below the minimum recommended rate of 200kg/hectare (Dercon and Christiaensen, 2007). Similarly, no substantial shift in cropping pattern was observed, and although cereals generate lower return per unit of resources used compared to oilseeds and other export crops, more than three-quarters of the area cultivated is still covered by cereals (CSA, 2006/07). Furthermore, in terms of the degree of commercialization, still 80-90% of the agricultural output is consumed at the farm level (Gebremeskel et al, 1998). When oilseeds and pulses are excluded, the share of total food grains marketed in 2002 was only 16.7 percent.

In addition to drought, soil degradation and poor technology adoption, tenure insecurity, which is attributed to the existing land tenure system, has been identified as the other most important factor for the poor performance of the farm sector (Degefe and Nega, 2000). Land insecurity contributed to low farm productivity through creating disincentive to work and invest on the land as well as through discouraging migration and increasing land fragmentation that inhibits sustainable and profitable use of modern technologies.

The extent to which land tenure insecurity has actually contributed to low farm productivity however is hotly debated. During the imperial period, land was privately owned by landlords and the majority of the rural population were tenants, who were paying up to 50% of their produce as a land rent. During this period, tenure insecurity and lower incentive to the producers were thought as the major contributors for low farm productivity[2].

Later in 1974, in order to address the land problem and improve the life condition of the peasantry, the Provisional Government of Ethiopia

[2] Although the imperial regime did not address the issue of land reform, in order to improve the condition of farmers, it introduced the Minimum Package Program (MPP). The package included provision of credit for the purchase of inputs (such as fertilizers, improved seeds, and pesticides); extension services; the establishment of cooperatives; and the provision of infrastructure, mainly water supply and all-weather roads. The package was introduced in the form of projects, such as Arsi Rural Development Program (ARDU), Chilaloto Agricultural Development Unit (CADU)). The impact of such programmes in improving farm productivity and the conditions of farmers however was limited due to the fact that they were confined to a limited area and also covered only locations that had huge agricultural potential.

implemented a far reaching land reform programme. The reform abolished the tenancy relationship and distributed the land to the peasant with usufruct right, but with no right to sell, mortgage or exchange it. Although improvement in crop output was observed at the outset of the reform period, the achieved growth however could not be sustained due to the policies of the government that created a disincentive to produce and invest [3] (World Bank, 2004).

In 1991, as soon as the present government came to power, it deepened the market reform programme but left the land policy intact except that it discouraged frequent land redistribution, which was the case during the *Derg* period[4]. In addition to encouraging market based activities, the government has also been allocating substantial public resources to support peasant agriculture.

Despite various supportive measures, however, farm productivity in peasant agriculture remains at a low level and in fact showed a declining

[3] The nationalization of all private commercial farms, suppression of private sector investment, involuntary collectivization, enforced quota deliveries of grain at low prices, and restriction of grain movements from surplus to deficit areas are among the policies pursued by the government that are believed to have adversely affected farm productivity growth.

[4] Although during its final years the *Dergue* implemented some market enhancing policy measures, a two decade neglect of the peasant sector coupled with high population growth had already done a lot of damage to the measures to bring productivity improvement.

trend (World Bank, 2005). Currently, tenure insecurity is again identified as a major inhibiting factor for farm productivity growth.

Unlike the imperial period, however, the extent to which tenure insecurity has been hindering farm productivity is hotly debated and presently there are diverging views. Those that are advocating privatization of land point to the negative effects of the current system on private investment in land, land management, and on the willingness to migrate and the intensification of agriculture that is claimed to be the major source of productivity growth. Mainly based on Chinese experience, the policy makers on the other hand are of the view that there is little empirical evidence that public ownership of land will necessarily retard productivity growth. They are of the view that sub-economic land size holdings will not necessarily constrain a widespread and sustainable application of modern agricultural technologies (Gebreselassie, 2006).

Although the debate is still on going and there is no consensus with respect to the ideal land policy, it is however generally expected that productivity is generally higher in an environment where there is a freely operating land market that permits land transfers to more efficient and productive users, and where farms are optimal size and owner-operated. Although cognizant that land policy is importance for farm productivity, in order to remain within the immediate objective of the research, such issues will not be explored further.

This research rather aims to explore the extent to which high transaction costs of production and marketing are contributing to the poor performance of the farm sector[5] (World Bank, 2004). High transactions costs, by acting as a barrier, increase the segmentation and isolation of spatial agriculture markets, limit the market size, depress crop prices, increase price volatility, discourage the adoption of modern technologies and make it less attractive to produce for the market (Ahmed and Hossain, 1990).

According to a recent estimate, over 72% of the agricultural marketing cost is attributed to transport cost. Given that 95% of the passenger and freight transport demand is met through road transport, low density and poor quality of the existing road network are expected to be important

[5] Apart from the above mentioned policy and institutional measures, government direct interventions to address the demand side constraints, such as the poorly functioning domestic markets, weak inter-sectoral linkages and high transaction cost of export, are very limited, albeit a recent recognition of its importance (World Bank, 2004).

contributors to high transport cost and subsequently, through the price mechanism, to low agricultural productivity and rural income. At present the road density stands at 33km per 1000km2, which is 50% below the African average (Diao and Pratt, 2007). It covers not only 30% of the total area of the country, but over 90% of this network is accounted by federal roads that serve urban areas. As a result, only 30% of the rural travel and transport demand is met by motorized transport and the remaining 70% of the rural transport demand is met through traditional means, such as walking, head loading, back loading and pack animals (MoFED, 2002).

At present, with the support of the donor community, the government has been investing a substantial amount of resources in expanding the road network, although the bulk of the resources are devoted to the construction of trunk roads. Although there is a significant increase in rural road construction, most of these roads are also dry weather roads which have lower impact on the farm sector as transport cost in such roads are high and also they only allow accessibility during dry season.

Despite the recognition of the importance of road infrastructure on rural income, there has not been adequate empirical evidence on the benefits of roads at the household level. Although previous studies undertaken on Ethiopia have identified access to road infrastructure as one key determinant of rural welfare, these studies used a functional specification that underestimates the productivity of road[6] (Dercon, et al, 2007; Dercon and Hoddinott, 2005). Although the available evidence elsewhere (Costa, 1998; Haughwout 1998, 2002) shows that spatial market prices endogenously adjust to the stock of local road infrastructure, almost all empirical studies implemented on Ethiopia employed a production function specification assuming that village market prices do not adjust to the stock of local road infrastructure. To the extent that village market prices endogenously adjust to the stock of local infrastructure, the findings of these studies will substantially understate the marginal productivity of road infrastructure. This research aimed at addressing some of these limitations, measuring the benefit of roads at farm household level and substantiating the pathways through which roads affect rural income and poverty.

[6] These studies also failed to decompose whether the effect of road on farm income is due to road induced overall productivity growth, higher rate of return, higher resource endowment or the interaction effect of these factors. Such issues are especially important as addressing them provides information about additional measures that should be taken to enhance the development effectiveness of road.

Accordingly, the research question, hypothesis of the research and the specific objective of the research are outlined below.

1.1.1 Research Question

The main research questions guiding the research are: "Does expanding road infrastructure in general and rural road access in particular boost rural income and reduce rural poverty?" And if it does, "what are the main mechanisms by which the effects of roads on rural poverty and income actually operate?"

1.1.2 Research Hypothesis

The main hypothesis of the research is that "As road infrastructure influences overall factor productivity, spatial rate of return and the magnitude of market and price risks, spatial difference in access to road infrastructure is one important contributor to spatial differences in average income and incidence of poverty".

1.1.3 Research Objective

The research has two objectives. The first one is to empirically substantiate if there is a robust link between the quality of road infrastructure farm households' have access to and their income level. In order to achieve this objective, while theoretically guided by a willingness to pay approach, the empirical net income model will be postulated on a spatial equilibrium framework. Since road infrastructure could be an endogenous variable in the income model to be postulated, i.e., roads could be placed in locations where per-capita income is already high or where there is good agricultural potential, in order to control the possible endogeneity problem, the net income model will be estimated on the basis of the Hausman and Taylor (1981) instrumental variable method. In addition, in order to explore if road infrastructure is pro-poor or whether it raises the income of the poor faster than the non-poor, the postulated income model will be estimated on the basis of inter-quantile regression method.

Second, once a robust link between road and farm income is established, the research is also aimed at empirically substantiating the pathways through which roads influence farm income and rural poverty. Mainly governed by data availability, crop prices, rural wage rates and farm level economic efficiency are identified as the main channels through which the effect of road infrastructure on rural income or poverty operates.

Accordingly, empirical models for crop prices, wage rate and efficiency models will be postulated.

In order to empirically establish the link between roads and farm gate crop prices, guided by a spatial equilibrium framework and building upon the point-space model, a village level price model will be postulated. In addition, in order to evaluate the level of efficiency with which spatial agricultural markets operate in Ethiopia, which has important implication for rural income and poverty, a threshold autoregressive model will be postulated.

In order to empirically substantiate the impact of roads on farm income that operates through its influence on farm level allocative and technical efficiency, a two stage approach will be followed. At the first stage, the technical and allocative efficiency of the sample will be parametrically estimated. Following that, in order to establish if road infrastructure indeed influences farm level efficiency, based on a random effect model, the estimated efficiency scores will be regressed on household and village characteristics, where road access condition for the household will be introduced as one explanatory variable of the model. In order to establish if technical and allocative inefficiency has an adverse impact on farm income in general and poor households in particular, random effect and inter-quantile regression models will be postulated. Finally, in order to empirically substantiate the link between road and rural incomes that operates through road induced improvement in rural wage rate, building on the framework of the market theory of wage determination, a rural wage model will be postulated and the model will be estimated on the basis of a fixed and random effect models.

1.1.4 Limitations of the Research

The major limitation of the research is related to its scope. Although road infrastructure could have a long-term impact on the earning level of farm households through enhancing their access to education and health services, such issues will not be dealt with. In addition, although road infrastructure may have an immediate impact on raising income, it could also have a detrimental long-term impact on income if such an intervention has a significant negative impact on the environment. Moreover, although improving road infrastructure improves welfare, it could also have a negative impact on some groups of people. By introducing new consumer goods and improved production implements, or fostering competition, an improvement in road infrastructure could drive small-scale producers, such as weavers and other small-scale traditional craftsmen out of the market. Although such issues are important and deserve due treatment, for the purpose of focused discussion and to remain within the immediate objective of the research, they will not be treated.

1.2. Basic features of the Road Transport Infrastructure

Ethiopia is a land locked country where the major share of passengers/freight movement in space takes place by means of road transport. Except for an old railway that runs from port Djibouti to Addis Ababa and a relatively well functioning air transport system, presently 95% of the passenger and freight transport is accommodated by road transport (ERA, 2005).

In the 1990's, due to civil war, financial constraints and limited capacity for planning and maintenance, much of the road infrastructure deteriorated. Recognizing the seriousness of the problem, since 1997 the government launched a road sector development program with the aim of expanding the road density to 67,300km as well as increasing the share of good quality roads from its level of less than 50% at the start of the program to 65% by the end of 2015.

As a result of the ongoing road sector development program, by 2004, the total road network of the country increased to 36,496 km, showing an increase of 9946 km from its level of 26550 km in 1997. From the total increase in road network, 927km is paved road, 1743 km is gravel road and the remaining 8856km are rural roads (ERA, 2005). As of the year 2004, almost 65% of the total classified road network (23,803 km) is in good or fair condition, in which main asphalt roads account 14% of the total while the balance is shared between gravel (36%) and regional roads (50%). This represents quite an improvement over the situation in 1997 when it is estimated that less than 35% of the road network was in good or fair condition (ERA, 2005). However, the improvement in road network is not uniform across regions. The major increase in road density while mainly concentrated in the four biggest regions of Tigray, Amhara, Oromia and SNNP, from this group, the major improvement is observed in Oromia region.

Despite the increase, the road density still stands at about 33 km per thousand square kilometres for the entire classified road network and around 22km/1000 km2 for roads in good or fair condition (ERA, 2005). This is well below the average road density of sub-Saharan countries (ibid). Moreover, since over 90% of the road network is accounted by federal roads, which are inter-regional trunk roads, still 70% of the rural population has to travel about six hours to reach a road (ERA, 2005).

Moreover, although there is a significant increase in rural roads, most of these roads are dry weather roads, with less improvement in all weather roads. This has far reaching implications on grain marketing, crop prices, and poverty reduction. It is not only that the vehicle operating cost in such roads are very high, it also puts pressure on limited marketing infrastructure as grain moved from production to consumption centre must be transported in a short period of time (World Bank, 2004).

1.3. Data Source and Measurements

1.3.1 Data Source

This thesis is based on secondary data and most of the data is 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 University of Oxford[7] (Dercon and Hoddinott, 2004). The survey data were made available to the researcher by Addis Ababa University and IFPRI with the consent of the University of Oxford.

While so far the survey is conducted in six rounds, the first round of the survey was conducted in 1989 on seven villages from which 450 farm households were randomly selected. The initial purpose of the survey was to study the response of farm households to food crises; and as a result, the villages initially included in the first round survey were the ones that had suffered from the 1984-1985 famine and other droughts that followed between 1987 and 1989. The villages were drawn from Amhara, Oromiya and the Southern Nations and Nationalities Region (SNNPR). Although Tigray region had also suffered from drought during these years, due to

[7] Details about the sampling framework and other relevant information are found in Dercon and Hoddinott (2004).

civil conflict in the region, no villages from this region were included in the first round survey. During the second round survey, which was undertaken in 1994, in order to make the sample more representative, on top of the previous six villages (one is dropped because it could not be revisited again due to violent conflict in the area), nine additional villages were included totalling the number of villages to 15 and the number of households to 1477.

As the survey was undertaken mainly on households that are in sedentary agriculture, although the survey may not be considered nationally representative, it is argued to be broadly representative of households that are in sedentary agriculture (Dercon and Hoddinott 2004). As can be seen from Table 1.1, the population shares within the sample are broadly consistent with the population shares in the three main farming systems, i.e., the grain-plough areas of the Northern and Central highlands, the enset-growing areas and the sorghum-hoe areas (ibid).

Although the household survey covers both the ox and the hoe-plough agriculture systems, the present research however will focus on households that are under grain plough agriculture[8].

[8] The detailed characteristics of the sampled villages and households are included in the appendix.

Table 1.1

The Sampling Frame of the Survey

Farming System	*Population share*	*Sampling Share*	*Number of Villages*
Grain-plough complex-Highlands			
• *Northern Highlands*	*21.2%*	*20.2%*	*3*
• *Central Highlands*	*27.7%*	*29%*	*4*
Grain plough/hoe complex	*9.3%*	*14.3%*	*2*
Sorghum plough/hoe Hararghe	*9.9%*	*6.6%*	*1*
Enset Growing	*31.9%*	*29.9%*	*5*
TOTAL			*15*

Source: Dercon and Hoddinott (2004)

The choice of grain-plough agriculture is motivated on the ground that the input use pattern and the crop choice are more influenced by degree of access to road infrastructure. In addition, since types of crops produced and the input use pattern under the two systems vary drastically, aggregating the whole sample is believed to entail specification and aggregation bias as they are operating under different production functions. Moreover, in the survey although the total number of households that are under ox-plough agriculture is 1200, due to missing and data inconsistency, only the data of 841 households could be used. 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 survey data of these rounds will be used.

In terms of representativeness of the sample, since most of the households are drawn from grain-plough agriculture, on the basis of population share, the findings of the research can be generalized for farm households that are under grain-plough agriculture, which accounts for more than 70% of the overall farming population. Moreover, as the sampled households are drawn from Tigray, Amhara, Oromiya and the SNNPR where 96.6% of the rural poor live, the sample can also be assumed to adequately reflect the rural life condition in sedentary agriculture.

Finally, although important economic, social and demographic characteristics of the sampled households are available in the survey, the information contained in the survey is inadequate to fully address the research questions. In order to supplement the survey data, data on economic, demographic and social characteristics of the nearest town centres was drawn from Central Statistical Office (CSA). Data on rainfall is drawn from the Ethiopian Metrological Service data base. The crop price data to estimate the threshold autoregressive model were obtained from the Ethiopian Grain Trading Enterprise (EGTE). The data covers 13 major nationally traded crops, 19 regional markets and a period of 11 years

(1994-2004)[9]. The markets covered in the data set are drawn from four regions and include both surplus and deficit markets.

1.3.2. Data Measurement

The net revenue of each household is calculated by deducting expenditure on fertilizer from income generated from crop production and off-farm employment. The value of family labour spent on the family farm is assumed to be captured in the value of crop output. Although some of the households have reported that they have used hired labour, the labour costs in some cases are six times higher than the total income of the households. Since there are group labour schemes in most of the sampled villages, some of these households must have reported group labour as hired labour. Since the number of households that have reported the use of hired labour is small, in order to avoid inconsistencies and measurement problems, the cost of hired labour is not included in the net income calculation. In estimating income from crop production, for those households that sold some of their crops, the reported sales price is used. But for those that did not sell crops, the average crop price of the village is used. Adult family members are assumed to be those that are between 15

[9] The crop price data covers 10 crops; and the types of crops included in the analysis are Teff (white, mixed and red), wheat (white and mixed), barley (white and mixed), sorghum (white and red) and maize.

to 60 years of age. The number of oxen households actually used for farm production is not available. As a result, for oxen input, the number of oxen the household owns is taken as a proxy with the assumption that all oxen were fully engaged in farm activity. The level of human capital asset of the household is measured in terms of the average years of schooling of adult members of the household (Rahman, 2003; Parikh, et al, 1995).

In the survey, data on the rain-shock is compiled by attaching a value of 1 or 0 for questions such as whether or not rain comes on time, was it enough or not, did it stop on time and also was it raining during harvest. In order to capture the effect of rain shock on income or production level, while including such variable is necessary, in the interest of reducing the number of variables to be included in the model, assuming that each types of shock will have equal impact on production, dummies were added to generate one single figure. In that case, if a household had experienced all shocks, it will have a figure of 4; and if it did not experience any shocks, the figure for rain shock variable for that particular household will be given a value of zero.

In the sampled households, a majority of the households did not use fertilizer. Since the net income model is estimated in natural logs, when the natural log is applied to the data, those that did not use fertilizer will have to be dropped. In order to retain the information of those that did not use fertilizer, alternative approaches can be followed. The first option is to use a dummy variable for fertilizer application, where 1 is given for those that applied fertilizer and zero otherwise. The second option is to add a value of 1 on the quantity of fertilizer used so that when the natural log is applied to the data, it is possible to retain households that did not use fertilizer (Johnson and Rausser 1971). Using the first option is likely to overestimate the productivity of fertilizer just because the fertilizer application dummy could also capture other characteristics of the household. The second option however will understate the productivity of fertilizer (ibid). For example, in the present sample, when the dummy variable is used in the net income model, the coefficient of the fertilizer variable was 0.4 compared to 0.12 when the actual quantity of fertilizer is used. In order to avoid overestimation, for the purpose of this research, the second option will be used.

In the survey, the road quality of the sampled villages was compiled through structured community level questionnaire. Respondents (as far as possible community leaders) were asked to attach a value of 1 to 6 depending on how the road allows accessibility from and to the village during the rainy season. Accordingly, respondents have attached a value of 1 to 6 respectively for a road that allows easy access to any vehicles, reasonable access to any vehicles, good access to trucks and buses, reasonable access to trucks and buses, access to carts and animals and finally only for foot traffic.

The survey also contains information on the material the road is constructed from, i.e., Tarmac/Concrete, Stones, Dirt Track and Other. On the basis of this, almost 70% of the villages are reported to have a road made of Dirt Track. This information however is inconsistent both with the qualitative study of the villages as well as with the view of community leaders on the quality of the roads. For example, in one village while the road is reported to be made of stone, which in terms of quality is next to concrete, the community leaders however claim that the road only allows foot traffic during the rainy season.

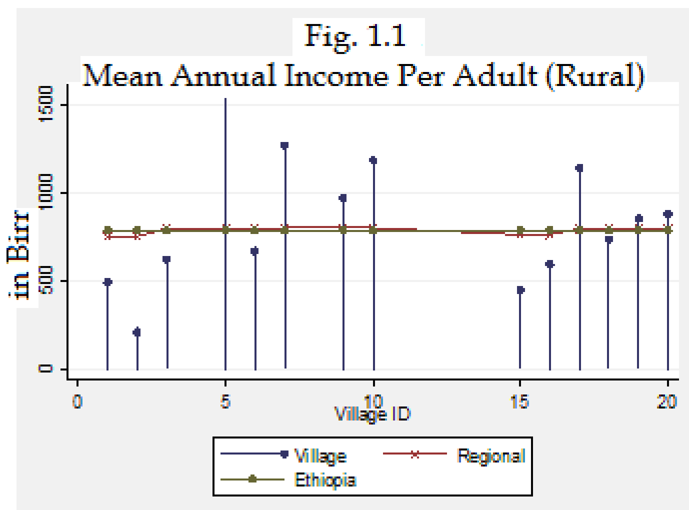
In assessing the effect of road infrastructure on household consumption growth, using the same data set, Dercon, et al. (2007) and Dercon and Hoddinott (2005) measured the road quality of the villages in terms of the degree to which the road allows accessibility from and to the village during the rainy season. In order to compare the findings of this research with the findings of previous research, a similar approach will be followed (Dercon, et al. 2007). Accordingly, for the purpose here, the road qualities of the villages will be categorized into two. The first is good road access, which includes roads that allow accessibility from any vehicle to good access to trucks and buses. The second one is poor road access, which includes roads that allow reasonable access to trucks and buses to foot traffic (Dercon, et al. 2007). Therefore, while estimating various empirical models where road access appears as an explanatory variable, a value of 1 is given for villages that have good road access and 0 for villages with poor road access. The classification of the villages is also more or less consistent with the findings of the qualitative studies undertaken on the sampled villages.

In order to capture the road quality, the use of one instead of six dummies is also expected to generate efficient estimates of the variables where road access appears as one explanatory variable of the model.

In order to estimate the crop price model, while categorizing the villages into surplus and deficit markets is necessary, the classification of the village markets into surplus and deficit is based on the per-capita crop production of the zones where the respective villages are located. Villages that are located in zones with a per-capita crop production that is less than the average for the all zones, i.e., those zones in which the sampled villages are located, are classified as deficit and surplus if it is otherwise.

1.4. Overview of the Sampled Villages and Households

As can be observed from Figure 1.1 below, in 7 out of 14 villages, the mean adult income in the sampled villages is well below the national and regional average, i.e., from where these villages are drawn. The average income in the other two villages is almost equal to the national and regional average; and in the other 5 villages the average adult income is above both the national and regional average.



Data Source: Own Calculation from Survey data and MoFED (2002b)

As the sampled villages are drawn from different parts of the country, across village differences in geographical characteristics must be a key contributing factor to the observed across village income differences. According to agro-ecological classification, the villages are classified into kolla (hot), woyena dega (moderate) and dega (cold) agro-ecological environment. Eight of the sampled villages have a moderate climate, four villages have hot climate and two villages have a relatively cold climatic condition. The altitude of the sampled villages also varies from the lowest of 1000m to the highest of 2850m above sea level. Similarly, the average annual rainfall level of the villages varies from the lowest of 504mm to the highest of 2205mm.

There were also across villages differences in land resource endowment. While the average per-capita land size of the sampled villages was 0.4 hectares, it ranges from the lowest of 0.1 hectare to the highest of 1.91 hectares, with a standard deviation of 0.56 hectare. From the total available land, on average close to 60% of the land is under cultivation while the remaining land is used either for grazing, or for residential areas and a significant size of the remaining land is unusable due to the nature of the terrain. From the total cultivated land 99% is rain-fed and only 1% is irrigated. At the household level in 2004, the average cultivable land holding size was close to 1.4 hectares with a standard deviation of 1 hectare. Across village variations in terms of access to other productive private resources (such as level of livestock owned and human capital) were also observed.

Significant inter-village differences in terms of access to social and economic infrastructural services, such as telephone, postal, banking, government hospital, government clinic, pharmacy, primary school, junior secondary school, and high school, were also observed. Measuring access in terms of distance, the average distance of these villages from these services was 14 km with a standard deviation of 12km. The geographical distances of these villages from the nearest town, zonal market and Addis Ababa market were also 15 km, 24km and 345 km respectively. The standard deviations of distance of the villages from these locations respectively were 7km, 15km and 242km. When the distance is measured in terms of walking distance, while assuming an adult farmer walks 6 km per hour, from the sampled villages, on average, it takes two to three hours to reach the nearest market.

In the sampled villages, there were also variations in terms of access to road infrastructure. When quality of the road is measured in terms of the extent to which the road allows accessibility to/from the villages during rainy seasons, in the first two villages accessibility is only possible through cart animals or walking; in three villages the road only provides reasonable access to buses or trucks and in the remaining six villages, reasonable accessibility is possible to any vehicles.

There were also spatial differences in the level of farm gate prices for goods and factors. Farm gate prices are generally better in villages that have better road access, i.e. while households in these villages on average earn more for outputs and the labour they supply, they pay relatively less for the inputs they purchase. Possibly due to favourable market conditions, farm households in these villages use more than six times the quantity of fertilizer as households that have poor road access. As a result, crop yield per hectare is generally 50% higher in villages that have good road access.

As a result of higher resource endowment, better market prices and higher overall productivity, the average per-capita income of households that have good road access was 54% higher. Although across village differences in agro-ecological and household specific factors may have contributed to the observed differences in per-capita income level, the contribution of across village differences in access to road infrastructure is expected to be a significant factor. The empirical section aims to isolate the effect of road access from these other covariates of income/poverty and also to empirically substantiate the main mechanisms by which the effect of road on income/poverty operates.

Table 1.2

Average Household and Village Characteristics of the Sample by type of Road Access

Key Variables	Poor Road Access	Good Road Access
Land Size in hectare	1.55	2.46
Land Quality	0.80	0.88
Human Capital (years of school attended)	0.51	0.92
Fertilizer used in kg	22.19	124.26
Number of Oxen Owned	0.95	1.54
Crop Output in quintal	9.85	21.16
Crop Marketed	2.77	5.63
Daily Wage Rate	4.69	5.85
Fertilizer Price per kg.	3.06	2.70
Crop Price	1.38	1.56
Share of Households that have applied Fertilizer	0.38	0.88
Family Size	5.87	6.43
Schooling of Head of the HH	0.66	1.04
Age	24.85	25.75
Distance from Zone Market in km.	30.89	13.37
Distance from Other Infrastructure Services in km.	24.35	8.70
Distance from Addis Ababa in km	467.90	179.08
Crop output per labor used	0.13	0.28
Crop Yield per Hectare	8.81	12.15
Share of off-farm Income	0.38	0.06
Annual Rainfall in mm	433.06	917.92
Share of HHs that have sold crops	0.54	0.65
Share of HHs participated in Off-farm	0.53	0.14
Crop Income	1327.20	3349.33
Number of Plots	3.39	6.24
Number of Crops Cultivated	2.15	3.36

Source: Calculated from The Survey Data

Table 1.3
Name and Location of the Sampled Villages

Village ID	Name of the Village	Location
1	Haresaw	Tigray
2	Geblen	Tigray
3	Dinki	N. Shoa
5	Yetmen	Gojjam
6	Shumsha	S.Wollo
7	Sirbana Godeti	Shoa
9	Korodegaga	Arssi
10	Turfe Kechemane	S.Shoa
15	Gara Godo	Sidamo (Wolayta)
16	Doma	Gama Gofa
	Debre Berhan	N.Shoa
17	-Fagy and Bokafya	
18	-Koremargefia	
19	-Karafino	
20	-Milki	

Source: Dercon and Hoddinot (2004)

1.5. Related Empirical Studies Undertaken on the Survey Data

Related empirical studies undertaken on the basis of the survey data include those carried by Dercon et al, (2007); Croppenstedt and Demeke (1997) and Abrar (2003). Dercon et al (2007) assessed the impact of roads and agricultural extension on consumption growth and poverty. Their research is in common with this research because they attempted to empirically substantiate the link between roads and poverty. They reported that access to all weather roads increases short run annual consumption growth by 15% and reduces the likelihood of a household being poor by 6-7%. Although in their study the mechanism through which roads affect consumption level has not been empirically substantiated, they claimed that it operates through the effect of roads on reducing the cost of acquiring inputs, increasing output prices, reducing the impact of shocks and permitting entry into new and more profitable activities. This research differs from their research both in terms of the sample covered, the objective and the modelling approach.

First, their samples include households that are both in ox-plough and hoe-plough agriculture, but this research is based only on households that are under ox plough agriculture. One major limitation of combining samples under different agriculture systems is that the input use pattern, the crop mix and the degree of commercialization under the two agricultural systems vary drastically such that specification and measurement bias is likely to be present. Second, since the effect of roads on consumption mainly operates through its influence on income and also since all the household's income may not necessarily be spent on household consumption expenditure, their model is expected to be misspecified and thus the reported coefficient estimate of the road variable cannot fully capture the productivity of the road infrastructure.

Finally, they used the standard empirical growth model inspired by Mankiw (1992). Apart from the question of its applicability on micro level data, since the growth model is normally based on the production function specification, the reported marginal productivity of roads is expected to be underestimated as such a model cannot adequately capture the direct and indirect impact of roads on income that works through altering farm gate prices, input use and the choice of crop mix. The present research aims to address some of these limitations and also attempts to empirically substantiate the various channels by which the road affects farm income.

Based on the 1994 round survey data and a sample of 344 households drawn from Ox-plough agriculture, Croppenstedt and Demeke (1997) also estimated the technical efficiency level of the sampled households. For the sampled households, they reported a 41% average technical efficiency level, in which 54% of the samples are in the range of 30%-60%. Although they analyzed the determinants of farm specific technical efficiency, they did not consider the role of roads.

Similarly, Abrar (2003), using four year panel data from nine villages that are under ox-plough agriculture, also assessed the supply response of the farm households in the presence of technical inefficiency. Using the Data Envelopment Approach, he reported a 55% average technical efficiency. In this study, although theoretically the effect of roads on improving technical efficiency level is emphasized, the road quality of the sampled villages' did not appear as one explanatory variable of the postulated profit, input and output supply functions. In order to introduce infrastructure/market access into the profit function, he used a proxy variable by dividing the total population of the nearest town to the road distance between the village and the nearest town. In his conclusion, while he claimed that providing an adequate infrastructure access, such as road is essential to increase the technical efficiency and hence supply response of the farmers, such a conclusion is not immediately apparent as the infrastructure proxy he used does not necessarily reflect the road quality or density of the village.

In addition, while specifying the profit function, he considered output and input prices as exogenous variables. Such a specification, given that market prices in the sampled village endogenously adjust to the stock of local transport infrastructure, is expected to under/overstate the technical efficiency estimate depending on the link between transport cost, market prices and households' response to market prices (Costa, 1998; Haughwout 1998, 2002). Moreover, since he used a profit function specification, the estimated technical inefficiency score also includes the allocative inefficiency component, an issue which was not discussed in the paper and could also affect the conclusion of the research.

This research differs from the previous studies in several respects. First, this research aims to substantiate the poverty impact of road through postulating the effect of road on farm income rather than consumption so that the impact of road access on poverty reduction will not be underestimated, which is likely to be the case when the effect of roads on consumption is indirect. Secondly, this research also attempts to empirically substantiate the various channels by which the effect of road access on income and poverty operates. Thirdly, in order to account for the endogeneity of village level market prices and thus circumvent biased estimates of the productivity of road, most of the models are postulated in a spatial equilibrium framework.

Chapter 2 Poverty in Ethiopia

2.1 *Poverty Profile*

In terms of economic development, Ethiopia is one of the least developed and poorest countries. The latest IMF rankings of GNP per capita put Ethiopia 168th (IMF, 2009).

Due to better macro-economic policy environment since the 1990's, good weather, relative peace and stability, the economy has registered a positive growth rate, but the number of people in absolute poverty remained high, mainly because the agriculture sector, which contributes for 87% of the income of the poor, registered a negative (-0.25%) per-capita growth rate for the period between 1992 and 2004[10] (MoFED, 2002b, World Bank, 2007). Although the industrial and service sectors respectively registered positive per-capita growth rates of 0.45% and 2.11%, since the elasticity of poverty to non-agriculture sector growth is very low, their contribution to poverty reduction was very limited (World Bank, 2005). Given that the Gini coefficient for Ethiopia is 0.29, low economic growth rate rather than

[10] In terms of income source, 87% of the rural income comes from farming while the balance is generated from non-farm activities (World Bank, 2007). Within farming, 64% of the value added comes from crops, 23% from livestock and the remaining from forestry (World Bank 2007).

wealth inequality is mainly responsible for the continued high incidence of poverty (World Bank, 2005).

In terms of spatial concentration of poverty, according to the available latest poverty estimates, in all types of poverty measures, poverty is worse in rural than in urban areas. The proportion of the rural population in absolute poverty stood at 45.4% while the figure for urban areas was 36.9% (MoFED 2002b). In recent years, however, although the incidence of poverty is still high, rural poverty has shown a declining trend while urban poverty has been increasing, although the increase is not statistically significant[11] (Table 2.1). The decline in rural poverty was attributed to favourable government policy towards the agriculture sector in general and rural areas in particular; and partly due to equitable access to land and out migration of the rural poor to towns and cities (Bigsten et al 2004; MoFED 2002b). For high urban poverty, despite a 5.13% and 6.8% real annual industrial and service sector growth over the period 1992-2004, inequitable access to physical, financial and human capital, high rate of migration to cities, low response of the private sector investment to

[11] In fact, it is claimed that had it not been for drought and the Ethio-Eritrea war, Ethiopia would have registered a substantial reduction in poverty by 1999/00 compared to the base year of 1995/96, where there was low inflation rate and bumper harvest (MoFED, 2002b).

various policy measures and weak inter-sectoral linkage are the major contributors[12] (Dercon, 2002).

In terms of regional concentration of poverty, the majority of the poor live in Tigray, Amhara, Oromiya, SNNP and Addis Ababa, which altogether account for 85% of the population of the country (World Bank, 2005). When the regions are categorized in terms of their agro-ecological characteristics, incidence of poverty is higher (40%) in the *enset growing* region (SNNP) compared to 33.5% in *cereal growing* regions (Dercon, 2002). High poverty incidence in *enset growing* regions is mainly due to high population pressure and low average per-capita cultivable land holding. Among cereal growing regions the highest proportion of population in absolute poverty is in Tigray region, the region is characterized by low per capita land holding, high rate of land degradation and frequent drought. Although lower in terms of their contribution to overall poverty, the proportion of people in absolute poverty is the highest in the sparsely populated regions of Benishangul-Gumuz, Gambela and Afar. These regions are relatively remote, have inhospitable climate, the share of

[12] Although the sectors that benefit more from the economic reform program are the transaction intensive sectors, due to imperfect capital market, the windfall gain is appropriated by the few that have access to capital (Dercon, 2002).

population with malaria risk is the highest and access to public infrastructure is generally poor (World Bank, 2005).

Table 2.1

Overall Poverty index, Rural and Urban Poverty

Poverty Indices	Sub-Population	1995/1996* Poverty Index	1999/2000 Poverty Index	%Change in Index	Z**-Statistics
P_0	Rural	0.475	0.454	-4.42	-1.187
	Urban	0.332	0.369	11.14	1.313
	Total	0.455	0.442	-2.86	-0.799
P_1	Rural	0.134	0.122	-8.96	-1.697
	Urban	0.099	0.101	2.02	0.194
	Total	0.129	0.119	-7.75	-1.768
P_2	Rural	0.053	0.046	-13.21	-1.650
	Urban	0.041	0.039	-4.88	-0.371
	Total	0.051	0.045	-11.76	-2.121

P_0= head count index, P_1= poverty gap and P_2= Squared Poverty gap (poverty severity).
*The index measures a condition where the individual is unable to meet the minimum required calorie in-take. ** Z statistics for Change in Head count index.
Source: MOFED (2002b)

Within the City Administrations, poverty is higher in Dire Dawa and Addis Ababa. In comparative terms, incidence of poverty is lower in Oromiya and Amhara regions. These regions have relatively better access to infrastructure, higher average per-capita land holding, above average annual rainfall, and are relatively less exposed to soil erosion and malaria risk. In addition, the per hectare fertilizer use is the highest (especially Oromiya) and the share of land devoted to commercial crops (such as teff) is also higher[13].

[13] In fact in recent years a substantial decline in poverty has been observed in Amhara Regional state.

As to the poverty status of the sampled villages, as previously discussed, although there is across village variation, the average per-capita income level of the whole sample is well below the national as well as the regional rural poverty line[14] (MoFED, 2002). Villages 1 and 2, which are the poorest sampled villages, are drawn from Tigray region where the incidence of poverty in 1999 was the highest, ranging from the 49% to 69% of the population (World Bank, 2005). The second poorest villages, which are villages 15 and 16, are drawn from the SNNP, where the incidence of rural poverty in 1999 is the third highest and ranges from the 48% to 65% of the population. Villages 3, 5, 6, 17, 18, 19 and 20 are drawn from the Amhara region where by national standard the rural poverty level is relatively low. However, except for villages 5 and 17, the other villages are below and equal to the rural poverty line of the region. Villages 7, 9 and 10 are drawn from Oromiya region, where the incidence of rural poverty ranges from 32% to 52% of the population. Villages 7 and 10 are surplus producing villages. Although village 9 is a drought prone and food deficit village, the village has higher per-capita income because a larger proportion of the village households participated in off-farm employment.

[14] The sources of income considered in calculating the per-capita income of the sampled villages are income from crop production and off-farm earning. Incomes from livestock products and remittance are not included. The exclusion of these sources of incomes in calculating the per-capita income is believed not to bring much change in the relative status of the sampled villages.

2.2. *Correlates of poverty*

While only focusing on rural areas, poverty at the household level arises more due to low resource base (physical, financial and human capital) than inequitable distribution of wealth. Given that the major share of the rural income comes from rain-fed agriculture, external factors, such as agro-ecological conditions (weather and soil characteristics), geographical conditions (remoteness, topography, population density, health related risks), socio-economic conditions (access to infrastructure) and shocks (both production and market) are also major determinants of rural poverty[15] (Jalan and Ravallion, 2002). The effect of external factors on poverty is felt through their impact on resource allocation and on the rate of return to land and labour.

Among privately owned productive resources, the size and quality of land owned are important determinants of rural poverty. Currently, the average land holding size in Ethiopia is very low and also highly fragmented[16]. Each rural household on average holds about one hectare of land and this corresponds to 0.21 hectare per rural person, which is 50%

[15]Where there is no free mobility of resources, while the assets possessed by the poor may exhibit a diminishing return, geographical capital, such as public infrastructure, tends to reverse that and increase the marginal productivity of private resources (Jalan and Ravallion, 2002).

[16] Although land is public property and farm households have a usufruct right, the land size they own is influenced by gender and age of head of the household, family size and location.

lower than the average land holding in the 1960's. The size of land holding is also generally lower (0.57 hectare) in food insecure areas than food surplus areas (1.38 hectare). Given a very low yield per hectare, which currently is estimated at 1.2 tons, the size of land rural households owned only allows them to produce half of their daily cereal requirements (World Bank, 2005).

In the majority of rural areas, livestock is the other key household asset both as a source of income and as a capital input for crop production. Its contribution to household income/consumption however is low mainly due to low levels of holding and low productivity of the existing stock. While farming activities at least requires a pair of oxen, only 29% of the rural households own two or more oxen and over time the proportion of farm households who owns at least one ox has also declined[17] (World Bank, 2005). Low productivity of the stock, drought, animal disease, lack of pasture, inadequate access to market and low level of modern technology application are the primary reasons (Diao and Pratt, 2007). For example, while the available evidence indicates that the use of simple technology, such as cross-breeding, could increase the yield of milk by 2 to

[17] Since crop output is elastic to draught animals, the welfare status of rural households is strongly associated with the number of draught animals they own.

3 times, the share of milking cows cross-bred from the overall stock is only 2%, suggesting that increased adoption of such technology could significantly improve the contribution of livestock to household income (ibid). It is claimed that remoteness from the market forced farmers either to accept low prices for live animals or livestock products that they market or consume them at farm level although they prefer to trade them (Staal, et al 1997).

Labour resource is the other key asset rural households own. Its marginal contribution to household income however is not substantial mainly due to inadequate access to land and limited off-farm employment opportunities (World Bank, 2005). Inadequate stock of rural infrastructure and low level of farm productivity not only reduced the number of people engaged in off-farm employment, but also depressed the rural wage rate (Tafesse, 2003). Similarly, although return to human capital is positive and significant, the human capital resource base of the rural households is also very low[18]. As a result, households with large family size tend to be poorer (ibid).

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[18] The average school grade completed for male and female adult family members respectively are 1.24 and 0.4, which is one of the lowest in the world (World Bank, 2005)

Due to low level of urbanization and limited opportunity for spatial mobility of labour, in the short to medium term, the major source of rural income is expected to come from crop and livestock production. Since the scope to push the land frontier further is very limited, mainly because most of the available marginal lands are located in areas that are inhospitable or suffer from one or more soil and terrain constraints, growth in crop production is expected to occur through improvement in farm productivity. Moreover, since off-farm employment opportunity is strongly linked with the level of farm productivity, factors that influence farm productivity will also determine off-farm employment earning and return to labour (Demeke et al 1997).

Low level of farm productivity and return from farming are also identified as important determinants of rural poverty. Farm productivity and returns from farming are influenced by household and geographical specific characteristics. Household specific characteristics, such as resource base, affect farm productivity through shaping risk preference and determining the risk bearing capacity of the household and thereby its resource allocation and technology uptake behaviour. Geographical factors, which will be discussed below, also influence farm productivity and return through inflating costs and generating production, health and market shocks.

Farm productivity in Ethiopia is very low and in fact shows a declining trend, albeit with a recent improvement (Geda and Degefe, 2002). Low level of chemical fertilizer application, high rate of soil degradation, high nutrient loss (due to dung and crop residue collection), high population pressure, production, health and market related shocks are the primary reasons (MoFED, 2002a). Although using fertilizer and fertilizer combined with improved seeds increase yield levels by 19% and 114% respectively, currently only 40% of the cultivable land is fertilized and it is only in 4% of the cultivated land that improved seeds are being applied [19](World Bank, 2005). According to some estimates, households that apply fertilizer enjoy 39% higher consumption than those that are not using fertilizer (ibid). In addition to low level, inefficient application of chemical fertilizer is the norm (Croppenstedt and Mulat, 1996; Diao and Pratt, 2007). Although the recommended or optimum level of fertilizer per hectare is 200kg, currently

[19] Although response is higher in maize and sorghum production, currently only 10% of sorghum area and 39% area of maize are fertilized. The improved seed use was non-existent for sorghum and 13% of the area cultivated of maize used improved seeds.

the actual average fertilizer application per hectare is 10.8 kg[20] (Demeke, et al, 1997).

In addition to yield level, the type of crops cultivated on the land is also a critical determinant of rural poverty (Diao and Pratt, 2007). It is generally observed that households that cultivate commercial crops (coffee, chat and teff) exhibit higher consumption expenditure and also are less likely to fall into poverty (Bigsten et al 2004). Households that grow chat, coffee, and teff have respectively a 31.4, 9.1 and 6.1% lower probability of being poor compared with households that do not cultivate these crops (ibid).

Adverse shocks, such as rainfall shocks, production damage due to insects, pests, floods and health shocks are also significant factors that govern the level and evolution of rural poverty. As 98% of the farms are rain-fed, the level and volatility of rainfall, through their impact on yield level, land allocation (particularly choice of crops), fertilizer use, off-farm employment opportunity and rural wage rate are critical determinants of rural poverty (Diao and Pratt, 2007). Annually, the average cultivated area damaged due to insects, pests and flood is also substantial. In terms of

[20] The contribution of nutrient loss of the soil and soil degradation for low land productivity is also substantial.

health shocks, malaria and serious illness episodes have an important effect on farm productivity (Gallup and Sachs, 1998). Currently two-fifth of the rural population is exposed to malaria risk (World Bank, 2005). In terms of illness, illness of the head of the household or one adult member is estimated to reduce the annual income by 7 to 11% (Dercon, 2004).

In addition to production and health related shocks, market risk, both in the form of low and volatile farm gate crop prices, is a significant determinant of rural welfare (Tafesse 2003). Low farm gate price and high crop price volatility reduces rural income directly as well as indirectly by discouraging the adoption of new technologies and market participation. Whether or not low crop prices generally harm the rural poor is an empirical issue, however the net market position of the farm households varies by season and also depends on production conditions and the prevailing wide price gap between spatial markets and high price volatility harms both net sellers and net buyers of food crops. The average spatial price gap is estimated to be in the range of 30-70% and it is expected to harm both net sellers and net buyers of food crops as it makes the former group earn lower prices for the crops they supply and the latter to pay higher prices for the crops they purchase[21] (Diao and Pratt, 2007). Given that farm income is highly sensitive to farm gate crop prices and also given that the demand for food crops is highly price inelastic, mainly because cereal alone commands more than 70% of consumption expenditure of the poor, the poverty impact of the spatial price gap will be substantial, both through income and consumption loss.

In addition to its level, seasonal volatility of crop prices is also important (Tafesse, 2003). Price volatility, in addition to its direct adverse effect on income, also indirectly reduces income or aggravates poverty by making rural households risk averse and reluctant to apply productivity enhancing modern inputs. It also creates uncertainties in the market and makes traders reluctant to increase their scale of operation, which further widens the spatial price gap and increases crop price volatility[22].

High population pressure is another geography related factor that has a significant impact on farm productivity and rural poverty. The three most

[21] High spatial price gap however tends to benefit food deficit households in surplus producing markets and surplus producers in deficit markets.

[22] Due to high price volatility and inter-annual variability of returns to storage, traders engage in short distance (average 67km), few storage days (27 days on average) and small transaction size (65 quintals), which entails large efficiency and welfare loss as traders do not fully capture returns to arbitrage opportunity over space and time (World Bank, 2004).

populous regions (Oromia, Amhara and SNNP) account for 81% of the total population while only accounting for 50% of the land mass. As a result, while average population density is 232 people per arable land, it differs across locations and ranges from 90 to 281 (World Bank, 2005). In addition to reducing per-capita land holding, as mentioned above, high population density reduces land productivity by increasing the use of manure as fuel and preventing fallowing, which are both estimated to entail a consumption loss of 37%. Its effect on household income through increasing the supply of labour and depressing the rural wage rate is also significant (Tafesse 2003).

Rural poverty is also associated with remoteness and low access to public goods. Poor access to publicly provided goods or services translates into rural poverty by preventing the development of markets, entailing market coordination failure, increasing transaction and transport cost, reducing access to opportunities and information, inflating the cost and reducing the diffusion of new technologies (World Bank, 2007). Only 1% of the rural population has access to electricity. Average distance of the rural households from food markets, health centres, primary and secondary school is also still high[23] (6km, 8.3km, 3.38km and 22km respectively).

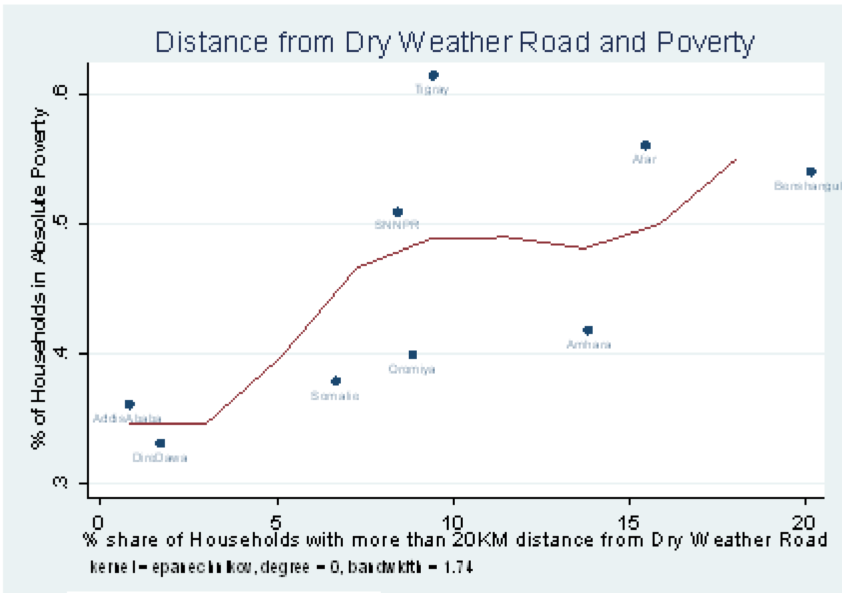
Despite sustained increase in public expenditure on road infrastructure, the mean distances rural residents travel to reach all weather and dry weather roads as well as transport services (bus and taxi services) respectively are 9.77 km, 7.17 km and 17.14 km (MoFED, 2002b). Moreover, since half of the existing road network is made up of trunk roads and link roads, linkage between regions is also a major problem.

Regional variation in access to road infrastructure is also wide. As can be seen from the Figure 2.1, in some regions more than 20% of the population live 20km away from a dry weather road while the distance in other regions is less than 5km. An inverse relationship between access to road and the number of rural people in absolute poverty suggests that improving road access could have a significant contribution to reduction in rural poverty. As will be demonstrated in the subsequent chapters, road

[23] Following increased allocation of government expenditure on social sectors in general and in rural areas in particular, access to health, education and water services have significantly improved. Education coverage at all level has improved, although by all standards the coverage still ranks Ethiopia as one of the lowest in the world. Similarly, although a modest and gradual improvement has been achieved in some health indicators, a lot is yet to be desired.

infrastructure is expected to have a great impact because it eases some of the above constraints that have been contributing to rural poverty.

Figure 2.1



Source: CSA (2004)

Despite similar road access conditions, rural households could have different welfare status, suggesting that the inverse link between road access and incidence of poverty could be compounded by other factors, such as agro-ecological or other location specific factors. For example, although it has comparatively similar road access status with Oromiya, the observed high incidence of poverty in Tigray region is mainly attributed to low and volatile rainfall, high population density and high rate of soil degradation. Similarly, despite a relatively better road access than Oromiya, poverty incidence in SNNPR is higher mainly due to land scarcity and high population density, suggesting that in assessing the link between road and rural income/poverty, controlling the role of other confounding factors is necessary.

2.3. *Conclusion*

From the above discussion it clearly emerges that both household specific factors, such as low resource base, as well as exogenous factors, such as geographical and agro-ecological conditions, are key determinants of rural poverty. Low resource base influences poverty status directly through determining the income generating capacity of the poor and indirectly through governing their risk preference and risk coping capacity. Low resource base makes the poor risk averse and less responsive to price and technical opportunities, thereby reducing the return to land and labour. High dependency of rural livelihood to the vagaries of nature, inadequate access to public goods and high production, health and market risks also contribute to rural poverty by reducing overall factor productivity and the rate of return to land and labour.

In order to achieve meaningful poverty reduction, it therefore requires a combination of measures that increase the resource base of the poor and nullify the adverse effect of external factors. Such interventions are justified both on the grounds of equity as well as efficiency. From the efficiency point of view, adverse external factors and inability to cope with risks, which are the result of imperfect financial market, prevent the poor from allocating their resources efficiently, which not only reduces micro level income but also retards macro level growth. From the equity point of view, geographical factors such as remoteness or unfavourable climate condition put the poor in a disadvantageous position both through limiting their opportunities and reducing the return to their assets.

Chapter 3 Measures to Reduce Poverty[24]

3.1 Introduction

In the previous chapter it was argued that since rural poverty in Ethiopia is partly driven by external constraints that are associated with externalities and market failure, government interventions to nullify the adverse effect of these factors were justified both on the ground of equity and efficiency.

In the Ethiopian context, since the poor live and work in the agricultural sector, a strategy to significantly reduce poverty must focus on generating rapid growth of the agriculture sector, which suggests that government intervention would be most effective if it directly addresses the growth constraints of the farm sector[25]. In this chapter, an attempt will be made to show how government expenditure on expanding the road network could address some of the growth constraints and help achieve faster reduction in rural poverty.

[24] Although currently poverty is understood in its multidimensional aspect, for the purpose of this thesis, the traditional definition of poverty will be retained. As a result, a reduction in poverty is assumed to be achieved through addressing growth constraints as well as enhancing the capacity of the poor to participate in the process of growth (Osmani, 2000; Fields, 1989; World Bank, 1990; Majid, 2004).

[25] The agriculture sector accounts for 50% of GDP; employs about 85% of the labour force; and accounts for 90% of total foreign exchange earning. In terms of household income, 72% of the rural income and 48% of the urban income depend on the agriculture sector. Moreover, given that the elasticity of poverty to agriculture growth is 0.72, the rate of reduction in urban poverty is also significantly influenced by the growth rate of the sector (Tafesse, 2003; MEDAC, 1999; MoFED, 2002b).

3.2 Road Infrastructure and Rural Poverty

As observed in the previous section, high transaction cost and risks associated with remoteness are critical determinants of rural poverty. Since expanding rural road access significantly reduces the level of transaction cost and market risks, such an intervention is expected to have a significant impact on rural poverty (Escobal and Ponce, 2002). It not only reduces transaction cost, but also alters other growth constraints, such as narrow and segmented markets, low factor productivity, inefficient cropping pattern as well as risks associated with the application of new technologies.

A number of empirical studies have been undertaken to substantiate if there is a significant link between the incidence of rural poverty and road infrastructure (Khandker, et al, 2006; Fan, et al, 2000; Warr, 2005). For example Warr (2005) attributed 13% of the decline in rural poverty in Laos People Democratic Republic to the improvement of road infrastructure. Khandker, et al, (2006) and Fan, et al (1999) also reported a significant link between government expenditure on rural roads and the rate of rural poverty reduction. Studies that have been undertaken on Ethiopia also reported similar findings (Bigsten, *et al*, 2003; Dercon and Krishnan, 1998;

Dercon, 1994, 2001). However, most of the existing studies, especially those that have been implemented on Ethiopia, fail to identify the mechanisms or show empirically how lack of adequate access to road infrastructure translates itself into high incidence of rural poverty.

In empirically establishing the causal link between road infrastructure and poverty, the existing studies also used different methodological approaches. Some studies adopted simultaneous equations models in order to capture the direct and indirect impact of roads on rural poverty (Fan, et al, 1999; Ahmed and Hossain, 1990). Others postulated linear models and regressed the indicator of poverty on road infrastructure and other covariates of poverty (Warr, 2005). Similarly, other studies measured the impact of road infrastructure on poverty through comparing the with and without intervention scenarios using the propensity score matching and difference-in-difference techniques (van de Walle and Cratty, 2004; Escobal and Ponence, 2002).

In order to empirically establish the link between road infrastructure and rural income/poverty as well as the mechanisms by which the effect of road on poverty works, this research will use reduced form econometric models (Ahmed and Hossein, 1990; Gibson and Rozelle, 2003; Minten 1999). The use of reduced form equations is mainly driven by data problems.

For example, the use of the propensity score matching technique normally requires finding a control group that have similar characteristics with the treated villages other than their road access conditions. Using the geographical characteristics of villages with poor road access, which serves as a control group, and villages that have good road access, which are assumed to represent the treated group, the propensity matching scores were estimated. Due to geographical heterogeneity between the two groups, however, there are significant differences in the calculated propensity scores and as a result the effective number of households that can serve as a control group is very small, which renders the benefit measure generated by this approach unreliable (Caliendo and Kopeinig, 2005). Similarly, although the difference-in-difference estimator is the other widely used method to measure the impact of road infrastructure, lack of base line data for the treated as well as control groups rules out the possibility of using such a method (Lokshin and Yemtsov, 2005; Van de Walle and Cratty, 2005).

In the remaining section of this chapter, the various mechanisms by which road infrastructure affects rural poverty will be highlighted. The subsequent chapters will dwell on empirically postulating the link between road and income/poverty as well as the channels by which road infrastructure influences rural income or poverty.

As previously pointed out, since the scope of pushing the land frontier further is very limited, an increase in farm income should come through an increase in farm productivity[26] (Tafesse, 2003). As currently there is a substantial gap between the recommended and the actual levels of fertilizer application, a large share of the increase in farm productivity is also expected to come through increased and efficient application of fertilizer (Mullat, et al, 1997). As fertilizer is labour augmenting and thus shifts the demand for labour, increased application of fertilizer is also expected to boost off-farm earnings of the rural poor. In Ethiopia, a high relative price of fertilizer is one major reason for the low level of fertilizer application. In 2000/2001, while the international market price ratio of Urea and DAP to maize price was about 1.7 and 1.2 respectively, the ratio

[26] Moreover, further agricultural extensification is also rapidly decreasing in the light of continued annual population growth of 2.5 to 3% (World Bank, 2005).

at the farm gate level for the same period was about 6.0 and 9.0 respectively, which makes the use of fertilizer uneconomic (World Bank, 2004). Given that over 72% of the variable marketing cost of fertilizer is accounted by transport cost, expanding road access will reduce the farm gate cost of fertilizer and thus boost farm level fertilizer application (ibid).

The demand for fertilizer is also obviously influenced by the level and volatility of crop prices. Following a fall in farm gate crop prices, fertilizer application in 2002/03 declined by 27% (World Bank, 2004). While this shows a strong elasticity of fertilizer demand to crop prices, it also implies that a substantial increase in fertilizer demand requires an increase in farm gate crop prices and a reduction in their volatility. Due to the low degree of urbanization and the low level of urban income, in the short to medium term, an increase in farm gate price is expected to come through improved inter-regional trade flows and through re-channelling some of the production for export [27](Diao and Pratt, 2007; Tafesse, 2003). Since high transfer cost is the principal factor that limits inter-regional trade flow and discourages the export of potentially exportable crops, expanding road

[27] Due to low degree of urbanization and low level of urban income.

infrastructure, which reduces the transfer cost, is expected to have a significant impact on rural poverty (Gabre-Madhin and Mezgebou, 2006).

A shift in cropping pattern from cereals to high value export crops is also the other potential avenue to reduce rural poverty. A 1% increase in potentially exportable crops is estimated to reduce the number of people in absolute poverty by 4% (World Bank 2005). However, high transaction cost makes it more rational for farmers to produce food crops than export crops that generate a higher return. For example, despite the high quality of Ethiopian oilseeds and pulses in international market, i.e. for their flavour and nutritional value (because they are mostly produced organically), the regions that have favourable agro-ecological conditions for the production of these exportable crops have been devoting a larger share of their land resources to the production of low value food crops[28] (CSA, 2006/07). This suggests that reducing the magnitude of transaction cost, such as through expenditure on road infrastructure, could enhance the incentive to shift the cropping pattern towards high value crops.

[28] Similarly, while Harar coffee with mocha flavour is among the high value coffee varieties in the world market, to a limited extent, the area devoted to its production is on a decline (Dercon and Ayalew, 1996).

Although labour is the most important asset the rural poor possess, as previously mentioned, its marginal contribution to rural income is quite low mainly due to low land-labour ratio and limited off-farm employment opportunity. As the scope for increasing the average land holding is limited, increasing the contribution of labour to household income should come through engaging the existing labour in non-farm employment, or fostering labour mobility out of agriculture or through increasing on-farm labour productivity. The option of rural-urban migration however is not feasible due to the low level of urbanization and the low degree of industrial development. Therefore an effective utilization of the existing labour resource will depend on the growth of the rural non-farm sector and farm productivity (Tafesse, 2003). Since the growth of the rural non-farm sector to a larger extent depends on farm productivity, an effective use of labour resources will ultimately be linked to the increase in farm productivity, which among other factors is expected to come through increased application of fertilizer. Moreover, as export crops are more labour intensive and generate five times more jobs per hectare than cereals, the shift in cropping pattern towards exportable crops will also expand rural employment opportunities and hence increase the return to labour (Diao and Pratt, 2007). Expenditure on road infrastructure, through promoting fertilizer application and encouraging the production of labour intensive exportable crops, will have a significant impact on rural wage income (World Bank, 2007).

Due to the fact that rural poverty is highly correlated with rainfall shocks and water availability, it is clear that investment in small scale irrigation will have a huge impact on poverty reduction (Diao and Pratt, 2007). Currently, although the yield gap between irrigated and rain-fed farms is estimated to be 40%, only 2% of the total crop area is under irrigation (ibid). Increasing the area under irrigation contributes to poverty reduction through increasing yield, increasing the effective area cultivated, enhancing the use of fertilizer and high yielding seeds and generating higher and more stable labour demand, which has an impact on rural employment and wages, and enables farmers to switch from subsistence towards a market oriented production pattern or specialization (Hanjra, et al 2009). The impact of irrigation on poverty through reducing inter-temporal and seasonal variation in output, employment and prices is also substantial. Irrigation also reduces the risk-averse behaviour of farm households and encourages them to grow commercial crops that generate a higher return than drought resistant but low return cereals (Ellis, 1993).

The sustainability of the poverty reducing impact of irrigation however among other factors depends on adequate market access. Adequate market access, which road infrastructure is expected to bring about, enhances the anti-poverty impact of irrigation through facilitating access to complementary inputs and also through reducing the price depressing effect of irrigation, i.e. because irrigation shifts supply (ibid).

As rural poverty is strongly correlated with the level and volatility of crop prices, addressing factors that have contributed to low farm gate crop prices and a high degree of price volatility will be critical in achieving a substantial reduction in rural poverty. High transaction cost, through making domestic agricultural markets thin and segmented as well as limiting the spatial flow of agricultural products, widens spatial price gaps and increases their volatility (Gabre-Madhin and Mezgebou, 2006). Expanding road infrastructure, through reducing transaction cost, enhancing the spatial integration of markets and forestalling the risk averse behaviour of farm households, will also significantly reduce rural poverty[29] (Faftchamps and Gavian, 1996). In integrated markets, as shocks are shared among different locations, the local harvest situation exerts less influence on local prices and as a result local prices tend to be more stable and farm households are less likely to be less risk-averse (Fackler, 1996). Similarly, by relieving localized gluts, market integration increases the incentive to adopt fertilizer, as increased application of such inputs shifts supply and causes crop prices to fall (Barrett, 1996). The role of well integrated spatial markets in fostering optimal allocation of spatial resources is also substantial (Negassa, et al. 2004).

Similarly, although Ethiopia has a huge livestock asset, due to low level of modern technology application, livestock productivity is extremely low. High transaction cost in dairy production and marketing is identified as the primary reason for the low level of modern technology application (Staal, et al 1997). High transaction cost not only reduces per-capita output of dairy products, but also makes diary imports more attractive; and as a result, despite huge livestock resources, per-capita dairy import of Ethiopia is relatively high (ibid). This suggests that expanding the road network could have an important impact on poverty through reducing

[29] Net sellers in deficit markets are however expected to benefit from road induced productivity growth, i.e. increased yield per hectare. The food deficit households are also expected to benefit from road induced growth of off-farm employment opportunities.

transaction cost in livestock marketing and facilitating access to modern technology and expanding rural employment opportunities.

Although the number of micro-level studies implemented on Ethiopia are very few, studies implemented in developing countries have substantiated the effect of road infrastructure on rural poverty through increasing efficiency (Von Oppen, et al 1997), increasing agricultural productivity (Stifel, et al, 2003), increasing wage rate and crop prices (Escobal and Ponce, 2002; Lanjouw, 1998); promoting fertilizer use (Demeke, et al, 1997) and altering decisions on land use and crop choice (Omamo 1998; Obare, et al 2003). For example, Omamo (1998) notes that the seemingly inefficient cropping choice is a rational response to higher transport cost that households may be required to pay in order to specialize in cash crop production. A reduction in transport cost, which makes food import substitution less attractive, was estimated to raise farm profits by at least one-third by growing a cash crop (cotton) rather than food crops (maize and sorghum). Jayne (1994) and Fafchamps and Shilpi (2003) also reported similar observations for semi-arid areas of Africa and Edmonds (2002) on Asia[30].

Currently, despite the fact that a sizable amount of resources has been allocated to expand road infrastructure, little work has been done to assess the micro level impact of roads. Those micro level studies that are implemented on Ethiopia while mostly using either poverty index or consumption level, reported a significant negative link between road development and poverty (Dercon and Krishnan 1998; Dercon, et al, 2007). These studies, however, as argued previously, are expected to understate the poverty impact of roads because they either use consumption or head count poverty index, which road infrastructure may not directly influence. Moreover, these studies did not empirically substantiate the channels through which the effect of road on poverty operates.

Although based on macro data, another study was implemented on Ethiopia (Agenor, et al, 2004). The major drawback of the macro-level study is that although it could tell the effect of road infrastructure on growth, it fails to provide information about the distributional impact of

[30] It is also argued that such micro-level sub-optimal crop choice will have important macro-level implications by skewing the cropping pattern away from comparative advantage (foreign exchange generation) and agricultural growth.

such investment, particularly on the poor. It is also silent about the impact of roads on relative prices, which is a key determinant of welfare. Thus, if the interest is how public investment benefits a certain group of society, micro level study is generally claimed more appropriate, although such studies still belittle the productivity of road as they inherently fail to capture the externalities generated by roads, for which macro level studies are comparatively better.

3.3. Conclusion

Given that most of the constraints that hamper rural income growth are associated with high transaction cost, a substantial reduction in rural poverty can be achieved through expanding rural road infrastructure. Such interventions will reduce rural poverty through promoting fertilizer application, through improving farm gate prices, reducing market risk, altering the existing cropping pattern and enhancing the poverty effectiveness of other interventions.

The poor also benefit from road expansion irrespective of whether they are net sellers or net buyers of food crops. As net buyers of food crops, they benefit from road infrastructure expansion as such an intervention reduces the cost of food, raises the market wage rate of labour and reduces the cost of fertilizer, thereby allowing them to produce more from their land. However, net food buyer households that reside in surplus producing locations could lose as roads tend to raise local prices, although they benefit from road induced productivity growth and improved market wage rate. Net sellers will gain from road induced productivity growth as well as through improved farm gate prices. The positive welfare effect of road through reducing price volatility will also be substantial.

The remaining sections of the research will focus on empirically substantiating the link between road and rural income/poverty as well as the mechanism through which the effect of road on rural income/poverty is felt. Although the effect of road on poverty works through many channels, mainly governed by data availability, the research assumed crop prices, rural wage and farm efficiency as the main channels through which the effect of road on income or poverty works.

Chapter 4 Road Infrastructure and Income

4.1. Introduction

In Ethiopia, while rapid agricultural sector growth is central to achieve a substantial reduction in rural poverty, it is envisaged to come through an improvement in the market return to relatively abundant resources (mainly labour), a change in the quality of inputs used and a shift in resource allocation (MoFED, 2002). The viability and sustainability of such shifts however, will depend on whether or not farm households have adequate market access. In a segmented and thin market environment even a modest growth in agricultural productivity could not be sustained as it ends up depressing the market prices and farm income that increased productivity is meant to bring about (World Bank 2004). A well integrated agricultural market also reduces spatial price divergence and thereby improves returns to immobile factors (Faftchamps and Gavian, 1996). In integrated markets, as shocks are shared among different locations, the local harvest situation exerts less influence on local prices; and as a result local prices tend to be more stable (Fackler, 1996). Similarly, well-integrated agricultural markets are also keys in stimulating adoption of improved production technologies (Barrett, 1996). The role of well integrated spatial markets in fostering fuller utilization and optimal allocation of spatial resources is also well acknowledged (Negassa, et al. 2004).

Among key structural factors that influence the degree of spatial market integration, mainly through its effect on transport cost, the speed of arbitrage and information flows and the density and quality of the road infrastructure are important[31] (Minten, 1999). In this chapter, an attempt will be made to empirically substantiate how providing adequate rural road access is effective in boosting farm income. The chapter also attempts to decompose whether the effect of road access on income is due to road induced overall productivity growth, higher rate of return, higher resource endowment or the interaction effect of these factors. Such issues are especially important as they provide information about additional measures that should be taken to enhance the development effectiveness of road.

In empirically establishing the link between road infrastructure and farm income, based on a spatial equilibrium framework, a net revenue function will be specified. In order to decompose the effect of roads on income, the

[31] Through its influence on these variables, it shifts the demand (supply) curve confronting local producers (consumers), and ultimately influences the volume of trade flows, the level and stability of spatial equilibrium prices (Badiane and Shively, 1998).

Blinder-Oaxaca decomposition technique will be used. In controlling the potential reverse causation that runs from income to road infrastructure, the net revenue function will be estimated on the basis of the Hausman and Taylor (1981) instrumental variable method. In order to determine whether the poor benefit from roads, the net income model will be estimated on the basis of quantile regression.

The remaining chapter is structured as follows. First, after a general definition of infrastructure, the literature on the link between road access and income both at macro and micro level will be briefly reviewed. Next, the conceptual framework that guides the empirical part will be highlighted. Following that, after the theoretical and empirical models are specified, the estimation strategy will be outlined. Finally, after a brief discussion of the empirical result, the chapter concludes.

4.2 Literature Review

4.2.1 Infrastructure and Growth

Infrastructure has always been recognized as a precondition for development[32]. According to Emmanuel (1995), it is defined as "The foundation on which the factors of production interact to produce output and services" (p.2774). Similarly, Hirschman (1958) considered infrastructure as services without which primary, secondary and tertiary production activities cannot function. Infrastructure is also claimed to include all public services from law and order through education and public health to transportation, communication, power, water supply, as well as agricultural overhead capital as irrigation and drainage systems (ibid. p. 83).

Although there are diverse services under infrastructure, they share common traits, in that they are mostly non-tradable, and are characterized by economies of scale (Emmanuel, 1995). Moreover, although they influence consumption as well as production, their influence on production is usually indirect through increasing total factor productivity,

[32] According to the Merriam-Webster Online Dictionary, infrastructure is defined as "the underlying foundation or basic framework (as of a system or organization)"

reducing costs, facilitating market transactions and promoting economies of scale[33] (Guild, 1998).

The growth-enhancing role of transport infrastructure has also been recognized long ago. According to Adam Smith, transport cost through limiting the size of the market and hence the extent of division of labour, acts as a major conditioning factor for growth to occur (Myint, 1977). Although less visible, the role of transport infrastructure has also been highlighted in subsequent growth theories. According to neoclassical growth theory, transport infrastructure contributes to growth through facilitating the accumulation of factors of production, increasing the supply of productive inputs and raising resource allocation efficiency (Guild, 1998). Under the Keynesian framework, the growth impact of infrastructure mainly comes through its effect on raising aggregate demand; and the productivity enhancing role of infrastructure is not much emphasized (Nourzad, 2000). In the context of endogenous growth theory, while growth is claimed to come through the accumulation of capital and

[33] The non-rival, non-excludability, and externality characteristics of these services have been the major justification for public policy as well as public provision or financing of these services (Emmanuel, 1995). However, currently there are debates, as to how much and what type of infrastructure services should be publicly provided, what is the appropriate balance between public and private provision, and if publicly provided, how should it be financed (ibid).

knowledge, transport infrastructure contributes to growth indirectly by enabling firms to make an optimal choice of firm location, technology, scale of production, through expanding market size and increasing the incentive for innovation (Guild, 1998; Barro 1990).

In order to substantiate the theoretical link between transport infrastructure and growth, a number of empirical studies have been implemented on the basis of macro and sector level data, and on single and cross-country cases and also employing different functional forms (Calderon and Serven, 2004). Although the consensus is a robust positive link between infrastructure and growth; the evidence remains ambiguous as to whether a significant positive correlation indicates that infrastructure raises growth or vice-versa (Guild, 1998). Moreover, from existing studies, it is hardly possible to draw clear policy conclusions as to what type of infrastructure interventions is most productive. Furthermore, most of the existing studies only considered infrastructure as a direct factor input in the production function, which, it is argued, understates the productivity of roads, as such a specification leaves out the effect of a road on altering the spatial allocation of resources (Jiang, 2001).

From the existing empirical studies it emerges that infrastructure in general and road infrastructure in particular raise growth by raising productivity, crowding-in private investment, reducing costs, raising the marginal productivity of private capital, enlarging opportunities and altering private sector input demand (ibid). Similarly, sector level studies noted that the impact of transport infrastructure on agricultural sector growth operates through enlarging market opportunities, increasing input availability, lowering cost of production, and increasing the availability of "incentive goods" (Creightney, 1993; Ahmed and Hossein, 1990).

4.2.2 Road Infrastructure and Micro level Income

In a rural setting, the impact of road infrastructure on micro level farm income is argued to work through enhancing a competitive price forming market environment, expanding market size and reducing the magnitude of transaction and transport cost (Shirar, 2005). Through such mechanisms, road infrastructure first affects the level of farm gate prices for output, inputs and factors and subsequently alters farm households' various micro level decisions, namely what to produce (the choice of the cropping pattern), how to produce (input use pattern in general and adoption of new techniques in particular), how much to produce, how much to sell and where to sell (Escobal and Ponce, 2002). These decisions in turn, through their effect on overall resource efficiency ultimately determine the level of income that can be generated from land and labour (Omamo 1998).

In empirically substantiating the micro impact of road infrastructure, a number of empirical studies have been implemented (Ahmed and Hossein, 1990; Gibson and Rozelle, 2003). While some of these studies assessed the effect of roads on income directly, others attempted to capture the link between the two indirectly, i.e., through the impact of roads on market prices, technology adoption, productivity and micro level resource allocation decisions (Minten 1999; Stifel, et al, 2003; Von Open, et al, 1997). In terms of the modelling approach followed, most of the existing empirical studies used reduced form and structural equation models (Obare, et al, 2003; Binswanger, et al, 1993). Some studies however, while assuming that the welfare effect of roads mainly works through its effect on transaction costs, first estimated the magnitude of transaction costs that households face in input and output markets; and at the second stage, they regressed the estimated transaction cost on the proxy of road infrastructure variable (Escobal, 2002). Others also estimated the welfare effect of roads by comparing an intervention scenario with a hypothetical (non-intervention) scenario (Escobal and Ponce, 2002). In such studies, as it is impossible to simultaneously observe individuals in intervention and non-intervention states, they used the propensity score matching technique.

Among the above empirical approaches, the use of the transaction cost method is expected to understate the productivity of roads as it fails to capture the dynamic impacts of roads that work through enhancing competition, fostering fuller utilization of resources and specialization. Similarly, as noted in the previous chapter, due to geographic heterogeneity between the control and treated households, the magnitude of impact generated using this approach tends to be unreliable.

This research therefore will rely on econometric techniques to measure the impact of road on farm income. Compared to the other approaches, although a reduced form specification is argued to be better in capturing the various channels through which roads affect income, the studies that are implemented on the basis of a production function specification are likely to suffer from similar limitations as such a specification does not capture the effect of roads on income that works through altering the input use pattern and crop choice (Haughwout 1998).

In order to address some of the limitations of the production function specification, some empirical studies postulated a cost and profit function (Mamatzakis, 2003; Evenson, 1986). Such specifications have several advantages over the production function framework but come at a cost. Apart from their considerable information requirement, such as price data availability and variability, the behavioural assumptions on which they are based may not be always satisfied. Moreover, the exogeneity of market prices under the dual functional specifications is still questionable as local market prices endogenously adjust to the stock of local road infrastructure (Costa, 1998; Haughwout 1998, 2002). To the extent that this is the case, dual functional form specifications could still understate the productivity of roads (Haughwout 1998).

With the intention of addressing some of the conceptual and data related limitations of the cost and profit function, some empirical studies used a net revenue functional form (Dercon, 2002; Anrequez and Valdes, 2006). Although this specification may address some of the limitations of the cost and profit functions, as it is still based on the exogeneity of prices, it still generates biased parameter estimates. However, if such a function form is specified in a spatial equilibrium framework and estimated on the basis of a reduced form specification, the problem of price exogeneity may partly be circumvented (Costa, 1998; Haughwout 1998, 2002).

For our purpose here, while a linear net revenue functional form will be postulated, it is to be postulated on the basis of a spatial equilibrium framework (Anrequez and Valdes, 2006). The use of a spatial equilibrium model enables better capture of the dynamic impact of roads on income as in such models income, prices, employment and input demand are a function of the stock of infrastructure and vary in response to change in the stock of local infrastructure (Costa, 1998; Haughwout 1998, 2002).

4.3 Conceptual Framework

The link between roads and income is mediated by household and village characteristics. In order to isolate the income effect of roads from other factors, identifying the key intervening variables and removing their independent impact on farm income will be essential. In order to do that, a comprehensive rural household model is generally preferred. However, this was not possible due to data limitations and partly due to the fact that the existing household models do not lead to consistent specification of the presumed link between road and income. Therefore, while guided by a household model, a reduced form equation that describes the relationship between farm income and its various determinants will be postulated, where road infrastructure is introduced as one explanatory variable of the model. In order to postulate the link between road and farm income, theoretically guided by the willingness to pay approach, farm households' demand for road infrastructure will be specified (Jacoby and Minten, 2009).

In the light of this, it is assumed that the main objective of the farm households is to maximize the utility function (U) defined by net revenue (M) and leisure (l). The income of the household comes from crop production and off-farm employment. 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* units are used on the family farm, N units are hired out for off-farm employment and the remaining time is consumed as leisure (*l*). Family and hired labour are perfect substitutes.

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 is $P_f^x = P_M^x - \tau_j$, where P_M^x is the price of the crop at the main market.

Similarly, while fertilizer is the only input that is imported from town, the effective price a household pays for the fertilizer input will be $\hat{\beta}_j = \omega + \tau_j$, where ω is the market price of fertilizer at the source of supply. Off-farm employment is rationed at the on-going market wage rate (*w*). In order to avoid complication, while the market wage rate is assumed to be unaffected by the level of transport cost, the available off-farm employment opportunity is affected by the magnitude of transport cost.

The household utility maximization problem can therefore be set up as:

$$Max \quad U(M, l) \tag{4.1}$$

Subject to:

$$M = P_f Q + wN - \alpha F \text{ (income constraint assuming labour market constraint)} \tag{4.2}$$

$$Q = f(K, L, F, Z) \text{ (production technology constraint)} \tag{4.3}$$

$$T = l + L + N \qquad \text{(time constraint assuming labour market constraint)} \tag{4.4}$$

$$N < H \qquad \text{(Labour Market constraints)} \tag{4.5}$$

The household's maximization problem can be re-written in the following Lagrangian form (£):

$$\text{Max } £ = U[M, l] + \lambda[P_f f(K, L, F, Z) + wN - \alpha F - M] + \mu_1(T - L - N - l) + \mu_2(H - N) \tag{4.6}$$

The choice variables for the household are, the level of net-income (M), the total labour time consumed as leisure (*l*), the number of hours worked on own farm (L), the number of hours worked off-farm (N) and the level of fertilizer used (F) for which the first order conditions respectively are

$$U_M = \lambda \tag{4.7}$$

$$U_l = \mu_1 \tag{4.8}$$

$$P_f f_L = \frac{\mu_1}{\lambda} \qquad \left(where \quad f_L = \frac{\partial f}{\partial L} \right) \tag{4.9}$$

$$P_f f_F = \alpha \qquad \left(where \quad f_F = \frac{\partial f}{\partial F} \right) \tag{4.10}$$

$$\frac{\mu_1 + \mu_2}{\lambda} = w \tag{4.11}$$

$$M = P_f f(K, L, F, Z) + wN - \alpha F \tag{4.12}$$

$$T - L - N - l = 0 \tag{4.13}$$

$$H - N = 0 \tag{4.14}$$

In the first order condition, if the labour market is not binding, $\mu_2 = 0$ and the shadow price of labour will be equal to the market wage rate, i.e.,$\left(\frac{\mu_1}{\lambda} = w \right)$. However, if the labour market constraint is binding$(\mu_2 \neq 0)$, the shadow wage rate will be lower than the market wage rate$\left(\frac{\mu_1}{\lambda} < w \right)$.

From the above first order condition, the equilibrium level of the choice variables will be:

$$M^* = P_f f(K, L^*, F^*, Z) + wN^* - \alpha F^* \tag{4.15}$$

$$L^* = f(P_f, \alpha, w, K, T, Z, H) \tag{4.16}$$

$$N^* = f(P_f, \alpha, w, K, T, Z, H) \tag{4.17}$$

$$F^* = f\left(P_f, \alpha, w, K, T, Z, H\right) \tag{4.18}$$

Since our interest here is to what extent a change in transport cost, which comes through improvement in road infrastructure, affects the net income position of the household, equation (4.15) can be totally differentiated with respect to the transport cost (τ), which becomes:

$$\frac{dM}{d\tau} = f(\bullet)\frac{\partial P_f}{\partial \tau} + \left(P_f\, f_F - \alpha\right)\frac{\partial F}{\partial \tau} - F\,\frac{\partial \alpha}{\partial \tau} + w\frac{\partial N}{\partial \tau} \tag{4.19}$$

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

From equation (4.19), it is clear that a change in transport cost affects the household net income position through its influence on output price, the level of fertilizer demand, the cost of fertilizer and the number of household members that can be engaged in off-farm employment. Depending on the position of the household in crop market, a reduction in transport cost affects farm income through improving farm gate crop prices. Assuming that fertilizer is the next best available technology and also given that the marginal value productivity of fertilizer is greater than its price, the reduction in transport cost increases household income through increasing the profitability, the application of fertilizer and thus the technical efficiency of the household's farm. As fertilizer input is sub-optimally applied in the sample, a substantial share of road induced rural income growth is expected to come through higher application of fertilizer. Households that have already been applying fertilizer are also expected to gain from road improvement in the form of a reduction in the price of fertilizer. The last term captures the income effect of transport cost reduction that comes through road induced expansion in off-farm employment opportunities.

Although not explicitly modelled, through the price mechanism, a reduction in transport cost also alters the crop mix households cultivate and thus the level of income they generate per hectare of land they cultivate. Lower transport cost boosts households' income by allowing them specialize in crops that they have comparative advantage (Omamo, 1998). In general, from equation (4.19), assuming zero income effect of leisure consumption, the reduction in transport cost rotates the budget constraints and thereby allows households attain higher level of utility.

In order to empirically measure the implied income benefit of a change in transport cost, following Jacoby and Minten (2009), either the equivalent or compensating variation approach can be used[34]. Assuming that either method generates similar benefit level or the measured benefit level will not be influenced by the approach followed, for the purpose here, the compensating variation approach will be followed.

[34] In the former approach, the income benefit of a change in transport cost is measured in terms of the level of income that would have to be taken from the household to leave it as well off as it would be after a change in transport cost. In the latter approach, the income benefit of the transport cost is measured in terms of the additional income required to bring back the household to the utility level it has attained before a change in transport cost.

Accordingly, let $\mu(\tau, K, T, Z)$ represent the additional income level that would make the household that resides in villages with good road access indifferent to the market situations prevailing in villages with poor road access, given its household specific endowments. The level of compensation required depends on the level of the transport cost, the level of household endowments and other geographical characteristics. Given the indirect objective function $V[(P_f, \alpha \ , w, T, K, Z)]$, at equilibrium, the level of compensation should be at least equal to the additional revenue the household will forgo due to the market prices it faces in villages with poor road access. This can be implicitly defined as:

$$V[(P_f^D, \alpha^D, w^D, T, K, Z) + \mu(\tau, T, K, Z)] \equiv V[(P_f^A, \alpha^A, w^A, T, K, Z)] \qquad (4.20)$$

Where the superscripts D and A respectively represent the market prices that prevail in villages with dry and all weather road access.

On the basis of the envelope theorem[35] and differentiating equation (4.20) with respect to transport cost (τ), it becomes

$$\frac{\partial V}{\partial \tau} \equiv \mu_\tau(\tau, K, T, Z) - Q - F \equiv 0 \qquad (4.21)$$

Letting $T(\tau) = Q + F$ and rearranging the terms, it becomes

[35] The theorem states that the partial derivative of the indirect objective function, which is the optimum level of the objective function given the constraints, with respect to the parameter, in this case the transport cost, equals the partial derivative of the direct objective function, which is the net income model that does not take into account the constraints, with respect to the same parameter evaluated at the optimum. The theorem provides a much more direct method of finding the effect of changes in parameters on the objective function (Toumanoff and Nourzad, 1994).

$$\mu_{\tau}(\tau, HH, GC) = T(\tau) \qquad (4.22)$$

As argued by Jacoby and Minten (2009), $T(\tau)$ resembles the composite commodity theorem where a group of commodities that have constant relative prices can be treated as a single commodity, and when applied to the present case, the term can be considered to represent the demand for freight transport while τ is acting as a price. The demand for transport service in this case constitutes transporting crop output (Q) and fertilizer input (F). The higher the transport cost, the lower the demand for transporting the crop to high price fetching distant markets and hence the household will receive a lower price for the crops it supplies. Similarly, the higher the transport cost, the lower the transport demand to transport fertilizer from sources of supply to the farm and hence the household either applies a lower quantity of fertilizer or pays a higher price, which in both cases will affect the net income position of the household .

As argued by Jacobi and Minten (2008), equation (4.22) represents a partial differential equation in μ and integrating both sides at the average transport cost level that prevails under poor and good road conditions, the benefit of transport cost reduction due to road improvement becomes

$$\mu\left(\tau_1, HH, GC\right) = \int_0^1 T(\tau)\, d\tau \tag{4.23}$$

In this case, the transport demand function is integrated at 0, which represents the average transport cost households incur in villages with good road access, and at 1, which represents the average transport cost farm households incur in villages with poor road access. As the objective is to generate the average benefit of road improvement on the farm households' net income level, equation (4.23) becomes:

$$E\left[\mu\left(\tau_1\right)\right] = \int_0^1 T(\tau)\, d\tau \tag{4.24}$$

Although a reduction in transport cost will not significantly influence the market wage rate, say due to the assumption of infinitely elastic labour supply, the change in transport cost will expand employment opportunity and hence off-farm income mainly through shifting the demand for labour. In order to accommodate that, following Jacoby and Minten (2009), the difference in the average off-farm income earned in villages with good [e(0)] and poor road access [e(1)] can be added onto equation (4.24) and hence it becomes

$$E\left[\mu\left(\tau_1\right)\right] = \int_0^1 T(\tau)\, d\tau + E\left[e(0)\right] - E\left[e(1)\right] \tag{4.25}$$

Equation (4.25) serves as the theoretical model on which the empirical part is based. As mentioned above, since we have no actual data on transport cost for each type of road access, the road quality dummy (i.e., whether or not the road allows good access to both passenger and freight transport at all seasons) will be used while empirically estimating the net revenue model[36]. The dummy that represents the road quality in the net revenue model is assumed to approximate the benefit level implied by equation (4.25).

[36]The econometric model is assumed to represent the indirect objective function because the coefficient estimates are generated in such a way that the squared residual term is at its minimum or the net revenue function is at its maximum. Based on Shephard's lemma, differentiating the net revenue function with respect to the transport cost gives the volume of transport demand. When this is integrated at two different level of transport cost, it gives the benefit of improving road on net income.

4.4 Empirical Model Specification

Considering only income from crop production and off-farm employment, the reduced form of the net-revenue function of farm households can be re-specified as:

$$M_{hjt} = f\left(P_{fjt}, w_{jt}, \alpha_{jt}, K_{hjt}, T_{hjt}, Z\right) \tag{4.26}$$

Where h represents household, j village, t time and the remaining variables as defined before.

Assuming that the local goods and factor markets are integrated with other spatial markets, spatial equilibrium requires that households cannot get excess net revenue because of their locations (Haughwout 1998, 2002). As a result, the zero-profit spatial equilibrium condition for households in village *j* will be:

$$C_{ij}(N_{ij}, K_{ij}, Z_{ij}, w_{jt}, \alpha_{jt}) = P_{fijt} \equiv P^{x}_{mit}\left(1-\tau\right) \tag{4.27}$$

Where i, j and t respectively represent the type of crop, village and time; C is the marginal cost of crop production in village j; P_m is the *crop price at the main market and* τ *is the magnitude of transfer cost traders would incur to move crops and fertilizer across spatial markets.*

Equation (4.27) states that at equilibrium the marginal cost of crop production at the surplus (deficit) market should equal the terminal market price less (plus) the transfer cost that traders incur in transporting the crop between markets. In a reduced form, this implies that in addition to local demand and production conditions, the local equilibrium price is a function of the price level of similar crops at the terminal market as well as the level of transfer cost. Following other empirical studies, the magnitude of transfer cost *(τ)* is assumed to be a function of the quality of road infrastructure *(Rd)* and the distance of the village market from the main market *(Dm)* (McGregor, 1999). Following similar reasoning for fertilizer price, but assuming that local wage formation is more influenced by local conditions, the local market equilibrium prices for crops, labour and fertilizer become endogenous.

Since the sampled villages are assumed to be price takers both in goods and factor markets, P_m^x and ω are exogenous to the villages. The extent to which local equilibrium prices vary in response to change in these spatial market prices, as argued previously, depend on the magnitude of transfer cost (McGregor, 1999; Minten and Kyle, 1999, Minten, 1999). Finally, since the local equilibrium prices are a function of local production conditions and quality of road infrastructure and also since these determinants are already included in the production function, the reduced form of equation (4.26) becomes:

$$M_{hjt} = f\left(P_{Mit}, w_{jt}, \omega_{jt}, RD_{jt}, DM_{j}, K_{hjt}, T_{hjt}, Z_{hjt}\right) \qquad (4.28)$$

In equation (4.28), the road variable captures the combined effect of road on net income that works through shifting the production function, enhancing fuller and efficient utilization of resources and altering farm gate prices for goods and factors (Mamatzakis, 1999). The sensitivity of net revenue to changes in spatial market prices, however, as argued previously, depends on whether the price difference between the village market and the terminal markets is greater or less than the transfer cost. The better the road infrastructure of the village or the closer of the village to the main market, the lower the transaction cost and hence the higher the sensitivity of net revenue to changes in spatial market prices[37] (Minten, 1999). Since the link between net revenue and spatial prices is conditioned by the distance and road quality of the village, the spatial market prices will not be needed (Haughwout, 2002).

Finally, in the context of the present sample, the household specific factors are assumed to include the size and quality of land holding, the number of adult family members[38] (*Lb*), the number of oxen the household owns (*Ox*), human capital asset of the household (*Ed*), the quantity of fertilizer used

[37] Minten (1999) postulated the local prices as a function of the terminal market price, distance and infrastructure, but when empirically estimating the model, he removed the terminal market assuming that the strength of the link between the two prices is determined by state of infrastructure and distance.
[38] Adult family member refers to those that are 15 years old or above.

(*F*), gender (*G*) and the average age of the household members (*Age*) (Rahman, 2003; Parikh, et al, 1995). To capture the impact of geographical factors on income, km distance of the household from market (*Dm*), the soil quality of the land the household cultivates (*SQ*), the proxy for rain shock (*R*), average temperature (*TE*) and altitude of the village (*El*) will be included as explanatory variables of the model (Limao and Venables, 2001; Escobal and Torero, 2000).

Given that crop production is land and labour intensive, the mechanism by which these private inputs affect household income is obvious and does not warrant further elaboration. Fertilizer input increases households' income through increasing the productivity of land and labour (Fafchamps and Quismbing, 1997). The effect of human capital (*Ed*) on income works by enabling the household to choose a better mix of activities and crops, increasing the likelihood of adopting an optimal application of modern inputs; and by enhancing access to non-farm employment opportunities (Barrett, 1997; Rahman, 2003).

Age composition of the household head may proxy experience and also influence income through its impact on risk preference and resource allocation (Parikh, et al, 1995). The gender of the household head influences income through shaping the risk preference and resource allocation behaviour of the household (ibid). The impact of geographical factors on rural income works through inflating transport cost, increasing health risk and reducing land and labour productivity (Gallup and Sachs, 1998; Evans and Harrigan, 2005; Leamer and Levinsohn, 1995; Disdier and Head, 2003).

The crop revenue that farmers generate comes from a number of crops, which ranges from a minimum of 1 crop to a maximum of 8 crops. Two identical households that cultivate different types of crops could generate different levels of income per unit of land and labour employed. In order to control the effect of cropping pattern on revenue, the use of crop dummies might be necessary. However, including 8 dummies entails a sizable loss of degree of freedom. In order to avoid that, given that teff is the crop that fetches the highest return; and also the crop that is not uniformly cultivated in all villages, a dummy of 1 is given for households that cultivates teff and zero otherwise. If difference in cropping pattern is a significant contributor for the observed income difference or the level of return per unit of resource employed, the dummy variable will be positive and significant.

After substituting the above variables, the reduced form of the net income function becomes:

$$NR = f\,(Ld, F, Ox, Lb, R, Rd, SQ, Ed, Age, G, Dm, El, T, cropDu) \tag{4.29}$$

Finally, assuming that the production function takes a Cobb-Douglas form, where output has a logarithmic relationship with the quantity of labour, oxen power, age, education level, land, altitude, temperature and road density of the zone, but a semi-log relationship with the other household and geographic characteristics (Meng and Wu, 1994), the empirical model of the net revenue function will become:

$$\ln NR_{ijt} = \alpha_0 + \beta_1 \ln Ld_{ijt} + \beta_2 \ln FR_{ijt} + \beta_3 \ln Ox_{ijt} + \beta_4 \ln Lb_{ijt} + \beta_5 R_{ijt} + \beta_6 Rd_{jt} + \beta_7 SQ_{jt} + \beta_8 \ln Ed_{jt} + \beta_9 \ln Age_{ijt} + \beta_{10} G_{ijt} + \beta_{11} \ln Dm_j + \beta_{12} \ln El_j + \beta_{13} \ln T_{jt} + \beta_{14} CropDu + v_{ijt} + \varepsilon_{ijt} \text{............}(4.30)$$

The empirical result of equation (4.30) provides information about how the household income is determined and how the included factors contribute to household income. But such information does not show how much of the village income differential is attributed to spatial differences in asset holding, how much is due to differences in overall productivity or how much is due to spatial differences in the rate of return to immobile factors

(Meng and Wu, 1994). In order to generate such information, the Blinder-Oaxaca decomposition technique will be employed (Blinder, 1973; Edmonds, 2002; Meng and Wu, 1994; Takahashi, 2007). To do that, equation (4.30) is estimated for the two groups separately. When the Net-Income function is written in a short form, it becomes:

$$\ln Y_{ijt} = \alpha_j + X_{ijt}\beta_{jt} + e_{ijt} \tag{4.31}$$

Where lnYijt represents the log net income of the i-th household in the j-th village at time t, β is the vector of coefficient to be estimated, α *and e are the constant and the random error term, respectively. X is the vector of household and village characteristics that are included as the explanatory variables in equation* (4.31).

According to equation (4.31), across village differences in income can be due to differences in the level of endowments, which are captured by X, or due to differences in village level rate of return, which are captured by β, as well as due to differences in overall productivity, which are captured by α (Meng and Wu, 1994). Since the regression passes through the mean of Y and X, and also since the mean of the random error term is assumed to be zero, the equations for each separate group will become:

For households with Good Road Access (G), the average income level estimated at the mean level of productive factors becomes:

$$\ln \overline{Y}_{Gt} = \hat{\alpha}_{Gt} + \overline{X}_{Gt}\hat{\beta}_{Gt} \tag{4.32}$$

Similarly, for households with Poor Road Access (P), the average income level estimated at the mean levels of productive factors will be:

$$\ln \overline{Y}_{Pt} = \hat{\alpha}_{Pt} + \overline{X}_{Pt}\hat{\beta}_{Pt} \tag{4.33}$$

In order to find the average income differential between the two groups, subtracting equation (4.33) from equation (4.32) yields:

$$\begin{aligned} \ln \overline{Y}_{Gt} - \ln \overline{Y}_{Pt} &= \left(\hat{\alpha}_{Gt} - \hat{\alpha}_{Pt}\right) + \left(\overline{X}_{Gt}\hat{\beta}_{Gt} - \overline{X}_{Pt}\hat{\beta}_{Pt}\right) \\ &= \left(\hat{\alpha}_{Gt} - \hat{\alpha}_{Pt}\right) + \hat{\beta}_{Gt}\left(\overline{X}_{Gt} - \overline{X}_{Pt}\right) + \overline{X}_{Pt}\left(\hat{\beta}_{Gt} - \hat{\beta}_{Pt}\right) \\ &= \left(\hat{\alpha}_{Gt} - \hat{\alpha}_{Pt}\right) + \hat{\beta}_{Pt}\left(\overline{X}_{Gt} - \overline{X}_{Pt}\right) + \overline{X}_{Gt}\left(\hat{\beta}_{Gt} - \hat{\beta}_{Pt}\right) \qquad (4.34) \end{aligned}$$

By taking the average of the last two equalities, the average income differential between the two groups can be re-written as:

$$\ln \overline{Y}_{Gt} - \ln \overline{Y}_{Pt} = \left(\hat{\alpha}_{Gt} - \hat{\alpha}_{Pt}\right) + \left(\frac{\hat{\beta}_{Gt} + \hat{\beta}_{Pt}}{2}\right)\left(\overline{X}_{Gt} - \overline{X}_{Pt}\right) + \left(\frac{\overline{X}_{Gt} + \overline{X}_{Pt}}{2}\right)\left(\hat{\beta}_{Gt} - \hat{\beta}_{Pt}\right) \tag{4.35}$$

The first term in the right hand side measures differences in income attributable to differences in factor productivity or other factors that shift the production or income function, such as the degree of marketization and other location specific externalities; the second term captures the income difference due to differences in private and public capital endowments; and the third term captures the income differences due to locational differences in the rate of return. As argued before, good road access improves farm gate prices, promotes efficient allocation of resources or generally increases total factor productivity. As a result, it is generally expected that those villages that have good road access earn higher rate of return per unit of land and labour employed and thus, either the intercept term or the slope coefficients of villages with good road access should be higher (Takahashi, 2007).

From the above regression results, one may reach a conclusion as to whether roads increase income or not. But from such a result it is hardly possible to draw conclusions as to whether providing better road access increases the income of the poor much faster or narrows down the income disparity between the poor and non-poor. In order to address such issues, the net-income model will be re-estimated on the basis of inter-quantile regression method (Koenker and Hallock, 2001). The model, by grouping the sample into different income quantiles, provides information as to whether the impact of roads differs by income quantile and also whether such differences are statistically significant. The structure of the model will be:

$$Q_{.75}(\ln Y_{ijt}) - Q_{.25}(\ln Y_{ijt}) = (\alpha_{.75} - \alpha_{.25}) + (\beta_{.75} - \beta_{.25})X \qquad (4.36)$$

Where Q is the indicator of the 75 and 25th quantile, Y is the net income of the ith household in village j at time t and X represents a vector of explanatory variables of the net-income model postulated above in which the road access dummy is one.

The model by grouping the sample into the 25th and 75th income quantile generates the coefficient estimates of each explanatory variable for each group. On the basis of bootstrapped standard errors, the model also generates t-statistics on the basis of which whether the differences in the coefficient estimate are significant or not will be judged. For example, if the coefficient of the road dummy in the estimated regression model is significant, it suggests that the impact of roads on income differs by income quantile; and if the sign of the road variable is negative, it implies that road access raises the income of the poor faster than non-poor or has a tendency to narrow down income disparity. The opposite holds if the sign of the road variable is positive. For the purpose here, the inter-quantile model will be estimated by categorizing the sample into the 75th and 25th income quantile.

4.5 Estimation Strategy

Since the model is estimated on the basis of panel data, in order to control for unobserved heterogeneities that could systematically influence the net income of the sample, the use of a fixed or random effect model will be necessary[39] (Holtz-Eakin, 1994). Before postulating either of these models, it is necessary to test the presence of fixed effects in the data. In order to do that a Lagrange multiplier test developed by Breusch and Pagan (1980) was conducted and the test confirmed the presence of fixed effects at 5%. In choosing between the fixed or random effect models, the Hausman (1978) specification test was conducted. The calculated $\chi^2(11)$ test statistics is 96.42 which is far greater than the tabulated critical value of 19.67. This suggests that since the unobserved individual effects are correlated with the explanatory variables of the model, the use of a fixed effect model will be more appropriate[40].

Estimating the net income model using the fixed effect model, however, does not generate the coefficient estimates of time invariant variables

[39] In such type of models, in addition to the noise term, the error structure of the model includes unobserved household, village and time specific components. As these unobserved heterogeneities are correlated with the regressors, estimating the model on the basis of OLS will give inconsistent estimates. It therefore calls for the use of panel data models.

[40] This means the presence of correlation between unobserved effects and the explanatory variable of the model will lead to significant differences in parameter estimates when the net income model is postulated on the basis of either fixed or random effect methods.

(Wooldridge, 2002). Although the random effect model allows the parameter estimation of time invariant variables, as the Hausman specification test showed, due to the presence of correlation between the fixed effects and some of the regressors, the parameter estimates generated by the model will be biased and inconsistent[41] (Dougherty, 2007). Under such a situation, estimating the model on the basis of instrumental variable method becomes necessary.

The other empirical issue that requires further consideration is related to the potential reverse causation that runs from income to road infrastructure. If rich areas attracted higher investment on roads, part of the effect of better environment will be picked up by the road variable. If that is the case, the error term of the net revenue function will be correlated with the road access variable, and this understates or overstates the coefficient of the road variable depending on whether road is over or undersupplied (Canning, 1999). In order to deal with such problems, various approaches have been suggested. One approach is to use a simultaneous equation model while the other approach is to derive an appropriate test in such a way that that the direction of causality is

[41] However, since the error term includes the individual effects and since they make the error terms to be serially correlated, the Random Effect model is estimated on the basis of GLS. Such a procedure transforms the data in such a way that the model yields a modified residual that does not exhibit serial correlation.

clarified (Fernald, 1997; Canning, 1999). The Generalized Method of Moments and the Instrumental variable method are also the other suggested approaches (Demetriades and Mamuneas, 2000).

Although the use of the simultaneous equation approach is the most intuitive way of solving the problem of reverse causality, it cannot be implemented mainly due to lack of region level data on the variables that affect the demand and supply of road infrastructure. Similarly, due to limited time series data (just two years), the error correction model (ECM) cannot be an option (Canning, 1999). Likewise, the GMM estimator, although consistent and efficient, could not be used since the panel data set is only two years (Greene, 2002). Moreover, since the model is estimated on the basis of first differences, it does not generate the parameter estimates of time invariant variables.

Therefore, while the instrumental variable method remains the only feasible option, due to the panel nature of the data, the instrumental variable method proposed by Baltagi (2005) and Hausman and Taylor (1981) can be used. The first instrumental variable approach controls for the correlation between endogenous variables, such as the road quality of the village and the idiosyncratic error term (ε_{ijt}), but it cannot address the correlation between the individual effects (v_{ijt}) and the explanatory variables. On the other hand, the instrumental variable method proposed by Hausman and Taylor (1981), cannot address the correlation between the error term and the explanatory variables, but it handles the problem of correlation between the individual effects and the explanatory variables as well as allows the parameter estimation of time invariant explanatory variables (Greene, 2002). Moreover, the instrumental variable method proposed by Baltagi (2005) requires the need to obtain exogenous instruments that are correlated with the endogenous variables, in this case the road and fertilizer variables, but uncorrelated with the error term of net income model. However, under the latter approach, there is no need to identify exogenous variables that can serve as instruments. Instead, the explanatory variables included in the model, after they pass various tests, are used to estimate their own coefficients and serve as instruments for endogenous variables.

In order to decide which approach to use, the income model was estimated on the basis of both approaches. After some search, the number of crops the household cultivates and the number of livestock it owns were found to satisfy Baltagi's criteria to serve as instruments. The estimation result of the net income model on the basis of both approaches is reported in Table 1 of appendix1. As can be observed from the result, although the road variable coefficient estimate in both models is almost the same, the coefficient estimates of the variables differ.

Moreover, when agro-ecological variables are included in the model, which could pick the productivity potential of a given location, the correlation between the error term and the road access variable may not be strong (Khandker, 1989; Gibson and Rozelle 2003). As claimed by Khandker (1989), the inclusion of variables that capture the agro-climatic endowments of a given location in the model represents a precise quantitative characterization of the agro-climatic potential of the location. This is also supported by empirical evidence from Ethiopia that regional government expenditure on infrastructure is motivated more by poverty considerations than agro-ecological potential (World Bank, 2005). Under this condition, due to its advantage over the Baltegi's instrumental variable approach, the interpretation of the net income model will be based on the model result generated by the Hausman and Taylor estimator.

4.6 Results and Discussion

The result of the net revenue model, which are reported in Table 4.1, showed that out of 14 variables of the model, except for the number of adult family members, the remaining variables are statistically significant at less than 5%.

As a-priori expected, the size and quality of land the household cultivates, the number of oxen it owns, its human capital endowment, the gender of the household head and the average age of the household members are important household specific factors that significantly influence the income level the farm household will generate. The degree of rain shock occurred in the village (in terms of adequacy and timely availability of rainfall), the road quality of the village, the distance from town centre, altitude and temperature are also among the village specific characteristics that significantly influence the level of net income farm households could generate.

Table 4.1

The Hausman-Taylor Random Effect Estimation Result for the Net Income Model

Independent Variables	Coefficients	Z	P>Z
Land Size (β_1)	0.20	5.78	0.00
Fertilizer* (β_2)	0.11	5.60	0.00
Number of Oxen (β_3)	0.24	4.12	0.00
Number of Adults* (β_4)	0.07	1.51	0.13
Rain Shock Dummy (β_5)	-0.03	-1.65	0.10
Road Quality* (β_6)	0.63	7.40	0.00
Soil Quality Dummy (β_7)	0.17	2.04	0.04
Schooling (β_8)	0.32	6.14	0.00
Average Age (β_9)	0.11	1.85	0.06
Gender Dummy (β_{10})	-0.17	-2.94	0.00
Distance to Town (β_{11})	-0.06	-2.64	0.01
Altitude (β_{12})	-0.47	-4.26	0.00
Temperature (β_{13})	-0.34	-2.48	0.01
Teff dummy (β_{14})	0.16	3.00	0.00
Constant (α_0)	10.30	8.62	0.00
sigma_u : 0.33 sigma_e : 0.92 rho : 0.11			

Note: The Unit of Analysis is Household; Road Quality and Quantity of fertilizer used are time varying endogenous variables. While distance to town, temperature and altitude are time invariant exogenous variables, the remaining variables are time varying exogenous variables.

For the same level of resources employed, female headed households generally generate less income than male headed households. The effect of the number of adult family members on the net income however is not significant reflecting a lack of adequate access to land and limited off-farm employment opportunities. The type of crop cultivated on the land also matters and a household that cultivates teff generally generates 17% higher net income.

The quantity of fertilizer a household applies is also a significant determinant of its net income level. According to the result, a 1% increase in the quantity of fertilizer applied increases income by 0.11%. The coefficient of the fertilizer variable however is expected to be underestimated compared with a 0.65 output elasticity reported by other similar studies on Ethiopia (Demeke, et al, 1997). One main reason for a lower coefficient estimate of fertilizer could be that the actual quantity of fertilizer applied and the proportion with which different kinds of chemical fertilizer are combined significantly diverge from the recommended optimum level and proportion.

Among exogenous factors, the frequency of rainfall shock that the household actually experiences has a strong adverse impact on the level of household's income. Its adverse effect works directly as well as indirectly through reducing the productivity of fertilizer. According to the result, for a one time rainfall shock, say inadequate rainfall at the time of cultivation, the net income of the household will decline by 0.3%. In order to determine the magnitude of its indirect adverse effect, the net income model is re-estimated by including the interaction term of the quantity of fertilizer used and the rain shock variable. As the result showed, which is reported under Appendix 1 Table 6, the interaction term (*RFR*) is negative and highly significant; suggesting that a one time rain shock through reducing the productivity of fertilizer reduces net income by 5.6%, which is substantially higher than the direct effect. Moreover, the coefficient estimates of the fertilizer variable has increased by 86%, suggesting that in a situation when the adverse effect of rainfall shock is controlled, for a 1% increase in quantity of fertilizer applied, the net income increases by 0.21%, which is almost twice the coefficient estimate reported before. In addition to reducing the productivity of fertilizer, rain shock is also expected to reduce income further through making a household risk averse and hence use lower quantity of fertilizer. In this case, rain shock reduces income not by reducing the return from fertilizer, but through reducing the quantity of fertilizer the household actually applies.

Geographical factors, such as the distance of the household from town, the altitude and the temperature level of area of residence were also found to exert a significant influence on the magnitude of income that a household could generate. Although the temperature variable is negative in the pooled samples, when the sample is split into villages with good and road access, its effect becomes insignificant (Table 4.2). The effect of altitude on net income however is significant but has a different sign conditional on the road access status of the household. Nonetheless, the distance from town remains a significant adverse factor irrespective of the road condition of the village. However, in villages that have poor road access, the adverse effect of distance on household income is more than four times worse.

As a-priori expected, the quality of road infrastructure farm households have access to has a significant impact on earning. For the same level of resource employed, households that have good road access generally generate higher income than those that do not have good road access. According to the result, controlling the other household and village characteristics, improving the rural road infrastructure that allows access to all types of vehicles and buses raises the average household income by 87.8%. While the current average net income of households with poor road access is 1131 Birr, an improvement in the quality of the road that these households have access to will raise their annual income by more than 990 Birr, which is equivalent to Birr 220 in per capita terms.

The result also implies that while the average income differential between households that have good and poor road access is 1971 Birr, a significant level of this income differential is attributable to spatial differences in road access. This difference is particularly attributable to higher overall factor productivity in villages with good road access.

As can be observed from Table 2, the intercept term of the net income model of households with good road access is substantially higher. This is also further substantiated by the Blinder-Oaxaca decomposition result (Table 4.3). According to the result, 38% of higher income in villages with good road access is due to higher overall productivity and better rate of return. The remaining 62% is due to better private resource endowment of households that reside in villages with good road access. The interaction effect of resource endowments, overall productivity and the rate of return however is not significant.

The finding is also consistent with the claim initially made that failure to use a spatial equilibrium framework while postulating the link between road infrastructure and farm income will significantly understate the productivity of roads. In this regard, using a similar data set but without specifying their model in a spatial equilibrium framework, Dercon et al (2006) reported that providing the sample households with all weather road access increases their average consumption by 15%. This level, which is equivalent to a 17% income increase when the average marginal propensity of consumption of the sample is assumed to be 0.9, is significantly lower compared with the road induced income growth reported here.

Table 4.2
The Random-Effects GLS Regression Result of the Net-Income Model

	POOR ROAD ACCESS			GOOD ROAD ACCESS		
Explanatory Variables	Coef.	Z	P>z	Coef.	Z	P>z
Land Size (β_1)	0.39	4.97	0.00	0.26	6.99	0.00
Fertilizer (β_2)	0.01	0.41	0.68	0.13	9.07	0.00
Number of Oxen (β_3)	0.20	1.91	0.06	0.23	3.83	0.00
Number of Adults (β_4)	-0.06	-0.68	0.50	0.10	1.96	0.05
Rain Shock (β_5)	-0.04	-1.19	0.23	-0.06	-3.01	0.00
Soil Quality (β_7)	0.30	2.38	0.02	0.36	3.28	0.00
Schooling (β_8)	0.47	3.79	0.00	0.29	5.93	0.00
Average Age (β_9)	0.19	1.74	0.08	0.05	0.74	0.46
Gender Dummy (β_{10})	-0.08	-0.72	0.47	-0.28	-4.57	0.00
Distance to Town (β_{11})	-0.44	-2.71	0.01	-0.10	-4.32	0.00
Altitude (β_{12})	1.23	3.04	0.00	-0.63	-6.38	0.00
Temperature (β_{13})	0.52	1.47	0.14	-0.17	-1.32	0.19
Teff dummy (β_{14})	0.36	3.02	0.00	0.17	2.91	0.00
Constant (α_0)	-4.35	-1.17	0.24	11.63	10.97	0.00
	Wald chi2(13)= 130.3 R^2 Overall 0.18 rho=0.027			Wald chi2(13) 581.9 R2 Overall 0.35 rho=0		

The marginal productivity of private and geographical endowment also differs by the type of road access (Table 4.2). Fertilizer and oxen inputs are more productive in villages that have better road access. Although the return to land and education is positive in both groups, return to these variables is higher in villages with poor road access. However, when the sample is further partitioned on the basis of fertilizer application, which mainly determines the productivity of land and labour, while the return to education is still higher in villages with poor road access, the return to land is 75% higher in villages with good road access. The return to fertilizer has also doubled from the 0.13 to 0.26. The return to labour however is consistently higher in villages with good road access. The adverse impact of rainfall shock is significant in villages with good road access possibly due to higher per hectare application of fertilizer. The gender dummy although having a negative sign in both groups was only significant in villages with good road access.

A high coefficient of land in villages with poor road access seems to suggest that land scarcity is a major binding constraint for farm income expansion. In contrast, lower elasticity of income to land but higher elasticity to fertilizer input in villages with good road access suggests that increased application of fertilizer, through augmenting land, could significantly mitigate the problem of land scarcity on rural income growth. Given the current high rate of rural population growth and limited option to push the land frontier, the result confirms that future rural income growth and a substantial reduction in rural poverty to a large extent will depend on increased and efficient application of fertilizer.

Table 4.3
Blinder-Oaxaca Decomposition of Households' Net Income by type of Road Access*

Differential	Coef.	z	P>z	[95% Conf. Interval]	
Prediction_1	6.35	133.23	0.00	6.26	6.44
Prediction_2	7.57	253.34	0.00	7.51	7.63
Difference	-1.22	-21.65	0.00	-1.33	-1.11
Decomposition					
Endowments	-0.76 (62%)	-12.89	0.00	-0.87	-0.64
Coefficients	-0.46(38%)	-3.19	0.00	-0.74	-0.18
Interaction	-0.006	-0.54	0.94	-0.29	0.27

NB:*1=Poor Road Access and 2=Good Road Access

To explore how far the poor benefit from road or such intervention reduces the income disparity between the poor and non-poor, the net income model was estimated on the basis of inter-quantile regression. The estimation result is reported under Table 4.4. From the result it emerges that land size of household, human capital asset of the household, gender of the household head, geographical factors (such as altitude and temperature) and road quality of the village are significant factors that alter the magnitude of income disparity between the poor and the non-poor. Difference in land size and human capital assets owned widens the income disparity between the poor and the non-poor. The return on human capital is higher for the poor than the non-poor. Geographical conditions, such as altitude and temperature, and the gender of the household matters and widens the income gap between the poor and the non-poor.

Table 4.4

Interquantile (75%-25%) Regression Results

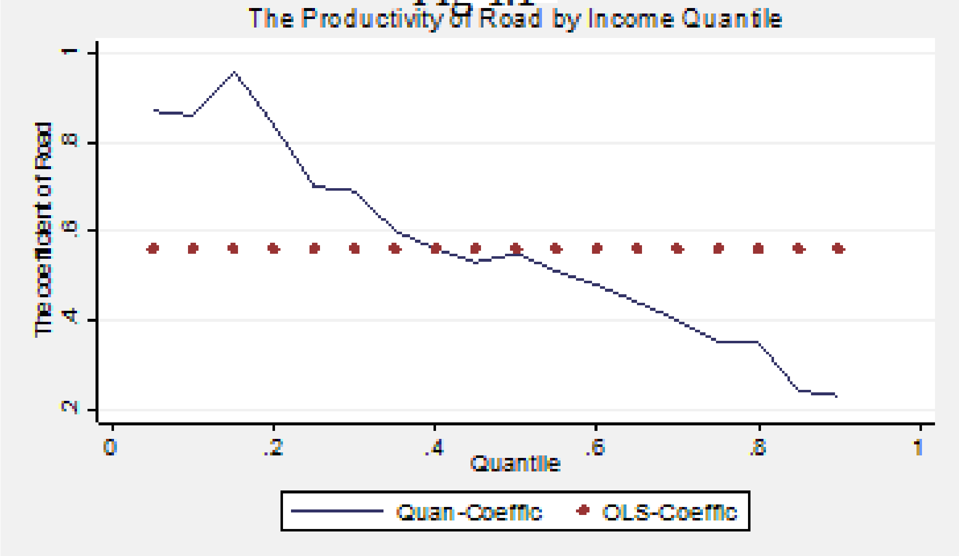
Dependent variable: Net Income

Independent Variables	Coefficients	Z	P>Z
Land Size	0.09	1.82	0.07
Fertilizer	-0.02	-1.23	0.22
Number of Oxen	-0.18	-2.59	0.01
Number of Adults	0.12	2.21	0.03
Rain Shock Dummy	0.02	0.97	0.33
Road Quality	-0.34	-3.08	0.00
Soil Quality Dummy	0.12	1.38	0.17
Schooling	-0.21	-3.88	0.00
Average Age	-0.19	-2.78	0.01
Gender Dummy	0.13	1.61	0.11
Distance to Town	-0.01	-0.15	0.88
Altitude	0.56	4.18	0.00
Temperature	0.52	2.88	0.00
Teff dummy	0.01	0.17	0.87
Constant	-4.09	-2.89	0.00

Number of obs = 1682
.75 Pseudo R2 = 0.2438
.25 Pseudo R2 = 0.3125

The significance of the negative sign of the road quality coefficient suggests that providing all weather rural road access significantly reduces the income disparity between the poor and the non-poor. As can be observed from figure 4.1 and Table 4.5, the return to road is higher for the lower income quantile and tends to consistently decline as the income quantile increases, which confirms the claim that expenditure on rural roads is pro-poor.

Fig 4.1



The return from road access also differs whether or not the household applies fertilizer (Figure 4.2). As can be observed from the figure, irrespective of the level of earning, the return to road is consistently higher in an environment where households apply fertilizer. As could be evident from the gap between the dotted and the solid line, a substantial share of road induced income growth seems to mainly come through road induced increased application of fertilizer, although its importance declines at higher income level.

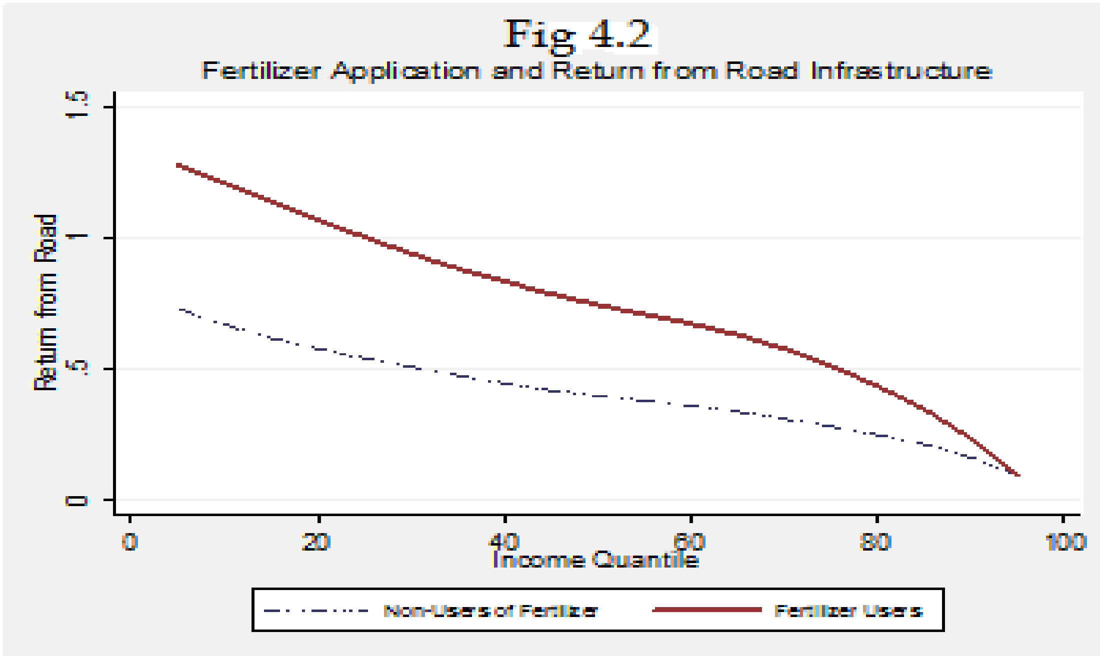


Table 4.5
Quantile Regression Result of Net Income Model

	5% Quantile		10% Quantile		20% Quantile		50% Quantile		75% Quantile		90% Quantile	
Explanatory Variables	coeffi.	t-Stat	coeffi.	t-Stat	coeffi.	t-Stat	coeffi.	t-Stat	coeffi.	t-Stat	coeffi.	t-Stat
RD (Road Dummy)	0.87	**4.43**	0.86	**6.08**	0.84	**10.71**	0.55	**7.90**	0.35	**6.47**	0.23	**2.76**
Ld (log land size)	0.14	1.15	0.15	1.72	0.23	**5.06**	0.33	**9.39**	0.32	**12.38**	0.30	**7.36**
FR (log kg fertilizer used)	0.12	**3.01**	0.15	**4.95**	0.10	**6.23**	0.08	**5.22**	0.09	**7.44**	0.07	**4.06**
Ox (log number of Oxen owned)	0.67	**3.91**	0.43	**3.32**	0.32	**4.55**	0.18	**2.98**	0.12	**2.41**	0.17	**2.09**
Lb (log number of adult members)	0.04	0.29	0.03	0.32	0.04	0.78	0.02	0.37	0.12	**2.97**	0.24	**3.55**
R (rain shock scale)	-0.01	-0.21	-0.02	-0.49	-0.03	-1.36	-0.02	-1.16	-0.02	-1.19	-0.01	-0.39
SQ (land soil quality)	0.02	0.07	0.14	0.75	0.21	**2.03**	0.18	**2.05**	0.32	**4.69**	0.36	**3.45**
Ed (log average schooling)	0.69	**4.90**	0.60	**5.24**	0.41	**6.58**	0.30	**5.55**	0.19	**4.60**	0.09	1.42
InaverageAge (log average age of HH)	0.03	0.18	0.02	0.20	0.17	**2.38**	0.13	1.98	0.01	0.10	-0.11	-1.18
Femaleheaded (gender dummy)	-0.30	-1.78	-0.36	**-2.83**	-0.31	**-4.25**	-0.27	**-4.25**	-0.11	**-2.28**	0.02	0.28
InDistTown (log distance to woreda town)	0.04	0.54	-0.02	-0.31	-0.07	**-2.59**	-0.10	**-4.02**	-0.10	**-5.36**	-0.08	**-2.64**
Inaltitude (log altitude of the village)	-1.34	**-4.96**	-1.06	**-4.78**	-0.73	**-5.80**	-0.55	**-5.24**	-0.17	**-2.14**	0.27	**2.15**
InTemperature (log temperature of the Village)	-0.98	**-2.72**	-0.88	**-3.13**	-0.59	**-3.74**	-0.41	**-2.99**	-0.06	-0.58	0.29	1.71
Teffdummy (teff dummy)	0.45	**3.03**	0.36	**3.04**	0.17	**2.52**	0.06	1.09	0.15	**3.37**	0.22	**3.12**
Cons	16.82	**5.61**	15.00	**6.21**	12.10	**8.90**	11.51	**9.97**	8.25	**9.31**	4.45	**3.20**

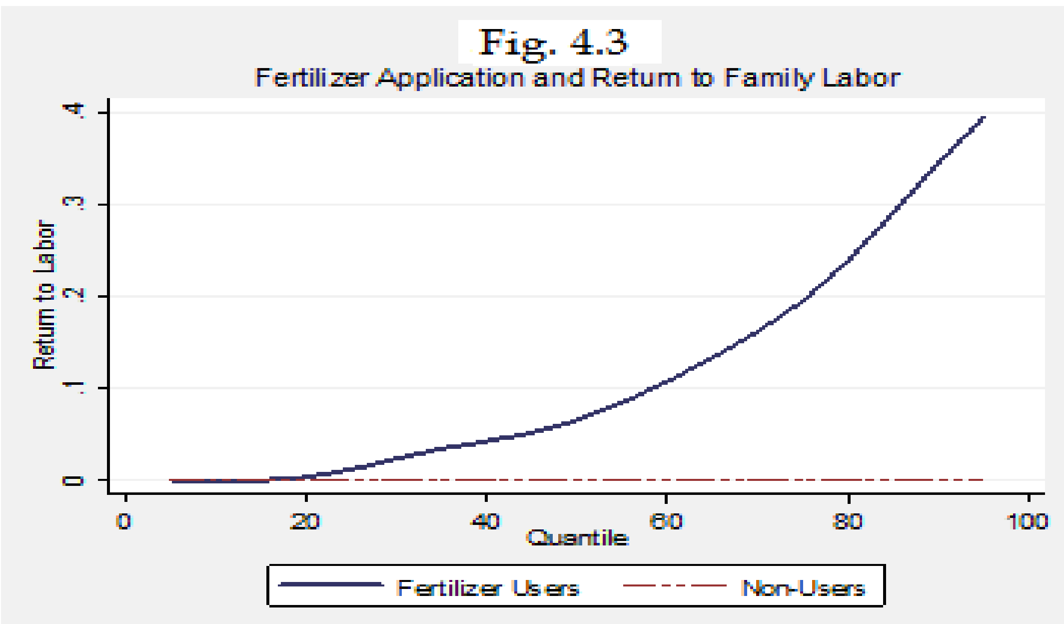
*The t-statistics in bold are significant at less than 5%

Differences in access to land size and quality are also found to significantly widen income disparity between the poor and the non-poor. As can be observed from Table 4.5, the return to land and soil quality is higher for the higher income quantile[42]. Since the land size the household owns is a key determinant of its earning, in order to see if the return to land differs under different road access conditions, the per-capita income level of households that have good road access and own ½ or less hectare of land is compared with that of those that own the same size of land but with poor road access. It is found that the mean income of those households with good road access is 88% higher.

The gender of the household head, altitude and temperature of the location where the household resides also contribute to income dispersion. Particularly households that are headed by females and reside in locations with high altitude and temperature, tend to be underprivileged. Distance from towns does not significantly contribute to income dispersion between the poor and the rich, its adverse effect is the same for the poor and the non-poor. As can be observed from Table 4.5, starting from the lower 20% of the income distribution, the coefficient of the distance variable is negative; suggesting that distance from town significantly lowers the income of the poor as well as the rich.

[42] The return to land reaches its maximum at the middle of the earning distribution where the average land holding is close to 1.5 hectare. If this level is assumed to be an optimal land size, 60% of the sampled households own a land size below the optimum level.

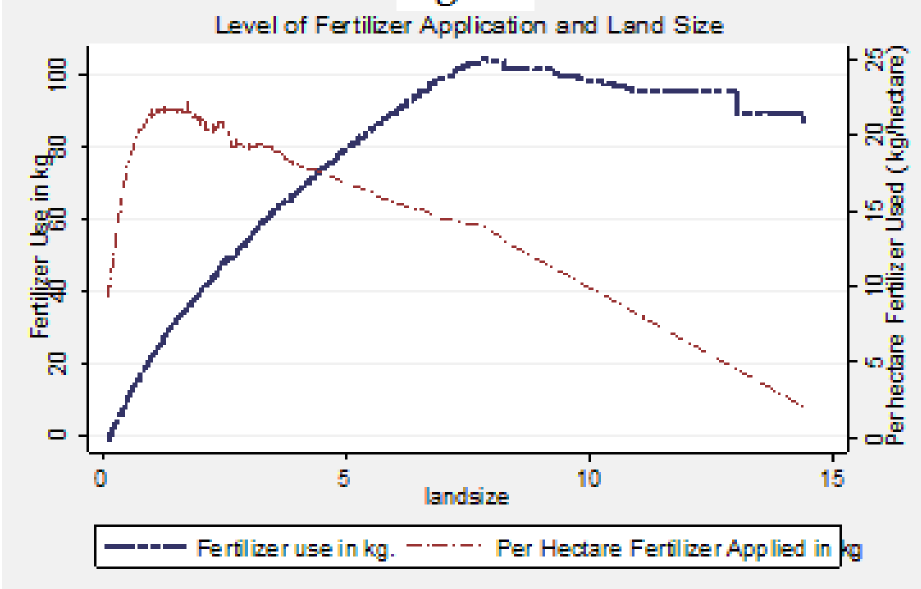
The number of adult family members in the household also matters and significantly contributes to income disparity among households. The return to family labour, while statistically insignificant at the lower income level, is positive and significant starting from the third quartile of the income distribution. However, when the samples are disaggregated into fertilizer users and non-users, while the return to family labour is statistically insignificant for households that did not use fertilizer, it is positive and significant for household that have applied fertilizer (Figure 4. 3).



The crop that farm households cultivate on their land also matters for poverty. Although it is not a significant contributor to income disparity, as can be observed from Table 4.5, the elasticity of income to teff production is the highest for the lowest income quartiles. The number of oxen the household owns and the level of human capital however significantly narrow down the income disparity between the poor and the non-poor. The return from education and farm animals is consistently higher at lower income levels. This suggests that investment in human capital of the poor and facilitating access to the finance that allows the poor to own their own farm animals are effective poverty reducing interventions.

Although the fertilizer input generally tends to narrow down income disparity, it is only significant at 10%. However, as can be observed from Table 4.5, its productivity is relatively higher for the lower quantile and declines thereafter. Despite a higher return to fertilizer application, both in terms of income and poverty reduction, as can be observed from Figure 4.4 below, the quantity of fertilizer applied per hectare however declines with land size, suggesting that inefficient application of fertilizer is substantial. This also holds irrespective of the type of road the sampled households have access to, although per hectare application of the input is substantially higher in villages with good road access. Given that fertilizer augments land and labour and also given that high population growth is shrinking the already low level of average land holding, increasing the quantity and the efficiency with which fertilizer is applied, will have a huge potential for future income growth and poverty reduction.

Fig. 4.4



In villages with good road access, although per-hectare fertilizer application is generally higher, inefficient application of fertilizer is large. It is also observed that the return to labour and farm animals is 10 times and 87.5% respectively higher in villages where fertilizer is intensively utilized. Unlocking the reasons for inefficient application of the input and the cost of inefficiency in terms of income loss will have important policy implications, an issue which will be partially explored in chapter six.

4.7 Conclusion

The chapter has investigated the empirical link between road infrastructure and farm income. The result showed that providing farm households with all weather road access could increase their income by close to 90%. It increases income because roads boost total factor productivity and raise the market rate of return.

It appears that households that possess a large number of farm animals, better human capital, larger land size and better land quality tend to benefit more from road infrastructure. Male headed households and households that apply fertilizer input generally benefit more. Households that own more labour resource benefit from road infrastructure if only they apply fertilizer. Households that have better endowments of livestock resources also fare better as they are more likely to apply fertilizer. Geographical and agro-ecological characteristics, such as the degree of rain shock households experience and the altitude and the locations where they reside also influence the productivity of road.

In terms of poverty reduction, road infrastructure generally boosts the income of the poor but its ultimate impact on poverty depends on resource endowment, risk preference and risk bearing capacity of the poor. The poor benefit from road infrastructure because it boosts the overall factor productivity and the return to assets possessed by the poor. The effect of roads on poverty is especially larger in a situation where poor farm households apply fertilizer, because fertilizer raises the return to land and labour.

Finally, although the empirical result of the chapter showed that providing road infrastructure is important for farm income growth and poverty reduction, it is not explicitly clear whether higher income is due to road induced increase in market prices (for crops and labour) or due to road induced improvement in resource allocation efficiency. Such issues are especially important since the magnitude of the benefit accrued to the poor depends on whether they are autarkic, net suppliers or net buyers in the goods and factor markets. In addition to its influence on the market prices, road infrastructure also influences welfare through reducing crop price volatility from which both food deficit and food surplus farm households would benefit. The remaining chapters aim to empirically substantiate the link between road and the various channels by which the effect of road on income operates. In the next chapter will look into the effect of road on income that operates through the effect of road on the level and volatility of spatial crop prices. In chapter six, the empirical link between road infrastructure and farm level efficiency (technical and allocative efficiency), the cost of inefficiency in terms of income loss and also whether inefficiency harms the poor more than the rich will be explored. Finally, chapter seven looks into the link between road and rural income that operates through the effect of roads on the rural wage rate.

Appendix 4A

Table 4A.1

The Estimation result of the Net Income Model by alternative IV Method

	Baltegi's EC2SLS			Hausman-Taylor IV		
	Coefficient	Z-Value	P-value	Coefficient	Z-Value	P-value
Ld	0.18	4.46	0.00	0.20	5.78	0.00
Ox	0.11	1.64	0.10	0.24	4.12	0.00
lnNAdults	0.04	0.57	0.57	0.07	1.51	0.13
R	-0.06	-3.07	0.00	-0.03	-1.65	0.10
FR	0.15	2.52	0.01	0.11	5.60	0.00
RD	0.64	3.11	0.00	0.63	7.40	0.00
SQ	0.11	1.34	0.18	0.17	2.04	0.04
Ed	0.31	5.38	0.00	0.32	6.14	0.00
lnaverageAge	0.30	3.65	0.00	0.11	1.85	0.06
femaleheaded	-0.05	-0.68	0.50	-0.17	-2.94	0.00
lnDistTown	-0.08	-2.19	0.03	-0.06	-2.64	0.01
lnAltitude	-0.58	-3.10	0.00	-0.47	-4.26	0.00
lnTemperat~e	-0.42	-1.71	0.09	-0.34	-2.48	0.01
teffdummy	0.22	3.74	0.00	0.16	3.00	0.00
_cons	10.84	5.37	0.00	10.30	8.62	0.00
sigma_u	1.11			0.33		
sigma_e	0.94			0.92		
rho	0.59			0.11		
Wald chi2(14)	514.34			977.44		
R-sq: within	0.13					
between	0.54					
overall	0.40					

NB: 1. For Baltegi's EC2SLS Model: Instrumented: FR RD
Instruments:Ld Ox lnNAdults R SQ Ed lnaverageAge femaleheaded lnDistTown lnAltitude lnTemperature teffdummy noofcropscultivated livestock

2.For Hausman Taylor IV: FR and RD are time varying endogenous variables; distance to town altitude and temperature are time invariant variables; and the remaining variables are time varying exogeneous variables.

Table 4A. 2

Hausman-Taylor estimation — Number of obs = 1682
Group variable: **HHidpanel** — Number of groups = 841

Obs per group: min = 2; avg = 2; max = 2

Random effects u_i ~ **i.i.d.** — Wald chi2(14) = 977.44; Prob > chi2 = 0.0000

lnNetIncome	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
TVexogenous						
Ld	.2001262	.0346288	5.78	0.000	.1322549	.2679974
Ox	.238462	.0578137	4.12	0.000	.1251492	.3517748
lnNAdults	.0710566	.0470612	1.51	0.131	-.0211817	.1632948
R	-.0312672	.0189492	-1.65	0.099	-.068407	.0058725
SQ	.1705759	.0836359	2.04	0.041	.0066525	.3344993
Ed	.3205638	.0522041	6.14	0.000	.2182457	.4228819
lnaverageAge	.1135913	.0613896	1.85	0.064	-.0067301	.2339127
femaleheaded	-.1741667	.0591724	-2.94	0.003	-.2901426	-.0581909
teffdummy	.1615906	.0539318	3.00	0.003	.0558862	.2672949
TVendogenous						
FR	.1141396	.0203987	5.60	0.000	.0741589	.1541203
RD	.6306439	.0851662	7.40	0.000	.4637213	.7975664
TIexogenous						
lnDistTown	-.0638268	.02421	-2.64	0.008	-.1112776	-.0163761
lnAltitude	-.4714693	.1105782	-4.26	0.000	-.6881985	-.2547401
lnTemperat~e	-.3433323	.1384685	-2.48	0.013	-.6147256	-.071939
_cons	10.30083	1.195052	8.62	0.000	7.958667	12.64308
sigma_u	.32688477					
sigma_e	.92040644					
rho	.11200573	(fraction of variance due to u_i)				

Note: **TV** refers to time varying; **TI** refers to time invariant.

Table 4A. 3

.75-.25 Interquantile regression
bootstrap(20) SEs

Number of obs = 1682
.75 Pseudo R2 = 0.2438
.25 Pseudo R2 = 0.3125

lnNetIncome	Coef.	Bootstrap Std. Err.	t	P>|t|	[95% Conf.	Interval]
Ld	.0902976	.0468313	1.93	0.054	-.0015567	.182152
FR	-.0194456	.0167354	-1.16	0.245	-.0522702	.0133789
Ox	-.1815126	.0822197	-2.21	0.027	-.3427773	-.0202479
lnNAdults	.1216027	.062944	1.93	0.054	-.001855	.2450603
R	.0235765	.020224	1.17	0.244	-.0160906	.0632437
SQ	.12177	.1017907	1.20	0.232	-.0778811	.321421
Ed	-.2133298	.0518535	-4.11	0.000	-.3150346	-.111625
lnaverageAge	-.1881249	.0900766	-2.09	0.037	-.3648	-.0114498
femaleheaded	.1277053	.0720844	1.77	0.077	-.0136801	.2690907
lnDistTown	-.0054277	.0259922	-0.21	0.835	-.0564086	.0455531
lnAltitude	.5580216	.1118438	4.99	0.000	.3386526	.7773906
lnTemperat~e	.5198697	.1553988	3.35	0.001	.2150725	.824667
teffdummy	.0102492	.0744997	0.14	0.891	-.1358736	.1563719
RD	-.3414906	.081785	-4.18	0.000	-.5019026	-.1810785
_cons	-4.089871	1.298787	-3.15	0.002	-6.637296	-1.542447

Table 4A.4

-> RD = 0

Random-effects GLS regression
Group variable: **Paidparel**

Number of obs = 624
Number of groups = 398

R-sq: within = 0.1154
between = 0.1701
overall = 0.1782

Obs per group: min = 1
avg = 1.6
max = 2

Random effects u_i ~ **Gaussian**
corr(u_i, X) = 0 (assumed)

Wald chi2(13) = 130.31
Prob > chi2 = 0.0000

lnNetIncome	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Ld	.3911723	.0787227	4.97	0.000	.2368788	.5454659
FR	.0145602	.0354393	0.41	0.681	-.0548996	.0840201
Ox	.2048152	.1070644	1.91	0.056	-.0050271	.4146575
lnNAdults	-.0625786	.0921371	-0.68	0.497	-.243164	.1180067
R	-.0431659	.0362348	-1.19	0.234	-.1141848	.0278529
SQ	.2994276	.1255723	2.38	0.017	.0533103	.5455448
Ed	.4743826	.1251048	3.79	0.000	.2291817	.7195836
lnaverageAge	.1901817	.1091373	1.74	0.081	-.0237236	.4040869
femaleheaded	-.0842889	.1165011	-0.72	0.469	-.3126268	.144049
lnDistTown	-.4411385	.1625291	-2.71	0.007	-.7596898	-.1225873
lnAltitude	1.228474	.4038306	3.04	0.002	.4369802	2.019967
lnTemperat~e	.5159318	.3498449	1.47	0.140	-.1697516	1.201615
teffdummy	.3588135	.1187902	3.02	0.003	.125989	.591638
_cons	-4.346676	3.704481	-1.17	0.241	-11.60732	2.913972
sigma_u	.17597517					
sigma_e	1.0418258					
rho	.02773929	(fraction of variance due to u_i)				

-> RD = 1

Random-effects GLS regression
Group variable: **Paidparel**

Number of obs = 1058
Number of groups = 615

R-sq: within = 0.0577
between = 0.5473
overall = 0.3576

Obs per group: min = 1
avg = 1.7
max = 2

Random effects u_i ~ **Gaussian**
corr(u_i, X) = 0 (assumed)

Wald chi2(13) = 581.18
Prob > chi2 = 0.0000

lnNetIncome	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Ld	.2608818	.0373481	6.99	0.000	.1876808	.3340827
FR	.1264004	.0139336	9.07	0.000	.099091	.1537098
Ox	.2345857	.0612692	3.83	0.000	.1145003	.3546711
lnNAdults	.0985788	.0501946	1.96	0.050	.0001993	.1969584
R	-.0620069	.0206239	-3.01	0.003	-.1024291	-.0215848
SQ	.3599017	.1095927	3.28	0.001	.1451041	.5746994
Ed	.2883539	.048603	5.93	0.000	.1930938	.383614
lnaverageAge	.0491977	.0663018	0.74	0.458	-.0807514	.1791468
femaleheaded	-.2830292	.0619268	-4.57	0.000	-.4044084	-.161655
lnDistTown	-.0973514	.0225487	-4.32	0.000	-.141546	-.0531568
lnAltitude	-.6278381	.0983948	-6.38	0.000	-.8206883	-.4349878
lnTemperat~e	-.168771	.128191	-1.32	0.188	-.4200208	.0824787
teffdummy	.168008	.0577128	2.91	0.004	.0548929	.281123
_cons	11.63269	1.060211	10.97	0.000	9.554713	13.71066
sigma_u	0					
sigma_e	.82295005					
rho	0	(fraction of variance due to u_i)				

Table 4A.5

Model for group 1

Source	SS	df	MS
Model	154.640136	13	11.8953951
Residual	712.998815	610	1.16885052
Total	867.638951	623	1.39267889

Number of obs =	624
F(13, 610) =	10.18
Prob > F =	0.0000
R-squared =	0.1782
Adj R-squared =	0.1607
Root MSE =	1.0811

lnNetIncome	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Ld	.3960172	.0784272	5.05	0.000	.241997	.5500373
FR	.0138655	.0353309	0.39	0.695	-.0555195	.0832505
Ox	.2044905	.1066153	1.92	0.056	-.0048872	.4138681
lnNAdults	-.0595498	.0918564	-0.65	0.517	-.2399429	.1208433
R	-.043238	.0361788	-1.20	0.233	-.1142881	.0278122
SQ	.3066345	.125404	2.45	0.015	.0603584	.5529105
Ed	.4623442	.1249178	3.70	0.000	.217023	.7076654
lnaverageAge	.17945	.1084083	1.66	0.098	-.0334487	.3923487
femaleheaded	-.0906055	.1160921	-0.78	0.435	-.3185942	.1373832
lnDistTown	-.4400719	.1607702	-2.74	0.006	-.7558022	-.1243416
lnAltitude	1.241818	.4008781	3.10	0.002	.4545496	2.029087
lnTemperat~e	.5252212	.34865	1.51	0.132	-.1594789	1.209921
teffdummy	.3500613	.1183811	2.96	0.003	.1175772	.5825453
_cons	-4.443272	3.683903	-1.21	0.228	-11.67794	2.791399

Model for group 2

Source	SS	df	MS
Model	353.9435	13	27.226423
Residual	635.802052	1044	.609005797
Total	989.745552	1057	.936372329

Number of obs =	1058
F(13, 1044) =	44.71
Prob > F =	0.0000
R-squared =	0.3576
Adj R-squared =	0.3496
Root MSE =	.78039

lnNetIncome	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Ld	.2608818	.0373481	6.99	0.000	.1875959	.3341677
FR	.1264004	.0139336	9.07	0.000	.0990593	.1537415
Ox	.2345857	.0612692	3.83	0.000	.1143609	.3548105
lnNAdults	.0985788	.0501946	1.96	0.050	.0000851	.1970726
R	-.0620069	.0206239	-3.01	0.003	-.102476	-.0215379
SQ	.3599017	.1095927	3.28	0.001	.1448547	.5749487
Ed	.2883539	.048603	5.93	0.000	.1929832	.3837246
lnaverageAge	.0491977	.0663018	0.74	0.458	-.0809022	.1792976
femaleheaded	-.2830292	.0619268	-4.57	0.000	-.4045443	-.1615141
lnDistTown	-.0973514	.0225487	-4.32	0.000	-.1415973	-.0531055
lnAltitude	-.6278381	.0983948	-6.38	0.000	-.8209121	-.434764
lnTemperat~e	-.168771	.128191	-1.32	0.188	-.4203124	.0827703
teffdummy	.168008	.0577128	2.91	0.004	.0547616	.2812543
_cons	11.63269	1.060211	10.97	0.000	9.552301	13.71307

Blinder-Oaxaca decomposition — Number of obs = 1682

1: RD = 0
2: RD = 1

lnNetIncome	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Differential						
Prediction_1	6.349197	.0476544	133.23	0.000	6.255796	6.442598
Prediction_2	7.566713	.0298684	253.34	0.000	7.508172	7.625254
Difference	-1.217516	.0562411	-21.65	0.000	-1.327747	-1.107286
Decomposit~n						
Endowments	-.7556423	.0586349	-12.89	0.000	-.8705645	-.6407201
Coefficients	-.4557082	.1428706	-3.19	0.001	-.7357294	-.175687
Interaction	-.0061659	.1432516	-0.04	0.966	-.2869339	.2746021

Table 4A.6

```
Hausman-Taylor estimation                       Number of obs      =      1682
Group variable: HHidpanel                       Number of groups   =       841

                                                Obs per group: min =         2
                                                               avg =         2
                                                               max =         2

Random effects u_i ~ i.i.d.                     Wald chi2(15)      =   1039.62
                                                Prob > chi2        =    0.0000
```

lnNetIncome	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
TVexogenous						
Ld	.2038972	.0336795	6.05	0.000	.1378866	.2699077
Ox	.1955341	.0578312	3.38	0.001	.0821871	.3088811
lnNAdults	.0406631	.0472783	0.86	0.390	-.0520006	.1333268
R	.1059853	.0312691	3.39	0.001	.044699	.1672716
SQ	.142576	.0822016	1.73	0.083	-.0185362	.3036882
Ed	.3110712	.0510813	6.09	0.000	.2109537	.4111886
lnaverageAge	.1286326	.0616528	2.09	0.037	.0077954	.2494698
femaleheaded	-.1852624	.0593758	-3.12	0.002	-.3016368	-.068888
teffdummy	.2015226	.0535241	3.77	0.000	.0966174	.3064278
RFR	-.0560107	.009766	-5.74	0.000	-.0751518	-.0368696
TVendogenous						
FR	.2120346	.0261513	8.11	0.000	.160779	.2632902
RD	.6531056	.0822918	7.94	0.000	.4918166	.8143946
TIexogenous						
lnDistTown	-.0553894	.0244688	-2.26	0.024	-.1033473	-.0074315
lnAltitude	-.4750019	.1058132	-4.49	0.000	-.6823919	-.2676119
lnTemperat~e	-.32769	.1373796	-2.39	0.017	-.5969491	-.0584308
_cons	9.982572	1.154509	8.65	0.000	7.719775	12.24537
sigma_u	.35526288					
sigma_e	.90822337					
rho	.13270338	(fraction of variance due to u_i)				

Note: **TV** refers to time varying; **TI** refers to time invariant.

Chapter 5 Road Infrastructure and Crop Prices

5.1 Introduction

As noted in chapter 2, the level and volatility of agricultural prices are identified as critical determinants of rural income and food security status. Among the key determinants of the level and stability of agricultural prices, the degree of spatial integration of agricultural markets and the efficiency with which these markets operate are important. Despite the fact that raising and stabilizing farm gate crop prices are critical in addressing rural poverty in Ethiopia, there has been little empirical research done on the impact of road infrastructure on the level and stability of spatial crop prices (Jayne, et al, 1998, Negassa, et al, 2004). This chapter aims to empirically substantiate the effect of road infrastructure on rural income/poverty by narrowing down spatial price gaps and reducing their volatility. In addition, the chapter also sheds light on the welfare impact of road that operates through the consumption side.

In accomplishing these tasks, on the basis of a spatial equilibrium framework, a farm gate crop price model will be postulated. In order to evaluate the efficiency of spatial grain markets, a threshold autoregressive model will be postulated. Partly due to a lack of monthly crop price data at the farm gate level, which is needed to measure market efficiency, and also partly with the view that measuring market efficiency at the regional grain markets level would be more appropriate, the threshold model will be estimated at the regional grain markets level.

The remaining section of the chapter will be structured as follows. First, the theory and empirical studies undertaken on related issues will be reviewed. Next, after the theoretical frameworks that guide the empirical part are highlighted, the empirical models and the estimation strategies will be outlined. Finally, after a brief discussion of the empirical findings, a concluding remark will be made.

5.2 Literature Review

The theoretical link between transport infrastructure and spatial prices levels has been well established. Adam Smith long ago underscored the key role of transport infrastructure on the level and stability of spatial prices through its effect on volume of trade flows (Myint, 1977; Faftchmans, 1992). Similarly, under the Heckscher-Ohlin trade model framework, the link between transport infrastructure, trade and prices were also analyzed. Although still under a general equilibrium context, the model predicts that transport infrastructure, through facilitating trade, influences the level of spatial prices directly as well as indirectly through inducing a shift in inter-sectoral resource transfer (Falvey, 1976).

Recently, employing a variant of arbitrage model, a number of empirical studies also assessed the link between transport cost, intra-regional trade and prices (Ravallion, 1986; Goletti, et al. 1995). The model, which is a variant of the "Law of One Price", stipulates that when spatial markets are well integrated, prices at a given spatial location behave interdependently; and the price differences between two markets cannot exceed the magnitude of transaction cost (Minten, 1999). Within the arbitrage model framework, both linear and non-linear models have been employed.

Correlation analysis, error-correction, cointegration and autoregressive models are among the major linear models that have been widely used. The threshold autoregressive and parity bound models are the most recent non-linear models mainly introduced to address some of the limitations of the linear models. In the context of the arbitrage model, road infrastructure affects spatial prices through reducing transaction costs and facilitating a spatial flow of trade (Escobal and Cordano, 2008). Facilitating the flow of trade between surplus and deficit areas, relieves localized gluts in the former and reduces scarcity in the latter and thereby not only narrows spatial price gaps but also stabilizes them (Jayne, et al, 1998; Fatchmans, 1992).

Since the objective of this chapter is to assess the effect of road on farm gate crop prices, the analysis should be in the context of a partial equilibrium framework. Accordingly in postulating the link between road and spatial prices, the use of the arbitrage model will be more appropriate. Empirical studies that are undertaken on the basis of this model, addressed the issue in two-stages (Goletti, et al. 1995). At first, they established if the "law of one price" actually operates in the commodity market, i.e. whether or not markets are spatially integrated. In order to do that they used correlation analysis, causality tests, error correction models, cointegration methods, and most recently threshold autoregressive and parity bound models[43]. At the second stage, assuming that the degree of spatial integration of markets is determined by structural factors, these studies regressed the market integration measures generated by the models (such as correlation coefficient, cointegration coefficients and the speed of price adjustment) on structural factors, such as distance between markets and the density and quality of road infrastructure (Goletti, et al. 1995; Aker, 2007; Van Vampenhout, 2007).

From a brief review of the existing empirical studies, three issues clearly emerge. First, although the issue of market integration is very important in the context of developing countries, the number of empirical studies undertaken on developing countries in general and rural markets in particular is very limited. Second, in most of the existing empirical studies much effort has been made on testing whether spatial markets are integrated or not and the effort made to assess the effect of structural factors, such as road infrastructure, on a spatial integration of markets is scarce (Goletti, et al. 1995; Escobal and Cordano, 2008). Third, even from

[43] Although these set of measures differ in terms of their specification and the information they generate, they are built upon the tenets of the point-space model that was first pioneered by Enke (1951) and Samuelson (1952) and later elabourated by Takayama and Judge (1964).

the existing few studies that have actually assessed the impact of structural factors on market integration and spatial prices, one cannot easily draw important policy conclusions such as to what extent farm gate prices will change following an improvement in road infrastructure, which is especially important when the policy objective is to raise farm gate prices. This chapter aims to address these limitations and also substantiate to what extent road induced rural income growth or poverty reduction is due to road induced improvement in spatial crop prices.

5.3 Empirical Model

5.3.1 The Linear Model

The theoretical framework that guides the formulation of the empirical model will be the point-space model that was first pioneered by Enke (1951) and Samuelson (1952). According to this model, if different markets are interconnected by transport cost that is unrelated with the direction and the volume of trade, if there is no artificial trade flow restriction between markets and also if consumers are indifferent as to the sources of supply, the crop price level at a given location will be determined by local specific production and demand conditions, by spatial market conditions and the cost of transferring the crop between markets (Judge and Wallace, 1958).

In algebraic terms, two spatial markets attain equilibrium level when the following condition holds *(see Fig. 5.1.1)*:

$$ES_{12}+ES_{21}=0 \text{ or } ES_{12}=-ES_{21} \qquad (5.1)$$

Where ES_{12} and ES_{21} are respectively the excess supply curve of location 1 and 2.

As can be observed from *diag. 1b* in Fig 5.1.1, since transfer cost wedges the gap between import and export price of the crop, the equilibrium price levels in each market (which is equal to a given point in their respective excess supply curve) are inversely related to the magnitude of the transfer cost. The higher the transfer cost, in other words the poorer the road infrastructure, the higher the spatial equilibrium price differences. In this case, if the road quality of the village is good, which implies a transfer cost of T_1 on *diag. 1b*, the spatial price gap will be narrower and hence while consumers pay a lower price, suppliers earn a higher price. However, if the road quality is poorer, the spatial equilibrium price gaps would be larger and hence while suppliers will receive a lower price, consumers will pay a higher price.

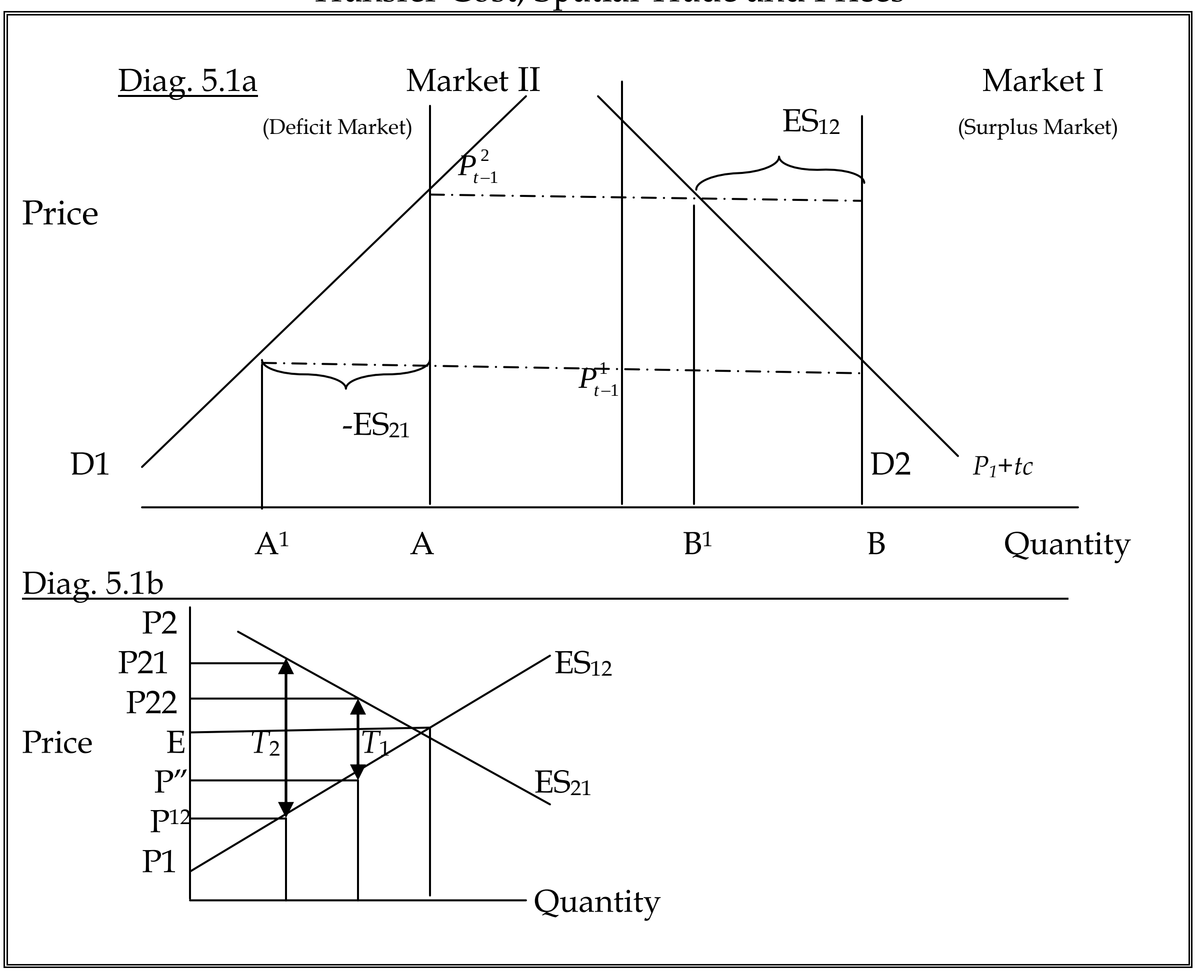
In order to introduce the price effect of road infrastructure, *diag.5. 1b* can be re-interpreted in algebraic terms. In this regard, export from market 1 to market 2 will only take place if traders get a price level that is greater than P_1, let us say P_E. Similarly buyers in market II will only buy more of the crop if its price level is less that P_2, say $P_{M.}$ Assuming that the trade functions of both exporting and importing markets are a linear function of prices, the general equilibrium condition of equation (5.1) can be re-specified (Enke, 1951) as:

$$ES_{12}= \beta_1(P_E - P_1) \quad (5.2)$$

$$ES_{21} = \beta_2(P_M - P_2) = \beta_2(P_E + T - P_2) \tag{5.3}$$

From equation (5B.2) it is evident that no export from market I takes place when $P_E = P_1$. Similarly, no further import from market I will take place in market II when $P_E + T = P_2$. Since the minimum price at which market I exports the crop to market II is $P_E + T$, P_M in equation (5.3) can be replaced by $P_E + T$.

Figure 5.1.1
Transfer Cost, Spatial Trade and Prices



Source: Adapted from Judge and Wallace (1958) and Samuelson (1952)

In order to determine market clearing equilibrium price at each market, after substituting equation (5.2) and (5.3) in equation (5.1), equation (5.1) can be re-written as:

$$\beta_1(P_E - P_1) = -\beta_2(P_E + T - P_2) \qquad (5.4)$$

In order to determine the equilibrium price of the crop at the village market, manipulating equation (5.4), it becomes

$$P_E = \frac{\beta_1}{\beta_1 + \beta_2} P_1 + \frac{\beta_2}{\beta_1 + \beta_2} P_2 - \frac{\beta_2}{\beta_1 + \beta_2} T \qquad (5.5)$$

Where P_E is the local market equilibrium price that will prevail at the exporting market when there is spatial trade, P_1 is the autarkic price of the crop at the exporting market, i.e. when there is no spatial trade, P_2 is the equilibrium price of the crop at the terminal market, T is the level of transfer cost traders incur to transport the crop between the village to the terminal market.

Equation (5.5) implies that the local equilibrium price of the crop at the exporting market is influenced by village specific market conditions (imbalances), which are captured by P_1 and β_1, the magnitude of the transfer cost (T) and finally by market conditions that prevail at the terminal market, which are captured by β_2 and P_2 [44] (Badiane and Shively, 1998). Following other empirical studies, the first term can be assumed to capture the location and crop specific effect that includes the distance of

[44] Similar models have been postulated to examine the degree of spatial integration of markets and spatial transmission of prices (Badiane and Shively, 1998; Getnet, et al, 2005).

the market from the central market as well as other location specific factors that shift the local demand and supply curve, namely among others the rainfall level. As there are no transfer cost data, in capturing the level of transfer cost (T), the quality of the road that connects the village with a spatial market (terminal market) will be used as a proxy. The poorer the road quality, the longer the time it takes and the riskier trade will be and hence the higher the transfer cost.

The effect of transfer cost on local prices differs by type of market, i.e. while transfer cost depresses prices in surplus markets; it inflates prices in deficit markets. In order to differentiate that and meaningfully interpret the road quality variable, a market dummy will be introduced, where a value of 1 is given if the village under consideration is in a surplus producing zone of the crop and 0 otherwise. The classification of the villages into deficit and surplus markets is based on the zonal per-capita production of the crop. If the village under consideration is located in a zone where per-capita production of the crop is above the average of all the zonal markets considered, that village will be designated as a surplus market and given a value of 1 and 0 if otherwise, i.e., if the village is located in a zone where per-capita production is below the average of all zones considered. In order to determine if roads, by relieving localized gluts improve farm gate crop prices, the market dummy will also be interacted with the road quality variable. In order to capture trade costs that vary through time, a time trend term will be introduced.

Thus, after replacing P_1 with the market dummy (M), interacting the market dummy with road quality of the village, introducing the time trend, *t*, and applying a natural log to the continuous variables, the empirical linear price model will become[45]:.

$$\ln P_{ijt}^{1} = \alpha_0 + \alpha_1 \ln P_{it}^{2} + \alpha_2 Rq_j + \alpha_3 M + \alpha_4 M * Rq + \alpha_5 t + \nu_{ijt} + \mu_{ijt} \tag{5.6}$$

*Where, P^1 is the price of the crop at the local market, P^2 is the price of the crop at the central market; i , j and t represent crop type, village market and time respectively; Rq represents Road quality, M is the market dummy, where 1 is for surplus and 0 for deficit markets, M*Rq is the interaction of road quality and market dummy, t is time trend and v captures unobserved crop and market specific effects and μ is the error term.*

The village market is said to be integrated with the terminal market if and only if α_1 is significant and has a positive sign. The sign of α_2 cannot be a-priori determined as it depends on the type of market. However, as

45 Similar model has been employed by a number of empirical studies (Badiane and Shively, 1998; Goletti, et al, 1995). The model will be estimated on the basis of a data of 5 major traded crops (white teff, wheat, barley, sorghum and maize).

distance and excess supply in surplus producing markets generally depress local prices, the sign of the market dummy coefficient (α_3) is expected to be negative. The interaction term of road quality and market dummy (α_4), however, is expected to be positive as good road quality by facilitating trade narrows down spatial price gaps and thereby raises prices in surplus markets. The sign of the time trend variable however cannot be a priori known.

5.3.2 Threshold Autoregressive Model (TAR)

In order to judge whether the spatial markets in Ethiopia operate efficiently or not, which is expected to have significant impact on farm income in general and poor households in particular, a threshold autoregressive model will be estimated. Since the major share of spatial grain trade takes place through regional grain markets and also since the efficiency with which these markets operate determines the overall spatial market efficiency, the model will be estimated at the regional market level. Accordingly, the threshold autoregressive model will be estimated based on the monthly price data obtained from Ethiopian Grain Trade Enterprise for 19 regional markets, 13 crops and covering a period of 10 years (1994-2004).

Before dwelling on the derivation of the model, however, a brief description of the structure of the model will be made.

Fig 5.2.1

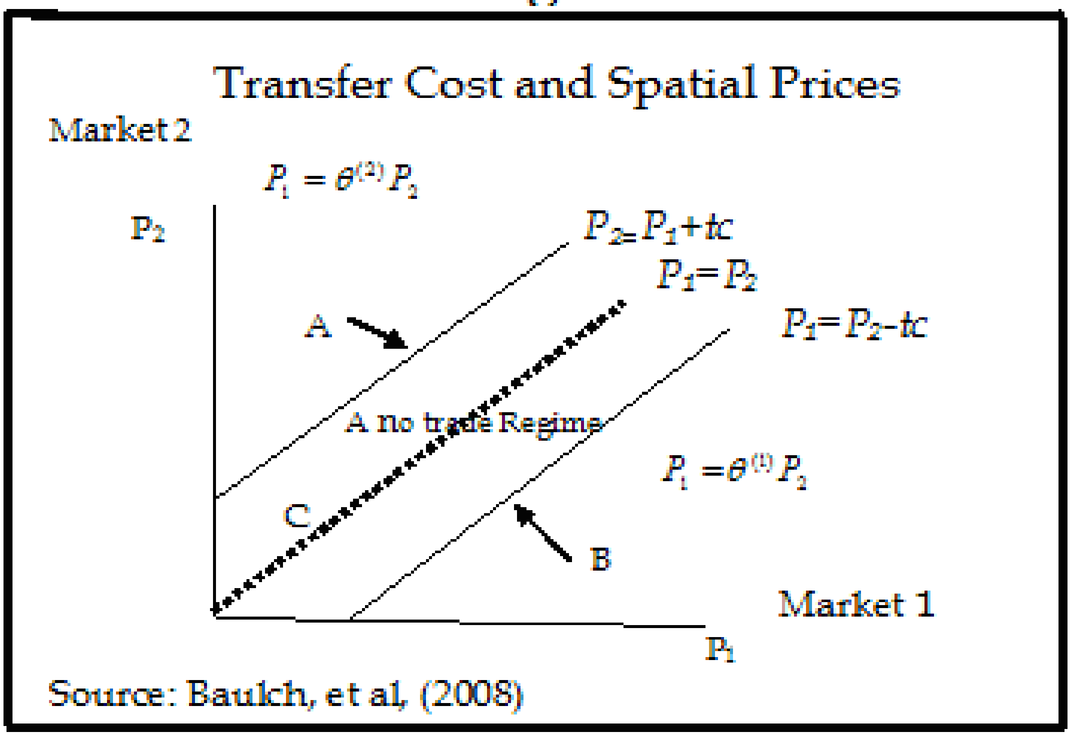


Figure 5.2.1 depicts two markets (Market 1 and Market 2) and market 1 is a surplus producing market and market two is a deficit market. Transferring crops between these markets involves a transfer cost of Birr tc/quintal. Trade between the two markets will take place only if the price difference between the two markets is above the transfer cost. If the local price level in market 2 is greater than P_1+*tc*, exporting the crop from market 1 is profitable and the ensuing trade flow increases the crop price in market 1, while it reduces the price in market 2 until equilibrium is restored where

the local price in market 2 is equal to P_1+tc. If the price of the crop at market 2 is below P_1+tc , say at C, trade between the two market is not profitable and hence the price interdependency between the two markets breaks and prices in both markets move independently and thus the overall price correlation between the two markets will be weak or zero. On the other hand, if the crop in market 2 is very low, say at point B, traders find it profitable to transport crops from market 2 to market 1, which would mean there will be a trade flow reversal, until equilibrium is restored where the price of the crop in market one (P_1) is equal to P_2-tc.

From the above diagram, three trade regimes are clearly apparent. The first one is where trade flows from market one to market two take place. The second one is a situation where there is no trade or the spatial price interdependency is weak because the price difference between the two markets is equal to or less than the transfer cost. And finally, a situation where the crop price level in the surplus market is higher than the price level at the deficit market or where a trade flow reversal will take place. Arbitrage takes place only in the first and the third regime and hence spatial price interdependency only exists in the first and the third regimes. The following section will dwell on the algebraic derivation of the model.

Under the TAR model, given the local supply level, the local price of the crop is a linear function of local supply level (X)[46] (Escobal and Cordano, 2008; Anker, 2007).

$$P_{1t} = \alpha_1 - \beta X_{1t} + \mu_{1t} \quad (5.7)$$

where P_{1t} *represents the price of a given crop at the local market at time t;* α_1 *and* β *are parameters to be estimated and* μ_{1t} *is the error term and captures demand side shocks.*

Assuming that the local market is a surplus market; and also assuming that there is no barrier for trade among spatial markets, the local price level of the crop is also influenced by price movement at the terminal markets. However, price movements at the terminal markets affect the local market price level only if the following condition holds:

$$P_{1t} \leq P_{Ct} - C_t^{1C} \quad (5.8)$$

where P_{Ct} *represents the price of the crop at the terminal market; and* C_t^{1C} *is the unit cost of transferring the crop from the local to the terminal market.*

In order to complete the model, it is necessary to specify the determinants of the transfer cost. Following Prakash and Taylor (1997) and Escobal and Cordano (2008), the transfer cost can be postulated as a quadratic function of trade flow:

$$C_t^{1C} = \omega_0 + \omega_1 \left|\Delta X_{1C}\right| + 1/2\, \omega_2 \left|\Delta X_{1C}\right|^2 \quad (5.9)$$

[46] The model is estimated for each crop type and market.

Here the magnitude of transfer cost is assumed to be a function of a change in the volume of trade flow between the two markets ΔX_{1C}.

As previously argued, traders will engage in arbitrage only if the marginal cost of arbitrage is equal to or less than the marginal income. In this case, the marginal income, which is designated as (MI), is equal to the prevailing price difference of the crop at the local and the terminal market, which is given by

$$MI_t = P_{1t-1} - P_{Ct-1} \tag{5.10}$$

The marginal cost on the other hand should be derived from equation (5.9), which is equal to

$$\frac{\partial C_{1C}}{\partial \Delta X_{1C}} = MC_{1t} = \omega_1 + \omega_2 \Delta X_{1C} \tag{5.11}$$

Equilibrium in two spatial markets is attained when the marginal cost is equal to the marginal income from arbitrage, which is given by

$$P_{1t-1} - P_{Ct-1} = \omega_1 + \omega_2 \Delta X_{1C} \tag{5.12}$$

From equation (5.12), three arbitrage conditions emerge, i.e., $P_{1t-1} - P_{Ct-1} = \omega_1 + \omega_2 \Delta X_{1C}$, $P_{1t-1} - P_{Ct-1} > \omega_1 + \omega_2 \Delta X_{1C}$ and $P_{Ct-1} - P_{1t-1} < \omega_1 + \omega_2 \Delta X_{1C}$

The first one is a situation where price difference between the two markets is just equal to or less than the marginal cost of trade. In this regime, which is also referred as the 'bands of inaction", arbitrage does not take place as trade is not profitable and as a result price levels at each market behave independently and mainly vary in response to local shocks (Obstfeld and Taylor, 1997). However, the second one is a situation where the price difference in the two markets is above the cost of trade. In this regime, as profit potential is not fully exploited, it attracts arbitrage and as a result the price level at each market moves interdependently until the price difference between the two markets reverts back to its equilibrium level, which is equal to $\omega_1 + \omega_2 \Delta X_{1C}$. In the third regime, the price difference between the two markets is above the marginal cost of trade, but now since the local price is higher than the terminal market price, there is a trade flow reversal and trade flows from the central market to the local market. In this regime, similar to the second regime, the error correction mechanism will operate until the price difference between the two markets reverts back to its equilibrium level.

Since the regime shifts from one state to the other, the three regimes can be written in a switching regression form (Escobal and Cordano, 2008).

$$\Delta x_{1Ct} = \begin{cases} \frac{-1}{\omega_2}(P_{1t-1} - P_{Ct-1}) - \omega_1 & if \ \left|P_{1t-1} - P_{Ct-1}\right| < \omega_1 \\ 0 ----------------- & if \left|P_{1t-1} - P_{Ct-1}\right| \le \omega_1 \\ \frac{1}{\omega_2}(P_{1t-1} - P_{Ct-1}) - \omega_1 & if \ \left|P_{1t-1} - P_{Ct-1}\right| > \omega_1 \end{cases} \tag{5.13}$$

In order to introduce the effect of local supply and demand side shocks, from equation (5.7), the change in local price level, i.e. $(P_{1t-1} - P_{1t-2})$, is expressed as a function of a change in local market conditions as well as local random shocks, which is $-\beta\Delta x_{1Ct} + e_{1t}$, where $e_{1t} = \mu_t - \mu_{t-1} \sim N(0, \sigma_1^2)$. Assuming a similar price elasticity of demand in both locations, substituting the expression in (5.13), it becomes:

$$\Delta P_{1Ct} = \begin{cases} \frac{\beta_1}{\omega_2}\left[(P_{1t-1} - P_{Ct-1}) - \omega_1\right] + e_{1t} & if \ \left|P_{1t-1} - P_{Ct-1}\right| < \omega_1 \\ 0 ------------------- & if \left|P_{1t-1} - P_{Ct-1}\right| \le \omega_1 \\ \frac{-\beta_1}{\omega_2}\left[(P_{1t-1} - P_{Ct-1}) - \omega_1\right] + e_{1t} & if \ \left|P_{1t-1} - P_{Ct-1}\right| > \omega_1 \end{cases} \tag{5.14}$$

In addition to local demand shocks, the magnitude of local market price change is also determined by price shocks in the central market as long as such shocks generate a price difference that is above the transfer cost. In order to introduce such an exogenous factor, designating the price differential between the two markets as $m_{t-1} = (P_{1t-1} - P_{Ct-1})$ and assuming fixed transfer cost, the final empirical model to be estimated becomes[47]

$$\Delta m_t = \begin{cases} \rho^{out}[m_{t-1} - \omega_1] + \eta_t^{out} & if\ |m_{t-1}| > \omega_1 \\ \eta_t^{in} ------------ & if\ |m_{t-1}| \le \omega_1 \\ \rho^{out}[m_{t-1} - \omega_1] + \eta_t^{out} & if\ |m_{t-1}| < -\omega_1 \end{cases} \tag{5.15}$$

Where $\rho^{out} = (\beta_1 + \beta_2)/\omega_2$, $\eta_t^{out} = e_{1t} - e_{Ct} \sim N(0, \sigma_{out}^2)$, $\eta_t^{in} = e_{1t} - e_{Ct} \sim N(0, \sigma_{in}^2)$.

Where Δm_t and m_{t-1} respectively represent the change in price differential and lag price difference between the two markets that are to be compared, ρ^{out}, which measures the speed of adjustment towards equilibrium, and ω_1, which is the threshold level, are parameter to be estimated, $\eta_t^{out} \sim N(0, \sigma_{out}^2)$ and $\eta_t^{in} \sim N(0, \sigma_{in}^2)$ are the outer and inner band error terms.

From equation (5.15), three trade regimes can be distinguished, which are $m_{t-1} > \omega_1$, $|m_{t-1}| \le \omega_1$ and $m_{t-1} < -\omega_1$. The first regime is a situation where the price difference between the local and central market is above the transaction cost. In this case, as trade is profitable, traders move the crop from the local market to the central market and as a result, the local price levels tend to increase until the profitable trade is fully exploited or a

[47] After introducing the interaction term of time and lagged price difference as another variable, which Van Campenhout (2007) proposed to capture the time varying transaction cost, the model was estimated. However, for most of the crops, the term variable was insignificant. As a result, we estimate the model without including the interaction term.

threshold equilibrium level is reached, i.e., until the price difference is just equal to or less than the transfer cost. Once the equilibrium level is reached, the trade regime shifts to the second band. In this regime, as trade is not profitable and the error correction mechanism is not active, spatial prices are independent of each other and vary in response to local shocks (η^{in}). In the third regime, a situation arises where the local market price level of the crop is above the central market price level. In this regime, which usually represents a pre-harvest period in surplus producing markets, the price difference between the local (normally surplus market) and the central market (normally a deficit market) is above the transaction cost. As the price difference is above the transfer cost, arbitrage activity becomes active and trade flows from the central market to the local market until equilibrium is restored or the price difference is just equal to the transfer cost.

In the model, $|\omega_1|$, which represents the transfer cost between markets and at which the spatial price interdependency switches, is unknown and should be estimated from the price data through a *grid search.*

Once the transaction cost estimates are generated for each crops and market, the number of times the price difference between the two markets were above the transfer cost (ω_1) will be determined. The number of times where the price difference between two markets is above the transfer cost will be used to evaluate the spatial market efficiency (Van Vampenhout, 2007). In this regard, the spatial markets are said to be efficient if a large proportion of the price differences between these markets are less than the transfer cost, i.e. if most of the price differences fall in regime two. Conversely, the markets are said to be inefficient if most of the price differences fall in regime one and three because potential profitable arbitrage opportunities have not been exploited and the additional benefit that could come through a further reduction in spatial price gaps would be lost

In order to estimate the model, first the level of threshold should be identified. As previously mentioned as there is no actual data on transfer cost, on the basis of a grid search, the threshold level should be identified from the price data (Balke and Fomby, 1997). In order to do that first the median of the lagged price difference between the two markets (local and terminal market) will be used as the initial candidate for the threshold.

Based on the chosen threshold level, the sample is partitioned into observations that are inside the band, which are below the median price difference, and outside the band, which are above the median price difference. Next, based on the partitioned samples, the change in price difference is regressed on lagged price difference. The same procedure is repeated by increasing one observation at a time until a price difference that minimizes the squared error term of the regression is identified. This level of price difference is assumed to measure the transaction cost because at that level of price difference the correlation between spatial prices is at its maximum. If the identified price difference is actually a threshold, additional regression, i.e., by adding one observation that is above the identified threshold, should increase the squared error of the regression or the coefficient estimates of that regression should be insignificant, which in effect mean there is weak spatial price interdependency.

Finally, in order to link the effect of roads on poverty that operates through altering spatial crop prices, the elasticity of the income of the poor to a change in transaction cost will be estimated. Generally, the magnitude of a price change on the real income of the poor will depend on the expenditure share of the crop the price of which has changed[48] (Son and Kakwani, 2006). In order to calculate the elasticity of the price change on the welfare of the poor, it is therefore necessary to determine the income poverty line or the income level at which an individual is considered poor as well as the share of expenditure of the crop from the total income (expenditure) of the poor. Assuming that $w_i(y)$ is the average share of the crop at the income poverty line, it follows that the effect of road induced price change on poverty will be $w_i(y)\frac{\partial p}{\partial Rq}$, where $\frac{\partial p}{\partial Rq}$ represents the change in price due to better road quality.

The effect of road induced price change on welfare also depends on the net market position of the individual as well as the location where he/she resides. Since roads normally narrow spatial price gaps, they raise prices in surplus producing markets, and lower prices in deficit markets. Therefore, road induced price change will not necessarily benefit all. From road

[48] Assuming that the real income of the consumer is y, the change in real income due to a change in price will be $\Delta y = -\left[e\left(u, p_i^*\right) - e\left(u, p_i\right)\right]$, where e is the expenditure function and u is the level of utility the individual enjoys and p_i is the price of the crop in the base year and p^* is the new price. Using Taylor expansion, it becomes $\Delta y = \Delta p_i f(y)$, Where $f(y) = \partial e(u, p_i)/\partial p_i$, which is the demand for crop i. Given that $\partial y/\partial p_i = f(y)$, it follows that the elasticity of real income change due to change in price[$\frac{\partial y}{\partial p_i}\frac{p_i}{y} = f(y)$] will be $-\frac{p_i f(y)}{y} = -w(y)$ (Son and Kakwani, 2006). It suggests that the magnitude of real income change due to a change in price depends on the expenditure share of the crop and implies that a 1% increase in the price of the crop reduces the real income of the consumer by $-w(y)$.

induced price changes while net buyers in deficit markets and net sellers in surplus markets will benefit; net buyers in surplus markets and net sellers in deficit markets will lose. In order to calculate the road induced price change on poverty, after appropriate transformation, α_2 and α_4 of equation (5.2) will be used to proxy $\frac{\partial p}{\partial Rq}$. Information on the average crop expenditure share of a rural poor (i.e., $w_i(z)$) as well as on the average share of crop income at the income poverty line will be taken from MoFED (2002).

In addition to its direct effect on poverty that works through the income and consumption side, the impact of roads on poverty also operates through road induced decline in spatial price volatility. High price volatility harms net buyers as well as net suppliers of crops. While the effect on the net buyers usually works through the consumption side alone, its effect on the latter works on income as well as on the consumption side. In this chapter, although a qualitative discussion will be made on the effect of volatility on poverty that operates through income and consumption, its effect on the production side will be discussed in chapter six.

5.4 Estimation Strategy

Since the price model is estimated on the basis of panel data, where the unit of analysis is both crop and village, the use of panel data models will be necessary. In order to determine if a random effect or fixed effect model is appropriate to the data, the Hausman specification test was conducted and the test result showed that the fixed effect model will be appropriate. However, since the model includes some time invariant explanatory variables, the fixed effect model could not generate the parameter estimates of these variables. Therefore, for the purpose of generating the coefficient estimates for time invariant variables, assuming that the bias will not be substantial, the price model will be estimated on the basis of the random effect method[49] (Wooldridge 2002).

Before estimating the model, stationarity, co-integration, exogeneity and Granger causality tests were conducted (Dickey and Fuller, 1979; Engle and Granger, 1987). The stationarity test is conducted on the basis of the approach proposed by Quah (1994), Levin and Lin (1993) and Im, et al, (1996). For almost all individual crops and markets, the calculated *tau* statistics of each individual market and price are far below the critical

[49] In order to check that the model is estimated by Least Square Dummy Variable Regression Model and the result is almost similar.

value suggesting that the price series are non-stationary. As the price series have unit-root, in order to justify the estimation of the model in level form, following a similar approach followed by Fafchamps and Gavian (1996), a cointegration test was conducted. The test result showed that the price series are cointegrated at 1% level, which suggests that although individually the price series are non-stationary, they have a stable long-run relationship and thus estimating the model in level form will not be a problem.

Since a substantial share of spatial grain flows takes place through the Addis Ababa grain market, this market will be designated as the terminal market. This is also consistent with the claim made by previous studies that traders set their prices by adding transportation cost on the Addis Ababa market price (Dercon, 1995). As a result, the terminal market price introduced in the village price model will be considered as an exogenous variable of the model.

5.5. Results and Discussion

The village crop price model estimated on the basis of a random effect method is reported in Table 5.1. The price model is estimated twice, which is reported as model 1 and 2. Both models have the same explanatory variables except that the second model includes the interaction term of the road quality of the village and the terminal market price. The variable is introduced in order to see if good road quality enhances the sensitivity of village prices to changes in terminal market prices. Generally the overall fit of the models, based on the *Wald-Chi*^{2} and R^2, is good. As can be observed from the Table, all the variables are significant and also have the expected sign. As a priori expected, the village market price of a crop is significantly influenced by local production and demand conditions, the road quality of the village as well as by terminal market condition.

Table 5.1

Random Effect Model Results of Village Price Model

Explanatory Variables	Model (1) Coeff.	Model (1) Z-stat	Model (1) P-value	Model (2) Coeff.	Model (2) Z-stat	Model (2) P-value
α_0 (Constant)	0.34	11.92	0.00	0.36	12.05	0.00
α_1 (Terminal Market Price)	0.72	15.67	0.00	0.67	13.24	0.00
α_2 (Road Quality Dummy)	-0.10	-2.61	0.01	-0.27	-3.16	0.00
α_3 (Market Dummy → Surplus=1)	-0.28	-8.00	0.00	-0.28	-7.97	0.00
α_4 (Road Quality*Market Dummy)	0.15	3.06	0.00	0.15	3.24	0.00
α_5 (Time trend)	-0.01	-2.81	0.01	-0.01	-3.13	0.00
α_6 (Terminal Market Price*Road Quality Dummy)				0.10	2.34	0.02
	No. of Observation: 505 Number of Groups: 46 Group Variable : Cropvillage Wald chi2(5)=1031.87 R-square: Within: 0.63 Between: 0.88 Overall: 0.79 sigma_u = 0.086 sigma_e = 0.11 rho = 0.36			No. of Observation: 505 Number of Groups: 46 Group Variable : Cropvillage Wald chi2(5)=357.8 R-square: Within: 0.64 Between: 0.88 Overall: 0.80 sigma_u = 0.084 sigma_e = 0.11 rho = 0.33		

While referring to the result of the first model, as priori expected, village level price formation is significantly influenced by price development at the terminal market. A 1% change in terminal market price respectively elicits a 0.72% change in village crop prices. As the terminal market represents the level of spatial demand, such a strong association between village and terminal market prices, suggests that demand conditions exert more influence on village price formation than supply side factors. Such a high degree of price interdependency may show that village and Addis Ababa are relatively well integrated. The result implies that, besides the measures to address structural constraints, government open market operation at the terminal market, such as through buying up crops when there is surplus production and selling its stock when supply is low, will have a significant impact on the level and stability of farm gate crop prices.

In terms of importance, next to the terminal market condition, local demand and supply conditions exert a significant influence on local price formation. As a priori expected, in surplus producing villages, local factors, such as distance from terminal market and the level of rainfall, depress local prices and as a result the average village equilibrium price in these markets was on average 28% lower compared to deficit markets.

As a priori expected, the result also shows that road infrastructure of the village exerts significant influence on the magnitude of village prices. In deficit villages that have good road access, local equilibrium prices are at least 10% lower compared with similar deficit villages that have poor road access. According to the result, while average prices in surplus producing villages were 28% lower, in surplus producing villages that have good road access prices were relatively higher. In these villages local prices are on average 15% higher compared with similar surplus producing villages that have poor road access. The result suggests that good road access generally improves prices in all locations. In this regard, it enables farm gate prices in surplus producing markets to be higher by close to 13% than would otherwise be the case. This confirms the claim that all weather roads, through shifting the local market demand curve and also making the curve more elastic, while reduces prices in deficit markets, raises prices in surplus markets.

The time trend variable is also negative and significant suggesting that over the period covered, village prices are showing a 1% annual decline.

The interaction term of the road quality and the terminal market price are also significant suggesting that in villages with good road access, local prices are 10% more sensitive to changes in terminal market price. A high response of local prices to terminal market conditions means that producers/consumers with good road access generally earn higher prices and also face lower price volatility, as the terminal market is generally a high demand market and also less affected by price volatility (Fatchamps, 1992). Since resource allocation decisions and a decision to adopt new technology are significantly influenced by market risk, which is usually measured by the magnitude of price volatility, the significance of the interaction term also suggests that the income increasing impact of road that operates through reducing market risk could be substantial. It means that through enhancing the integration of village markets with a more stable terminal market, good road access allows farm households to generate higher income because they are likely to face relatively lower market risk and thus more likely to adopt new technologies and cultivate riskier high value crops. This holds both for food deficit and food surplus households. As observed in chapter one, households that have good road access are three and a half times more likely to adopt fertilizer. This is not only because better road access raises crop prices and reduces the cost of fertilizer, but also because better roads reduce price volatility and make households less risk averse in their choice of technology and crops.

In order to determine if spatial agricultural markets in Ethiopia are efficient, based on regional grain market data that covers 19 markets, 13 crops and a period of 10 years, as explained earlier, a threshold autoregressive model was estimated and the estimation result is reported in Table 5.2. According to the result, based on a number of cases where the efficient arbitrage conditions are violated, i.e. where the spatial price difference is above the estimated transaction cost level, in 41% of the cases, the sampled markets were inefficient in that the profitable arbitrage opportunities have not been fully exploited. Had there not been market inefficiency, the spatial price gap would have been narrower than currently observed and hence while farmers would have earned higher prices, consumers would have paid lower prices. High frequency of such inefficiency is observed in surplus producing markets. In these markets, while the average level by which spatial price difference exceeded the transaction cost is Birr 30 per quintal, the level reaches as much as Birr 128/quintal. In deficit producing regions, while the average level is Birr 18/quintal, it reaches as high as Birr 85/quintal. Such a high magnitude of inefficiency entails a substantial welfare cost in terms of revenue loss for producers and higher food cost for consumers in deficit markets. There is no doubt that such a level of inefficiency could be one key contributor for the reported high crop price volatility in Ethiopia, although the reverse causation could also be present, i.e. high price volatility increases the risk of arbitrage and hence traders will not undertake arbitrage activities even if the price difference is above the transaction cost. Uncovering the underlying reasons and taking the necessary measures will have a significant impact on rural income and poverty.

Table 5.2
The Estimation Result of the TAR Model

Name of the Market	AR(1) Coeff.*	AR(1) Const.	AR(1) Half Life	TAR Coeff*.	TAR Const.	TAR Half Life	TAR Estimated Transaction cost Level
Mekelle	-0.36	9.44	2.04	-0.55	16.26	1.33	30.67
Debre-Berhan	-0.47	-1.23	1.49	-0.63	-0.25	1.01	7.22
Debre-Markos	-0.41	-9.94	1.52	-0.51	-10.03	1.27	12.00
Dessie	-0.38	2.55	1.67	-0.62	-3.26	1.08	14.91
Debre-Zeit	-0.48	1.08	1.32	-0.82	1.62	0.65	9.33
Asebe Teferi	-0.55	-3.87	1.21	-0.79	-9.82	0.58	13.43
Assela	-0.25	-2.21	1.24	-0.44	-3.09	0.59	9.14
Shashemene	-0.43	-14.35	1.28	-0.87	-12.65	1.03	13.40
Hossana	-0.48	-1.72	1.15	-0.66	-6.42	0.69	12.29
Ziway	-0.49	-5.31	1.13	-0.73	-10.15	0.87	16.00
Ambo	-0.29	-4.36	2.16	-0.40	-7.45	1.59	20.50
Bahirdar	-0.28	11.23	2.25	-0.46	22.60	1.88	46.08
Diredawa	-0.39	-0.17	1.51	-0.56	-1.38	1.22	13.22
Jimma	-0.35	-1.34	1.98	-0.37	-4.75	2.05	37.33
Metu	-0.30	-7.33	2.09	-0.82	-27.77	1.67	21.43
Nekemte	-0.49	-14.13	1.23	-0.53	-13.23	0.97	26.50
Robe	-0.28	1.33	2.27	-0.53	-2.55	1.21	15.00
Woldia	-0.58	-11.17	0.93	-0.60	-11.31	0.98	19.80
Average	-0.39	-1.09	1.62	-0.61	-2.13	1.17	19.39

N.B. Almost 95% of the coefficients are statistically significant at less than 5%.

In terms of poverty, the above reported road induced spatial price changes will also have an important effect on rural poverty both through the income and consumption side. In the previous chapter, it was observed that better road quality raises the income of the poor more than the non-poor. In the same chapter, based on the Blinder-Oaxaca decomposition technique, it was also loosely mentioned that farm households with better road access generate a higher income just because of the road induced increase in overall factor productivity and market rate of return. In this chapter, although one channel by which roads affect farm income is empirically substantiated, which is improving farm gate crop prices, it is not yet clear by how much the poor will specifically benefit from road induced increase in crop prices.

The effect of road induced price changes on the poor depends on their market position. If the poor are net suppliers of crops, they directly benefit from road induced price increase shown above. In villages with good road access 37.5% of households that are in lower income quantile (the first 25%) have supplied crops to the market. Taking the 60%[50] national average share of crop income from total rural income and taking the 44% average share of marketed surplus from total cereals production and also given the above result where good road access raises farm gate prices by 15%, providing all weather road access is expected to improve the income of poor net crop suppliers by a minimum of 4% ($w_i(z)\frac{\partial p}{\partial Rq} = 0.44 * 0.60 * 0.15 \approx 4.0\%$). However, road induced higher crop prices in these villages, which are 15% higher than in villages with poor road access, are expected to reduce the real income of net buyers of crops

[50] Based on the average of six villages estimated by the World Bank (2005).

by almost the same magnitude. Given that expenditure on cereals in rural Ethiopia account for[51] 48% of the budget share of the poor; and also given that the average share of purchased crops from total crop consumption is 33%[52], the average annual real income gain of net grain buyers due to road induced price change will be: $w_i(z)\frac{\partial p}{\partial Rq} = 0.48 * 0.33 * 0.15 \approx 2.4\%$. Nevertheless, both net buyers and sellers of crops would benefit from more stable prices than would be the case if these villages had not had good road access.

In deficit producing villages, road induced reduction in local crop prices is also expected to benefit grain deficit poor households. According to the village price model, given that better road access on average lowers prices by 10% and using the national average budget share of cereal expenditure of the poor (48%) and the 33% average share of purchased crops from total crop consumption, the average annual real income gain of net grain buyers due to road induced price change will be: $w_i(z)\frac{\partial p}{\partial Rq} = 0.48 * 0.33 * 0.10 \approx 2.0\%$. In contrast, net suppliers of crops in deficit producing villages are likely to lose as road induced price decline tends to reduce the price they will

[51] MoFED, (2002)
[52] World Bank (2005)

receive for their crops. Using the national average data on the income share of crops and the share of crops marketed, net suppliers of crops in food deficit villages will at least face a real income decline of 2.6% ($w_i(z)\frac{\partial p}{\partial Rq} = 0.44 * 0.60 * 0.10 \approx 2.6\%$).

5.6 Conclusion

The chapter explored the link between road infrastructure, spatial market integration, the level and stability of farm gate prices. From the result it emerges that although village markets are integrated with the terminal market, local market conditions still exert a significant influence on local price formation. The results also showed that good road infrastructure fosters spatial integration of markets, ameliorates the adverse effect of local excess supply and demand on local prices; and thereby not only improves prices at all locations but also stabilizes them. In both deficit and surplus producing villages that have good road access, the role of spatial market conditions exerts more influence on local price formation. As a result not only are local crop prices generally higher in surplus producing villages and lower in deficit markets, but also prices in both types of villages are expected to be more stable as the central market exhibits high degree of price stability.

In the chapter an attempt was also made to quantify the impact of road induced spatial price change on poverty. The result showed that both net buyers and suppliers of crop will benefit in the form of increased revenue and reduced food expenditure. The increased revenue from road induced price changes works directly and indirectly through altering households' production related decisions. However, it was also highlighted that net buyer poor households that reside in surplus producing villages as well as net crop suppliers that reside in deficit producing villages tend to lose as road raises prices at the former location and depresses them at the latter locations, although these households are expected to benefit from road induced reduction in price volatility and productivity growth. Since most of the net buyer households are net suppliers of labour, as to be discussed in chapter seven, they are however expected to benefit from road induced improvement in off-farm employment opportunity and village market wage rate.

As the efficiency of spatial grain markets exerts a significant influence on rural income and poverty, the chapter also explored if regional grain markets are operating efficiently. The result showed that although the spatial grain markets are integrated, they are inefficient in that profitable arbitrage opportunities have not been fully exploited. Such inefficiency, by preventing a further narrow-down in spatial price gaps, is expected to entail a substantial income and consumption loss. Although the results showed that road infrastructure has a significant impact on the economic welfare of the poor, by narrowing spatial price gaps and reducing price volatility, its potential impact is expected to be undermined by market inefficiency. Since high price volatility, by increasing the variability in grain marketing margins, increasing the risk of arbitrage and dampening the incentive of traders to undertake arbitrage activities, could be one significant contributor for the observed spatial market inefficiency, expanding the road density and improving its quality, through facilitating trade flows and reducing price volatility are also expected to improve spatial market efficiency. In addition to expanding road infrastructure, relaxing entry barriers, which are mainly associated with access to capital, and removing information asymmetry among various market participants would thus be essential to maximize the poverty impact of road infrastructure.

Finally from the findings of the chapter, important policy conclusions can be drawn. First, the significant link between the quality of road infrastructure and spatial prices implies that government interventions to expand the road infrastructure will have significant influence on farm income, rural employment and food security status of the urban and rural households. This is because grain production in Ethiopia contributes over

75% of the rural income and farm employment, and also over 70% of the households' consumption expenditure is spent on cereals (World Bank, 2004).

Secondly, despite concerted effort by the government to enhance modern technology application, the rate of technology adoption still remains at a very low level (World Bank, 2005). One factor claimed behind the low rate of modern technology adoption is associated with the low profitability but high risk of applying such technologies. As the empirical result showed since good road quality reduces the responsiveness of farm gate prices to local supply shocks but increases their responsiveness to spatial market conditions, providing good road access tends to enhance modern technologies, which is in fact the case as the rate of technology adoption in villages with good road access is higher.

Thirdly, the result also suggests that expanding road connectivity will enhance the capacity of the government, at a lower cost, to influence farm gate prices or micro level resource allocation through open market operation at the central market level.

Finally, the extent to which roads narrow spatial price gaps and influence the level of farm gate prices will however depend on the structure or the degree of efficiency with which spatial markets operate. Although, the threshold model result showed that spatial markets are exhibiting substantial inefficiency, it is unclear whether these markets are competitive. For example, the observed strong correlation between Addis Ababa market and regional market prices could be the outcome of non-competitive base point pricing rather than an efficient arbitrage. In other words, such strong price correlation may be due to the fact that the markets are a linked oligopoly (oligopsony) where traders are setting their prices by adding transportation cost on Addis Ababa price. If that is the case, the observed spatial price difference, in addition to transaction cost, also includes traders' rent. Since asymmetrical price transmission is usually the case in such non-competitive market structures, in order to ensure that the benefit of roads is equitably shared, exploring whether the market structure is competitive and also whether spatial price transmission is symmetrical or not will be essential.

In addition, this chapter only assessed the link between village and Addis Ababa market crop prices and the role of road quality in narrowing the price gaps. Given that some regional markets, such as Shashemene, Nazareth and Bahir Dar, are also becoming important hubs where a substantial volume of grain trade flows through, future research that takes into account intra-regional trade will shed more light on the efficiency of spatial markets and the areas where government intervention is required to enhance market efficiency or competition.

Appendix 5A

Table 5A.1

Village Market Linear Price Model Result

Random-effects GLS regression — Number of obs = 505
Group variable: **CropsVillage** — Number of groups = 46

R-sq: within = **0.6352** — Obs per group: min = 10
between = **0.8764** — avg = 11.0
overall = **0.7937** — max = 11

Random effects u_i ~ **Gaussian** — Wald chi2(5) = 341.94
corr(u_i, X) = **0** (assumed) — Prob > chi2 = 0.0000

(Std. Err. adjusted for clustering on CropsVillage)

lnvillPrice	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnaaPrice	.7238397	.046186	15.67	0.000	.6333169	.8143626
RD	-.096221	.0368025	-2.61	0.009	-.1683526	-.0240894
SurplusMar~t	-.2790223	.0348965	-8.00	0.000	-.3474181	-.2106265
RDQualProd~y	.1451003	.047456	3.06	0.002	.0520883	.2381123
time	-.0052356	.0018648	-2.81	0.005	-.0088905	-.0015806
_cons	.3353163	.0281322	11.92	0.000	.2801782	.3904545
sigma_u	.08602156					
sigma_e	.11459253					
rho	.36041363	(fraction of variance due to u_i)				

Table 5A.2

. xtreg lnvillPrice lnaaPrice SurplusMarket RD RDQualProdndummy RDAAprice time, re

Random-effects GLS regression — Number of obs = 505
Group variable: **CropsVillage** — Number of groups = 46

R-sq: within = **0.6404** — Obs per group: min = 10
between = **0.8848** — avg = 11.0
overall = **0.8028** — max = 11

Random effects u_i ~ **Gaussian** — Wald chi2(6) = 1134.47
corr(u_i, X) = **0** (assumed) — Prob > chi2 = 0.0000

lnvillPrice	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnaaPrice	.6688418	.0279157	23.96	0.000	.6141279	.7235556
SurplusMar~t	-.2758599	.0344174	-8.02	0.000	-.3433168	-.208403
RD	-.2709015	.0621501	-4.36	0.000	-.3927135	-.1490895
RDQualProd~y	.1479879	.0465813	3.18	0.001	.0566901	.2392856
RDAAprice	.1014669	.0295598	3.43	0.001	.0435308	.1594031
time	-.0057961	.0017531	-3.31	0.001	-.0092321	-.0023601
_cons	.3611039	.0280087	12.89	0.000	.3062078	.416
sigma_u	.08379438					
sigma_e	.11390413					
rho	.35115133	(fraction of variance due to u_i)				

Chapter 6 Road Infrastructure and Farm Level Efficiency

6.1 Introduction

In chapter 4 it was indicated that land size is a critical determinant of rural income and poverty. In the same chapter it was also mentioned that disparity in the size and quality of land holding are significant factors that contribute to the income gap between the poor and non-poor. Given that the currently sampled households are almost operating on their land frontier, i.e., the average land size is shrinking, and also given that the option of pushing the land frontier is very limited, the rate of future income growth and rural poverty reduction will depend on the degree of efficiency with which the existing resources are employed. Therefore, understanding factors that undermine the level of farm efficiency and implementing counteracting measures will be essential to realize future income growth and reduction in rural poverty.

This chapter has two main objectives. The first one is to assess if there is a significant link between the level of farm efficiency and the road access condition of the household. The second one is to assess the cost of inefficiency on rural income in general and the rural poor in particular. Accordingly, the chapter is structured as follows. First, a brief literature review on the subject will be made. Second, the empirical models to measure efficiency and its determinants will be specified and their estimation strategy will be outlined. Finally, after discussing the empirical results, the chapter concludes.

6.2. Literature Review

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

The issue is vital for policy makers because the strategy pursued 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 farmers are assumed to be reasonably efficient, it means that improving resource allocation at the farm level will not significantly increase farm output; and in that case raising farm output through the introduction of new inputs or technology becomes necessary (Sherlund, et al, 2002; Shultz, 1964). On the other hand, if the farm sector is considered to be operating inefficiently, interventions, such as institutional investment on input delivery, infrastructure and extension services that encourage the effective use of existing resources would be more appropriate (Ali and Byerlee, 1991).

In view of its important policy implication, clarifying whether or not peasant farmers are operating efficiently and also identifying the determinants of efficiency has attracted a lot of debate. While Schultz was the first to come up with his "poor but efficient' hypothesis, subsequent empirical studies challenged his claim (Shapiro, 1983). Currently there seems to be a general consensus that although peasant agriculture exhibits sizable inefficiencies, such inefficiencies, however, are not inconsistent with the rationality of small farmers (de Janvry, et al, 1991). Although household specific factors, such as inadequate information about the existing technology and the lack of sufficient skill to effectively utilize the technology, risk aversion and capital constraints are important contributors, these conditions are mostly externally driven or can be altered through government intervention. Imperfect capital and factor markets, high transaction cost and information asymmetry, among others, make it rational for small farmers to exhibit a resource allocation behaviour that deviates from the neo-classical efficiency conditions. This is especially conspicuous when farmers face high transaction costs, production and market risks.

In terms of input use pattern, these external adverse conditions, by increasing the cost of modern inputs and lowering the opportunity cost of traditional inputs, makes it more rational for farmers to use more traditional rather than modern inputs. In a narrow and segmented market environment, for example, adoption of supply shifting new technologies tends to depress crop prices and increases their volatility (Barrett, 1997). Therefore, farmers rationally tend to choose traditional inputs rather than riskier but highly productivity commercial inputs. Although such choice is rational, given the constraints, it is not without cost and the effort to minimize risk will always leads to a lower average output and farm income[53] (see appendix 2 for detail). Given that most of the factors that make farmers adopt a seemingly inefficient pattern of input use are traced to external factors, government interventions to address these external constraints will have significant pay off as such interventions ensure a short run increase in farm income. Among such interventions, providing farm households with good rural road access will have a critical impact on farm efficiency.

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[53] Inadequate information and lack of sufficient technical skills on the part of the farmer, such as errors in timing and method of application of the inputs, are among the major internal factors for technical inefficiency (Ali and Byerlee, 1991). Imperfection in input or factor markets, such as inadequate and untimely input supply, lack of adequate markets or high transaction cost of accessing such markets, are among the important exogenous factors (ibid). Similarly, the sources of allocative inefficiency can be either due to a failure on the part of the farmer, such as due to risk aversion, capital constraints, inadequate information and skill, or due to external factors, such as missing/imperfect market or institutional constraints (Ali and Byerlee, 1991)

Theoretically, rural road infrastructure affects farm level efficiency through modifying the incentive, the ability and willingness of farm households to efficiently allocate and fully utilize their resources. Through reducing transaction costs and expanding market access, roads affect farm gate prices first and then through the price mechanism alter various micro level decisions, such as how to produce, what to produce and how much to produce, which have significant influence on the farm efficiency level (Gabagambi and von Oppen 2003). In addition, through expanding market outlets, roads not only allow households to specialize in areas in which they have comparative advantage, but also permit them to fully utilize their existing productive potential and adopt new production techniques (Ahmed and Hossain, 1990). Through fostering a more competitive price forming market environment, road infrastructure also puts pressure on farm households to be allocatively more efficient (Shriar, 2005).

Although there are several empirical studies on farm efficiency analysis, the number of studies that have considered the effect of road infrastructure in their efficiency analysis are very few (Gabagambi and von Oppen 2003; Ahmed and Hossein, 1990; Craig, et al, 1997). Based on a cross section data of nine developing countries, Gabagambi and von

Oppen (2003) reported that farm households that have good road access are generally 1.43 times more productive than those that have no road access. They reported that, if the distance of the farm household to a road was reduced by 10%, aggregate productivity will increase by 10.8%. When the sources of productivity increase are decomposed, 8.8% is claimed to come from specialization effect and the remaining 1.98% from intensification effects, such as use of fertilizer, pesticides and HYV seeds. Similar findings were also reported by Craig, et al, (1997) and Ahmed and Hossein (1990).

Although the stake of improving farm level efficiency is substantial in the context of Ethiopia, the number of empirical studies undertaken on Ethiopia is few (Croppenstedt and Demeke, 1997; Seyouma et al, 1998; Abrar, 2003; Gebreegzabher et al. 2004). Moreover, despite its importance, none of these studies have considered the role of road infrastructure on farm efficiency. Similarly, while agro-ecological conditions, such as rain shocks and soil quality, are important determinants of peasant sector production, in estimating farm level efficiency, apart from Croppenstedt and Demeke (1997), most of these studies did not control the effect of these factors. The omissions of these variables are likely to generate biased parameter estimates of the production frontier, technical and allocative efficiency as well as the parameter estimates of the correlates of efficiency (Ali and Byerlee, 1991; Sherlund, et al, 2002).

A brief review of the literature also shows that there are considerable variations in the methods employed in measuring farm efficiency. The methods used by existing studies can be distinguished on the basis of the way the frontier is specified and estimated, on the assumption regarding whether the frontier is deterministic or stochastic and also whether the frontier is estimated parametrically or not. These studies also used different functional forms. While some studies used a production function or its dual profit and cost function specifications (Ahmed and Hossein, 1990; Evenson, 1986), others, still based on a competitive market assumption, used reduced form specifications[54] (Gabagambi and von Oppen, 2003; Stifel and Minten, 2004).

In general, the choice of a particular approach is governed by the objective of the research, the nature of the sample under investigation and data availability (Wadud and White, 2000). If the samples are drawn from

[54] The use of production function or its duals is argued to be theoretically more vigorous than the reduced form equations, especially as the latter one fails to capture both the direct and indirect impact of road (Mamatzakis, 2003).

different geographical locations, and thus operate under different levels of land access and market conditions, the non-frontier efficiency measurement approach proposed by Lau and Yotopoulos (1971) is generally claimed to provide a meaningful estimation of the technical and allocative efficiency of the sample (Ahmed and Hossain, 1990). Such an approach, however, does not enable one to generate the household specific efficiency estimates, which are needed to relate roads to. In addition, the model can only be valid if there is a high degree of spatial price variation in the sample.

In order to circumvent some of the limitations of non-frontier approaches, among others to generate farm specific efficiency measures, a parametric approach is generally employed. Within the parametric approach, either a stochastic or deterministic method is used. The main differences between the two are to do with both the method of constructing the frontier and also in the interpretation of the distance from the frontier (Worthington, 2004). Although each approach has its own strength and weakness, due to the nature of the data available and other relative advantages of the stochastic approach, this research will follow a stochastic approach of efficiency measurement.

Within the stochastic approach, although a production function or its dual profit and cost functional forms can be employed, the use of profit and cost functions is not possible at least for the following reasons. In the case of the profit function, its use is not feasible here because, given the current market price, a substantial number of farm households have negative profit, which would mean that the effective sample size will have to be reduced, i.e., those with negative profit will be dropped from the analysis. In the case of a cost function, although it is widely used in the efficiency analysis, it suffers from theoretical as well as empirical limitations, among which, its assumption of output exogeneity is the major one (Kumbhakar and Wang, 2006). As a result, for our purpose, despite its limitations, a stochastic production function specification will be employed. The technical as well as allocative efficiency estimates will be parametrically generated (Kalirajan, 1990).

6.3. Empirical Model

6.3.1 Empirical Model for Technical Efficiency

In measuring technical efficiency, while the output oriented approach will be followed, it is measured by the level of the deviation of the actual output level from the frontier, which is the maximum level of output that can be produced given the existing state of technology (Morrison 2002).

Assuming that the production frontier takes the following form:

$$y_{it} = f(x_{it}, Z_{it}; \beta) + v_{it} - \mu_i \qquad (6.1)$$

Where y_i is the aggregated crop output of household 'i" at time t, X is the quantity vector of variable inputs, Z is a vector of fixed inputs and agro-ecological variables, β is a vector of parameters to be estimated, $\varepsilon_i = v - \mu$ *, v* where *represents the random error term and μ represents the short fall in output that arises due to technical inefficiency.*

In equation (6.1), $f(x_i; Z, Rd, \beta)_i + v$ represents the stochastic part of the production frontier and μ represents the one-sided error term and measures the household specific technical efficiency level (Kalirajan, 1990). Exp(μ_i) takes the value between 0 and 1 depending on how close the output of household (y) is to the frontier. If the household is technically efficient μ takes the value of zero, and thus the actual output level of the household will be equal to the maximum possible level[55].

The error term of the production frontier is composed of two components (v,u). The normal error term provides the production frontier to be stochastic, which makes the frontier to vary over time for the same household. However, the one sided component u, which measures technical efficiency level, is assumed to be half normal and identically and independently distributed as $N(0, \sigma_u^2)$. Then, it follows that

$$\sigma^2 = \sigma_\mu^2 + \sigma_\nu^2 \qquad (6.2)$$

However, when the stochastic frontier is estimated, what is usually generated is a single number, i.e. just the error term ε_i (Aigner, et al, 1977). 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[56]:

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[55] In the present case, better road access, through facilitating access to market, access to better quality inputs and enhancing the overall productivity of productive inputs, enables households to produce "closer" to the frontier.

[56]Jondrow, et al., (1982) were first to suggest 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 $\sigma^2 = \sigma_\mu^2 + \sigma_\nu^2$, $\mu_* = \frac{\sigma_u^2 * \varepsilon}{\sigma^2}$

$$E[\mu \mid \varepsilon] = \frac{\sigma_{\mu}\sigma_{v}}{\sigma} \left| \frac{f(\varepsilon\lambda / \sigma)}{1 - F(\varepsilon\lambda / \sigma)} - \frac{\varepsilon\lambda}{\sigma} \right|, \quad (6.3)$$

Where $\lambda = \frac{\sigma_{\mu}}{\sigma_{v}}{}^{2}_{v}$, 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 are more dominated by variability emanating from technical inefficiency.

Once point estimates of μi are obtained, a technical inefficiency level for each farm household is given by:

$$TE_i = E(\exp\{-\mu_i\} \mid \varepsilon_i = \left[\frac{1 - \Phi(\sigma_* - \mu_{*i} / \sigma_*)}{1 - \Phi(-\mu_{*i} / \sigma_*)} \right] \exp\{-\mu_{*i} + \frac{1}{2}\sigma_*^2\} \quad (6.4)$$

In postulating the frontier, although a flexible form of production function, such as translog, is generally preferred, when such functional form is postulated, a serious multicollinearity problem emerges between each input such that either some of the interaction terms become insignificant or have unexpected sign. While estimating a production frontier for sample farmers of Northern Ethiopia, a similar observation was reported by Gebreegziabher, et al, (2004). As a result, for our purpose here, a Cobb-Douglas production function specification will be used (Gebreegziabher, et al. 2004).

$$\ln y_i = \beta_0 + \sum_{i=1}^{6} \beta_i \ln x_i + u + v \qquad (6.5)$$

where $\boldsymbol{y_i}$ *is the level of total output of household "i",* $\boldsymbol{x_i}$ *is a vector of inputs; and includes land in hectare* (x_1)*, labour input in man days* (x_2)*, quantity of fertilizer used* (x_3)*, the index for rain shock* (x_4)*, number of oxen* (x_5)*, and the average soil quality of land the household cultivates* (x_6)*, where 0 is for poor quality, 1 for semi fertile and 2 for top soil;* $\boldsymbol{u_i}$ *is one side error term that capture the technical inefficiency and* $\boldsymbol{v_i}$ *is the two sided error term.*

Regarding the sign, higher land size, more labour and oxen power allow households to produce closer to the frontier. Adequate labour and oxen power allow households to undertake timely farm activities and efficient farm operations; and thus are expected to have a positive sign (Gebreegziabher, et al. 2004). Fertilizer input, by increasing productivity of land and labour, makes households produce closer to the frontier; and as a result its sign is expected to be positive. Rainfall shock by reducing factor productivity reduces households' output below the potential; and as a result, it will have a negative sign (Seyoum, et al, 1998). As soil quality raises the productivity of variable inputs, it is expected to have a positive sign.

In terms of policy implications, it is probably more important to determine what actually causes inefficiency (or to which variables it is related to) than simply to measure it. In order to determine the significance of various correlates of technical inefficiency, the inefficiency score generated from equation (6.5) will be regressed on household and village specific covariates, where road quality of the village will be one (Kalirajan, 1990; Rahman, 2003). In identifying the variables to be included in the model, the approach of previous similar empirical studies was followed (Kalirajan, 1990; Rahman, 2003).

$$\mu_{it} = \alpha_0 + \alpha_1 Z_1 + \alpha_2 \ln Z_2 + \alpha_3 \ln Z_3 + \alpha_4 \ln Z_4 + \alpha_5 Z_5 + \alpha_6 Z_6 + \alpha_7 Z_7 + \alpha_8 Z_8 + \varepsilon_{it\,i} \quad \textbf{(6.6)}$$

Where u_{it} is the technical efficiency score of household "i" at time t, and the Z's respectively are dummy variable for the quality of road that connects the village with the nearest market town (1=good), average educational attainment of the adult household members, age of household members, family size, dummy for gender of the household head (1=Female), number of plots cultivated, number of crops cultivated and dummy for whether the household had access to credit (yes=1).

The road variable, for the reasons mentioned before, is expected to have a positive sign (Kalirajan, 1990; Rahman, 2003). Higher educational attainment enhances the capacity of the household to acquire, process and interpret market information; and thus enables the household to make optimal decisions (Vakis, et al, 2003; Huffman, 1977). As a result the education variable is expected to have a positive sign. The age level of the household head, through its effect on experience, is expected to raise the technical efficiency level (ibid). However, it could also have a negative impact on efficiency if higher age makes the head of the household risk averse in adopting new production techniques (Seyouma, et al, 1998). Thus, the sign of this variable cannot be determined a priori.

Family size, by allowing the household to attain a more effective division of labour as well as ensuring availability of adequate labour for farm activities to be performed on time, tends to make farm households attain higher technical efficiency[57] (Ali, et al, 1996; Parikh, et al, 1995). Similarly, in households that have low land-labour ratio, higher family size could motivate them to adopt productivity enhancing commercial inputs (Haji, 2006). As a result, this variable is expected to have a positive sign.

As land cultivation is undertaken by men, female headed households have to rely on relatives, which adversely affects the timely implementation of

[57] In some households, labour shortage was reported as one problem and thus households with larger family size are less likely to have such problems.

farming activities, where the technical efficiency level of female headed households is expected to be lower and as a result, the variable of the gender of the household head is expected to be negative (Gebregzaber et al 2004). The number of plots that the household cultivates, which is assumed to measure the degree of land fragmentation, by preventing the household from having scale economies, making supervision and protection of the land difficult and entailing long distance travel and loss of working hours, reduces its technical efficiency level (Haji, 2006; Parikh, et al, 1995; Ali, et al, 1996; Bizimana, et al, 2004). As a result, the variable is expected to have a negative sign. The number of crops cultivated, which is usually the outcome of high transaction cost of accessing food market, is expected to have a negative sign as it makes the household to be self-sufficient at higher cost (Omamo, 1998; Haji, 2006). Access to credit by reducing the shadow cost of risky but productive commercial inputs raises their probability of adoption and hence the technical efficiency of the household. As a result this variable is expected to have a positive sign.

6.3.2 Allocative Efficiency

As previously argued, due to risk consideration, farm households generally employ riskier inputs at the point where the expected marginal value product of the input is greater than its marginal cost. Such an allocation minimizes the possible loss in case of production and price decline, but it does not generate the highest return to the factors employed and hence it is not without a cost. It was also mentioned that good road access by influencing some of the variables that shape the allocative decision of farm households generally boosts returns to higher levels than otherwise would be possible. In order to statistically substantiate that, first the magnitude of allocative deviation will be generated. Allocative efficiency occurs when the marginal revenue contribution of fertilizer input is equal to its cost (price), which is:

$$p_y \frac{\partial \ln y}{\partial \ln x_i}\left(\frac{y}{x_i}\right) = p_{X_i}, \tag{6.7}$$

Where y and P_y respectively represent output level and its unit price; x_i and P_{Xi} represent the quantity of fertilizer and its market prices respectively.

After re-arranging the terms, a profit maximizing fertilizer demand or application will be:

$$\frac{p_{xi}x}{p_y y} = S_i = \frac{\partial \ln y}{\partial \ln x_i} \tag{6.8}$$

The left hand side of Equation (6.8) is the share of the cost of fertilizer from total revenue; and it implies that for the profit to be maximized or cost minimized, fertilizer should be used up to the point where its marginal revenue contribution is equal to the ratio of its cost to total revenue (Lau and Yotopoulos, 1971). The magnitude of the deviation between the actual share (S_i) and the optimal share, i.e. $\left(\frac{\partial \ln y}{\partial \ln x_i}\right)$, thus measures the degree of misallocation (Carter, 1984). Accordingly, the magnitude of the deviation will be given by

$$\mu_{FR} = S_{FR} - \frac{\partial \ln y}{\partial \ln x_{FR}} \qquad (6.9)$$

The coefficient estimates for the elasticity of fertilizer inputs will be taken from the production frontier estimated for households that have applied fertilizer. The coefficient estimate and thus the level of inefficiency however is expected to be underestimated as the level of fertilizer application of the sample is substantially below the optimum level, i.e. the minimum level recommended for high response of fertilizer (Demeke, et al, 1997).

Finally, in order to statistically substantiate if roads have an impact on farm income through reducing allocative inefficiency, the following model will be estimated.

$$\mu_{FRit} = \eta_0 + \eta_1 m_1 + \eta_2 \ln m_2 + \eta_3 \ln m_3 + \eta_4 m_4 + \eta_5 m_5 + \eta_6 \ln m_6 + \eta_7 \ln m_7 + \eta_i V_i + \varepsilon_{it} \quad (6.10)$$

Where μ_{FR} *is the magnitude of the deviation between MC and MVP of fertilizer input of the household in village i at time t,* m_1 *is the dummy for road quality of the village,* m_2 *is the average schooling of adult household members,* m_3 *is family size,* m_4 *is a dummy for the gender of head of the household,* m_5 *is a dummy for whether the household had credit access,* m_6 *is average age of the household members,* m_7 *is the size of the livestock asset of the household and V is the village dummy.*

Better road access as previously argued, through altering price ratios and reducing market risk, is expected to make households to be less risk averse and hence the variable is expected to have a negative sign. The education variable, as education makes the household less risk averse, is also expected to have a positive sign (Rahman, 2003). Households with large family size and those that are headed by females are generally likely to take a risk averse stance and hence these variables are expected to have positive signs. Credit access by easing cash constraints tends to increase the willingness of the household to take risk and hence the variable is expected to have a negative sign. The higher the age of the head and other adult household members tends to make the household risk averse and thus is expected to have a positive sign. A large livestock holding, by increasing the risk bearing capacity of the household, increases the willingness of the household to take risk and thus expected to have a positive sign. The sign of the village dummy cannot be a-priori determined as it captures other village characteristics that affect demand for fertilizer.

Once the significance of the link between road access status and levels of allocative efficiency is substantiated, in order to determine the cost of inefficiency on rural income in general and income of the poor in particular, the net income of the sample will be regressed on the allocative inefficiency score. The relation between the two will also be postulated on the basis of the random effect and the quantile regression models. The random effect model will provide information if such allocation deviation generally entails a reduction in the amount of income the household could generate. The quantile regression model result provides information as to whether or not allocative inefficiency significantly harms the poor. In order to claim that roads have significant impact on rural income and poverty, the regressor in both models should be negative.

6.4 Estimation Strategy

In estimating efficiency and its determinants, currently two approaches are generally followed. In the first approach both the variables that affect production level and those that influence the technical efficiency level are included while estimating the production frontier (Gebreegziabher, et al 2004). In the second approach however, a two-step approach is followed. At the first stage, from the estimated production frontier, household specific inefficiency scores are generated; and at the second stage, using OLS, the generated inefficiency scores are regressed on variables that are assumed to influence technical efficiency level.

The use of the second approach is criticized on two grounds. First, the exclusion of variables that affect the level of efficiency from the production frontier is based on the implicit assumption that variables that determine technical efficiency and the variables included in the production frontier are orthogonal. The consistency and unbiasedness of the coefficient estimates of the production frontier therefore depend on whether these variables are truly orthogonal (uncorrelated) (Gebreegziabher, et al 2004; Kumbhakar, 1994). Second, while estimating the production function, the basic assumption is that the error term has a zero mean, which means variables that are not included in the model will not have any systematic effect on the dependent variable and on balance they cancel each other out, which is claimed to be a contradiction using variables to explain the error term (Greene, 2002; Gebreegziabher, et al 2004).

Despite such criticism, however, the two step approach remains the most widely used method mainly because it clearly separates technical factors that directly affect production from managerial related factors, which influence how these inputs are used[58] (Ali and Byerlee, 1991). In order to see if the effect of road infrastructure on farm efficiency could vary depending on the model used, the technical efficiency of the sample was estimated on the basis of both approaches. The results generated on the basis of both approaches however are similar in that according to both approaches households with good road access are 16% technically more efficient. For the purpose of discussing the result however, the two step approaches will be followed; and accordingly first on the basis of a production frontier specification, the inefficiency score will be generated, and at the second stage, the inefficiency scores are regressed on the road

[58] Ali and Byerlee (1991) argued that such approach avoids the simultaneity problem of including both conventional and non-conventional inputs in the production function (p. 9).

access conditions as well as other households and village specific factors that are presumed to affect technical efficiency[59].

Due to the panel nature of the data, the production frontier will be estimated on the basis of time invariant efficiency model (Bravo-Ureta and Pinheiro, 1993). The major advantages of the panel data model are that, the derivation of efficiency estimates does not necessarily require imposing a half normal-distribution of *u*. Such an assumption implies that inefficiency has a mode of zero and suggests that most farmers approach the frontier, which is debatable given the nature and the likely distribution of the factors that give rise to inefficiency (Muller, 1974). In addition, in panel efficiency models, there is no longer a need to assume that inefficiency is independent of the level of inputs used, which otherwise implies that farmers are ignorant about their inefficiency and do not vary their input use level to compensate for their inefficency, which is again questionable (Hallam and Machado, 1996). The use of a panel model also resolves the problem of estimating efficiency when the management factor is unobservable (Greene, 1980).

[59] The estimation result of the one step approach is reported in appendix 1 Table 2.

6.5. Discussion of the Results

6.5.1 Technical Efficiency

The production frontier of equation (6.5) was estimated and all the variables are significant and also have the expected sign (Table 6.1). The presence of technical inefficiency is also confirmed by the significance of "mu' as well as on the basis of the likelihood ratio (LR) test. The null hypothesis (i.e., γ =0) is rejected at less than 1%. As can be seen from Table 6.1, γ (gamma), which measures the extent to which the observed variation in the level of output is due to inefficiency, is significant at less than 1%, suggesting that 15% of the variation between the actual and the potential output is due to technical inefficiency[60] (Bravo-Ureta and Pinheiro, 1997).

The presence of technical inefficiency suggests that there is ample room to increase farm output through improving access and enhancing the effective use of the existing technology. According to the result, the average technical efficiency level of the entire sample was 49%; and it ranges from the lowest of 22% to the highest of 90%.

[60] 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).

Table 6.1

Time-Invariant Technical Efficiency Model Result

Variables	Coef.	z	P>z
Constant (β_0)	1.86	8.25	0.00
log(Hectare of land) (β_1)	0.39	11.63	0.00
log(labor input in man days) (β_2)	0.07	3.32	0.00
log(Fertilizer input in Kg.) (β_3)	0.10	7.48	0.00
Rain shock index (β_4)	-0.04	-2.37	0.02
log(number of Oxen) (β_5)	0.34	6.96	0.00
Soil Quality index (β_6)	0.24	3.27	0.00
/mu	0.78	3.43	0.00
/lnsigma2	-0.29	-3.78	0.00
/ilgtgamma	-1.72	-3.68	0.00
sigma2	0.75		
γ (gamma)	0.15		
sigma_u2	0.11		
sigma_v2	0.64		

Group variable (i): paid, Time variable (t): year

Number of obs=1674, Number of groups=14, Wald chi2(7)= (553, 1279), Prob > chi2=0.0000

The size and quality of land households own, the number of oxen they own and their adoption of fertilizer in general and its level of use in particular are significant determinants of the technical efficiency level of the sample. Although significant, the marginal contribution of labour however is not substantial, which is expected given the presence of underemployed family labour (Rahman, 2003). Besides, when the production frontier is estimated separately by splitting the sample into villages with good and poor road access, the labour coefficient while positive and insignificant in the estimated frontier for villages with poor road access, is positive and significant for villages with good road access[61]. This result further confirms the claim made in chapter 4 that better road access raises the marginal productivity of labour. The level of rain shock that the household would experience will also have a significant adverse effect on technical efficiency, suggesting that agro-ecological factors are also important determinants of farm efficiency. The result suggests that, on average, rainfall shocks reduce the potential output level by close to 3.7%.

When the sample households are categorized according to whether they have used fertilizer or not, households that applied fertilizer are on average 13% technically more efficient than non-users. This variation in technical efficiency level suggests that the technology that the sample households are using is not homogeneous and without introducing new technology but through facilitating access to the existing technology, a substantial increase in farm output can be realized.

As previously argued, providing adequate road access could be one intervention through which access to and effective use of the existing technology can be enhanced. When the samples are grouped according to

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

the quality of road infrastructure that they have access to, the average technical efficiency of households that have good road access was 13% higher than those with poor road access[62]. The gap also ranges from the lowest of 10% to the highest of 25% (Table 6.2). The result implies that in comparative terms, for the same level of resources employed, farm households that have good road access generally generate 13% more output[63] (Table 6.2 below). According to the result, 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 and most efficient ones also will respectively realize a 28.6% and 27.8% growth in output.

Table 6.2

Level of Technical Efficiency by Type of Road Access

Type of Road	Mean	Standard deviation	Min	Max
Poor Access	0.44	0.14	0.25	0.65
Good Access	0.57	0.16	0.35	0.90
Total	0.52	0.16	0.25	0.90

In order to substantiate the significance of the association between road access condition of the sampled households and their technical efficiency

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[62] As to be noted in the next section, when the efficiency score is regressed on the determinants of farm technical efficiency, in which road access condition is one, the result showed that households that have good road access are 16% technically more efficient, which is a bit higher. However, the 16% result is more reliable as it controls other factors that affect efficiency directly as well as indirectly through mediating the link between road condition and efficiency level.

[63] 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%.

level, the technical efficiency score was regressed on the road quality dummy as well as other variables that capture household and village characteristics. The result is reported in Table (6.3). According to the result, the variables included in the model, depending on which model is considered, explained for up to 28% of the variation in technical efficiency. Household specific factors, such as age, average schooling level, gender, family size, and degree of land fragmentation are significant determinants. Among village specific factors, the road quality of the village is a significant determinant of technical efficiency. According to the result, on average, farm households that have good road access are 16% technically more efficient. In other words households that have good road access generally operate closer to the frontier or generate 16% higher output from the same unit of land employed[64].

As previously argued, the main mechanism by which road access raises the technical efficiency of the farm households mainly works through enhancing fertilizer application (Model II). More than 62% of households that applied fertilizer are in villages with good road access; and the per-hectare application of fertilizer in these villages was also 52% higher.

[64] As it was noted in the footnote of the previous page, the 16%, rather than the 13% result generated on simple average, is more reliable as it controls other factors that affect efficiency directly as well as indirectly through mediating the link between road condition and efficiency level.

As can be observed from both models, while good road access generally increases average technical efficiency by 16%, close to 9% of this technical efficiency 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 occur through road induced improvement in overall productivity or expansion in market opportunities that allow farm households to generate higher output from a given resource. This finding further substantiates the claim made in Chapter 4 that the return to roads is higher in a situation when households adopt fertilizer.

Table 6.3

Determinants of Technical Efficiency

	Model I			*Model II*		
Variables	*Coefficient*	*Z*	*P-value*	*Coefficient*	*Z*	*P-value*
Road Quality	0.16	17.43	0.00	0.07	5.66	0.00
log Av. Years of Scooling	0.05	6.94	0.00	0.05	6.82	0.00
log Average Age of the HH Members	-0.05	-5.20	0.00	-0.04	-4.37	0.00
log Family Size	0.00	0.77	0.44	0.01	0.93	0.36
Dummy for Female Headed HHs	-0.03	-3.00	0.00	-0.02	-1.77	0.08
No. of Plots Cultivated	-0.01	-4.96	0.00	-0.01	-6.23	0.00
No. of Crops Cultivated	-0.01	-3.00	0.00	-0.01	-3.20	0.00
Dummy for Credit	0.03	4.62	0.00	0.02	3.38	0.00
*RoadQuality*fertuse Dummy*				0.09	5.20	0.00
Fertilizer Use Dummy				0.03	2.07	0.04
Constant Term	0.59	17.59	0.00	0.56	17.04	0.00
	F(7,1667) =63.2			F(8, 1667) =65.2		
	R-squared = 0.23			R-squared= 0.28		
	Adj R-squared = 0.23			Adj R-squared =0.28		

* The unit of Analysis is Village

More years of schooling of the adult family members, as a priori expected, positively influences the technical efficiency level (Ali and Flinn, 1989). According to the result, on average, more years of schooling, by increasing the probability of adopting better technology and enhancing its effective use, raises the technical efficiency level by as much as 5%. The result also shows that although family size has no significant impact on the technical efficiency level, the average age of the household members matters and households with higher ratio of adult family members are technically less efficient, suggesting that the adverse effect of age that works through inducing a risk averse behaviour is more dominant. Compared with male headed households, female headed households, as a priori expected, on average 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 works on Ethiopia (Mulat 1999). As noted in chapter 2, high population growth is one major contributor to rural poverty. As land fragmentation normally increases with rural population size, this result confirms that 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%. As households diversify crops with the objective of minimizing risk or avoiding higher price of purchase or due to lack of purchasing power, the significance of this variable indicates that high transactions costs, product and factor market imperfection have important influence on farm technical efficiency. The coefficient estimate is also expected to measure the output loss farm households could experience by devoting their limited land area to crops that they are less efficient at producing[65] (Fafchamps, 1992; Wolgin 1975). The positive sign and significance of the credit dummy variable also suggests that households' access to credit, by easing the liquidity constraint and promoting their fertilizer use, enhances their technical efficiency level.

In order to generate information on the impact of technical inefficiency on rural income in general and the income of the poor in particular, the log of net income is also regressed on technical inefficiency score; and the result

[65] 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).

is presented in Table 6.4. According to the result, technical inefficiency reduces the income of the sample. A 1% decline in technical efficiency level reduces the net income of the whole sample by 2.4%.

Table 6.4

The Impact of Inefficiency on Net-Income by Income Quantile

	OLS on the Whole Sample			On the 25% Income Quantile			*On the 75% Income Quantile*		
Variables	*Coefficient*	*Z*	*P-value*	*Coefficient*	*Z*	*P-value*	*Coefficient*	*Z*	*P-value*
Technical Inefficiency	-2.38	-14.98	*0.00*	-2.55	*-8.43*	*0.00*	-2.40	-21.40	0.00
Constant Term	8.31	98.28	*0.00*	7.78	48.93	*0.00*	9.10	150.94	0.00
	R2=0.12	F(1,1680)=224.3		Pseudo R2=0.05			Pseudo R2=0.07		
	AdjR2=0.12			no of obs. 1682			no of obs. 1682		

On the basis of inter-quantile regression, although the effect of inefficiency on widening the income gap between the poor and non-poor is not significant, from the result, it emerges however that the poor lose proportionately a little more than the non-poor; and a 1% decline in technical efficiency level reduces the net income of the poor and the non-poor by 2.6% and 2.4% respectively.

Previously the claim was also made that the other channel through which roads influence rural income and poverty works through promoting a more efficient allocation of resources. In order to substantiate if such a claim actually holds in the sampled villages, the magnitude of the deviation between the optimal and actual use of fertilizer was calculated. The result shows that all sampled households, as expected, exhibited a risk averse behaviour in that they employ fertilizer sub-optimally in that the average MVP of fertilizer is higher than the MC of fertilizer. In order to see if good road access alters risk aversion and on average narrows down the level of allocative inefficiency, the calculated allocative inefficiency was regressed on road quality as well as other characteristics that influence the risk preference of farm households. The result is reported in Table 6.5.

On the basis of the F-test the estimated model is significant at less than 1%. Except road quality and village dummies, most of the household specific characteristics are not significant. As a priori expected, the road quality of the villages significantly influences the magnitude of allocative inefficiency in fertilizer use. Farm households that reside in villages with good road access are on average 22% more efficient in their application of fertilizer. It means households with good road access combine fertilizer with other inputs relatively more efficiently so that they are able to generate higher return from their land and labour resources. In view of the fact that the marginal revenue productivity of fertilizer (Birr 19) significantly diverges from the average market price of fertilizer (Birr 3), it suggests that the underutilization of the input is substantial and, as argued before, promoting fertilizer application could be one potential avenue by which a substantial increase in rural income can be realized.

Table 6.5
Fertilizer Allocative Inefficiency and Its Determinants

Variables	Coefficient	Z	P-value
Road Dummy	-0.22	-4.52	0.00
log Av. Years of Scooling	0.01	0.26	0.79
log Family Size	0.00	0.08	0.93
Dummy for Female Headed HHs	0.03	0.97	0.33
Dummy for Access to Credit	-0.02	-0.98	0.33
log Average Age of the HH Members	-0.04	-1.29	0.20
log Number of Livestock Owned	0.02	1.59	0.11
Village dummy (1)	-0.02	-0.25	0.80
V2	(dropped)		
V3	-0.04	-0.57	0.57
V4	0.37	4.44	0.00
V5	0.15	2.29	0.02
V6	0.30	3.68	0.00
V7	0.22	2.84	0.01
V8	0.34	4.43	0.00
V9	0.33	5.06	0.00
V10	-0.03	-0.51	0.61
V11	0.29	3.51	0.00
V12	0.26	3.12	0.00
V13	0.33	3.71	0.00
V14	0.37	3.96	0.00
Cons	-0.05	-0.44	0.66
Number of obs==1534	R-squared=0.05		
F(20, 1513)=3.76	Adj R-squared=0.03		

In order to see if such allocative inefficiency actually reduces the income of the sample in general and the income of the poor in particular, the net income of the sample is regressed on the calculated allocative inefficiency level. The estimation was implemented both on the random effect model and on the basis of quantile regression method. The random effect model result provides information about the mean effect of inefficiency on the net income of the whole sample. The quantile regression model on the other hand helps to draw information as to whether inefficiency particularly harms the poor. The estimation result is reported under Table 6.6. Although the magnitude of R^2 in both models is very low, both models are significant.

Table 6.6

Fertilizer Allocative Inefficiency and Net-Income by Income Quantile

	Random Effect GLS Model on the Whole Sample			Quantile Regression On The 25% Income Quantile		
Variables	***Coeffi.***	***Z***	***P-value***	***Coeffi.***	***Z***	***P-value***
Allocative Inefficiency	***-0.56***	***-8.59***	***0.00***	***-0.64***	***-7.82***	***0.00***
Constant Term	***7.08***	***208.44***	***0.00***	***6.39***	***138.08***	***0.00***
	sigma_u=0.7		**rho=0.35**	**Pseudo R2=0.08**		
	sigma_e=0.95		**R2=0.03**			
	Wald chi2(1)=73.71					

****The net income is measured in natural log.***

The result generally suggests that allocative inefficiency reduces income in general and the income of the poor in particular. A 1% increase in the magnitude of allocative inefficiency reduces the income of the whole sample by 0.56%, but it reduces the income of the poor by 0.65%. The result is also almost the same when the effects of technical and allocative inefficiency on income are jointly estimated (Table 6.7). The inter-quantile regression model result also shows that inefficiency is indeed one factor that contributes to the income gap between the poor and the non-poor. Although technical inefficiency positively contributes to widening the income gap between the poor and the non-poor, its contribution however is not significant.

Table 6.7

Inefficiency and Net-Income by Income Quantile

	Random Effect GLS Model on the Whole Sample			Inter-Quantile Regression 25% & 75% Income Quantile		
Variables	*Coeffi.*	Z	*P-value*	*Coeffi.*	Z	*P-value*
Allocative Inefficiency	*-0.58*	*-9.16*	*0.00*	*0.51*	*2.03*	*0.04*
Technical Inefficiency	*-2.46*	*-14.00*	*0.00*	*0.24*	*0.95*	*0.34*
Constant Term	*8.31*	*89.26*	*0.00*	*1.29*	*9.45*	*0.00*
	sigma_u=0.6		rho=0.26	.75 Pseudo R2=0.09		
	sigma_e=0.95		R2=0.15	.25 Pseudo R2=0.08		
	Wald chi2(2)=268.96					

**The net income is measured in natural log.*

The positive sign and significance of the allocative inefficiency variable, however, suggests that an increase in allocative inefficiency significantly widens the income gap between the poor and the non-poor. A 1% increase in allocative inefficiency increases the income gap between the 25 and 75 income percentiles by close to 0.5%. Given that the magnitude of technical and allocative inefficiency of the sample is significantly and negatively related to the quality of the road infrastructure of the village, it can be concluded that road infrastructure, in addition to its effect on income that operates through altering market prices, has an income effect that works through enhancing resource use and allocation efficiency.

Assuming that risk and profitability considerations are the major factors that shape the farm households decision to adopt and efficiently apply fertilizer, in addition to the previous chapter results which show the significant impact of road on the level and volatility of farm gate prices, which are the key critical factors that affects the risk and profitability of fertilizer use, a village level fertilizer model was also estimated. The estimation result of the farm gate fertilizer price model is reported in Table 6.8 below. According to the result, after controlling for the port price and other factors that affect the domestic cost of fertilizer distribution, in villages with good road access, the average fertilizer price is 15% lower compared to villages that have poor road access[66].

[66] All the included variables have the expected sign. The road density of the zone was included in the model because it influences the magnitude of the transaction cost of supplying fertilizer to the village market. The distance of the village from Addis Ababa is also introduced in the model because Addis Market is the main supply centre for chemical fertilizer.

Table 6.8

Random Effect Model for Village Market Fertilizer Price

Independent Variables	*Coefficient*	*Z*	*P-value*
Village Road Quality Dummy	*-0.15*	*-3.10*	*0.00*
Distance from Addis in km.	*0.001*	*2.80*	*0.01*
Port Price per kg.	*0.74*	*38.98*	*0.00*
Road Density of the Zone	*-0.01*	*-2.74*	*0.01*
Constant	*1.68*	*12.15*	*0.00*
R^2 =0.94, Wald chi-sqre. 1572			

Given that the demand for fertilizer and the magnitude of fertilizer use are significantly influenced by the profitability of the input, which roads are shown to significantly influence, the observed lower allocative inefficiency and higher per-hectare application of fertilizer is likely to be a direct consequence of road induced changes in village level price ratios. The result generally substantiates the previously reported high return of roads in terms of poverty reduction that works through altering farm gate price ratios, and also reinforces the effect of roads on poverty that works through altering the risk preferences of the poor as well as enhancing their adoption and efficient application of fertilizer.

Acknowledging that farmers rationally utilize more traditional inputs, such as labour than fertilizer, in order to see if road alters the manner in which the sampled households combine labour and fertilizer input, input specific efficiency scores were estimated for labour and fertilizer. The estimated result is reported in Table 6.9.

According to the result, on the basis of the current market price of labour and fertilizer, the sampled households underutilized the fertilizer input by close to 7% less than the profit maximizing level. The estimated allocative inefficiency of fertilizer however is expected to be understated at least for three reasons. First, as previously mentioned, rain related shock is the critical factor that reduces the productivity of fertilizer. When the rain shock effect is controlled, the elasticity of output to fertilizer was increased by 38% and so does the underutilization of fertilizer input. Second, the average fertilizer use of the sample is 79 kg per hectare compared to the minimum recommended rate of 150-200kg/hectare. The shortfall is also higher in villages that have poor road access as fertilizer use per hectare in these villages was on average 17kg compared to 114 kg in villages that have better road access. Thirdly, for better output response, while it is generally recommended that DAP and UREA should be applied in equal proportion, the sampled farmers are biased towards using more DAP (Croppsedant and Demeke, 1997).

Table 6.9
Average Deviation between Actual and Optimal Input Use
By Road Quality of the Village

Type of Input	*Obs.*	*Mean*	*Std. Dev.*	*Min*	*Max*
Fertilizer	*1682*	*-0.07*	*0.42*	*-0.18*	*12.00*
Poor Road Access	*624*	*-0.08*	*0.53*	*-0.18*	*12.00*
Good Road Access	*1058*	*-0.06*	*0.33*	*-0.18*	*9.20*
*Labour**	*1682*	*0.9*	*4.35*	*0.00*	*131.00*
Poor Road Access	*624*	*1.50*	*6.21*	*0.01*	*130.71*
Good Road Access	*1058*	*0.54*	*2.66*	*0.00*	*75.29*

* *Assuming Perfectly Competitive Labour Market*

The sampled households, however, possibly in response to the labour market constraint, applied labour input by an average of 90% above a profit maximizing level. In comparative terms, in villages with good road access, the underutilization of fertilizer and overutilization of labour is lower, suggesting that in these villages the shadow price of labour is relatively higher.

6.6. Conclusion

The chapter has investigated the significance of the effect of road infrastructure on rural income and poverty that operates through altering farm level technical and allocative efficiency. The empirical result showed that the samples have exhibited a high level of technical as well as allocative inefficiency.

The major factors that have contributed to technical as well as allocative inefficiency are also found to be related to specific household as well as village specific characteristics. Among village level characteristics, the empirical result showed that there is a strong link between the road quality to which farm households have access and their technical and allocative efficiency level. The mechanisms by which roads affect technical and allocative efficiency is also shown to operate through altering farm gate price ratios and reducing market risks. Although technically and allocatively inefficient, in comparative terms, farm households that have good road access have exhibited a high degree of efficiency. Among household related factors, land and family size, land fragmentation, the adoption and level of fertilizer use, age and human capital endowment of farm households are important ones. Again although most of these factors appear to be internal to farm households, they are however externally induced, such as in response to imperfection in goods and factor markets.

High technical as well as allocative inefficiency are also found to be major contributors to the low income level of the sample in general and the income of the poor in particular. Compared to allocative inefficiency, technical inefficiency is the major adverse contributor to low rates of return to land and labour. Although not substantial in terms of reducing rural farm income, the result showed that allocative inefficiency marginally contributes to widening the income disparity between the poor and the non-poor.

The presence of technical inefficiency suggests that there is ample room to increase farm output through improving access and enhancing the effective use of the existing technology. Similarly, the presence of allocative inefficiency also suggests that with the existing resource level and technology, reallocation of the existing inputs could boost farm productivity and income. This is especially important given that the sampled households are already operating on their land frontier and any income growth and rural poverty reduction will depend on the efficiency with which farm resources are allocated. As the empirical results of the chapter showed, despite the risk aversion behaviour and the absence of perfect market conditions, providing farm households with good road access is an effective public intervention in achieving the desired improvement in farm efficiency level.

Appendix 6A

Table 6A.1

Time-invariant inefficiency model
Group variable: paid

Number of obs = 1682
Number of groups = 14

Obs per group: min = 46
avg = 120.1
max = 178

Wald chi2(6) = 563.77
Log likelihood = -2026.3358
Prob > chi2 = 0.0000

y	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ld	.3906047	.033599	11.63	0.000	.3247518	.4564577
lb1	.0690209	.0208197	3.32	0.001	.0282151	.1098267
fr	.1027771	.0137332	7.48	0.000	.0758606	.1296936
r	-.038026	.0160534	-2.37	0.018	-.0694901	-.0065618
ox	.336734	.0483853	6.96	0.000	.2419005	.4315675
sq	.2404382	.0735517	3.27	0.001	.0962794	.3845969
_cons	1.863676	.2259657	8.25	0.000	1.420792	2.306561
/mu	.7806913	.2277235	3.43	0.001	.3343614	1.227021
/lnsigma2	-.2889836	.0763822	-3.78	0.000	-.43869	-.1392772
/ilgtgamma	-1.722956	.4686193	-3.68	0.000	-2.641433	-.8044793
sigma2	.7490245	.0572121			.6448807	.8699868
gamma	.1514908	.0602369			.066519	.3090682
sigma_u2	.1134703	.0529957			.0096006	.21734
sigma_v2	.6355542	.0220095			.5924163	.6786921

Table 6A.2

Time-invariant inefficiency model
Group variable: paid

Number of obs = 1676
Number of groups = 14

Obs per group: min = 45
avg = 119.7
max = 177

Wald chi2(14) = 854.71
Log likelihood = -1899.1873
Prob > chi2 = 0.0000

Y	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Ld	.4304996	.0396253	10.86	0.000	.3528354	.5081638
Lb1	.0619564	.0198925	3.11	0.002	.0229678	.1009449
FR	.0993199	.0129474	7.67	0.000	.0739435	.1246963
R	-.0370981	.0151256	-2.45	0.014	-.0667438	-.0074525
Ox	.3027922	.0470299	6.44	0.000	.2106153	.3949692
SQ	.2383351	.068212	3.49	0.000	.1046419	.3720283
RD	.7697919	.0866881	8.88	0.000	.5998864	.9396974
Ed	.2040876	.0410281	4.97	0.000	.123674	.2845011
lnaverageage	.0804825	.0522564	1.54	0.124	-.0219383	.1829032
FZ	-.085604	.0411503	-2.08	0.038	-.1662571	-.0049509
femaleheaded	-.0901749	.0480145	-1.88	0.060	-.1842816	.0039319
noofplots	-.036487	.0111612	-3.27	0.001	-.0583626	-.0146115
noofcropsc~d	.1112426	.0204322	5.44	0.000	.0711962	.1512891
credit	.0284528	.0385497	0.74	0.460	-.0471032	.1040087
_cons	1.280721	.3236679	3.96	0.000	.6463437	1.915099
/mu	.9524488	.2906779	3.28	0.001	.3827305	1.522167
/lnsigma2	-.3446877	.109243	-3.16	0.002	-.5588001	-.1305754
/ilgtgamma	-1.233103	.4729918	-2.61	0.009	-2.16015	-.3060558
sigma2	.7084415	.0773923			.5718949	.8775904
gamma	.2256388	.0826439			.1033866	.4240778
sigma_u2	.1598519	.0753166			.0122341	.3074697
sigma_v2	.5485896	.019042			.511268	.5859113

Table 6A.3

```
. regress Finalinefficiencyfert RD ed FZ femaleheaded credit lnaverageage lnlivestock V1- V14

      Source |       SS       df       MS              Number of obs =    1534
-------------+------------------------------           F( 20,  1513) =    3.76
       Model |  13.0758325    20  .653791623           Prob > F      =  0.0000
    Residual |  263.267032  1513  .174003326           R-squared     =  0.0473
-------------+------------------------------           Adj R-squared =  0.0347
       Total |  276.342864  1533  .180262795           Root MSE      =  .41714

------------------------------------------------------------------------------
Finalineff~t |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          RD |  -.2223217    .049198    -4.52   0.000    -.3188251   -.1258182
          ed |   .0063165   .0241271     0.26   0.794    -.0410096    .0536426
          FZ |   .0015883   .0187283     0.08   0.932    -.0351479    .0383245
femaleheaded |   .0273358   .0282265     0.97   0.333    -.0280315    .0827031
      credit |  -.0222398   .0226466    -0.98   0.326    -.0666618    .0221823
lnaverageage |  -.0379224   .0294784    -1.29   0.198    -.0957452    .0199003
 lnlivestock |   .0222029   .0139401     1.59   0.111    -.0051412     .049547
          V1 |  -.0160622   .0636905    -0.25   0.801    -.1409932    .1088689
          V2 |  (dropped)
          V3 |  -.0354078   .0625559    -0.57   0.571    -.1581133    .0872977
          V4 |   .3707578   .0835759     4.44   0.000     .2068208    .5346948
          V5 |   .1459289   .0635887     2.29   0.022     .0211976    .2706602
          V6 |   .2964443   .0805991     3.68   0.000     .1383464    .4545422
          V7 |   .2214149   .0778917     2.84   0.005     .0686277    .3742022
          V8 |   .3376338   .0763014     4.43   0.000     .1879661    .4873015
          V9 |    .329986   .0651521     5.06   0.000      .202188    .4577839
         V10 |  -.0335261   .0652124    -0.51   0.607    -.1614425    .0943902
         V11 |   .2874286   .0819475     3.51   0.000     .1266857    .4481714
         V12 |   .2582903   .0827017     3.12   0.002     .0960682    .4205123
         V13 |   .3322183   .0895008     3.71   0.000     .1566596     .507777
         V14 |   .3724928   .0941446     3.96   0.000     .1878252    .5571605
       _cons |  -.0506448   .1153297    -0.44   0.661    -.2768679    .1755782
------------------------------------------------------------------------------
```

Table 6A.4

Crop Output Elasticity of Labor and Fertilizer by Type of Road Access

	Model I*			Model II**			
	Coefficient	*Z-Value*	*P-value*	*Coefficient*	*Z-Value*	*P-value*	*Average***
Good Road Access							
Fertilizer	0.16	13.51	0.00	0.13	9.70	0.00	96.20
Labor	0.06	2.92	0.00	0.08	3.56	0.00	208.70
Crop Output							19.05
Poor Road Access							
Fertilizer	0.04	1.52	0.13	0.02	0.77	0.44	12.87
Labor	0.05	1.26	0.21	0.05	1.21	0.23	118.10
Crop Output							7.11

**The Unit of Analysis is Household. Although convergence could not be achieved, the estimates are based on the 29th iterations.*

*** The Unit of Analysis is Village*

**The average of Fertilizer applied is measured in kg; the labor input is in man days and output is in quintal

Table 6A.5

Allocative Inefficiency of Labour and Fertilizer by Road Quality

Type of Road	*Mean*	*Sd.*	*Min*	*Max*
Poor Quality	*3.51*	*1.84*	*-2.27*	*7.24*
Good Quality	*1.54*	*1.79*	*-3.02*	*7.35*
Total	*2.21*	*1.95*	*-3.02*	*7.73*

Appendix 6B

Road Infrastructure and Farm level Efficiency

Given that a farm household's resource allocation decisions, such as crop choice and input use pattern, are influenced by market prices, roads affect farm efficiency through altering farm gate price ratios. In this section an attempt will be made to graphically illustrate the link between road access and farm efficiency.

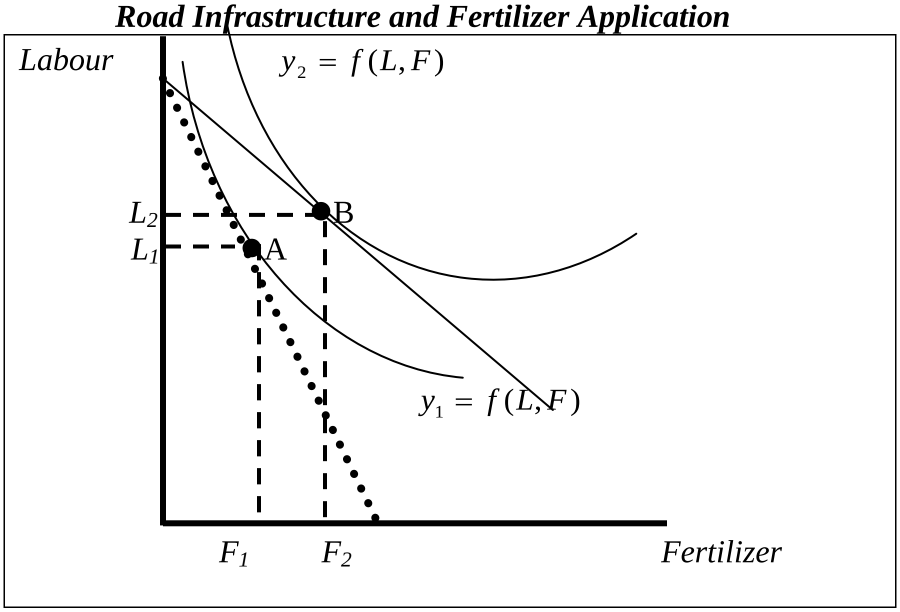
As can be observed from Figure 6.1 below, due to production and market risk, labour market imperfection as well as lack of credit access, the shadow price of fertilizer is very high, which is represented by a dotted line, and as a result farm households rationally tend to use less fertilizer, such as at point A. At that point, farm households combine L_1 units of labour and F_1 units of fertilizer to produce y_1 units of output. At this point, although the isoquant is tangent to the ratio of the shadow price of fertilizer and labour, the use of more labour will not generate additional output as the marginal product of labour is already very low, but since the marginal productivity of fertilizer is very high, a small increase in the volume of fertilizer applied will generate higher output.

Given the market price of fertilizer, , households that operate at A are therefore inefficiently applying fertilizer and such inefficient application of fertilizer would entail output loss.

Therefore, assuming that fertilizer is the next best available technology, farm households tend generate different levels of output per unit of land if they differ in their degree of fertilizer application.

Fig 6.1

Road Infrastructure and Fertilizer Application



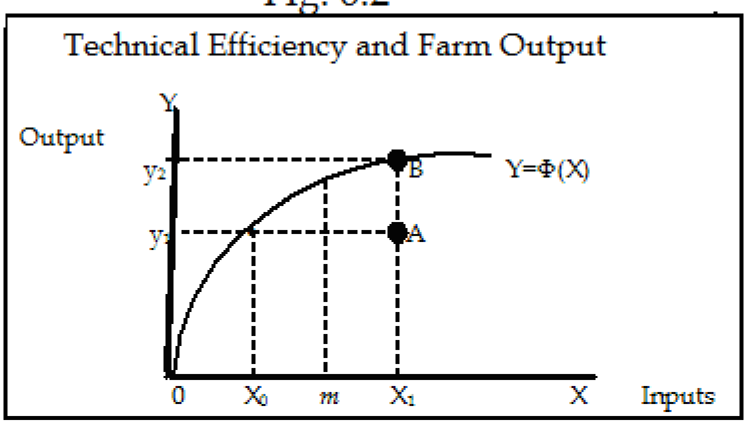
Any exogenous shocks that increase the profitability of fertilizer and thus demand for fertilizer will therefore increase farm production and income. Moreover, as fertilizer and labour inputs are complements and their marginal cross productivity is positive, increased application of fertilizer will also raise the productivity of labour and hence the demand for labour.

The main argument here is that providing good rural road access, through improving crop prices, reducing the price of fertilizer and price volatility and expanding off-farm employment opportunities, shifts the market price ratios first and then shadow prices and subsequently micro level input use pattern and hence the level of output generated from a given unit of land. As can be observed from figure 6.1, since road access relatively raises the shadow price of labour and reduces the farm gate price of fertilizer, it rotates the budget constraint, which in this case is represented by the smooth line.

At the new price ratios, which in this case are assumed to prevail in villages with good road access, farm households are more likely to use more fertilizer, such as F_2 units of fertilizer, and as a result they operate closer to the production frontier and thus technically more efficient or produce a higher output level (y_2) for a given unit of land.

This is depicted in Figure 6.2. A household that applies more fertilizer is expected to operate at point B. The application of fertilizer allows the household to produce y_2 units of output from X_1 units of land or alternatively produce y_1 units of output for a lower level of land inputs (i.e. X_0). However, a household that uses less modern inputs tends to operate at point A where for the same level of inputs employed (X_1), it gets lower (y_1) units of output. If the household were to use fertilizer, it would have produced a higher level of output (y_2) or could produce the same level of output (y_1) while employing a lower input level, i.e., X_0.

Fig. 6.2



Thus, if good road access indeed influences the technical efficiency level, the output gap shown in figure 6.2 or the distance between point A and B, which is equivalent to $\Phi(X_1)-\Phi(X_0)=\Phi'(m)\times(X_1-X_0)$, must be strongly and positively correlated with their road access condition[67].

In addition to adoption of modern inputs, the efficiency with which such inputs are utilized will also matter. The question here is not whether the new technology, such as fertilizer is adopted or not, but once adopted whether its level of application is efficient or not. Economic rationality in the neoclassical sense demands that farmers utilize inputs up to the point where the marginal value product of the input (MVP) is equal to the marginal cost of the input (MC). Under uncertainty however, farmers rationally tend to utilize the riskier input up to the point where MC>MVP so that the possible loss that arises due to production failure and market fluctuation is minimized (Ellis, 1993). Since risk consideration is one factor for such a sub-optimal allocation of resources, and also as better road access generally tends to make farm households hold a less risk averse stance (i.e., as roads improve crop prices, reduce the cost of fertilizer, and reduce price volatility), farm households that have good road access

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[67] Such formulation is based on the reminder term of the Taylor series approximation where the production function is evaluated at X_1 and X_0 . It is equivalent to $R_n=\frac{\Phi^{(n+1)}(m)}{(n+1)!}(X_1-X_0)$, which is the Lagrange form of the reminder of the Taylor series approximation. When n=0, it measures the error of approximating $\Phi(X_1)$ *by* $\Phi(X_0)$. *m is the average of* X_1 *and* X_0.

should be relatively more efficient in allocating resources. Thus, if this indeed holds, the average deviation between the MC and MVP of fertilizer input should be lower in villages with good road access.

Chapter 7 Road Infrastructure and Rural Wage

7.1 Introduction

In the face of high population growth and growing land scarcity, ensuring a remunerative employment opportunity is central in rural poverty alleviation. Thus, understanding the factors that affect the employment level and the level of the wage is important in designing policy interventions. This chapter aims to empirically substantiate if providing good road access has a significant impact on rural poverty through altering the level of the rural wage rate.

With this objective in mind, the chapter is structured as follows. First, in order to guide the empirical specification of the wage model, the existing theoretical and empirical studies that have been undertaken on related issues will be briefly reviewed. Following that, the empirical model will be specified and its estimation strategy will be outlined. Finally, after a brief discussion of the empirical results, the chapter concludes.

7.2 Literature Review

The issue of rural wage determination has attracted a lot of debate (Ezeala-Harrison, 2005; Hossain, 1990). Although a number of theories, such as subsistence, efficiency, the theory of implicit co-operation, two-tier wage theory and market theory of wage determination, have been proposed to explain rural wage formation, the issue has not yet been satisfactorily resolved (Kanwar, 1998; Osmani, 1991). As a result, currently although there is no single theory on which rural wage formation could be adequately analyzed, consensus seems to emerge that although each existing theory might not be sufficient by itself to fully explain rural wage formation, each theory nevertheless identifies some important aspects that one should take into account in analyzing rural wage formation (Ahmed, 1981). For example, although subsistence and efficiency wage theories are generally claimed to reflect factors that influence long-term wage formation, they are essentially inadequate to explain short-term rural wage formation (ibid). Similarly, although the market theory of wage determination may partly explain short run movements in the rural wage rate, it is inadequate to explain why wage rates remain at a certain level despite extensive unemployment and underemployment, which traditional theories are comparatively better to explain[68] (ibid). Therefore, the choice of a particular model is governed more by data availability and the objective of the study.

For the purpose here, given that there are no individual level data and also considering that the influence of roads on the village wage rate mainly works through the market mechanisms, albeit with its limitations, the link between roads and wages will be analyzed in the context of market based theory of wage determination[69] (Ahmed and Hossain, 1990; Abdulai and Delgado, 2000).

In the context of this theory, the impact of roads on rural wage rates works through its effect on the demand as well as the supply side of the labour market (Ahmed and Hossein, 1990). Through making access to a more distant labour market easier, road infrastructure shifts the demand curve of the local labour market and thus expands the opportunity for rural households to earn better wage rates (Escobal and Ponce 2002). Through

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[68] Moreover, Bardhan (1984) also reported that demand and supply factors only explained 12% of the inter village wage differentials in Bangladesh, thus further attesting the insufficiency of the theory.

[69] Despite its limitations, most empirical studies undertaken on developing countries in general and on Ethiopia in particular employed this framework[69] (Ahmed, 1981; Hossain, 1990; Abdulai and Delgado, 2000; Woldehanna, 2000). Most of these studies only considered the influence of the local demand and supply factors; and except Ahmed and Hossain (1990), the majority of the specialized studies have not considered the effect of inter-sectoral or spatial labour mobility on local wage formation (Abduli and Delgado, 2000).

enhancing profitability and facilitating the expansion of farm and non-farming activities, road infrastructure generates new employment opportunities, which in effect mean shifting the demand curve of local labour, thereby putting an upward pressure on the local wage rate (Escobal, 2001). Through reducing the cost and facilitating the diffusion of labour intensive technology, it also raises the demand for labour. Finally, through its impact on increasing the wage rate, which raises the opportunity cost of leisure, road infrastructure will also have an influence on the labour supply decisions of households (Lanjouwa, et al, 2001).

Although roads have such a significant impact on rural wage formation, apart from a few studies (Ahmed and Hossein, 1990; Fan et al, 2004), most of the specialized empirical studies that dealt with the issue of rural wage formation, included road infrastructure as an explanatory variable in the postulated wage models. Although few, the existing empirical studies however have substantiated that road infrastructure has a significant impact on the rural wage rate (Fafchamps and Shilpi 2003; Lanjouw, 1998). Ahmed and Hossain (1990) reported that in Bangladesh households that have better road access are more likely to participate in the labour market and also earn a higher wage rate. Similarly, Escobal (2001) and Escobal and

Ponce (2002), based on Latin American countries, also reported that access to a rehabilitated road network increases the wage by facilitating access to better income opportunities. Fan, et al, (2004), while working on China, India and Vietnam, reported that improved rural roads contribute to an increase in agricultural wages directly and indirectly through boosting rural non-farm employment opportunities. In Ethiopia to our knowledge, Woldehanna (2002) is the only study to look at rural wage formation in detail. However, the study did not consider the role of roads on rural wage formation.

Finally, although postulating the wage model in a spatial equilibrium framework would have been preferred, due to lack of data on the urban wage rate and the rate of urban unemployment, the wage model will be postulated on the assumption that the village wage rate is wholly determined by local demand and supply conditions. This assumption also seems to be supported by the data. In the context of the sampled villages, almost 99% of the location of employment is in the village or in the neighbouring villages, which suggests that either there is a lack of employment opportunities (such as due to high urban unemployment) or there are other factors that deter mobility of labour. At any rate, the impact of spatial labour market conditions on the local wage rate seems to be very weak.

As mentioned before, while the link between roads and the rural wage rate will be specified in the context of the market theory of wage determination, highlighting the limitation of the framework in the context of the present sample will be appropriate. In the sampled villages, from the total 4400 adult family members, 50% of them have reported that although they are willing to work, they are unable to find job opportunities. In these villages, the rate of labour utilization compared to the available supply, measured in terms of labour time spent on farm and off-farm activities was 33% of the potential; and it ranges from the lowest of 13% to the highest of 68%[70]. Such a low level of labour utilization raises a question as to whether the market wage rate is determined competitively, as households are unable to get employment at the existing wage rate. In addition, as can be observed from Table 7.1 below, the marginal productivity of labour is only positive in 3 out of the total of 14

[70] Following Datt (1996), the involuntary unemployment is calculated by the following formula: $\frac{\sum_i E_i}{\sum_i (U_i + E_i)}$, where E is the total days adult family member involved in farm and non-farm activities; and U is total days unemployed.

villages[71]. Moreover, even in villages where labour had a positive marginal productivity, the marginal value product of labour is less than the wage rate. Under such conditions, it is clear that the market based theory of wage determination by itself is insufficient to fully explain wage formation in the sampled villages[72]. However, as noted before, since the effect of road on rural wage rate mainly works through the market mechanisms, despite its limitations, the framework is more appropriate for the purpose.

Table 7.1

The Average Marginal Productivity and Output Elasticity Estimates for Labor Input by Village | **Number of HHs Participated in Off-Farm Employment**

	Including Harvesting Labor		Excluding Harvesting Labor			Off-Farm Employment			%
Village ID	Elasticity*	MPL	Elasticity	MPL	Village ID	Yes	No	Total	Participated
1	**0.35**	**0.97**	**0.30**	**0.75**	**1**	65.00	49.00	114.00	0.57
2	0.00	0.00	0.00	0.00	**2**	54.00	56.00	110.00	0.49
3	0.00	0.00	0.00	0.00	**3**	60.00	68.00	128.00	0.47
5	0.00	0.00	0.00	0.00	**5**	12.00	80.00	92.00	0.13
6	0.00	0.00	0.00	0.00	**6**	97.00	81.00	178.00	0.54
7	0.00	0.00	0.00	0.00	**7**	15.00	113.00	128.00	0.12
9	**0.22**	**0.41**	**0.17**	**0.31**	**9**	151.00	25.00	176.00	0.86
10	0.00	0.00	**-0.08**	**-0.12**	**10**	32.00	138.00	170.00	0.19
15	0.00	0.00	**-0.17**	**-0.39**	**15**	40.00	126.00	166.00	0.24
16	0.00	0.00	**-0.19**	**-0.34**	**16**	48.00	52.00	100.00	0.48
17	0.00	0.00	**-0.18**	**-0.32**	**17**	18.00	92.00	110.00	0.16
18	0.00	0.00	0.00	0.00	**18**	15.00	91.00	106.00	0.14
19	**0.19**	**0.31**	0.00	0.00	**19**	5.00	53.00	58.00	0.09
20	0.00	0.00	0.00	0.00	**20**	5.00	41.00	46.00	0.11
					Total	617.00	1065.00	1682.00	0.37

*The elasticity is measured in terms of lnY/lnLb

*The elasticity/MPL is reported only if it is significant at less than 10%

Source: Own Calculation Based on the Household Survey Data

7.3 Empirical Model Specification and Estimation

[71] The result should be cautiously taken in that although the contribution of labour to output is insignificant when the production function is postulated for each village separately, it is positive and significant when the production function is estimated for the whole villages. In addition, while households usually understate the amount of crops they produced in their land, they usually overstate the amount of labour time they spent on the farm, which tends to make the labour variable insignificant.

[72] One may argue that subsistence and efficiency theories may also partly explain the observed wage formation process.

In empirically postulating rural wage determination, existing studies generally followed two modelling approaches. Some studies used a Mincer-type wage equation and regressed wage receipts of the individual on certain attributes of the worker as well as on variables that are meant to capture demand side factors (Deolalikar, 1988). Other studies however postulated the wage model in a reduced form or estimated it jointly with labour demand and supply functions (Ahmed and Hossein, 1990; Abdulai and Delgado, 2000). In the latter approach, the individual worker characteristics are not included as covariates[73]. In the present case, given that data on individual characteristics are lacking and also the type of labour under consideration is unskilled male farm labour, which is homogeneous across all villages, the village wage model will be postulated in a reduced form (Hossain, 1990).

According to the market theory of wage determination, the rural wage rate is assumed to be determined by the interaction between the supply of and demand for labour. Assuming profit maximizing behaviour of the employers and diminishing returns to labour, while the shape of the demand curve is assumed to be downward sloping, the supply curve is

73 This modelling approach however is claimed flawed in that competitive market condition is imposed before testing it (Datt, 1996). As a result, the model is incapable of informing whether the labour market clears or not, and whether wage is determined competitively (ibid).

assumed to be upward sloping (Wolfson, 1958). Following previous empirical studies, the demand for labour is assumed to depend on the level of nominal wage rate, the price of output and on the production function (Boyer and Hatton, 1997), which is:

$$L^D = f(w_A, P_y, f(Z)) \qquad (7.1)$$

Where L^D is labour demand, w_A is the village level daily real wage rate, P_y the weighted village level output price and f(Z) is the farm production function.

Following the conventional assumption, an increase in the real wage rate reduces demand for labour, but an increase in the output price generates additional demand for labour. Demand for labour is also positively related to the marginal productivity of labour and the type of technology employed, which will be elaborated later.

Assuming no migration, the labour supply in the local labour market is a function of the size local population (η_A) and the local wage rate, which is given by:

$$L^S = f(\eta_A, w_A) \qquad (7.2)$$

Equalizing the supply of labour with demand and applying the natural log, the reduced form of rural wage rate will become:

$$\ln W_A = \alpha_0 + \alpha_1 \ln P_y + \alpha_2 \ln f(Z) - \alpha_3 \ln \eta_A \qquad (7.3)$$

According to equation (7.3), a rise in the price of farm output shifts the labour demand curve upward and thus increases the rural wage rate. An increase in the size of the local population, by shifting the local supply curve of labour, will tend to depress the local real wage rate. Positive associations between the labour demand and the output price and an inverse association between demand for labour and the wage rate are well substantiated by empirical evidence and thus do not warrant further elaboration (Kanwar, 1998).

Regarding the link between the wage and the production function, in controlling the level of supply, the wage rate is expected to be higher in villages where demand for labour or productivity of labour is high. Empirical studies have also shown that, among others, demand for labour is higher in villages that have high per-capita supply of land, where the fertilizer input is intensively utilized and where there is adequate rainfall or where there is adequate supply of irrigation facilities and also where farm gate crop prices are higher (Datt, 1996). Therefore, in the context of the present sample, the average per-capita land size, the average per-hectare application of fertilizer and the average annual rainfall level of the village will be introduced as the major determinants of demand for labour.

For the reasons mentioned before, since the road infrastructure of the village has important influence on the local equilibrium wage rate, the road quality of the village will also be introduced.

Finally, as shown in chapter 5, as farm gate crop prices endogenously adjust to the stock of local road infrastructure, introducing crop price as one explanatory variable jointly with the road infrastructure in the wage model will not be appropriate. Therefore, after dropping crop prices and incorporating the other identified variables into equation (7.3), the empirical wage model becomes:

$$\ln W_{it} = \delta_0 + \delta_1 \ln F_{it} + \delta_2 \ln PCL_{it} + \delta_3 \ln R_{it} - \delta_4 \ln \eta_{it} + \delta_5 Rd_{it} + v_{it} + \varepsilon_{it} \qquad (7.4)$$

*Where **W** is the village wage rate in village i at time t, F is the average per-hectare fertilizer use of the village, **PCL** is the village level average per-capita land holding, which is measured by dividing land holding to family size, **R** is the average annual rainfall level of the village, **η** is the population size of the village, Rd is the road quality of the village and it is in a dummy form and 1 is given for villages with good road access and 0 otherwise.*

Higher degree of fertilization, through shifting the production function and hence raising the productivity of labour, will have a positive impact on labour demand (Hossain, 1990). Moreover, since fertilization generally leads to the growth of weeds, increased application of such input requires more labour time per unit of area cultivated and thereby puts an upward pressure on the local wage rate (Bardhan, 1984). In the case of per-capita land, due to the labour intensive nature of the farm technology employed and the complementarity of land and labour input, higher per-capita land size of the village will exert a positive influence on the local wage rate both through the demand side (shifting the demand curve upward) as well as the supply side (through reducing the size of off-farm labour supply)[74] (Mduma, 2003; Bardhan, 1984). As agricultural activities are heavily dependent on rainfall availability, higher rainfall, by raising the extent of cultivation, boosts demand for labour and hence puts an upward pressure on the local wage rate (Ahmed, 1981; Ahmed and Hossain, 1990). The direction of the impact of local population size on the local equilibrium rate will be empirically determined as it could work both ways.

As road infrastructure positively affects the rural wage rate, by raising crop prices, which raises the marginal value product of labour and hence the labour demand, facilitating the availability and raising the profitability of labour intensive inputs (such as fertilizer) and also expanding off-farm opportunities, the road variable is expected to have a positive sign (Escobal and Ponce 2002).

[74] In addition to land size, soil quality and topographic condition of the land as well as the extent to which the land is intensively cultivated have an influence on magnitude of labour demand (Boyce, 1989; Ahmed, 1981).

In order to estimate the above model, since the model is estimated on the basis of panel data, either a fixed or random effect model can be used. In order to determine which model will be more appropriate for the data, the Hausman Specification test was conducted. The test however is inconclusive in that the data fail to meet the asymptotic assumptions of the Hausman test. The chi-square statistic generated by the test however is higher, which would normally mean that the use of a fixed effect model would be more appropriate. Assuming that increasing the sample size, which would meet the asymptotic assumptions of the test, will not substantially reduce the chi-square statistic, the wage model will be estimated on the basis of a fixed effect model.

7.4 Results and Discussion

The village wage model estimated on the basis of fixed effect is reported in Table 7.2. The hypothesis that all the slope coefficients are zero is rejected on the basis of F statistics. All the included variables in the model have the expected sign and also most of these variables are significant at less than 1%, except the road variable which is significant at 8%. The result generally suggests that spatial variation in local demand and supply shifting factors are significant contributors for the level as well as across village variations in the rural wage rate.

Table 7.2

Fixed-Effects (within) Regression Result of the Wage Model

lnWage	Coef.	z	P>z
δ_0 (constant)	1.36	3.4	0.00
δ_1 (Fertilizer per hectare)	0.16	10.0	0.00
δ_2 (per-capita land size)	0.47	8.6	0.00
δ_3 (Annual rainfall)	0.50	11.1	0.00
δ_4 (local population size)	-0.49	-10.6	0.00
δ_5 (Road Dummy)	0.08	1.97	0.08
Number of obs.= 27 Number of groups = 14 Wald chi2(6)= 267.3 R-sq: Within = 0.99, Between = 0.22, Overall = 0.23 F(5, 8) = 201, Prob.>F=0.00			

As a priori expected, the magnitude of per-hectare fertilizer application of the village positively affects the local wage rate. For a 10% increase in per-hectare fertilizer use, on average, the local wage rate increases by 1.6%. The result is also consistent with the findings of chapter four where the return to labour is higher in an environment where fertilizer application is higher. The result confirms that fertilizer technology is pro-poor in that it increases the income of the poor both through increasing the level of output they could generate from the land they cultivate as well as through expanding the employment opportunity and raising the wage rate. For the reason mentioned before, i.e. since the fertilizer input is generally sub-optimally applied, the elasticity of the wage to fertilizer however is expected to be understated.

The average per-capita land owned is also found to significantly influence the local market wage rate. The impact, as argued before, is also expected to operate both through the effect of land size on demand as well as on the supply side of the labour market. According to the result, for a 10% increase in average per-capita land holding, local wage level will increase by 4.7%. The importance of size of per-capita land on wage rate is not surprising given that the average land/labour ratio of the sampled villages is close to 0.49 hectare per person/year, which means that an individual can only cultivate less than half hectare throughout the year. Although the elasticity of the local wage rate to per-capita land is strong, given that the option of expanding per-capita land is very limited, the result also suggests that future increases in the wage rate to a large extent should come through the application of land saving and labour intensive new technologies. As fertilizer input is land and labour augmenting, and also since there is a significant association between the wage rate and fertilizer application, the result generally suggests that increasing fertilizer application will have significant influence on future rural income growth in general and the return to labour in particular. Promoting fertilizer application, by easing the existing land constraints, will have a significant impact on rural poverty both through increasing farm output, from which poor households with land access will benefit, as well as through shifting the demand for labour and raising the rural wage rate, from which landless or poor households with large family size would benefit.

The annual average rainfall level of the village, in terms of its level of impact and significance, is also the other important factor that influences the village wage rate. According to the result, for a 10% mm increase in rainfall, the village wage rate increases by 5%. Such a high elasticity is not surprising given that agriculture activities in the sampled villages are heavily rain dependent and also highly labour intensive. In terms of policy implication, the result generally suggests that interventions that address water scarcity, such as expansion of irrigation infrastructure, will have a significant impact on rural poverty both through expanding employment opportunities and raising the wage rate. Such an intervention improves the rural wage rate not only through increasing water availability, but also through increasing the effective area cultivated (because irrigation allows the cultivation of the existing land throughout the year) and also through reducing the risk of fertilizer application (which usually occurs in the rain fed agriculture).

As initially expected, the result also confirmed that the higher population size of the village, through shifting the local labour supply significantly depresses the local wage rate. According to the result, for a 1% increase in the population size of the village, the equilibrium wage rate declines by close to 0.5%. Under free mobility of labour, high local population size should not have been a significant adverse factor that reduces local wage rate. The result seems to suggest that either there is a high transaction cost of mobility or there are limited employment opportunities in nearby cities and towns, which is consistent with the observation of other studies (Tafesse, 2003; World Bank, 2005).

Although its effect on village level wage rate is not substantial, the road quality of the village, as a-priori expected, is among the village specific characteristics that influences the local wage rate. According to the result, controlling other factors, providing villages with all weather road access increases the local equilibrium wage rate by an average of 8%. Since by assumption the coefficient of road is net of its indirect wage raising effect that operates through increasing fertilizer application, it is expected that the coefficient only captures the effect of road access on the local wage rate that works through improving farm gate crop prices, altering cropping pattern and expanding market outlets, which shift the demand for labour and hence the level of wage rate[75]. The result suggests that one mechanism by which road infrastructure boosts the income of the poor, which is reported in chapter 4, works through increasing the rural wage rate and expanding employment opportunities. As the population size variable is significant, as argued before, the direct wage raising effect of road access that operates through facilitating access to spatial labour markets however seems to be insignificant.

[75] Possibly due to high profitability of fertilizer in villages that have good road access, average per hectare fertilizer use is close to five times greater than those with poor road access.

From the result it generally emerges that, in the face of high population growth and land constraint, improvement in the rural wage rate to a large extent depends on increased application of fertilizer and investment in irrigation infrastructure. Providing villages with an adequate road access will also have a significant impact on the rural wage directly, through expanding market access and increasing overall productivity, as well as indirectly through increasing the profitability of labour intensive and productivity enhancing fertilizer inputs.

7.5 Conclusion

The results generally confirm that interventions that influence the demand and supply side of the labour market will have a significant impact on the village wage rate and rural poverty.

The elasticity of the rural wage to land is high. However, given serious land scarcity and high rural population growth, agricultural productivity growth is the only source of future increase in rural wage rate. In this regard, since the elasticity of the rural wage rate to per-hectare fertilizer application is reasonably strong, it suggests that promoting fertilizer application is one effective mechanism to improve rural wage rate. Expanding irrigation infrastructure is also expected to be pro-poor as the elasticity of the rural wage to rainfall level is high.

The road quality of the village is also a significant determinant of the rural wage rate. Given that it is usually poorer households that are engaged in rural labour markets, the result suggests that the rural poor will benefit from road induced increases in the rural wage rate. As previously shown, as roads also reduce the cost of food, it implies that road has a significant impact on the real income of the poor. Although an increased application of fertilizer and investment on irrigation infrastructure tends to put upward pressure on rural wage rate, their sustainability however depends on the market access condition of the villages, in which adequate road access is critical. Without adequate access to distant markets, which can absorb excess local supply, increased use of fertilizer input or investment in irrigation infrastructure could nullify their positive impact.

Appendix 7A

Table 7A. 1

Fixed-effects (within) regression — Number of obs = 27
Group variable: **paid** — Number of groups = 14

R-sq: within = 0.9921; between = 0.2173; overall = 0.2320

Obs per group: min = 1; avg = 1.9; max = 2

F(5, 8) = 201.21
corr(u_i, Xb) = -0.9217 — Prob > F = 0.0000

lnwage	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnFertkghe~e	.1570783	.0156992	10.01	0.000	.1208758	.1932807
lnpercapit~d	.469858	.0546534	8.60	0.000	.3438271	.595889
lnrainannual	.5030046	.0454198	11.07	0.000	.3982665	.6077428
lnvillagepop	-.48538	.0457932	-10.60	0.000	-.5909794	-.3797806
RD	.0757471	.0383535	1.97	0.084	-.0126963	.1641905
_cons	1.361045	.4008611	3.40	0.009	.4366578	2.285432
sigma_u	.68527123					
sigma_e	.02830352					
rho	.998297	(fraction of variance due to u_i)				

F test that all u_i=0: F(13, 8) = 65.89 — Prob > F = 0.0000

Table 7A.2

. regress lnwage lnFertkghectare lnpercapitaland lnrainannual lnvillagepop RD V1 V2 V4-V14

Source	SS	df	MS
Model	2.32684912	18	.129269395
Residual	.006408716	8	.000801089
Total	2.33325783	26	.089740686

Number of obs = 27
F(18, 8) = 161.37
Prob > F = 0.0000
R-squared = 0.9973
Adj R-squared = 0.9911
Root MSE = .0283

lnwage	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnFertkghe~e	.1570783	.0156992	10.01	0.000	.1208758	.1932807
lnpercapit~d	.469858	.0546534	8.60	0.000	.3438271	.595889
lnrainannual	.5030046	.0454198	11.07	0.000	.3982665	.6077428
lnvillagepop	-.48538	.0457932	-10.60	0.000	-.5909794	-.3797806
RD	.0757471	.0383535	1.97	0.084	-.0126963	.1641905
V1	.2604447	.0636142	4.09	0.003	.1137502	.4071392
V2	.3598595	.0951486	3.78	0.005	.1404465	.5792726
V4	-1.474577	.1354293	-10.89	0.000	-1.786877	-1.162276
V5	-.6390524	.0955263	-6.69	0.000	-.8593365	-.4187684
V6	-1.280417	.1175524	-10.89	0.000	-1.551493	-1.009341
V7	-.6405364	.0805445	-7.95	0.000	-.8262722	-.4548005
V8	-.7944191	.1254411	-6.33	0.000	-1.083687	-.5051513
V9	-.9776847	.0984757	-9.93	0.000	-1.20477	-.7505995
V10	-.2438034	.0358338	-6.80	0.000	-.3264363	-.1611704
V11	-1.470972	.1430487	-10.28	0.000	-1.800843	-1.141101
V12	-1.41818	.1403995	-10.10	0.000	-1.741941	-1.094418
V13	-1.54934	.1472425	-10.52	0.000	-1.888882	-1.209798
V14	-1.524993	.1459075	-10.45	0.000	-1.861456	-1.18853
_cons	2.195991	.3292365	6.67	0.000	1.43677	2.955212

Table 7A.3

Random Effect Regression of Village Market Fertilizer Price on

Independent Variables	*Coefficient*	*t-statistics*	*P-value*
Road Quality	*-0.15*	*-3.10*	*0.00*
Distance from Addis in km.	*0.00*	*2.80*	*0.01*
Port Price per kg.	*0.74*	*38.98*	*0.00*
Road Density of the Zone	*-0.01*	*-2.74*	*0.01*
Constant	*1.68*	*12.15*	*0.00*
R^2=0.94, Wald chi-sqre. 1572, N=22			

A1 Table 7A.4

Kilogram of Fertilizer Use per Hectare by Type of Road Access

Type of Road	Mean	Standard deviation	Min	Max
Poor Access	16.8	23.31	0.00	84.28
Good Access	78.7	43.37	15.46	157.00
Total	39.35	42.83	0.00	157.00

Chapter 8 Conclusions

Rapid agricultural sector growth, while central to achieving a substantial reduction in rural poverty, is expected to come through increases in farm productivity. While increasing agricultural productivity requires various interventions, the sustainability of such interventions, among others, will depend on adequate market opportunities. Due to the small size of domestic markets, even a modest growth in agricultural productivity however could not be sustainable as it ends up depressing domestic grain prices and farm income. In Ethiopia, although generally a weak domestic consumer demand is a significant constraint, high transaction cost, through limited inter-regional trade flow, is a critical factor for low agricultural productivity. It makes potentially exportable crops less competitive, increases the risk and reduces the profitability of adopting productivity enhancing technologies, which are considered essential in achieving agricultural sector growth.

Therefore, in designing poverty alleviation strategies, understanding the extent to which transaction cost is actually constraining farm productivity growth and the pathways through which its effects are felt is essential. This research provides empirical evidence regarding the effect of road infrastructure, which is assumed to be one important factor that determines the level of transaction cost, on rural income as well as the pathways by which road access affects income.

The research first qualitatively reviewed the poverty situation in Ethiopia and the main correlates of poverty. It was shown that rural poverty in Ethiopia is the outcome of a low resource base, low return to assets, inadequate access to public goods and adverse agro-ecological and geographical factors. In order to empirically substantiate whether providing adequate road infrastructure raises farm income and reduces rural poverty based on a competitive spatial equilibrium framework, the research postulated a net income model. The model was also estimated on the basis of the Hausman-Taylor Instrumental Variable Random-effects method. The model results showed that the quality of road infrastructure that farm households have access to is a significant determinant of their income level. And households that have access to all weather roads generally earn higher income than those that have no good road access.

In order to ascertain if each private endowment and geographical capital have different marginal contribution under different types of road access, the net income model is re-estimated by partitioning the sample on the basis of the quality of road infrastructure they have access to (i.e. all weather road and dry-weather road). The objective was to see to what extent the level of overall productivity and the input use pattern of households, which road access claimed to alter, differ under different conditions of road access. According to the result, the return to land, fertilizer and oxen inputs are more productive in villages that have better road access. While the marginal return to labour is positive in villages with good road access, in villages with poor road access its return is zero. Although the level of education is an important determinant of income in both groups, its return is consistently higher in villages with poor road access. The gender of the household head matters and although it has a negative sign in both groups, female headed households tend to generate a lower return to land and labour in villages with good road access. The intercept term of the net income model was also substantially and significantly higher in villages with good road access signalling that overall factor productivity is higher in these villages.

For the observed inter-village income differences, although the postulated net income model generally illuminates the respective role of locational differences in resource endowments, the rate of return and overall factor productivity, it cannot provide information as to the relative importance of each factor. In order to generate such information, Blinder's decomposition technique was employed. According to the result, households that have access to all weather roads generally generate over 90% higher income, of which, 38% is due to higher overall productivity and higher rate of return in villages that have good road access while the remaining 62% is due to higher resource endowment of households in these villages. The interaction effect of village differences in resource endowments, overall productivity and the rate of return on overall income difference was however found insignificant.

The inter-quantile regression model result, which was postulated to explore if roads in addition to raising income also narrow down the income disparity between the poor and the non-poor, also showed that poorer households tend to benefit more from road infrastructure than non-poor households. The return to roads is consistently higher for the lower income quantile, confirming that the poor tend to benefit proportionately more from improved road infrastructure.

After a robust link between road and income is established, in order to further illuminate the mechanisms by which roads increase rural incomes and reduce rural poverty, the research also postulated empirical models for farm gate crop prices, village wage and farm efficiency models. The postulated village price model result showed that the level of farm gate prices significantly responds to the road quality of the village. According to the result, by enhancing the spatial integration of markets, good road quality while reducing prices in deficit markets, increases prices in surplus producing markets. Moreover, in villages with good road access, it was found that local prices respond more to central market price shocks and thus prices in these villages are generally expected to be more stable.

It was also shown that the road induced improvement in crop prices and a reduction in crop price volatility also has a significant impact on rural income and poverty through second round effects, mainly through altering farm level resource allocation decisions, such as what to produce and how to produce. As a result of road induced increases in price and reduction in price volatility, it was also argued that households with good road access applied fertilizer with a predicted probability of 0.93 compared to 0.36 for households with poor road access.

The observed strong spatial price interdependency also suggests that targeted intervention at the central market level can significantly alter price dynamics at the farm gate level. The empirical result also confirmed that local supply shifting specific factors, such as distance from central market and rainfall, are significant adverse factors that depress local crop prices. It was also argued that the presence of such market segmentation lowers welfare by making farmers more risk averse and thus less responsive to price and technical opportunities. High local price instability that is mainly driven by rainfall variability could also be the major contributor for the observed spatial arbitrage inefficiency, mainly through increasing the risk of arbitrage. In terms of whether road induced price changes benefit the poor, the empirical result has also shown that they do benefit. As producers, they benefit from better prices for the crops they supply as well as through enhancing their rate of technology adoption. As consumers, they also benefit because road reduces food prices and also stabilizes them.

The threshold autoregressive model result, which is postulated to measure the efficiency of the regional grain markets, also showed that in 41% of the cases, the spatial markets are inefficient in that the arbitrage opportunities are not fully exploited. It was argued that such a level of market inefficiency could be a key contributor for the observed high spatial price gap and hence a considerable welfare loss. Such inefficiencies are also expected to nullify the potential impact of road in narrowing spatial price gaps and raising farm gate prices and income.

As the second potential channel, the research also empirically assessed if road infrastructure affects farm income through its influence on the farm efficiency level. Along this line, using the parametric approach of efficiency measurement, the technical and allocative efficiency of farm households were estimated. According to the result, the average technical efficiency level of the entire sample was very low (49%); and ranges from 22% to 90%[76]. When the samples are grouped according to the quality of road infrastructure that they have access to, the average technical efficiency level of households that have good road access was 16% higher than those with poor road access, suggesting that for the same level of resources, households with good road access on average generate 16% more output.

[76] The result is similar to a 55% technical efficiency level reported by Abrar (2000).

Based on the result, if road quality improves, *ceteris-paribus*, the average farmer in villages with poor road access could realize a 27% increase in output level. The least and most efficient ones will also respectively realize a 41% and 28% growth in output. The main mechanism by which improved road access raises farm level technical efficiency is also expected to come through increased application of fertilizer. More than 62% of households that use fertilizer are in villages with good road access. In these villages the per-hectare fertilizer application was also 52% higher. On average, households that use fertilizer are also 33% technically more efficient than non-users. The empirical result also showed that a 1% increase in technical efficiency raises farm income by 0.28%. In terms of crop output, the result showed that a 1% improvement in technical efficiency improves output by 1.06% and the increase in income and output level due to efficiency improvement is also higher for households with poor road access.

In terms of allocative efficiency, given the market price of fertilizer, the sampled farm households underutilized fertilizer in that the quantity of fertilizer applied is below what the profit maximization criteria would dictate. According to the result, sampled households generally underutilized fertilizer by close to 7%. The estimated level of underutilization of fertilizer however is expected to be understated as both the level applied and the proportion at which various types of chemical fertilizer combined substantially deviate from the optimum level recommended for high response of fertilizer. The under utilization of fertilizer however is comparatively lower in villages that have good road access. The empirical result also showed that a 1% increase in allocative efficiency raises farm income by 0.02%. In terms of crop output, a 1% improvement in allocative efficiency improves output by 0.064%. Due to the low opportunity cost of family labour, the sampled households tend to utilize more labour than fertilizer. The overutilization of labour and underutilization of fertilizer is also higher in villages that have poor road access.

The research also investigated if inefficiency reduces farm income in general and the income of the poor in particular. The empirical result showed that both technical and allocative inefficiency reduces farm income in general and the income of the poor in particular.

As a third channel, the research also empirically assessed the link between road infrastructure and village level wage rates. Based on a competitive market framework, the wage model estimation result showed that both demand and supply shifting factors are important determinants of village wage rate. It was found that road infrastructure has a significant direct and indirect impact on village wage formation. The indirect effect mainly works through promoting fertilizer application, expanding market access and raising farm gate prices. According to the empirical result, a one kilogram increase in per-hectare use of fertilizer raises the village wage rate by Birr 1.17 a day. Given that the probability of fertilizer adoption and the magnitude of per-hectare fertilizer applied are higher in villages with good road access, it was argued that the indirect effect of roads on the rural wage rate is stronger than its direct effect.

The empirical wage model result also showed that the level of rainfall is the most significant determinant of village wage level, suggesting that increasing the supply of irrigation infrastructure would be one of the potential avenues by which the government could influence the rural wage rate. The size of the adult population of the village is also found to exert an adverse effect on the rural wage rate. Based on the findings, it was argued that government intervention through expanding the road and irrigation infrastructure as well as through implementing public programs is critical as the scope to expand the area cultivated is very limited. Such interventions are also pro-poor as the poor benefits both from infrastructure induced productivity growth, i.e. by producing more output on their land, as well as from road induced increase in rural wage from which land less or poor households with large family size tend to benefit.

In summary, in line with the hypothesis of the research, the research showed that road infrastructure has a significant impact on rural income and poverty through shifting the market demand curve confronting farm households for the crop they supply, increasing farm productivity, fostering a competitive market environment, reducing transaction cost, promoting the profitability and reducing the risk of new technology adoption and increasing the market return to labour. Although due to lack of appropriate instrumental variables the reported impact of road on farm income may need to be taken cautiously, the significance of the road dummy variable in the crop price, fertilizer price, wage and efficiency models, which are the major determinants of farm income, attests that road infrastructure indeed has significant impact on farm income.

The findings of the research also suggest that, in addition to boosting micro level income , expanding rural road access will also have an impact on macro level growth through enhancing inter-sectoral linkages. For the government's Agricultural Development Led Industrialization (ADLI) growth strategy to bring about sustainable growth and industrialization, the integration and efficient operation of markets will be critical. It is only when spatial markets are interconnected and operate efficiently that agriculture sector growth can be achieved and also for agriculture sector growth, through forward and backward linkage, to foster the growth of non-agricultural sectors. Therefore, as the impact of road access on farm income reported here does not include the multiplier effects of road infrastructure, the impact level reported here is expected to be underestimated.

While expanding rural road access is essential, it is not however a panacea in that such intervention should be complemented by other policy and institutional measures that enhance the capacity of the farmers to reap the benefit induced by road infrastructure. As the empirical result showed, apart from road access condition, household and location specific factors are important determinants of household income and poverty status.

In this regard, given that the land the household cultivates and its quality are critical determinants of income, raising average holding and preventing further land fragmentation, such as through resettlement programmes will be important to achieve meaningful reduction in rural poverty. As observed in Chapter 6, land fragmentation for example reduces farm income through reducing technically efficiency. Given that land fragmentation is partly the outcome of the existing land tenure system, rationalizing the existing land policy will be important in order to maximize the developmental effectiveness of rural road infrastructure.

As the empirical result, both in chapter 4 and chapter 6, showed the oxen holding and human capital base of a household significantly influence its capacity to benefit from road induced growth. Therefore, raising the human capital base or their access to other productive resources, such as through providing credit, education and health services, will be necessary for road infrastructure to raise farm income in general and the income of the poor in particular.

In terms of future research areas, although in this research attempt is made to capture the various channels by which road infrastructure affects rural income and poverty, the three channels identified and empirically substantiated by no means are the only ones. For example, although road infrastructure, through expanding market access and altering farm gate price ratios, influences farm households' crop choice and market participation decisions, such issues are not explicitly treated. These issues are important both from micro as well as macro perspective. Farmers' crop choice, in addition to its impact on micro level income and food security status, will also have important macro level implications. Suboptimal crop choice at the micro level retards overall growth through entailing efficiency loss, i.e., as resources are allocated in areas that are not consistent with the comparative advantage of the country, and also through the consequent loss of foreign exchange earning of the economy (Omamo, 1998).

Therefore, exploring both the extent to which the existing cropping pattern in each agro-zone is consistent with comparative advantage and also the extent to which expanding road infrastructure promotes the specialization of each agro-zones according to their comparative advantage will provide important inputs for policy making. The findings of such research will also shed light on the impact of roads on overall growth through enhancing the foreign exchange earning of the economy.

In addition to crop choice, the magnitude of farm production marketed is also critical as, through forward and backward linkages, it determines both agricultural and non-agricultural sector growth. For example, the growth of agro-processing industries in Ethiopia significantly depends on the magnitude of raw materials supplied by the farm sector as well as by the level of farmers' spending on non-agricultural goods and services. Given that road infrastructure through its influence on transport and transaction costs could have an influence on farmers' market participation decisions, exploring the extent to which it actually holds in the Ethiopian case will provide important policy inputs.

Macro level policy measures, such as exchange rate and tax policies, are usually aimed at altering overall growth through inducing a shift in resource allocation at micro level. The effectiveness of such policy measures in achieving their intended goals therefore, among others, depends on the degree of spatial market interdependency. It is only when domestic spatial markets are integrated that the effect of macro policies on altering economic incentives can be dispersed widely and the desired shift in resource allocation can be realized. Exploring the extent to which expanding road infrastructure enhances the spatial integration of markets and hence enhances the effectiveness of macro level policy measures will also be essential.

Finally, the impact of road on farm income in general and the income of the poor in particular will depend on whether spatial price transmission is symmetrical or not. Exploring the extent to which spatial price transmissions in Ethiopia is symmetrical or asymmetrical will provide important guidance as to the additional measures that need to be taken to ensure that any interventions that alter price ratios will not harm the poor.

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