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The effect of rural roads on consumption in Ethiopia

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Abstract

Purpose – This study empirically examines the impact of rural roads on consumption of households in Ethiopia.

Design/methodology/approach – Both descriptive statistics and econometric techniques are used to address the aforementioned objective. Specifically, quantile regression, fixed- and random-effect models are used to understand the impact of rural road quality on welfare.

Findings – The econometric analysis revealed that improving the quality of rural roads and/or creating access to all-weather roads raises households' average real consumption per capita by as much as 10%. The other transport indicator – mode of transport – also has a positive effect on real consumption per capita. The result indicated that real consumption per capita for households using the traditional mode of transport would increase by as much as 7% compared to those using foot as a major mode of transport. However, the fixed quantile estimation result revealed that rural road access has a positive and significant effect on consumption per capita only for the 0.8th and 0.9th percentiles, indicating that the access to roads is not pro-poor.

Research limitations/implications – Improving rural roads to a level of all-weather road standards and provision of agricultural transport facilities should be strategic priorities.

Originality/value – This study provides empirical evidence pertinent to the effect rural mobility has on the consumption of households as well as the pro-poorness of such investments in rural settings.

Keywords Rural road transport, Access to all-weather roads, Pro-poor growth, Mode of transport, Quantile regression, Consumption per capita, Fixed effects, Random effects

Paper type Research paper

1. Introduction

In Ethiopia, about 50% of the rural population still needs to travel about six hours to reach all-weather roads. To make matters worse, most rural roads are dry-weather roads that are not passable by formal transport modes during the wet season (ERA, 2020). Interestingly, while the average rural accessibility index for the country is around 50%, the proportion of the rural population within 2 km of access is only 28.8% (ERA, 2021). Furthermore, reports indicate that the level of rural mobility is low by any measure. Rural communities mainly rely upon pack animals and carry loads on their heads and backs to get goods to market (Arethun and Bhatta, 2012).

Rural road transport is expected to significantly enhance agricultural growth and improve rural livelihoods, thereby reducing poverty. In this regard, empirical studies showed that access to rural roads could play a meaningful role in fostering rural income (Lulit, 2012; Wondemu and Weissb, 2019; Kishor and Basanta, 2021; Jemal and Genet, 2019) and in reducing poverty through accelerating agricultural production and product marketing (Haloi and Simhachalam, 2021; Qin *et al.*, 2022; Kishor and Basanta, 2021).

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Empirical results are inconclusive. For example, a study on rural roads in Ethiopia suggested that when connected to roads, rural residents were about 10.4% less likely to fall into or remain in poverty between 2012 and 2016 than their counterparts (Nakamura and Nuru, 2019). The same authors found that households with access to rural roads exposed to the 2015–16 drought lowered their chance of becoming poor by around 14.4%. Another study in India found that a new road did not significantly change the share of landless households owning less than 2 acres or having between 2 and 4 acres of agricultural land (Asher and Novosad, 2018). However, a 3.4% increase in the share of households with over 4 acres of land was observed. Another study by Nguyen *et al.* (2017) revealed that rural road projects significantly increased the household wealth index by 0.17%. However, the aforementioned studies did not consider the pro-poorness of rural roads. On top of that, these studies ignored the mobility effect of access to roads. Therefore, this study is motivated by the need to provide empirical evidence pertinent to rural mobility's effect on households' consumption and the pro-poorness of such investments in rural settings in sub-Saharan Africa, taking Ethiopia as a case point.

2. Literature review

Empirical studies have shown that access to rural roads can play a meaningful role in reducing poverty. Early empirical works such as those by Jalan and Ravallion (2002) found a geographic poverty trap of rural households using longitudinal data from 1985 to 1990 on 5,600 farm households in rural provinces of China. The study takes road density per 10,000 persons as one of the geographic variables affecting private capital's productivity. Using generalized method of moments (GMM) estimation, the authors find that roads positively and significantly impact consumption growth in China. A similar study on China by Fan and Chan-Kang (2005) shows that low-standard feeder roads contribute to poverty reduction and economic growth in China.

A study by Fan *et al.* (2002) indicates that government's spending on infrastructures such as rural roads, telecommunication and irrigation greatly contributes to poverty reduction. However, they did not explicitly show infrastructure investment priories, and more importantly, they did not show which infrastructure investment would bring more impact on poverty reduction. This is important, especially for developing countries, as they cannot simultaneously invest in rural infrastructure projects.

Dercon *et al.* (2011) used panel data from 15 rural villages in Ethiopia and examined the impact of an agricultural extension program and road access on poverty and consumption growth. Based on GMM estimation, the study finds that access to all-weather roads reduces poverty by 6.9% and increases average consumption growth by 16.3% after controlling for regional fixed effects and seasonal shocks. However, the paper fails to show the pro-poorness of rural roads across consumption quantile groups.

Khandker and Koolwal (2011) examined the impact of rural roads in the long run, using household-level panel data from Bangladesh between 1997 and 2005. They estimated the benefit of road projects on consumption expenditure before and after the project in control and treatment villages. Results from GMM estimation show positive and significant outcomes of roads on per capita expenditure in the short run, especially for extremely poor households. They also identified the initial difference in the households' characteristics, and the quality of roads determines the long-run impact of the roads. However, some studies did not include the use of modes of transport (traditional or modern) as one component of the road transport system. The pro-poorness effect also has not been addressed in the analysis.

A study by Worku (2012) analyzed the impact of road sector development on economic growth in Ethiopia. The study used time series data on the country's road network and gross domestic product (GDP) growth from 1971 to 2009. The author used the total road network per worker, and he tested the significance of paved and gravel roads independently. Results from a two-step GMM estimator show that paved roads positively and significantly impact economic growth, while gravel roads do not. Although he finds a positive impact of the road on the overall GDP, it did not show that this might affect consumption or poverty at lower levels of administrative units and households.

A recent study by Qin *et al.* (2022) using the difference–indifference method shows that rural transportation infrastructure indirectly promotes poverty reduction by stimulating economic growth. However, they only show the effect of road investment and neglect the effect of the mode of transport. Moreover, they fail to show whether providing better road access increases the consumption of the lower income quantile faster than the upper consumption quantiles.

Overall, there are few studies about whether providing better road access increases the consumption of the lower income quantile faster than the upper consumption quantiles. On top of that, the mobility effect has been largely ignored in empirical studies. This study is, therefore, unique in that it looks at both the effect of mobility and physical aces. Above all, it examines the pro-poorness of access to rural roads.

3. Econometric approach

3.1 Farm-housed consumption model

From a transaction cost theory perspective, providing rural roads reduces transport costs and/or travel time, leading to increased production. Improved rural road systems stimulate socioeconomic development by increasing mobility and improving physical access to resources and markets (Jacoby, 2000). By the same token, reducing the transport cost of goods increases farm gate prices of agricultural products while decreasing farm gate prices of agricultural inputs and other consumer goods (Arethun and Bhatta, 2012).

On the other hand, from an agricultural location theory perspective, access to rural road infrastructure (e.g. distance from farm to market) hampers rural development in general and the agriculture sector by lowering yield and increasing market (Kellerman, 1989). On the other hand, from the theory of production and consumption perspectives, rural road investment can further reduce production costs by lowering the prices of delivered inputs (Allen and Arkolakis, 2014). In this regard, the effect is increased net farm gate prices and farm incomes, increasing consumption (food and nonfood expenditure) at the household level.

From the aforementioned theoretical discussion, the empirical modeling in this article follows the consumption approach. This consumption model estimates the effect of access to rural roads and mobility on consumption. Moreover, the theoretical model serves as a basis to estimate the pro-poorness of investment in rural roads.

Following the works of Yesuf (2007), let us assume that a household's income consists of both earned income (Y^{e}) and unearned income (Y^{u}). The earned income is derived from business activities. The unearned income is comprised of government transfers and private transfers. Moreover, households may also send some of the members to participate in the nonfarm sector with the expectation of receiving remittances. This relationship is expressed as follows:

$$y^u = A + R = f(PC.\, HC, DC) \tag{1}$$

$$Y^e = f(p, Y, w) \tag{2}$$

where A refers to aid or any support from the government and/or private individuals in kind or cash; R stands for remittances, which is the transfer of money from relatives; PC denotes physical capital; *HC* is a vector of human capital; *DC* is the demographic characteristics of the households; *Y* is the total output; *p* is the price of inputs and outputs and *w* is the wage earned. Price can be suppressed for simplicity (Yesuf, 2007.) The total output (*Y*) depends on factors of production and can be expressed by using a Cobb–Douglas technology function, which can be written as follows:

$$Y = A\left[PC^{\alpha}HC^{\beta}\right] \tag{3}$$

where *PC* and *HC* stand as defined above and α and β are parameters. In addition, the wage earnings of the households take the Mincerian-type function based on the human capital model developed by Becker (1993 in Yesuf, 2007).

$$W = \gamma_1 HC + \gamma_2 expi + \gamma_3 expi^2 \tag{4}$$

where *W* is wage; *HC* stands as defined above; *expi* stands for experience, $expi^2$ is its squared value and γ_1, γ_2 and γ_2 are parameters to be estimated. This model can be used as the model for off-farm earnings; *HC* measures the educational attainment of the household head and household members, and *expi* can be replaced by proxy variables such as the age of the household head and its members. In sum, the total income of the household Y^T can be written as follows:

$$Y^T = Y^e + Y^u = f(PC, HC, DC) \tag{5}$$

The theoretical establishment is based on the notion that a household maximizes utility from consuming commodities and home production activities. The household's problem is to choose the level of consumption *C* and home production activity level *x* subject to the budget constraint given her/his welfare function. This function is formulated as follows:

$$\text{Max}\, U(C, x) \tag{6}$$

$$\text{Subject to}\, C + x = Y^t \tag{7}$$

Substituting (6) into the budget constraint and the budget constraint into the welfare function, the household's optimization will have the following functional form:

$$MaxU(f(PC, HC, DC), x \tag{8}$$

The first-order condition implies that marginal utility from both consumption and home production activities should be zero. Given this framework, households' utility/welfare depends on several factors. Using consumption expenditure per adult equivalent to measuring household welfare, we can get the following consumption model at any time *t*.

$$C_{it} = f(PC, HC, DC, x) \tag{9}$$

3.2 Measuring pro-poorness of rural roads

The quantile regression method is employed to see the pro-poorness of rural roads. The quantile regression model is selected from other regression methods because it is more appropriate wherever there are policy implications and conclusions to be drawn in empirical analysis (Koenker and Bassett, 1978 in Kedi and Sookram, 2010), and it is also common in the case of consumption/welfare studies as it is more robust than ordinary least squares (OLS) in the presence of heteroscedasticity (Kedi and Sookram, 2010). The quantile regression approach also has the advantage of allowing parameter variation across quantiles of the income or consumption distribution (Pede *et al.*, 2011). Moreover, this approach is considered in this study for two reasons: (1) with a skewed distribution, the median may become the more appropriate measure of central tendency, and (2) examining the marginal effects of rural road accessibility at different quintiles of consumption can provide a better picture of the benefits of rural road transport for farmers with varying unobserved characteristics. Thus, in order to estimate the effect of accessibility and mobility on total consumption per adult equivalent of different household categories, quantile regression is employed.

As far as the dependent variable is concerned, to run the quantile regression, the consumption approach was considered an indicator of welfare or poverty because of its relative importance over the income approach in the context of developing countries (Ravallion, 1992).

The quantile regression can generate different responses in the dependent variable (total expenditure per adult equivalent) at different quantiles. These different responses are interpreted as differences in the response of the dependent variable to changes in the regressors at various points in the conditional distribution of the dependent variable (Montenegro, 2001 in Caglayan and Astra, 2012). In this respect, in order to estimate the pro-poorness of rural roads, one can assume the conditional quantile of a random variable Y to be linear in the regressors X, where Y is the sum of food and nonfood expenditure within a year, and it takes the natural logarithm of total expenditure per adult equivalent. Following Caglayan and Astra (2012), the quantile regression model for panel data has the following form:

$$L(y_{it}) = \beta X_{it} + \varepsilon_{it} \tag{10}$$

where $L(y_{it})$ is the natural logarithm of the total expenditure per adult equivalent of household i in period t, X_{it} is a vector of the individual characteristics of the ith household in period t, β is a vector of unknown parameters to be estimated and ε_{it} is the random disturbance term which is assumed to satisfy the usual properties of zero mean and constant variance.

Following Koenker and Bassett (1978), equation (10) can be specified in the form of the quantile regression as follows:

$$Q_\tau = ln\left(\frac{Y_{it}}{X_{it}}\right) = X_{it}B_{it} + \varepsilon_{it,\tau} \tag{11}$$

where $Q_\tau = ln\left(\frac{Y_{it}}{X_{it}}\right)$ is used to estimate the logarithm of total expenditure per adult equivalent at τth quantile (Q_τ) of the distribution of the dependent variable (Y_{it}) conditional on the value of X_{it} (a vector of explanatory variables). Following Koenker and Bassett (1978), total expenditure per adult equivalent is in the τth quantile if total expenditure per adult equivalent is higher than the proportion τ of the reference group of individuals and lower than the proportion $(1-\tau)\beta_\tau$ where B_τ is the estimated parameter for each explanatory variable. Assuming that the γth quantile of the error term conditional on the regressors is zero $\left(Q_\tau\left(u_{i,z}/X_{it} = 0\right)\right)$, then the γth conditional quantile of y_{it} with respect to x_{it} can be written as follows:

$$Q = \left(\frac{y_{it}}{X_{it}}\right) = \frac{X_{it}}{B_\tau} \tag{12}$$

Moreover, to control for the effect of household-level unobservable heterogeneous effects, the study used an unconditional quantile regression estimator for panel data introduced by Powell (2009). The estimator conditions on fixed effects for estimation purposes, but the resulting estimates can be interpreted similarly to traditional cross-sectional quantile estimates (Powell, 2009). The fixed effects do not define the estimator conditions on fixed effects but the quantiles themselves. The structural quantile function (SQF) is given by

$$S_y(\tau|x) = x'\beta(\tau) \quad (13)$$

The SQF defines the quantile of the latent outcome variable $y_d = x'\beta(u)$ for a fixed x and a randomly selected $u \sim U(0,1)$. The estimator uses the following two-moment conditions defined:

$$E\left\{\frac{1}{N}\sum_{i} 1\left(y_{it} - x'_{it}\beta(\tau) \leq 0\right)\right\} = \tau \text{ for all } t \text{ and;} \quad (14)$$

$$E\left\{\sum_{i}\sum_{t}\sum_{s<t}(x_{it} - x_{is})[1(y_{it} - x_{it}'\beta(\tau) \leq 0) - 1(y_{it} - x_{is}'\beta(\tau) \leq 0)]\right\} = 0 \quad (15)$$

The first condition defines the quantile category. This equation implicitly assumes the inclusion of year-fixed effects by forcing the condition to hold for all t. The second condition makes within-group pairwise comparisons, implicitly conditioning the firm-fixed effect. Finally, the fixed quantile regression model developed by Powell (2009) was estimated at the 10th through the 90th percentiles of the distribution of expenditure of the households (these percentiles were selected in order to show both the lowest and the highest income groups).

4. Empirical model specification

Given the panel nature of the data, an estimable form (empirical speciation) of the consumption model is formulated with its fixed and random effects following Wooldridge (2009).

$$lnC_{it} = \gamma_i + \alpha X_{it} + \varepsilon_{it} \quad (16)$$

where γ_i captures all the unobserved household factors that affect C_{it}, α is a vector of parameters to be estimated, X_{it} represents exogenous regressors which serve as controls and ε_{it} is the idiosyncratic error term which is assumed to be uncorrelated with the exogenous variable X_{it}. However, in the case where the unobserved heterogeneity is uncorrelated with any of the explanatory variables in all periods, then estimating equation (19) using fixed effects is not efficient. This calls for the estimation of the random-effect model, which is specified as follows:

$$lnC_{it} = \alpha_0 + \alpha X_{it} + \varepsilon_{it} \text{ Where } \varepsilon_{it} = \alpha_i + \mu_{it} \quad (17)$$

The random-effect model allows the inclusion of time-constant variables. Once the fixed- and random-effect models are specified, the next step is to select between the fixed- and the random-effect models, which was carried out using the Hausman specification test. The estimable form of the fixed-effect model is given as follows:

$$lnC_{it} = \gamma_i + \alpha_1 age_{it} + \alpha_2 edu_{it} + \alpha_3 dratio_{it} + \alpha_4 famil_{it} + \alpha_5 yield_{it} + \alpha_6 oxen_{it} + \alpha_7 ext_{it} + \alpha_8 cred_{it} + \alpha_9 irr_{it} + \alpha_{10} accroad_{it} + \varepsilon_{it} \quad (18)$$

In the same way, the estimable form of the random-effect model for real consumption expenditure per capita is given by the following equation. All the variables are as defined above.

$$lnC_{it} = \alpha_0 + \alpha_1 age_{it} + \alpha_2 edu_{it} + \alpha_3 dratio_{it} + \alpha_4 famil_{it} + \alpha_5 yield_{it} + \alpha_6 oxen_{it} + \alpha_7 ext_{it} + \alpha_8 cred_{it} + \alpha_9 irr_{it} + \alpha_{10} accroad_{it} + \varepsilon_{it} \quad (19)$$

The empirical data were drawn from two consecutive panel surveys of the Ethiopian Rural Socioeconomic Survey – Living Standard Measurement Survey. The Central Statistics Agency prepared these data. The first round of the survey was conducted in 2011, and the second wave was conducted after two years (in 2013). The panel data were created using two criteria: (1) households must be from rural areas; (2) households cultivated some plot of land and must have a positive production value. Finally, a balanced panel of 2,176 households with 4,352 observations over two rounds was created.

5. Findings

5.1 Descriptive statistics

5.1.1 Heterogeneity in rural accessibility and mobility. The comparison of the mode of transport used between households in villages with good access and households in villages with poor access is presented in Table 1. The result shows that the proportion of households in villages with poor and good access tend to use a similar mode of transport facilitates for agricultural purposes. In both categories, the dominant mode of transport is foot, followed by traditional and modern modes of transport in the order of mention. The implication is that the adoption of both modern and traditional modes of transport is low for both households in villages with good access and poor access.

Similarly, the comparison of modes of transport across time is presented in Table 2. The result shows a similar transport pattern used for agricultural purposes in both periods. In both years, the dominant mode of transport was foot, followed by traditional and modern modes. The implication is that the level of adoption of both modern and traditional modes of transport is low in both periods. Table 2 further shows that foot is the dominant mode of transport in both periods, suggesting that much remains to be done to improve the transportation modality of rural areas in Ethiopia.

5.1.2 Descriptive statistics for consumption. The mean comparison of covariates used to explain real consumption per capita is presented in Table 3. According to the result, the mean real monthly consumption per capita has increased from Ethiopian Birr (ETB) 126 to ETB 138 ($p < 0.01$) in the years considered. The land-to-family labor ratio decreased from 0.63

Table 1. Comparison of households based on the mode of transport and type of road quality

Type of mode	Good access (pooled)	Poor access (pooled)
On foot	1,033 (77.79)	2,377 (78.6)
Modern mode of transport	78 (5.87)	163 (5.39)
Traditional mode of transport	217 (16.34)	484 (16.01)

Source(s): Authors' own work using data from the Ethiopian Rural Socioeconomic Survey (ESS)

Table 2. Type of mode of transport used by period

Type of mode used	2011	2013
On foot	1,841 (84.6%)	1,569 (72.1%)
Modern mode of transport	99 (4.55%)	142 (6.53%)
Traditional mode of transport	236 (10.58%)	465 (21.37%)

Source(s): Authors' own work using data from the Ethiopian Rural Socioeconomic Survey (ESS)

Explanatory variable	2013	2011	Difference	p value	
Real consumption per capita	138.12	126.011	11.587	0.0002	***
Land-to-family labor ratio	0.5924	0.6316	−0.039	0.0334	**
Dependency ratio	0.7329	0.6987	0.034	0.0767	*
Participation in off-farm income	0.2472	0.2578	−0.011	0.4224	
Sex of the head	0.8111	0.8226	−0.011	0.3273	
Age of the head	46.3625	44.7499	1.613	0.0003	***
Head's years of schooling	1.8888	1.8617	0.027	0.7384	
Access to credit	0.1788	0.2597	−0.081	0.000	***
Access to irrigation	0.1443	0.1553	−0.011	0.3081	
Road quality	0.3079	0.3024	0.006	0.6929	
Oxen in tropical livestock units (TLUs)	7.1992	6.3639	0.835	0.000	***
Logarithm of agricultural yield	7.9254	6.8532	1.072	0.000	***
Family size in adult equivalent	4.8731	4.5382	0.335	0.000	***

Note(s): Level of significance *10%; **5%; ***1%
Source(s): Authors' own work using data from the Ethiopian Rural Socioeconomic Survey (ESS)

Table 3. Mean comparison of covariates used for the real consumption per capita model

in 2011 to 0.59 in 2013 ($p < 0.05$). The family economic burden is measured in terms of the dependency ratio. Results show that the dependency ratio increased from 0.069 in 2011 to 0.73 in 2013 ($p < 0.1$). The number of oxen owned measured in tropical livestock units (TLUs) increased from 6.3 units in 2011 to 7 units in 2013 ($p < 0.00$). Table 4 further shows that while the logarithm of agricultural yield increased from 6.8 in 2011 to 7.1 in 2013 ($p < 0.00$), family size in adult equivalent (which is a proxy for family labor) increased from 4.5 in 2011 to 4.8 in 2013 ($p < 0.00$). On the contrary, access to credit decreased from 25% in 2011 to 18% in 2013 ($p < 0.00$).

Table 4 presents the mean comparison of the key covariates affecting real consumption per capita by type of road quality. The mean comparison test result shows a significant difference between households in villages with good access to all-weather roads and those in villages without access to all-weather roads, at least for some of the covariates. For example, while the mean value of real consumption per capita for households in villages with good access to all-weather roads is ETB 173, the mean value of real consumption per capita for households in villages with poor access to all-weather roads is ETB 113.38 ($p < 0.00$). The household heads' mean years of schooling for households in villages with good

Explanatory variables	Good access	Poor access	Difference	p value
Real consumption per capita	173.7248	113.3951	60.33	0.00
Land-to-family labor ratio	0.6662	0.5882	0.078	0.00
Dependency ratio	0.6865	0.7287	−0.042	0.04
Participation in off-farm income	0.2688	0.2454	0.023	0.10
Sex of the head	0.8148	0.8178	−0.003	0.81
Age of the head	45.9683	45.3746	0.594	0.22
Head's years of schooling	2.1145	1.7702	0.34	0.00
Access to credit	0.2154	0.2209	−0.006	0.68
Access to irrigation	0.2319	0.1138	0.118	0.00
Oxen ownerships (TLUs)	6.5791	6.8704	−0.291	0.17
Logarithm of agricultural yield	7.3615	7.4016	−0.04	0.60
Family size in adult equivalent	4.6409	4.7341	−0.093	0.14

Source(s): Authors' own work using data from the Ethiopian Rural Socioeconomic Survey (ESS)

Table 4. Mean comparison of variables of real consumption per capita

access to all-weather roads is 2.11, while it was just 1.77 for their counterparts. A significant variation is also observed in the level of access to irrigation and land-to-family labor ratio (Table 4).

According to results presented in Table 5 for the year 2011, the mean real consumption per capita was ETB 166 for households in villages with access to all-weather roads, while the mean real consumption per capita was ETB 108 for households with poor access to all-weather roads ($p < 0.00$). For the year 2013, the mean real consumption per capita was ETB 180 for the first group, while the mean real consumption per capita was ETB 118 for the control group ($p < 0.00$).

5.2 Choice of variables

The selection of control variables is based on empirical studies in Ethiopia and elsewhere. More emphasis is given to variables frequently used in empirical studies. In this regard, the following variables are selected for the empirical analysis.

Age: Age of the household head is measured in years, and a study conducted in Ethiopia by Kebede and Sharma (2014) shows that the age of the household head is negatively correlated with the probability of being poor. Hence, the age of the household head is expected to be negatively associated with the consumption/welfare of rural households.

Gender: The gender of the household head is a categorical variable where 0 represents females and 1 otherwise. Workneh (2008) argues that cultural and societal norms in rural areas often negatively impact the nutritional status of women and children, making them vulnerable social groups. The household head being female is positively correlated with the probability of being poor (Kebede and Sharma, 2014).

Education: Education is measured in the years of schooling of the household head. Education has contributed to poverty reduction and welfare increment for the poor (World Bank Institute, 2005). It increases earning potential and improves labor's occupational and geographic mobility (Kebede and Sharma, 2014). Hence, it is hypothesized to have a positive impact on the welfare of rural households.

Access to road and model of transport used: The more a household has access to transport facilities, the better the access to markets and to public services, as well as to private service providers, ultimately leading to a lower chance of falling into poverty (Teka *et al.*, 2019; World Bank Institute, 2005).

Access to credit: Previous studies show that credit is positively associated with the welfare of households (Teka *et al.*, 2019). Access to credit increases or helps households diversify income sources as an escape from poverty. A study by Kassie *et al.* (2014) found that access to credit positively affects the rural well-being of sample households in Malawi. So, access to credit is expected to be positively associated with the welfare of rural households.

Family size and dependency ratio: A household's total family size affects rural households' welfare. Households with larger family sizes are likelier to be poor (Bersisa and Heshmati, 2016). This implies that the effect of family size will be expected to be positive when a household has large household size. This implies more economically active household members (less dependency ratio) and negative otherwise.

Table 5.
Comparison of consumption variables by accessibility

Variables	Year	Good access	Poor access	Diff	*p* Value
Consumption per capita	2011	166.47	108.471	58.003	0.00
Consumption per capita	2013	180.85	118.35	62.488	0.00

Source(s): Authors' own work using data from the Ethiopian Rural Socioeconomic Survey (ESS)

Non/off-farm income: A measure of the income in Ethiopian Birr obtained from off-farm and nonfarm livelihood activities during the last 12 months. It is the most important factor in explaining consumption and poverty. In the empirical works, it is remarked that participation in nonfarm opportunities had notable impacts on the likelihood of a household being poor in Ethiopia (Shibru *et al.*, 2013). For rural households in Mozambique, engagement in off-farm activities is positively related to the well-being of households (Kassie *et al.*, 2014). Hence, non/off-farm income is expected to affect the welfare of rural households positively.

Access to irrigation and extension: It is measured in dummy form (those with access 1 or 0 otherwise for both considered separately). Access to irrigation would increase marketable agricultural output and improve welfare (Tesfay, 2020). In the same manner, better access to extension service helps farmers to produce more crop and other agricultural produce, which improve income and hence improve rural welfare (Kidanemariam, 2015).

5.3 Result from the econometrics analysis

5.3.1 Fixed- and random-effect models. In order to understand the impact of rural road quality on welfare (measured as real consumption per capita), fixed- and random-effect models were estimated. The dependent variable is the logarithm of real consumption per capita. It is estimated using fixed- and random-effect models to identify the possible factors explaining the covariates of real consumption per capita among rural households. The human test was used to select fixed- and random-effect models (Table 6). The Hausman test statistics are formulated in Table 6:

The results of the Hausman test indicate that the fixed-effect model is better than the random-effect model ($p < 0.05$). So, the modeling of welfare determination in this study is based on the fixed-effect model, where the estimation results of the fixed-effect model are shown in Table 7.

Road investment involves policy decision-making by governments about where to construct rural roads or upgrade existing ones. As a result, the estimation of the impact of roads faces endogeneity problems. Thus, the decisions are often made based on unobserved

Test summary	Chi-square statistic	Prob
Cross-section random	49.298190	0.0000

Source(s): Authors' own work using data from the Ethiopian Rural Socioeconomic Survey (ESS)

Table 6.
Hausman test

	Measurement
Household control variables	
Dependency ratio	Ratio
Age of household head	In competed year
Household head is female	Categorical
Average years of schooling	Years
Location-specific control variables	
Annual rainfall (m)	Mm
Altitude (m)	Meter

Source(s): Authors' own work using data from the Ethiopian Rural Socioeconomic Survey (ESS)

Table 7.
Summary statistics of household control variables and location-specific control variables

factors like local productivity, investment cost and political benefits of placing roads in particular areas. In this regard, in panel data settings, it is common to use time-invariant village or household fixed effects (Khandker *et al.*, 2010). The fixed-effect model accounts for endogeneity caused by time-invariant characteristics of the location.

Moreover, using multiple periods, instrumentation was performed using lagged outcomes (Dercon *et al.*, 2011). Moreover, to deal with the endogenous placement of road infrastructure programs, we employ a correlated random-effect model that corrects for location-specific changes in road quality. The final model is estimated by including household and location-specific control variables (see Table 7). The variables are selected based on empirical works of similar studies (Dercon *et al.*, 2009).

As evident in Table 8, most of the covariates used as control variables in the real consumption per capita analysis are significant with their expected signs. The findings from the fixed-effect model show that access to all-weather roads has a positive and significant impact on rural welfare. That is, improving rural roads' quality to allow access to all-weather roads raises households' average real consumption per capita. This result is similar to those of other studies conducted in Ethiopia. For example, Dercon *et al.* (2009) found that while access to all-weather roads has increased consumption growth by 16%, it has reduced the incidence of poverty by 6.7%. The theoretical and empirical argument for the rise in real consumption per capita is that road infrastructure can alleviate transaction costs by allowing access and reducing household travel time (Khandker *et al.*, 2010). An immediate effect of road infrastructure is job creation and income diversification, which directly augments households' real consumption per capita (Aderogba and Abiodun, 2019). Similarly, other studies corroborate the abovementioned findings suggesting that households' access to major roads increases the economic value of agricultural and nonagricultural employments or outputs, generating high household wages and further reducing poverty (Haloi and Simhachalam, 2021).

Interestingly, the effect of access to roads on consumption is consistent with empirical studies elsewhere. For example, Thomas *et al.* (2008) found that road access substantially impacts consumption growth in rural Madagascar. Results in this study show that access to paved roads would increase consumption by 8% while remoteness decreases consumption growth by 4%. The other transport indicator (mode of transport) also positively affects welfare. The result indicated that real consumption per capita for households using the traditional mode of transport would increase by as much as 7% compared to those using the foot as a major mode of transport ($p < 0.05$). The findings from the fixed-effect model revealed that land-to-family labor ratio, participation in off-farm income activities, access to irrigation, access to extension, oxen owned in TLUs and the logarithm of output per capita were found to have a significant positive effect on real consumption per capita (Table 7). This result is consistent with what other studies have already found (Hagos and Holden, 2008).

The coefficient of the land-to-family labor ratio shows that as land-to-family labor ratio increases by one unit, real consumption per capita will increase by 6% ($p < 0.05$). Since the outcome variable is log-transformed, it can be interpreted as exponentiated regression coefficients. Thus, the availability of land at the household level that meets the growing family size means securing food at the household level.

The coefficient of participation in off-farm income is positive and significant. For rural households participating in rural off-farm activities, consumption would increase on average by 10% compared to households not participating in off-farm activities ($p < 0.05$). This result corroborates with findings of other similar studies (Woinishet, 2010). However, the effect of participation in off-farm activities on consumption or poverty depends on the activity farmers are engaged in and the level of off-farm income earned (Davis, 2003).

Explanatory variable	Fixed-effect model	Random-effect model
Access to all-weather roads (1 = yes)	0.100***	0.209***
	(0.0272)	(0.0232)
Mode of transport used[1] (1 = foot)		
Modern mode of transport	0.0542	0.0927**
	(0.011)	(0.0457)
Traditional mode of transport	0.0765**	0.0727**
	(0.068)	(0.0286)
Logarithm of yield	0.0186***	0.0307***
	(0.006)	(0.005)
Land-to-family labor ratio	0.0615**	0.0731***
	(0.025)	(0.021)
Participation in nonfarm income	0.102***	0.0926***
	(0.031)	(0.0244)
Dependency ratio	−0.0741**	−0.107***
	(0.038)	(0.0212)
Age of the head	0.00321	−0.00264**
	(0.032)	(0.001)
Altitude	0.3421	0.13423
	(0.025)	(0.022)
Gender of the head (1 = male)	0.0702	0.0609
	(0.097)	(0.038)
Years of schooling	−0.0371	0.0218***
	(0.005)	(0.009)
Annual rainfall	0.0515**	0.026**
	(0.014)	(0.045)
Access to irrigation (1 = yes)	0.370***	0.342***
	(0.048)	(0.032)
Access to extension (1 = yes)	0.0864**	0.115***
	(0.0351)	(0.0244)
Access to credit (1 = yes)	0.0317*	0.0448*
	(0.0299)	(0.026)
Number of livestock owned in TLU	0.00984***	0.0140***
	(0.00272)	(0.00175)
Family size in adult equivalent	−0.0840***	−0.0723***
	(0.0213)	(0.00848)
Constant	6.470***	7.481***
	(0.232)	(0.0807)
Observations	4,346	4,346
R^2	0.073	
Correlated random effects (CRE) terms included	Yes	Yes
Household controls p value CRE	Yes	Yes
	0.018	

Note(s): Robust standard errors in parentheses ***p < 0.01, **p < 0.05, *p < 0.1
[1]Foot is drooped for comparison reasons
Source(s): Authors' own work using data from the Ethiopian Rural Socioeconomic Survey (ESS)

Table 8. Fixed- and random-effect model estimation result

As expected, dependency ratio and family size in adult equivalent have a negative and statistically significant effect on the real consumption per capita at 5% and 1% levels, respectively. The coefficient of the dependency ratio and family size in adult equivalent parameters is also consistent with the theoretical expectations (Bigsten *et al.*, 2003). The result shows that the dependency ratio reduces expenditure per adult equivalent by at least 7%. The most plausible reason is that for a given household size, a larger number of children and elderly members would imply a smaller number of earners in the household and hence a smaller support ratio. This means there is a high burden on labor force members (Bigsten *et al.*, 2003). Similarly, the coefficient of family size (in adult equivalent unit) is found to reduce real consumption per capita by 8%. Similar patterns are observed in most developing and low-income countries (Asogwa *et al.*, 2012; Ojimba, 2013).

Among the key policy variables, access to irrigation and extension increased consumption expenditure. The coefficient of irrigation shows that, based on the fixed-effect estimator, it is positive in raising the average real consumption per capita of households by as much as 3% ($p < 0.01$). Huang *et al.* (2005) in China, Dillon (2008) in Mail and Fitsum *et al.* (2012) in Ethiopia found similar results indicating the role of irrigation as a key factor for poverty alleviation and improvement of rural households' welfare. The coefficient for access to extension service shows that, on average, consumption per capita increases by as much as 8% compared to households with access to irrigation ($p < 0.05$). This result is constant with Dercon *et al.* (2011) and Asogwa *et al.* (2012). However, Dercon's *et al.* (2009) result is more robust because the endogeneity problem is controlled for. According to Dercon *et al.* (2011), farmers receiving at least one visit from an extension agent raise consumption growth by 7% and reduce poverty incidence by nearly 10%.

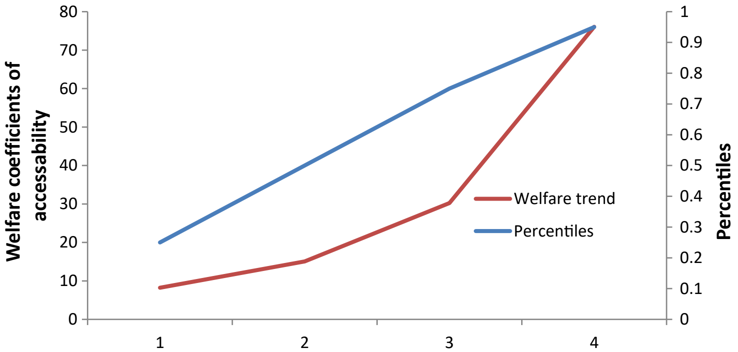
5.3.2 The pro-poorness of access to rural roads. Quantile regression is estimated to assess how different groups of households are affected by a change in access to roads. Thus, the welfare model is estimated using a fixed quantile regression model technique and classifying the households into different strata. Although the model is estimated by including all the potential covariates of consumption since our interest here is only to look at the pro-poorness of rural road accessibility, only the real consumption per capita coefficients with their z statistics and p values are reported (Table 9). The result of the fixed quantile estimation in Table 9 indicates that access to rural roads has a positive and significant effect on welfare only for the 0.8th and 0.9th percentiles. (The results with the covariates of poverty are presented in Annex).

Thus, according to the result in Figure 1 (drawn using the result in Table 8), rural roads are not pro-poor in the period considered. This is an important result as the question of who is benefiting (which consumption group) from rural road investment has not been adequately answered in their analysis. In this regard, the findings of this study give important insight to policymakers. Given the short period considered, one should be cautious about making strong conclusions. Although the period considered is brief, the change in road infrastructure cannot be underestimated; hence, the conclusions about rural roads' pro-poorness are reliable.

Table 9.
Welfare distribution and rural access

Percentiles	Welfare effect	Std. Err	Z	P>|z|
0.1	3.232322	15.453	0.12	0.413
0.2	3.126336	17.949	0.17	0.862
0.3	9.468921	26.186	0.36	0.718
0.4	12.93196	13.430	0.96	0.336
0.5	10.00797	17.821	0.84	0.456
0.6	20.47958	34.328	0.6	0.551
0.7	26.62714	16.762	1.59	0.112
0.8	34.00285	10.297	3.3	0.000
0.9	77.25115	12.008	3.5	0.000

Source(s): Authors' own work using data from the Ethiopian Rural Socioeconomic Survey (ESS)



Source(s): Authors own work using data from the Ethiopian Rural Socioeconomic Survey (ESS)

Figure 1. Welfare coefficients of accessibility and rural road access

6. Conclusions and policy implications

Rural communities in Ethiopia have different levels of accessibility and mobility regarding access to all-weather roads and the use of modes of transport. Utilization of modern modes of transport for agriculture-related activities is low, and the foot is still the dominant mode of transport for agricultural purposes. Even though there is an increase in access to all-weather roads, most rural farmers still use the foot as a major means of transport for agricultural purposes. Thus, the agricultural transportation system has not been well developed. This calls for the adoption of the intermediate mode of transport.

The study found that heterogeneity in rural accessibility and mobility can explain real consumption per capita differences. The study found that creating access to all-weather roads increases real consumption per capita by at least 10% ($p < 0.05$). However, the study did not support the pro-poorness of rural road investment. From a theoretical perspective, rural road investment is a core component of a "pro-poor" or "inclusive growth" strategy. Therefore, improving roads in areas where the poor live should help lower poverty, but this study found that the effect of investment in rural roads might not be automatically progressive. (Gains are proportionately higher for the higher consumption group than for the lower consumption group.) The implication is that, apart from the investment in rural road access, the lack of evidence for the pro-poorness of rural road investment calls for inclusive growth that addresses equity to bring about pro-poor growth and overall welfare improvement. This would include the provision of the light mode of transport, which provides an efficient transport system, and other interventions such as the provision of credit access, extension service and irrigation, which directly impact agricultural production and hence can improve consumption.

The results of this study do not necessarily imply that further investment in road infrastructure will continue to have the same poverty reduction effect in the future. Building more roads for villages that already have road access may give them alternative routes to markets but may not necessarily increase their productivity. Perhaps further studies shall be needed to investigate the impact of the road in the long run, and better road access indicators (e.g. index and GIS-based measurements of mobility) could strengthen the result made by this paper. Moreover, our paper only provides the outcome in terms of growth in consumption expenditure.

References

Aderogba, B.A. and Abiodun, A. (2019), "Assessing the impact of road infrastructure on poverty reduction in developing economies: the case of Nigeria", *Modern Economy*, Vol. 10 No. 80, pp. 2430-2449.

Allen, T. and Arkolakis, C. (2014), "Trade and the topography of the spatial economy", *The Quarterly Journal of Economics*, Vol. 129 No. 3, pp. 1085-1114.

Arethun, T. and Bhatta, B.P. (2012), "Contribution of rural roads to access to and participation in markets: theory and results from Northern Ethiopia", *Journal of Transportation Technologies*, Vol. 2 No. 2, pp. 165-174.

Asher, S. and Novosad, P. (2018), "The impact of rural roads and irrigation on household welfare: evidence from Vietnam", *International Review of Applied Economics*, Vol. 31 No. 6, pp. 734-753.

Asogwa, C.B., Okwoche, V.A. and Umeh, J.C. (2012), "Analysing the determinants of poverty severity among rural farmers in Nigeria: a censored regression model approach", *American International Journal of Contemporary Research*, Vol. 2 No. 5, pp. 166-176.

Bersisa, M. and Heshmati, A. (2016), *Poverty and Wellbeing in East Africa a Multi-Faceted Economic Approach*, Springer International Publishing, available at: https://link.springer.com/article/10.1007/s11205-021-02606-w (accessed 20 March 2023).

Bigsten, A., Berket, K. and Shimeles, A. (2003), "Growth and poverty reduction in Ethiopia: evidence from household panel surveys", *World Development*, Vol. 31 No. 1, pp. 87-106.

Caglayan, E. and Astra, M. (2012), "A microeconometric analysis of household consumption expenditure determinants for both rural and urban areas in Turkey", *American International Journal of Contemporary Research*, Vol. 2 No. 2, pp. 24-34.

Davis, J.R. (2003), "The rural non-farm economy, livelihoods, and their diversification: issues and options", available at: http://www.nri.org/rnfe/papers.htm (accessed 20 March 2023).

Dercon, S., Gilligan, D.O., Hoddinot, J. and Tassew, W. (2009), "The impact of agricultural extension and roads on poverty and consumption growth in fifteen Ethiopian villages", working paper, IFPRI, Washington, DC.

Dercon, S., Hoddinott, J. and Woldehanna, T. (2011), "Growth and chronic poverty: Evidence from rural communities in Ethiopia", *Journal of Development Studies*, Vol. 48 No. 2, pp. 238-253.

Dillon, A. (2008), "Access to irrigation and the escape from poverty: evidence from Northern Mali", available at: https://www.ifpri.org/publication/access-irrigation-and-escape-poverty (accessed 20 June 2019).

Ethiopian Road Authority (ERA) (2020), *Assessment of 19 Years Performance Road Sector*, Addis Ababa, available at: https://www.scribd.com/document/406121531/19-Years-Assessment-Reportl (accessed March 20 2023).

Ethiopian Road Authority (ERA) (2021), *Assessment of 15 Years Performance of Road Sector Development Program*, Addis Ababa.

Fan, S. and Chan-Kang, C. (2005), "Road development, economic growth, and poverty reduction in China", available at: https://ideas.repec.org/p/fpr/resrep/138.html (accessed 20 May 2021).

Fan, S., Zhang, L.X. and Zhang, X.B. (2002), "Growth, inequality, and poverty in rural China: the role of public investments", available at: https://www.ifpri.org/publication/growth-inequality-and-poverty-rural-china-role-public-investments (accessed 20 November 2021).

Fitsum, H., Jayasinghe, G., Mekonnen, L., Aster, D.Y. and Seleshi, B.A. (2012), "Agricultural water management and poverty in Ethiopia", *Journal of Agricultural Economics*, Vol. 43, pp.1-13.

Hagos, F. and Holden, S. (2008), "Rural household poverty dynamics in Northern Ethiopia 1997-2000 analysis of determinants of poverty", *Asian Journal of Agriculture and Development*, Vol. 9 No2, pp. 66-78.

Haloi, K. and Simhachalam, A. (2021), "Impact of the MGNREGS rural roads connectivity initiatives on the socio-economic sphere in Jorhat District", *Assam, Research Highlights*, Vol. 8 No. 10, pp. 91-92.

Huang, Q., Dawe, D., Rozelle, S., Huang, J. and Wang, J. (2005), "Irrigation, poverty and inequality in rural China", *The Australian Journal of Agricultural and Resource Economics*, Vol. 49 No. 2, pp. 159-175.

Jacoby, H.G. (2000), "Access to markets and the benefits of rural roads", *The Economic Journal*, Vol. 110 No. 465, pp. 713-737.

Jalan, J. and Ravellion, M. (2002), "Is transit poverty different? Evidence from rural China", *Journal of Development Studies*, Vol. 36, pp. 92-99.

Jemal, M. and Genet, G. (2019), "Affecting marketing of vegetable product: the case of Qewet Woreda, Ethiopia", *Journal of Business Management*, Vol. 21 No. 3, pp. 82-93.

Kassie, G.T., Abate, T., Langyintuo, A. and Maleni, D. (2014), "Poverty in maize growing rural communities of southern Africa", *Development Studies Research*, Vol. 1 No. 1, pp. 311-323.

Kebede, T. and Sharma, M.K. (2014), "The determinant of poverty in Ethiopia", *Ethiopian Journal of Economics*, Vol. 12 No. 1, pp. 113-130.

Kedi, A.M. and Sookram, S. (2010), "Poverty and household welfare in Trinidad and Tobago: evidence from the survey of living conditions (SLC)", available at: https://www.academia.edu/21930886/Poverty_and_household_welfare_in_Trinidad_and_Tobago_Evidence_from_the_Survey_of_Living_Conditions_SLC_2005_1 (accessed 10 June 2020).

Kellerman, A. (1989), "Agricultural location theory: basic models", *Environment and Planning: Economy and Space*, Vol. 21 No. 10, pp. 1381-1396.

Khandker, S.R. and Koolwal, G.B. (2011), "Estimating the long-term impacts of rural roads: a dynamic panel approach", available at: https://openknowledge.worldbank.org/handle/10986/3633 (accessed 10 July 2022).

Khandker, S.R., Bakht, Z. and Koolwal, G.B. (2010), "The poverty impact of rural roads: evidence from Bangladesh", *Economic Development and Cultural Change*, Vol. 57 No. 2, pp. 685-722.

Kidanemariam, G.G. (2015), "The impact of agricultural extension on households' welfare in Ethiopia", *International Journal of Social Economics*, Vol. 42 No. 8, pp. 733-748.

Kishor, B. and Basanta, P. (2021), "Impact of vegetable farming on farmer's livelihood patterns in Dhankuta, Nepal", *Nepal Journal of Geography*, Vol. 14 No. 2, pp. 131-150.

Koenker, R. and Bassett, G. (1978), "Regression quantiles", *Econometrica*, Vol. 46 No. 1, pp. 33-50.

Lulit, A.T. (2012), "Impact of road on rural poverty. Evidence form fifteen rural villages in Ethiopia", available at: https://www.semanticscholar.org/paper/Impact-of-Road-on-Rural-Poverty-Evidence-Form-Rural-Terefe/f3ddec636a2d21166f8285ca15f30c77b10757d2 (accessed 20 June 2019).

Nakamura, S.T., Bundervoet, T. and Nuru, M. (2019), "Rural roads, poverty and resilience: evidence from Ethiopia", available at: https://openknowledge.worldbank.org/bitstream/handle/10986/31495/WPS8800.pdf?sequence=4&isAllowed=y (accessed 20 March 2020).

Nguyen, C.V., Phung, V.K.T. and Tran, D.T. (2017), "The impact of rural roads and irrigation on household welfare: evidence from Vietnam", *International Review of Applied Economics*, Vol. 31 No. 6, pp. 734-753.

Ojimba, P.T. (2013), "Socio-demographic factors as determinants of poverty in crude oil polluted crop farms in rivers state, Nigeria", *International Journal of Food and Agricultural Economics*, Vol. 1 No. 1, pp. 13-25.

Pede, V.O., Paris, T.R., Luis, J.S. and McKinley, J.D. (2011), "Determinants of household income: a quantile regression approach for four rice-producing areas in the Philippines", *Asian Journal of Agricltural Economics*, Vol. 9 No. 2, pp. 69-78.

Powell, D. (2009), "Unconditional quantile regression for panel data with exogenous or endogenous regressors", available at: https://www.rand.org/content/dam/rand/pubs/working_papers/2011/RAND_WR710-1.pdf (accessed 23 February 2020).

Qin, X., Wu, H. and Shan, T. (2022), "Rural infrastructure and poverty in China", *PLoS ONE*, Vol. 17 No. 6, pp. 34-56.

Ravallion, M. (1992), "Poverty comparisons: a guide to concepts and methods", available at: https://documents1.worldbank.org/curated/en/290531468766493135/pdf/multi-page.pdf (accessed 23 April 2020).

Shibru, T., Muktar, J., Haji, M. and Yohannes, M.W. (2013), "Dimensions and determinants of agro-pastoral households' poverty in Dembel district of Somali regional state, Ethiopia", *Journal of Economics and Sustainable Development*, Vol. 4 No. 15, pp. 201-215.

Teka, A.M., Woldu, G.T. and Fre, Z. (2019), "Status and determinants of poverty and income inequality in pastoral and agro-pastoral communities: Household-based Evidence from Afar Regional State, Ethiopia", *World Development Perspectives*, Vol. 15 No. 5, pp. 100-123.

Tesfay, M.G. (2020), "Impact of irrigated agriculture on welfare of farm households in northern Ethiopia: panel data evidence", *Irrigation and Drainage*, Vol. 70 No. 2, pp. 306-320.

Thomas, A.C., Gubert, F. and Henry, D.F. (2008), "Consumption growth and agricultural shocks in rural Madagascar", *Paper Presented at the Congress of the European Association of Agricultural Economists*, March 25th–30th, Ghent, Belgium, available at: https://ideas.repec.org/p/ags/eaae08/43610.html (accessed 20 February 2020).

Woinishet, A.S. (2010), "Participation into off-farm activities in rural Ethiopia: who earns more?", available at: https://www.semanticscholar.org/paper/Participation-into-off-farm-activities-in-rural-who-Sisay/bd291777c0ab413ccd1ef9dc142546111abcba66 (accessed 19 March 2022).

Wondemu, K.A. and Weissb, J. (2019), "Rural roads and development: evidence from Ethiopia", *European Journal of Transport and Infrastructure Research*, Vol. 12 No. 4, pp. 417-439.

Wooldridge, J.M. (2009), *Introduction to Econometrics: A Modern Approach*, 4th ed., South Western Educational Publishing Mason, OH.

Workneh, N. (2008), "Food security and productive safety net program in Ethiopia", in Assefa (Ed.), *Digest of Ethiopia's National Policies, Strategies and Programs. Forum for Social Studies*, Addis Ababa, pp. 30-50.

Worku, I. (2012), "Road sector development and economic growth in Ethiopia", Working Paper, Ethiopian Development Research Institute, Addis Ababa.

World Bank Institute (2005), "Introduction to poverty analysis", available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/775871468331250546/introduction-to-poverty-analysis (accessed 23 February 2020).

Yesuf, M.A. (2007), "Vulnerability and poverty dynamics in rural Ethiopia", available at: https://www.duo.uio.no/bitstream/handle/10852/17402/MPhilxThesisxFinal.pdf?sequence=1&isAllowed=y (accessed 20 June 2022).

Further reading

Becker, S.O. and Ichino, A. (2002), "Estimation of average treatment effects based on propensity scores", *The Stata Journal*, Vol. 2 No. 4, pp. 358-377.

Jan, D., Chishti, A. and Eberle, P. (2008), "An analysis of major determinants of poverty in agriculture sector in Pakistan", available at: https://ageconsearch.umn.edu/record/6241/ (accessed 20 June 2020).

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Annex

Table A1. Full estimation result for the quintile model

Explanatory variable	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Access to all-weather roads (1 = yes)	3.23	3.126	9.4621	12.93196	10.00797	20.4758	26.62714	34.0028***	77.2511***
	(0.0172)	(0.032)	(0.0272)	(0.062)	(0.067)	(0.024)	(0.025)	(0.061)	(0.042)
Mode of transport used[1] *(1 = foot)*									
Modern mode of transport	27.42	29.142	78.42	94.22	96.22*	110.42	78.42	120.42	159.41
	(0.041)	(0.31)	(0.121)	(0.0321)	(0.0321)	(0.041)	(0.051)	(0.141)	(0.211)
Traditional mode of transport	27.265	58.65	78.65	86.45**	116.45**	178.65	78.65	132.65	128.65
	(0.018)	(0.028)	(0.178)	(0.068)	(0.078)	(0.118)	(0.125)	(0.013)	(0.013)
Logarithm of yield	124.23*	18.6	67.2**	186.5***	106.5***	127.2**	67.2**	114.23*	114.6
	(0.006)	(0.08)	(0.01)	(0.056)	(0.016)	(0.041)	(0.081)	(0.006)	(0.012)
Land-to-family labor ratio	66.26**	71.25**	54.22**	62.65**	130.65**	154.22**	54.22**	115.26**	141.25**
	(0.0214)	(0.026)	(0.073)	(0.0291)	(0.0271)	(0.076)	(0.049)	(0.114)	(0.026)
Participation in nonfarm income	98.02***	56.72**	68.2**	171.02*	121.02*	128.2**	68.2**	198.02***	161.72**
	(0.0314)	(0.064)	(0.011)	(0.0314)	(0.0345)	(0.016)	(0.067)	(0.014)	(0.056)
Dependency ratio	−87.4*	−69.21**	−58.21**	107.41	107.41	−126.21**	−58.21**	−147.4*	−139.21**
	(0.0338)	(0.026)	(0.021)	(0.0138)	(0.0348)	(0.041)	(0.025)	(0.0338)	(0.021)
Age of the head	12.21	74.8	67.31	121.4	111.4	127.31	67.31	123.21	174.8
	(0.00432)	(0.232)	(0.0138)	(0.042)	(0.052)	(0.0321)	(0.0137)	(0.012)	(0.051)
Gender of the head (1 = male)	34.02	65.72	35.31	161.342	121.342	135.31	35.31	152.02	65.72
	(0.0975)	(0.0175)	(0.012)	(0.0975)	(0.0975)	(0.087)	(0.067)	(0.072)	(0.052)
Years of schooling	54.271	62.2	−56.1	−157.671	−125.671	−156.1	−56.1	124.271	142.2
	(0.0112)	(0.002)	(0.001)	(0.021)	(0.021)	(0.054)	(0.043)	(0.072)	(0.002)
Access to irrigation (1 = yes)	25.7	77.80	78.00*	170.56**	140.56**	178.00*	78.00*	135.7	157.80
	(0.051)	(0.048)	(0.086)	(0.081)	(0.0381)	(0.0181)	(0.041)	(0.021)	(0.048)
Access to extension (1 = yes)	87.64	76.54**	77.14	148.54**	128.54**	127.14	77.14	122.64	126.54**
	(0.027)	(0.02)	(0.011)	(0.037)	(0.038)	(0.064)	(0.051)	(0.032)	(0.013)
Access to credit (1 = yes)	89.67	77.75	58.17	146.17	126.17	128.17	58.17	119.67	125.15
	(0.022)	(0.0299)	(0.12)	(0.0299)	(0.0299)	(0.12)	(0.12)	(0.022)	(0.023)

(*continued*)

Table A1.

Explanatory variable	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Number of livestock owned in TLU	68.4***	53.6*	69.52	198.41**	128.41**	161.52	69.52	151.4*	103.5
	(0.002)	(0.041)	(0.012)	(0.015)	(0.0272)	(0.082)	(0.154)	(0.052)	(0.017)
Family size in adult equivalent	−86.40***	−137.7	−158.50	−184.0***	−124.0***	−124.50	−158.50	−152.42*	−137.7
	(0.013)	(0.053)	(0.011)	(0.025)	(0.0273)	(0.053)	(0.411)	(0.116)	(0.513)
Constant	4.470***	6.70*	8.270***	9.47***	6.80***	3.270***	8.270***	4.470**	6.70*
	(0.212)	(0.232)	(0.212)	(0.321)	(0.432)	(0.212)	(0.612)	(0.132)	(0.026)
Observations	4,346	4,346	4,346	4,346	4,346	4,346	4,346	4,346	4,346
R^2	0.23	0.21	0.35	0.37	0.56	0.34	0.28	0.32	0.38

Note(s): [1]Foot is drooped for comparison reasons
Source(s): Authors' own work using data from the Ethiopian Rural Socioeconomic Survey (ESS)