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# Farmers' Health Status, Agricultural Efficiency, and Poverty in Rural Ethiopia

## A Stochastic Production Frontier Approach

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Knowledge Capacity and Innovation Division

## INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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# ABSTRACT

The stochastic frontier production function is used to estimate agricultural efficiency index. Then, controlling for household characteristics and other exogenous variables, the efficiency index is regressed on the probability of being sick. Estimation is performed using the treatment effect model where the probability of being sidelined by sickness is modeled as a probit. This framework allows policy simulations that underscore the impact of farmers' health status on both agricultural efficiency and poverty reduction. Overall, regression results confirm the negative impact of health impediment on farmers' agricultural efficiency. Simulation results show that improving farmers' agricultural efficiency by investing in farmers' health may not necessarily lead to poverty reduction. Additional policy instruments may be needed to achieve simultaneous increase in agricultural productivity and reduction in poverty rate.



**Keywords: Health, Agriculture, Productivity, Poverty, Farmer, Efficiency, Stochastic, Production**

# 1. INTRODUCTION

The literature linking health to labor productivity is built on the concepts of household production theory developed by Becker (1965). In Becker's framework, households are treated also as producers of "commodities" instead of solely consumers of goods and services. This framework was extended by Grossman (1972, 1999) to analyze the demand for health. In Grossman's model, health is viewed as a durable capital stock that yields an output of healthy time. Individuals are endowed with an initial amount of this stock that depreciates over time and can be increased by investment. By investing in health, households expect to increase the stock of available healthy time, which will increase the amount of time available for earning income or for producing consumption goods. Extending traditional agricultural household models, Pitt and Rosenzweig (1986) developed a framework that allows the evaluation of the impact of change in health on productivity, labor supply, and overall farmer income. Pitt and Rosenzweig's extension involves incorporation of a health variable into the utility function and introduction of an explicit production technology for health.

Health as a capital good can either improve or reduce households' productive ability. A study of women farmers in mixed cropping systems found that the vast majority suffered from intense muscular fatigue, heat exhaustion, and skin disorders, forcing them to take days off from attending to crops (Cole 2006). Poor health will result in a loss of days worked or in reduced worker capacity, which, when family and hired labor are not perfect substitutes or when there are liquidity constraints, is likely to reduce output (Antle and Pingali 1994). For example, prolonged exposure to pesticides could cause cardiopulmonary problems, neurological and hematological symptoms, and adverse dermal effects (Spear 1991), which could significantly hamper farmers' work capacity in the field and reduce their management and supervision abilities.

As pointed by the World Bank (2007), illness and death from HIV/AIDS, malaria, tuberculosis, and other diseases reduce agricultural productivity through the loss of labor, knowledge of productive adults, and assets to cope with illness. For Lipton and de Kadt (1988), the lack of coordination of policymaking between agriculture and health undermines efforts to overcome ill health among the rural poor and gives short shrift to agriculture's role in alleviating many of the world's most serious health problems.

The relationship between agricultural efficiency and poverty goes both ways. As pointed out by Hawkes and Ruel (2006), in agricultural communities, poor health reduces income and productivity, further decreasing people's ability to address poor health and inhibiting economic development. Higher agricultural productivity affects family earnings and nutrition, which in turn improves labor productivity and results in better health and well-being (Oshaug and Haddad 2002). The relatively low level of endowments in farming assets that characterizes poor households can significantly impede agricultural efficiency. In Pakistan, Ahmad (2003) found that production elasticity of land is substantially higher for rich farmers compared with poor farmers.

This paper intends to address some policy-relevant questions such as (1) What is the poverty-elasticity of change in household income induced by health improvement? (2) How different is the effect of health improvements on inputs productivity, output, per capita income, and poverty? (3) How does illness affect the distribution of labor supply within households? (4) Is the impact of health impediment similar across different sources of income?

In addition to a comprehensive nonparametric analysis, the parametric approach followed in this paper consists in estimating first a stochastic frontier production function from which the agricultural efficiency index is computed. Second, controlling for household characteristics and other exogenous variables, the efficiency index is regressed on the probability of being sick. Regression is performed using the treatment effect model where the probability of being sidelined by sickness is modeled as a probit.

The rest of the paper is organized as follows: In the Section 2, the analytical framework where households appear as both producers and consumers is presented. The expected impact of farmers' health status on poverty via household income is explicitly derived. Section 3 presents empirical findings from previous studies. In Section 4, the stochastic production frontier approach and the treatment model are presented. Data and nonparametric analysis are described in Section 5. Estimation and simulation results are discussed in Section 6. Concluding remarks are presented in the final section.

## 2. PREVIOUS FINDINGS

The importance of the role of health in promoting economic development has been highlighted by Sachs (2001) in the Report of the Commission on Macroeconomics and Health. Indeed, improvements in health care increase the productivity of labor, especially if people switch from low-productivity jobs to high-productivity jobs as their health improves. In particular there is strong evidence that growth in early industrialized countries was associated with significantly increased caloric intake and therefore greater height and body mass (Fogel 1994, 2004). In addition, healthiness interacts positively with schooling; healthy children learn more in school and are more likely to stay in school (Bhargava et al. 2001; Miguel and Kremer 2004). In addition, improved levels of human capital may increase the rate of return to further investments in human capital. This is particularly true of increases in life expectancy; people who expect to live longer earn the returns to education over a longer period of time. Lleras-Muney and Jayachandran (2007) report that decreases in maternal mortality led Sri Lankan girls to stay in school longer; the reduced probability of dying in childbirth increased the return to schooling by increasing life expectancy for girls. At the micro level, empirical evidence of the link between health and agricultural productivity results from the implementation of agricultural household models as extended by Pitt and Rosenzweig (1986). As pointed out by Hawkes and Ruel (2006), in agricultural communities, poor health reduces income and productivity, further decreasing people's ability to address poor health and inhibiting economic development. Using cross-section data on hoe-cultivating farm household data from Sierra Leone, Strauss (1986) investigates the efficiency wage hypothesis, or the relationship between nutritional quality and agricultural productivity. He finds that "effective family labor," which is a function of actual labor and per capita daily calorie intake, is a significant input in the production process. His study shows a highly significant effect of calorie intake on labor productivity. Working with panel data from rural South India, Deolalikar (1988) does not find similar results. Neither market wages nor farm output is observed to be responsive to changes in the daily energy intake of workers. However, both are highly elastic with respect to weight-for-height.

Combining production data from farm-level survey and health data from the same population of farmers in two rice-producing regions of the Philippines, Antle and Pingali (1994) find that pesticide use has a negative effect on farmer health, while farmer health has a significant positive effect on productivity. In Ethiopia, Croppenstedt and Muller (2000) found evidence of a significant link between health and nutritional status and agricultural productivity. Their results show that the distance to the source of water as well as nutrition and morbidity status affect agricultural productivity; elasticities of labor productivity with respect to nutritional status are very significant. The results also show a large scope for productivity improvement through better nutrition.

Estimating the worker productivity benefits of health, Audibert and Etard (2003) use a quasi-experimental design along with a generalized linear model for longitudinal data. Contrary to Pitt and Rosenzweig (1986), Audibert and Etard assume that the family members and the hired labor who are working in the fields are imperfect substitutes because of the cost of hired labor and the low agricultural yield. They observed an increase of 26 percent of the production per family labor person-day in the experimental group relative to the control group. Their results also suggest that agricultural households prefer to utilize the additional time available to them for leisure activities or for cultivating crops other than those currently under cultivation.

Analyzing productivity and attendance of tea estates in western Kenya, Fox et al. (2004) found that HIV-positive workers plucked between 4.11 and 7.93 kilograms per day less in the last year and a half before termination. Compared with non-HIV-positive pluckers, HIV-positive workers used between 9.2 and 11.0 more sick leave days, between 6.4 and 8.3 more annual leave days, between 11.8 and 19.9 more casual leave days, and spent between 19.2 and 21.8 more days doing less strenuous tasks in the two years before termination. Tea pluckers who terminated because of AIDS-related causes earned 16.0 percent less in their second year before termination and 17.7 percent less in the year before termination.

In a Côte d’Ivoire study of farmers engaged in intensive vegetable production, Girardin et al. (2004) found that malaria sufferers produced about half the yields and half the incomes that healthy farmers did.

Kim, Tandon, and Hailu (1997) analyzed the impact of onchocercal skin disease (OSD) on productivity at a coffee plantation in southwest Ethiopia. Their results revealed that permanent male employees, the core of the plantation labor force, suffer significant losses in economic productivity (in the form of lower daily wages earned) as a result of OSD. Depending on the severity of OSD, and controlling for such factors as age, daily wages were 10 to 15 percent lower among those exhibiting skin-related problems. Relatively older (35+) permanent male employees have the biggest OSD-related loss in economic productivity in terms of diminished earnings and an adversely impacted labor supply.

## 3. ANALYTICAL FRAMEWORK

As pointed out earlier, following Becker's framework, consumption or labor supply analysis of agricultural households must account for the interdependence between household production and consumption decisions. To account for the sequential nature of agricultural households' decision-making processes, Singh, Squire, and Strauss (1986) propose a recursive analytical model with profit- and utility-maximizing components. More specifically, every household is assumed to maximize a utility function of the following form:

$$U = U(C_a, C_m, C_l), \quad (1)$$

where the commodities comprise an agricultural staple $(C_a)$, a market-purchased good $(C_m)$, and leisure $(C_l)$. Utility is maximized subject to a cash income constraint,

$$p_m C_m = p_a(Q_a - C_a) - w(L - L^f) - w_x X + E, \quad (2)$$

where $p_m$ and $p_a$ are respectively the prices of the market-purchased commodity and the staple; $Q_a$ is the household's production of the staple; $w$ is the market wage; $L$ is total labor inputs; $L^f$ is family labor input (so that $L - L^f$, if positive, is hired labor, meaning that family labor alone is not sufficient to cover the need for agricultural labor; and if negative, is off-farm labor, meaning the supply of family labor is higher than needed for farming activities); $X$ is a variable input (for example, fertilizer); $w_x$ is the variable input's market price; and $E$ is any nonlabor, nonfarm income such as remittance.

Every household also faces a time constraint; it cannot allocate more time to leisure, on-farm production, or off-farm employment than the total available amount of time ($T$). Welch (1970) suggests that household farm management ability should be reflected in both the technical efficiency of the production process and the allocative efficiency of input and output decisions. Accordingly, the total stock of household time available for farm production ($L^f$) is divided between management $M$ and field work $F$. Following Bliss and Stern (1978) and Antle and Pingali (1994), effective management input is given by

$$M^e(I, M) = m(I)M, \quad \partial m/\partial I < 0, \quad (3)$$

where $I$ is the index of health impairment. Similarly, effective family labor input is given by

$$F^e(I, F) = f(I)F, \quad \partial f/\partial I < 0. \quad (4)$$

Total effective field labor is then $L^e = F^e + H^e$, where $H^e$ is hired labor. The household faces a production constraint or production technology that links inputs and farm output as follows:

$$Q_a = Q(X, L^e, M^e, Z), \quad (5)$$

where $Z$ represents fixed inputs such as land and capital.

After allocating the amount of time available, each farmer is assumed to choose $X$, $H^e$, $F$, and $M$ to maximize net returns

$$\pi = p_a Q(X, L^e, M^e, Z) - w_x X - wH^e \quad (6)$$ [1],

1 The marginal value of family labor is equated to the hired wage rate. In competitive labor market equilibrium, the hired wage is also equal to the net off-farm wage, and thus the marginal value of family labor is equalized across all farm and nonfarm production and leisure activities (Antle and Pingali 1994).

subject to

$$T^p = F + M, \; L^e = F^e + H^e. \tag{7}$$

Hence,

$$Q_a = Q\left(X, F^e(I,F) + H^e, M^e(I,M), Z\right), \tag{8}$$

so that the overall effect of illness on production is given by

$$\partial Q_a / \partial I = \frac{\partial Q}{\partial M^e}\frac{\partial M^e}{\partial I} + \frac{\partial Q}{\partial F^e}\frac{\partial F^e}{\partial I} < 0. \tag{9}$$

Theoretically, the decrease in production is due to reduced effective management input and effective family labor input. However, the comparative static effects of illness $I$ on actual family labor inputs $M^e$ and $F^e$ and on other inputs are not straightforward (Antle and Pingali 1994): (1) The effect of lower overall productivity may be partially offset by the substitution of hired labor or other inputs for family labor input; (2) the allocation of family labor to management and field labor depends on the relative marginal productivities of management and field labor and the relative impacts of illness on the ability to perform field labor and management tasks.

Pitt and Rosenzweig (1986) conclude that production performance is independent from change in farmers' health only if inputs markets are perfect and there is no missing market for any of the consumed commodities or inputs in health production. As for farmers' income, no prediction is possible because the effect of the health environment on the farmers' work time depends on the properties of unknown utility function as well as on the characteristics of the health production and efficiency labor functions.

The difficulty to predict change in income as a result of change in health environment implies that change in poverty induced by sickness-related shock cannot be exactly predicted. To see this, following Besley and Kanbur (1988), let us express $FGT_\alpha$ indexes as follows:

$$P_\alpha = \int_0^z \left[\frac{z - y_T(\bullet)}{z}\right]^\alpha f(y)dy, \tag{10}$$

where $z$ is the poverty line; $y_T(\bullet) = y_T\left(X, F^e(I,F), H^e, M^e(I,M), Z\right)$ is the total household income (see equation 2); and $f(y)$ is the density function of income. Hence, the marginal effect of change in health impediment $I$ on poverty index $P_\alpha$ can be derived as

$$\frac{\partial P_\alpha}{\partial I} = \frac{\partial P_\alpha}{\partial y_T}\frac{\partial y_T}{\partial I} = \left(\frac{\alpha}{z}\right)\left(\frac{\partial y_T}{\partial I}\right)\int_0^z \left[\frac{z - y_T(\bullet)}{z}\right]^{\alpha-1} f(y)dy, \tag{11}$$

or

$$\frac{\partial P_\alpha}{\partial I} = \frac{\partial P_\alpha}{\partial y_T}\frac{\partial y_T}{\partial I} = \left(\frac{\alpha}{z}\right)\left(\frac{\partial y_T}{\partial I}\right)P_{\alpha-1}. \tag{12}$$

It follows that

$$\frac{\partial P_\alpha}{\partial I}\begin{cases} < 0, \text{ if } \partial y_T(\bullet)/\partial I < 0, \\ = 0, \text{ if } \partial y_T(\bullet)/\partial I = 0, \\ > 0, \text{ if } \partial y_T(\bullet)/\partial I > 0. \end{cases} \tag{13}$$

# 4. EMPIRICAL MODEL

Apart from Croppenstedt and Muller (2000), most of the previous empirical works on the relationship between farmers' health status and agricultural productivity do not account for inefficiency in the production process. For policymaking purposes, it is important to separate the loss in production due to a decrease in the quantity of inputs from the loss induced by inefficiency as a result of farmers' health status. Accordingly, I assume a stochastic production frontier of the following form (Battese and Coelli 1995; Kumbhakar and Lovell 2000):

$$q_i = f(x_i, \beta)\varepsilon_i \exp(\upsilon_i), \tag{14}$$

where $i = 1,..., N$ and indexes farmers, $q_i$ is a $(n \times 1)$ vector of output for farmer *i*, $x_i$ is a $(1 \times k)$ vector of associated inputs, $\beta$ is a $(k \times 1)$ vector of unknown parameters to be estimated, and $\varepsilon_i$ represents farmer *i*'s level of efficiency, with $0 < \varepsilon_i \leq 1$. If $\varepsilon_i = 1$, the farmer is achieving the optimal output under technology $f(x_i, \beta)$. However, if $0 < \varepsilon_i < 1$, then farmer *i* is not making the most of the inputs ($x_i$) and therefore the level of production is suboptimal. In addition, the farmer's production activity is subject to a stochastic shock $\upsilon_i \sim N(0, \sigma_\upsilon^2)$.

In log form, equation (10) can be written as

$$\ln q_i = \beta_0 + \sum_{j=1}^{k-1} \beta_j \ln x_{ij} + \ln \varepsilon_i + \upsilon_i \, . \tag{15}$$

Let $u_i = -\ln \varepsilon_i$; therefore, it follows that

$$\ln q_i = \beta_0 + \sum_{j=1}^{k-1} \beta_j \ln x_{ij} - u_i + \upsilon_i \, , \tag{16}$$

where $u_i \sim N^+(0, \sigma_\upsilon^2)$, and $\lambda = \sigma_u / \sigma_\upsilon$ .

To capture the impact of health impediment on agricultural efficiency, the treatment model developed by Maddala (1983) is applied using the maximum likelihood estimation approach. Explicitly, farmers' agricultural efficiency is modeled as follows:

$$\varepsilon_i = z_i\theta + \delta h_i + \mu_i \, , \tag{17}$$

where $z_i$ is the vector of exogenous variables influencing farmers' efficiency. The binary variable $h_i$ represents farmers' health status, which stems from an unobservable latent health variable $h_i^*$ according to the following rule:

$$h_i = \begin{cases} 1, \text{if } h_i^* > 0 \\ 0, \text{otherwise} \end{cases} \, , \tag{18}$$

where $h_i^* = w_i\phi + \eta_i$, and $\mu_i$ and $\eta_i$ are bivariate normal with mean zero and covariance matrix given by

$$\begin{bmatrix} \sigma & \rho \\ \rho & 1 \end{bmatrix}.$$

Vector $w_i$ includes policy instruments that influence agriculture output through farmers' health status and efficiency level. In other words,

$$\frac{\partial q_i}{\partial w_i} = \frac{\partial q_i}{\partial \varepsilon_i}\frac{\partial \varepsilon_i}{\partial h_i}\frac{\partial h_i}{\partial w_i} \tag{19}$$

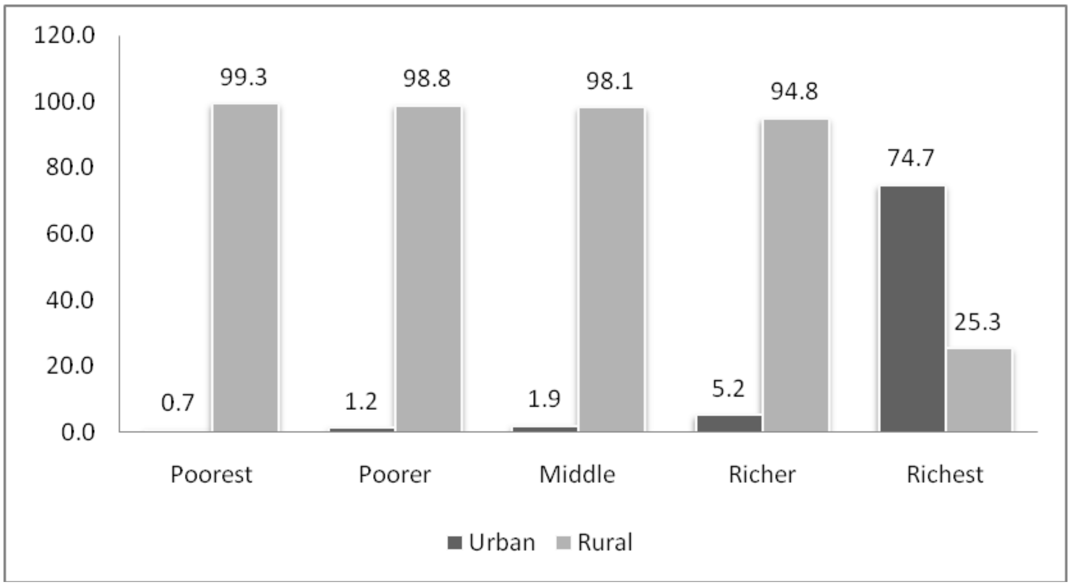
From equation (10), it is clear that $\partial q_i / \partial \varepsilon_i > 0$, and by assumption, $\partial \varepsilon_i / \partial h_i < 0$. Thus,

$$\frac{\partial q_i}{\partial w_i}\begin{cases} < 0, \text{if } \partial h_i / \partial w_i > 0, \\ = 0, \text{if } \partial h_i / \partial w_i = 0 \\ > 0, \text{if } \partial h_i / \partial w_i < 0. \end{cases} \tag{20}$$

# 5. DESCRIPTIVE ANALYSIS

I use an asset-based measure of poverty, the DHS wealth index (see Rutstein and Kiersten 2004 for details), to highlight the difference in living standards between rural and urban areas in Ethiopia. This asset-based measure of poverty includes household assets such as type of flooring, ownership of refrigerator, water supply, type of vehicle, sanitation facilities, number of people per sleeping room, electricity, ownership of agricultural land, telephone, radio, and domestic servant. In the case of Ethiopia, as shown in Figure 1, the distribution of wealth index confirms the existence of significant disparity in living standards between urban and rural areas in Ethiopia. Indeed, among the poorest, only 0.7 percent live in urban areas against 99.3 percent in rural areas. On the contrary, only 25.3 percent of the richest households live in rural areas compared with 74.7 percent in urban areas.

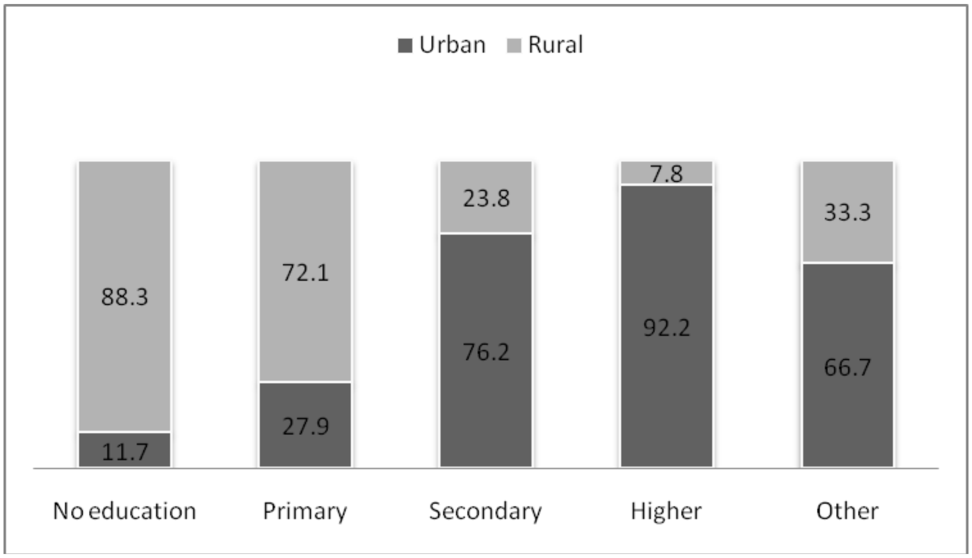
**Figure 1. Wealth index between urban and rural areas (%)**




Source: Author's calculation from Ethiopian Demographic and Health Survey 2005 (Central Statistical Agency [Ethiopia] and ORC Macro 2006)

Inequality is also found in educational attainment. For example, in education (Figure 2), 88.3 percent of uneducated Ethiopians live in rural areas and 11.7 percent in urban areas. While 76.2 percent and 92.2 percent of the population with secondary and higher education, respectively, live in urban areas, only 23.8 percent and 7.8 percent respectively live in rural areas.

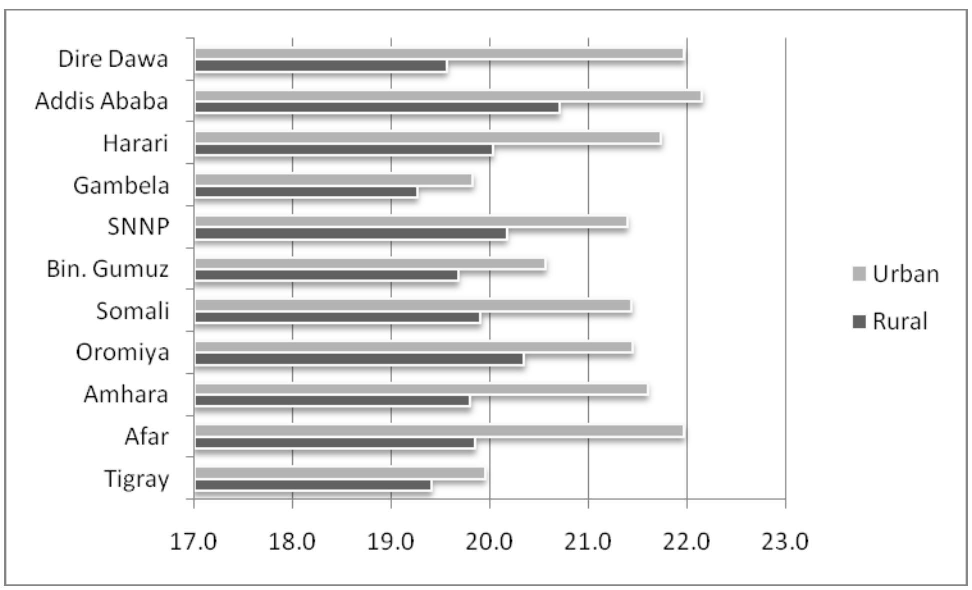
**Figure 2. Educational attainment between urban and rural areas (%)**




Source: Author's calculation from Ethiopian Demographic and Health Survey 2005

The BMI (body mass index) is used to evaluate nutritional status between rural and urban areas. The BMI is defined as weight in kilograms divided by height in meters squared ($kg/m^2$). A cutoff point of 18.5 is used to define thinness or acute undernutrition, and a BMI of 25 or above usually indicates overweight or obesity. As shown in Figure 3, across regions, the average BMI index is within the cutoff points. However, it is clear that compared with urban areas, rural areas are consistently at the lower end of the scale, suggesting higher risk in terms of health degradation.

**Figure 3. Body mass index (BMI) between urban and rural areas.**




Source: Author's calculation from Ethiopian Demographic and Health Survey 2005

Data used for estimation are from the Ethiopian Rural Household Survey (ERHS) conducted in 1999. The survey is a longitudinal household data set covering households in a number of villages in rural Ethiopia since 1989. In this paper, I use the data from the fifth round. These data have been made available by the Economics Department of Addis Ababa University, the Centre for the Study of African Economies at the University of Oxford, and the International Food Policy Research Institute.

The fifth round of the survey included about 1,500 rural households living in 20 peasant associations. Of these households, 80.4 percent are headed by males. Farming (77.6 percent) and domestic work (14.9 percent) are the main activities among surveyed households. For those involved in agriculture, each household produces on average 353.3 kg of agricultural output a year, of which about 80.0 percent is sold. Overall, fertilizer and pesticides application, along with pruning, consumed 10.4 percent of the time available. Of the remaining time, 21.4 percent was used for clearing, land preparation, and planting; 7.2 percent for transportation of output to the storage facility, 13.4 percent for harvesting; 16.7 percent for weeding; 12.6 percent for guarding the crops, and 18.3 percent for shelling, leveling, and threshing. Of all working hours directly imputable to family labor (89.6 percent), males account for 72.9 percent of agricultural labor force, compared with 18.3 percent for females and 8.8 percent for children. Households spent almost 35 percent of their annual income in acquiring agricultural inputs. Fertilizer alone accounts for 55.7 percent of the total inputs expenses, compared with 23.8 percent for hired labor, 13.1 percent for seed, and 3.2 percent for herbicides.

Land quality is not evenly distributed across locations. Indeed, most farming activities on flat land are concentrated in *Amhara* and *Oromiya*. About 70 percent of farming activities on land with steep slopes is encountered in Tigray. As expected, the difference in land quality leads to a great deal of heterogeneity in land productivity. As for overall productivity, farmers realize 94.3 kilograms per hectare (kg/ha) on flat land, compared with 79.7 kg/ha on gentle slope land, and 69.2 kg/ha on steep slope land. Across locations, the Southern Nations, Nationalities, and People's Region (SNNPR), comprising peasant associations Gara Godo–Areka and Domma, emerges as the more productive with 161.1 kg/ha, followed by Oromiya (102.5 kg/ha). In all other regions, land productivity falls below 100 kg/ha.

Data also suggest that 60.8 percent of surveyed households live below the poverty line.2 In other words, about 60 percent of households cannot afford the average cost of food expenses. Poor households produce on average 279.3 kg of overall agricultural output, compared with 415.1 kg for nonpoor households. The results also suggest that poor households are less productive than their nonpoor counterparts. They produce 26.4 kg per unit of fertilizer used, versus 30.8 kg for nonpoor households. Agricultural output per hectare of land is higher among the nonpoor households (105.4 kg/ha) than among the poor (80.7 kg/ha). Similarly, productivity per animal (days worked) favors nonpoor households (10.8 kg/animal) compared with poor households (7.6 kg/animal). Even labor productivity is higher among nonpoor households (11.8 kg) than among poor households (8.4 kg).

Among households that suffered from sickness, about 39 percent declared having a problem hoeing fields. On average, sickness led to a loss of 33 person-days of farming activity per year. Because a household member was ill at critical periods of farming activity, 17.8 percent of households experienced output loss.

**Table 1. Sickness and labor supply by agricultural tasks (hours/person-day)**

| | Not affected by sickness | Affected by sickness |
|---|---|---|
| Clearing | 1.50 | 1.54 |
| Land preparation | 4.28 | 4.07 |
| Planting | 2.32 | 2.10 |
| Shelling | 4.43 | 7.22 |
| Leveling | 0.61 | 0.54 |

2 I use the average per capita food consumption expenditure as a lower bound poverty line.

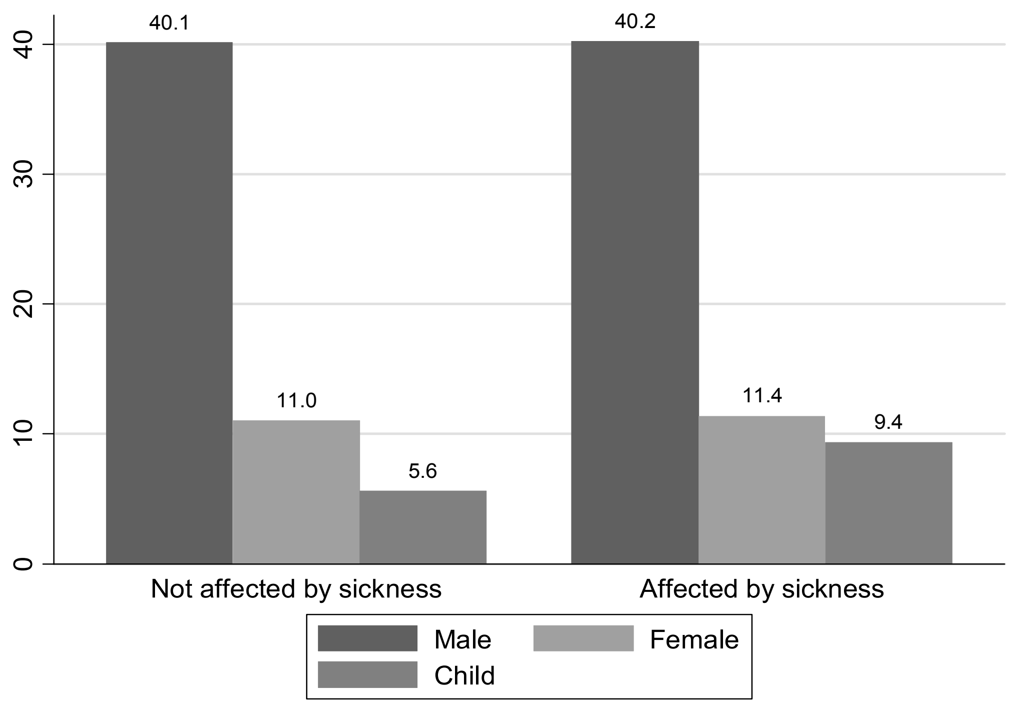
**Table 1. Sickness and labor supply by agricultural tasks (hours/person-day) (continued)**

| | Not affected by sickness | Affected by sickness |
|---|---|---|
| Threshing | 5.19 | 7.82 |
| Weeding | 6.68 | 6.78 |
| Guarding | 12.14 | 9.95 |
| Pruning | 0.10 | 0.18 |
| Harvesting | 4.88 | 8.91 |

Source: Author's calculation from 1999 ERHS.

The results in Table 1 suggest that farmers affected by sickness take longer to accomplish agricultural tasks than do farmers not affected by sickness. Activities such as clearing, shelling, threshing, weeding, and harvesting appear to be more time-consuming for affected farmers than for those who were not affected by sickness. Activity such as guarding the crops probably requires healthy bodies, which may explain why time devoted by farmers not affected (12.1 hours) is higher than time allocated by farmers affected by sickness (9.9 hours). Analysis within households (Figure 4) does not indicate a significant decline in the time spent on the field for households affected by sickness. However, child labor is almost two times higher among households affected by sickness compared with those not affected.

**Figure 4. Labor supply and sickness (hours/person-day3) during *meher* and *belg* farming seasons.**




Source: Author's calculation from 1999 ERHS.

**3 Time allocated to inputs applications is not included.**

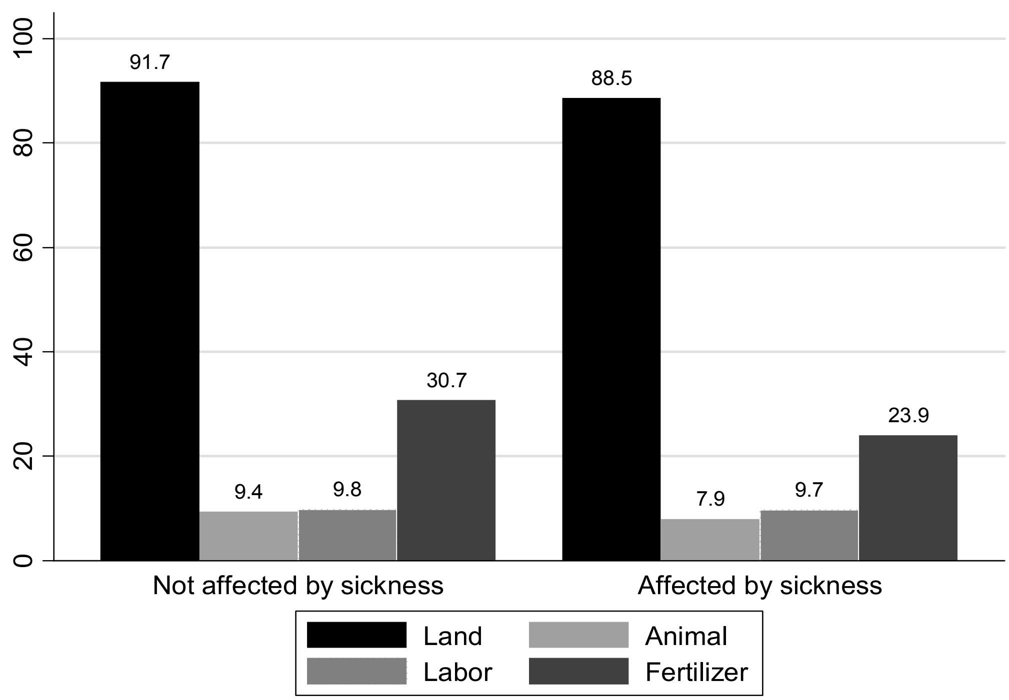
**Table 2. Time allocated to inputs applications and machine use (hours/person-day) during *meher* and *belg* farming seasons.**

| | Not affected by sickness | Affected by sickness |
|---|---|---|
| Fertilizer | 50.17 | 26.60 |
| Pesticide | 0.08 | 0.08 |
| *Shilshalo*4 | 0.57 | 0.44 |
| Tractor | 0.27 | 0.17 |
| Harvester | 0.21 | 0.11 |

Source: Author's calculation from 1999 ERHS.

Whenever agricultural tasks involve inputs applications or the use of machines, farmers affected by sickness tend to supply much less time compared with nonaffected farmers (see Table 2). An illustration is given by the application of fertilizer, where nonaffected farmers devoted on average 50.2 hours compared with 26.6 hours for farmers affected by sickness. Although overall labor supply does not decline because of sickness, the difference in time devoted to inputs applications and use of machines might explain the observed loss of productivity due to illness.

**Figure 5. Agricultural productivity (kg per unit of input)**



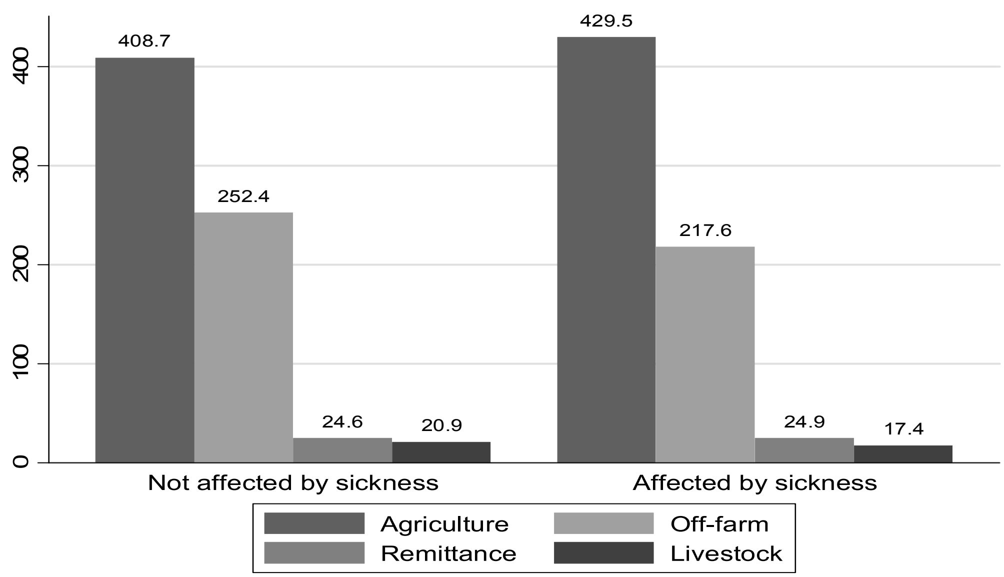

Source: Author's calculation from 1999 ERHS.

4 *Shilshalo*, or thinning, consists of turning the soil, both to aerate plant roots and to reduce the plant population to the required density. It involves the use of oxen.

Results in Figure 5 show that with respect to all major agricultural inputs, agricultural productivity is systematically higher for farmers not affected by sickness than for those affected. Still, the difference in labor productivity between the two groups is the least significant, only 0.1 kg per unit of labor. This is probably due to farmers' ability to compensate for loss in efficiency labor due to illness by increasing child labor. The latter should raise a concern considering the impact of increasing child labor on child schooling.

The survey data reveal that farmers not affected by sickness earned an average income of 669.1 birr, compared with 697.2 birr for those affected by sickness. As pointed out by Pitt and Rosenzweig (1986), the prediction of the impact of farmers' sickness on income is not straightforward. In addition, the results suggest that sick farmers are less productive than nonsick farmers; however, because of possible heterogeneity in output and inputs prices facing both sick and nonsick farmers, an advantage in productivity may not necessarily translate into an advantage in income. As shown in Figure 6, unlike off-farm and livestock incomes, farming does not decline because of illness. The results suggest that sickness would prevent farmers from undertaking off-farm activities and caring for their livestock in a productive fashion. This should be a concern, given that off-farm and livestock incomes account for 43.5 percent and 3.6 percent of total household income.

**Figure 6: Sickness and household incomes (birr)**




Source: Author's calculation from 1999 ERHS.

# 6. ESTIMATION AND SIMULATION RESULTS

In addition to the above descriptive analysis, a Cobb-Douglas stochastic production frontier is estimated. As pointed out earlier, the stochastic production frontier approach allows the computation of an index of farmer's efficiency, which is then explained using the treatment model approach. The results are discussed below.

The estimation results in Table 3 suggest that all inputs including land, labor, and animals5 influence agriculture output significantly and positively. The output elasticity to land (0.35) is the highest compared with that of labor (0.22) and of animals (0.12). The results also suggest that the production technology exhibits decreasing returns to scale.

**Table 3. Estimation results 6**

| **Dependent variable: Agricultural production (kg)** | | |
|---|---|---|
| **Independent variables** | **Coefficient** | **Standard Error** |
| Land (ha) | .3487* | .0302 |
| Labor (hours/person-day) | .2236* | .0209 |
| Animal (days) | .1198* | .0327 |
| Intercept | 4.5420* | .1088 |
| $\sigma_v$ | .6037 | .0387 |
| $\sigma_u$ | .5804 | .1095 |
| $\sigma^2$ | .7013 | .0884 |
| $\lambda$ | .9614 | .1449 |
| Number of observations: 1000 | | |
| Log likelihood: -1057.7 | | |
| Allen's partial elasticity of substitution | | |
| Labor, Land | 0.0001 | |
| Labor, Animal | -0.0002 | |
| Land, Labor | 0.0001 | |
| Land, Animal | 0.0003 | |
| Animal, Labor | -0.0003 | |
| Animal, Land | 0.0009 | |

Source: Author's calculation from 1999 ERHS.
Note: * means significant at 1 percent.

Another source of labor substitution in the event of sickness is the substitution between factors of production. To investigate this, I computed Allen's partial elasticity of substitution7 (see Table 3), which

5 Most of the animals used are oxen.
**6 All variables are in natural log.**
7 Elasticity of substitution between inputs *i* and *j* is computed as follows:
$\sigma_{ij} = \left(\left(\sum_i f_i x_i\right) / x_i x_j\right)\left(\left|H_{ij}\right| / \left|\overline{H}\right|\right)$,

technically measures the percentage change in the ratio of inputs due to a 1 percent change in the ratio of their prices.

The results suggest that substitution between production factors is rather weak; labor and land can be characterized as substitutes, but labor and animal appear to be complements. This implies that to maintain the same level of output after a sickness shock, substitution between factors of production is probably not a viable option.

**Table 4. Factors explaining agricultural efficiency**

| **Dependent variable: Log of agricultural efficiency index ($\hat{\varepsilon}$)** | | |
|---|---|---|
| **Independent variables** | **Coefficient** | **S.E.** |
| *Main equation* | | |
| Gender | | |
| Female (default) | | |
| Male | -0.0376*** | 0.0192 |
| Land slope | | |
| *Medda*: flat (default) | | |
| *Dagethema*: gentle slope | -0.0234 | 0.0180 |
| *Gedel*: steep slope | -0.0755** | 0.0351 |
| Cultural seasons | | |
| *Belg* (default) | | |
| *Meher* | -0.0035 | 0.0263 |
| Extension services | | |
| Access to extension service (1 if access, 0 otherwise) | 0.0044 | 0.0305 |
| Regions | | |
| Tigray (default) | | |
| Amhara | 0.0637* | 0.0230 |
| Oromiya | -0.0749* | 0.0268 |
| SNNPR8 (Indibir, Durame-Azedebos) | 0.0473 | 0.0325 |
| SNNPR (Adado-Dilla) | -0.0181 | 0.0790 |
| SNNPR (Gara Godo–Areka, Domma) | 0.1322* | 0.0299 |
| Fertilizer (kg) | 0.0026* | 0.0004 |
| Probability of sickness | -0.2116* | 0.0290 |
| Intercept | -0.4246* | 0.0471 |

where $x_i$ and $x_j$ are quantities of inputs *i* and *j*, respectively; $f_i$ is the marginal product of input *i*; $|H_{ij}|$ is the cofactor of the second derivative $f_{ij}$ in the Hessian matrix; and $|\overline{H}|$ is the determinant of the bordered Hessian matrix.

8 SNNPR is disaggregated into peasant associations.

**Table 4. Factors explaining agricultural efficiency (continued)**

| Dependent variable: Log of agricultural efficiency index ($\hat{\varepsilon}$) | | | |
|---|---|---|---|
| **Independent variables** | | **Coefficient** | **S.E.** |
| *Treatment equation* | | | |
| Dependent variable: health status (1 if cannot easily hoe field for a morning because of sickness, 0 otherwise) | | | |
| Food expenditures (1,000 birr) | | -0.0031 | 0.0364 |
| Main activity (1 if agriculture, 0 otherwise) | | -0.1435 | 0.1469 |
| Farming assets (birr) | | -0.0213** | 0.0109 |
| Interaction between main activity and farming assets | | 0.0208*** | 0.0112 |
| Distance to nearest public hospital (km) | | 0.0014 | 0.0031 |
| Distance to nearest town (km) | | 0.0398* | 0.0131 |
| Daily wage rate (birr) for adult male (planting) | | -0.1526 | 0.1060 |
| Daily wage rate (birr) for adult male (planting) squared | | 0.0216*** | 0.0119 |
| Access to public piped water (1 if access, 0 otherwise) | | 0.2141*** | 0.1132 |
| Intercept | | -0.1526*** | 0.1060 |
| | $\hat{\rho}$ | 0.6871* | 0.0656 |
| | $\hat{\sigma}$ | 0.1783* | 0.0090 |
| | $\hat{\lambda}$ | 0.1225* | 0.0171 |
| Number of observations: 590 | | | |
| Log likelihood: -99.3 | | | |
| LR test of independence ($\rho$ = 0): $\chi^2(1) = 15.52$ with p-value =0.00 | | | |

Source: Author's calculation from 1999 ERHS.
Note: *, **, and *** means significant at 1 percent, 5 percent, and 10 percent, respectively; S.E.: means Standard Error.

Estimation results in Table 4 suggest that gender as well as land slope matter. Indeed, males' agricultural efficiency is 3.8 percent lower than that of females. Farmers cultivating on steep slope land are found less efficient compared with those on flat land. However, no significant difference is found between agricultural efficiency on flat land and that on gentle slope land. Although not significant, farmers with access to extension service are more efficient than those without access. The findings suggest that agricultural efficiency is independent from agricultural seasons (*meher* and *belg*).

Agricultural efficiency is not evenly distributed across regions. Indeed, compared with the Tigray region, Amhara is 6.4 percent more efficient. Overall, SNNPR, except for the peasant association of Adado-Dilla, performs better than the Tigray. However, Tigray outperforms Oromiya by 7.5 percent. As expected, the use of fertilizer plays a significant role in improving agricultural efficiency. An increase of 1 kg in fertilizer is expected to significantly increase agricultural efficiency by 0.3 percent. Finally, the results confirm that an increase in the probability of being sick significantly decreases farmers' efficiency.

Health production itself is estimated as a probit model while controlling for food consumption, households' main activity, and farming assets. Although not significant, the results suggest that agricultural households are more likely to be affected by sickness than nonagricultural ones. Increasing farming assets is expected to reduce the probability of sickness; each percent change in the value of farming assets will reduce the probability of sickness by 0.20 percent. It might be that farming assets such as hoe, plow, hammer, saddle, and ax would limit physical effort and therefore prevent households from illness. As expected, the results also show that the downward effect of farming assets is lower for households whose main activity is agriculture. The relationship between daily wage for planting and the odds of being sick is nonlinear. Indeed, the relationship is negative up to a certain level of daily wage; however, beyond that level, every additional birr increases the probability of sickness. The incentive induced by increasing wage may push farmers to extra physical effort and therefore increase the probability of sickness.

It turns out that the remoteness of peasant association, measured by the distance to the nearest hospital as well as the distance to the nearest town, increases the probability of being sick. This is in line with the finding by Klemick, Leonard, and Masatu (2007) that in rural Tanzania, improvements in roads have a greater impact on health-care access than improvements in health facilities because travel costs are one of the major impediments to health-care access. Similarly, villages in Indonesia, the Philippines, and Sri Lanka participating in rural roads projects reported better access to health services based on several indicators compared with nonproject villages (Hettige 2006).

Health impediment tends also to increase with daily wage rates offered to adult males for planting and weeding activities. Unexpectedly, the results suggest that households with access to public piped water are more likely to be sick. This might not be linked directly to the water itself but rather to the consequence of water delivery activities. For example, analyzing disease, microdams, and natural resources in Tigray, Amarcher et al. (2004) found that government-sponsored microdams increase productivity of both fuelwood collection and crop production, but the cost of these dams to households was significant. In villages close to dams, disease prevalence was particularly high.

**Table 5. Results of policy simulation (%)**

| | Increase farming assets by 50% | Increase daily planting wage by 50% | Reduce distance to nearest town by half |
|---|---|---|---|
| Odds of being sick | -1.14 | -33.22 | -20.16 |
| Production | | | |
| Efficiency | +0.09 | +2.70 | +1.62 |
| Marginal productivity | | | |
| Labor | +0.10 | +2.82 | +1.25 |
| Land | +0.12 | +2.49 | +1.71 |
| Animal | +0.11 | +2.63 | +1.53 |
| Agricultural income | +0.11 | +2.94 | +1.51 |
| Headcount ratio (FGT0) | 0.00 | 0.00 | 0.00 |
| Poverty gap (FGT1) | 0.00 | -0.07 | -0.03 |
| Squared poverty gap (FGT2) | 0.00 | -0.11 | -0.05 |

Note: FGT stands for Foster-Greer-Thorbecke

Within the pro-poor growth literature (Kraay 2006; Ravallion 2004) there is a consensus that economic growth is a necessary condition for poverty reduction. The results presented in Table 5 intend to illustrate the fact that at the household level, productivity growth is not necessarily poverty reducing. To do so, we simulate the impact of 50 percent increase in farming assets and daily planting wage, and the impact of 50 percent decrease in the distance to the nearest town. The results show that the probability of being sick decreases for each scenario, but more so for increase in daily planting wage (-33.4 percent) than reduction in remoteness (-20.2 percent) or increase in farming assets (-1.1 percent). As for poverty, none of the simulated interventions is effective enough to move at least one household above the poverty line and therefore reduce the headcount ratio. However, despite the inability to reduce poverty significantly, increase in daily planting wage and decrease in the average distance between peasant association and the nearest town have the potential to affect income distribution. The latter is shown by the decrease in normalized poverty gap (FGT1) and squared poverty gap (FGT2).

Overall, although investment in farmers' health is expected to increase productivity, it might not be enough to move farmers above the poverty line. Indeed, this simple exercise illustrates the difference between improving farmers' agricultural efficiency and alleviating poverty as defined by the headcount ratio. It requires probably more than one policy instrument to reach both goals simultaneously. As pointed out by Jayne et al. (2006), an approach that combines cash transfer to help the poorer smallholder households to hire labor, more secure land tenure for women, and expanded agricultural extension programs could have a greater impact on welfare. Assessing the impact of Ethiopia's Productive Safety Nets Programme (PSNP), the second largest social protection program in sub-Saharan Africa, Gilligan, Hoddinott, and Taffesse (2008) conclude that the program had little impact on participants, due in part to transfer levels that fell far below program targets. In contrast, households with access to both PSNP transfers and agricultural support packages were more likely to be food secure, borrow for productive purposes, use improved agricultural technologies, and operate their own nonfarm business activities.

# 7. CONCLUDING REMARKS

Compared with previous studies, the present analysis sheds more light on the relationship between farmers' health status and agricultural production. The results suggest that the labor market might not be the only mechanism through which households adjust their loss of efficiency in labor as a result of illness shock. Labor supply adjustment is also possible by increasing child labor. How sustainable these nonmarket options are in the long run is still debatable. For example, it is likely that increase in child labor to compensate for the illness of the household head is at the expense of child education.

The present analysis also found that households affected by sickness tend to allocate less time to input application and to mechanization. This is probably the main reason why farmers hit by sickness experience lower productivity with respect to land, fertilizer, and animal.

Controlling for household characteristics and locational attributes, regression results confirm the negative impact of health impediment on farmers' agricultural efficiency. Moreover, simulation results show that improving farmers' agricultural efficiency by investing in farmers' health may not necessarily lead to poverty reduction. Additional policy instruments may be needed to achieve simultaneous increase in agricultural productivity and reduction in poverty.

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