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Social Services, Human Capital, and Technical Efficiency of Smallholders in Burkina Faso

Fleur Wouterse

West and Central Africa Office

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AUTHOR

Fleur Wouterse, International Food Policy Research Institute
Research Fellow, West and Central Africa Office
F.Wouterse@cgiar.org

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ABSTRACT

This study applies regression analysis as well as a non-parametric method to survey data from Burkina Faso to analyze the role of human capital in explaining technical efficiency in smallholder agricultural production. Exploiting the panel nature of the data and explicitly treating human capital inputs as endogenous, a two-stage estimation method is used for the analysis of determinants of data envelopment analysis (DEA) technical efficiency scores in a double-bootstrap procedure. Findings suggest that the impact of human capital on technical efficiency differs strongly by gender. Strong positive returns exist for education of females, whereas male education is associated with higher inefficiency. Body mass index of adult females also positively relates to technical efficiency. At the community level, presence of a clinic, connection to the electrical grid, presence of a secondary school, and year-round accessibility of the community are found to be vital for human capital formation.

Keywords: public services, smallholders, human capital, West-Africa, non-parametrics

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1. INTRODUCTION

The need to achieve the United Nations Millennium Development Goals (MDGs) has led to a renewed focus on social-sector investments in Africa and developing countries elsewhere. Due to limited resources, African governments face the key challenge of ensuring consistent policies and strategies to promote long-term economic growth, raise smallholder productivity, achieve food security, and reduce poverty, while at the same time providing the social services that meet immediate welfare requirements (Badiane and Ulimwengu 2009). Policymakers thus face a trade-off between addressing short-term concerns related to the symptoms of poverty and raising smallholder productivity and incomes in the longer term, thereby addressing the root causes of poverty. This trade-off—having to choose between growth and poverty interventions—has been described as the African dilemma (Badiane and Ulimwengu 2009). In the face of tight budget constraints, the only feasible option to escape this dilemma is to devise strategies that maximize the contribution of social services to labor productivity in agriculture and the rural economy.

Social services have long been analyzed from an entitlement point of view, with a primary objective of meeting people's welfare needs. Once it has been recognized that social services are not growth-neutral, a crucial question becomes how synergies between social services and investments that directly enhance productivity can be maximized in the short and long run—that is, what are the types of social services that have the largest impact on labor productivity in rural areas and to what extent does the composition of such services affect their impact on labor productivity? In order to maximize convergence—meeting both the income growth needs and the social needs of populations under tight budget constraints—the heterogeneity in social services thus needs to be recognized (Badiane and Ulimwengu 2009). Human capital has been associated with increases in productive capacity of the individual over the long run, while its formation can be attributed in part to social investments. From a policy perspective, two important issues remain: First, there is a need to disentangle production impacts of human capital from efficiency impacts, and second, in recognition of the heterogeneity of social services, there is a need to identify those that play an important role in human capital formation.

In this study, I use nationally representative, three-year panel data from Burkina Faso, regression analysis, and nonparametric techniques in a comprehensive analysis of the converging impact of social services related to human capital formation on the technical efficiency of smallholders. Taking into account the endogeneity of human capital formation, I first estimate four ordinary least squares (OLS) regressions for human capital indicators—years of education and body mass index (BMI) by gender—and use predicted values to explain output-oriented measures of technical efficiency in a truncated regression. A double bootstrap is applied to make consistent inference possible and to take account of the bias that arises due to serial correlation of the efficiency terms. Findings suggest that the relation between human capital and technical efficiency differs by gender: A negative relation exists between education of males and household technical efficiency, while this relation is positive for females, for whom greater body mass is also associated with higher efficiency. Community characteristics that are found to play a critical role in the formation of human capital are the presence of a clinic, a secondary school, year-round accessibility, and electricity provision through the grid.

The paper is structured as follows. In Section 2, I discuss the relationship between human capital and productivity in agriculture. Section 3 presents the analytical model used to estimate the relation between rural services and human capital indicators as well as between these indicators and technical efficiency. The data and study area are described in Section 4. Section 5 presents the estimation results. I conclude in Section 6 by discussing some of the implications of my findings for understanding the influence of rural services on human capital variables and therefore on technical efficiency in agricultural production.

2. TECHNICAL EFFICIENCY AND HUMAN CAPITAL INPUTS

Technical efficiency is a measure of a farm's productive performance. In the context of rural Burkina Faso, it can be defined as the ability of an agricultural household to obtain maximal output from a given set of inputs. Technical inefficiency should be considered as a measure of management error rather than a measure of income or gross output; higher inefficiency does not correspond to lower yields or less income. Human capital inputs have been recognized as critical factors in achieving recent sustained growth in productivity in some African countries (Schultz 2003). Education may enhance technical efficiency directly by improving the quality of labor, by increasing the ability of farmers to adjust to disequilibria, and through its effect on input utilization (Moock 1981). Farmers affected by ill health could experience lower technical efficiency due to impaired work capacity in the field and reduced management and supervision abilities (Antle and Pingali 1994). Farm work, particularly hoe agriculture, is physically demanding; it is thus likely that nutrition affects labor productivity through its effect on the person's energy expenditure level (Strauss 1986).

Schooling and weight for height are human capital attributes of farm household members associated with their current productivity. Both forms of heterogeneity are to some degree reproducible. Schooling is created by well-described processes, and weight for height is formed by the biological process of human growth, in which the inputs of nutritional intakes, protection from exposure to disease, health care, and activity levels combine to yield a net cumulative effect on the individual's realization of his or her genetic potential. These characteristics of farm household members are viewed here as indicators of human capital because they can be augmented by social or private investments, but they also vary across individuals because of genetic and environmental factors that are not controlled by the individual, family, or community (Schultz 2003).

There are several difficulties with discerning causal links between human capital and technical efficiency in a regression framework. First, endogeneity may arise due to simultaneous effects. Though it may be intuitively appealing to believe that better-nourished and healthier individuals are more efficient, the causality of the relationship between nutrition, health, and productivity is difficult to establish. Improved nutritional status and better health could lead to increased productivity, but it is equally plausible that increased productivity leads to higher incomes, thereby improving nutritional and health status (Garcia and Kennedy 1994). Second, endogeneity could manifest itself if there are exogenous unobserved differences across individuals in their original endowments, and if these endowments influence how parents and children invest in human capital, in either a compensatory or a complementary manner (Schultz 2003). Examples of this phenomenon could be "ability" affecting the demand for education (Willis and Rosen 1979) and "frailty" affecting the demand for health inputs (Rosenzweig and Schultz 1983). These forms of innate, unobserved heterogeneity could cause a correlation between the human capital inputs and the error in determinants of technical efficiency. Third, in the case of both health status and schooling, there may be lags during which the formation of human capital occurs before a farm household member becomes more productive. These potentially long gestation lags add to uncertainties about the precise quantitative payoff of policy interventions (Schultz 1999).

To obtain consistent estimates in the presence of endogeneity, one may use instrumental variable methods in which the instruments are sufficiently correlated with the human capital variables but strictly not correlated with the technical efficiency equation error. Using data from Sierra Leone on local relative prices, household demographic characteristics, and farm assets as instruments to predict household energy intake per capita, Strauss (1986) found that household energy consumption was a positive, significant determinant of farm output. Sahn and Alderman (1988) used a similar approach with data from Sri Lanka. Here again, predicted household energy consumption per capita was used as the measure of nutritional status and related to wage earnings. Interestingly, household energy per capita was a significant, positive determinant of men's but not of women's wages. This differential result between men's and women's productivity is a finding that emerges in a number of the studies linking nutrition to productivity. Sahn and Alderman (1988) also found that years of formal education were positively related to the wage rate.

Haddad and Bouis (1991) used BMI and height measures to explain agricultural wage rates. They developed equations to instrument individual energy consumption and BMI, and used these in the wage equations. Identifying instruments for the wage equations were household size, nonfarm income, and distance to the nearest market. Haddad and Bouis (1991) found a lack of impact of short-run nutritional status on agricultural wage determination. However, they qualified this finding by noting that variation in wages across individuals is a crude measure of differences in productivity.

Exploiting the panel nature of his data for India to eliminate the potential bias in regression coefficient estimates due to time-invariant, individual-specific effects, Deolalikar (1988) concluded that while the human body can adapt to inadequate nutrition in the short run, it cannot adapt as readily to chronic malnutrition that eventually results in loss of weight for height. He also found years of schooling of the household head not to be a significant determinant of agricultural productivity. More recently, in a study of reproducible human capital and wage rentals for Côte d'Ivoire and Ghana, Schultz (2003) resorted to an instrumental variable approach and analyzed demand for four human capital factors: education, migration, height, and body mass index. He emphasized the important role that public spending plays in explaining demand for human capital and included community characteristics: distance to local schools, existence of medical facilities, and community infrastructure in health and sanitation as proxy for public spending on social services. In the current study, I continue along these lines and use the first-stage estimations of human capital demand not only to address problems of endogeneity but also to analyze the role of public spending on social services in human capital formation.

3. ANALYTICAL MODEL

The measurement of productive efficiency has important implications for both economic theory and economic policy. Measuring productive efficiency allows for the testing of competing hypotheses regarding sources of efficiency or differentials in productivity. Furthermore, the measurement of productive efficiency makes it possible to quantify the potential increases in output that might be associated with an increase in efficiency (Farrell 1957). Two main methods are generally used to analyze the efficiency of production. The parametric approach, as proposed by Aigner, Lovell, and Schmidt (1977), consists of specifying and estimating a parametric production function frontier, and calculating technical inefficiency. A production frontier reflects the maximum obtainable output given a set of inputs; technical efficiency, in this case, describes the proximity of a farm household's output to this maximum feasible output (Coelli, Rahman, and Thirtle 2002). Although this approach provides a convenient framework for conducting hypothesis testing, the results can be sensitive to the parametric form chosen (Chavas, Petrie, and Roth 2005).

This study makes use of the second method and applies nonparametrics, which has the advantage of removing the necessity of making arbitrary assumptions regarding the functional form of the frontier and the distributional form of the error. A second advantage of the nonparametric approach is that it is less data-demanding and thus works better with small samples than does the parametric approach. However, a major drawback is that because the nonparametric method is deterministic and attributes all the variation from the frontier to inefficiency, the frontier it estimates is likely to be sensitive to measurement errors or other noise in the data. In particular, efficiency tends to be overpredicted in finite samples. I employ a bootstrap method, set out below, to address this problem. Data envelopment analysis (DEA) is used to compute technical efficiency scores. DEA involves the use of linear programming methods to construct a nonparametric piecewise frontier over the data in order to calculate efficiencies relative to this surface, along the lines suggested by Farrell (1957). Given that many households are not perfectly competitive, the assumption of constant returns to scale (CRS) is often not appropriate. Banker, Charnes, and Cooper (1984) suggest an extension of the CRS DEA model to account for variable returns to scale (VRS) situations; theirs is the approach used here. To measure production efficiency, both input- and output-oriented efficiency measures have been used. Although the two approaches are equivalent under CRS, they differ under VRS. In the context of missing markets, it is likely that households are using fixed quantities of inputs (land, labor) to produce a maximum amount of output, which means an output-oriented efficiency measure, as also used by Chavas, Petrie, and Roth (2005) and Wouterse (2010) for rural households in, respectively, The Gambia and Burkina Faso is appropriate.

To estimate technical efficiency, we can use the Farrell (1957) measure of output technical efficiency, which is the reciprocal of the Shephard (1970) output distance function. Define a measure δ for some point $(\boldsymbol{x}_i, \boldsymbol{y}_i) \in \mathbb{R}_+^{p+q}$ such that

$$\delta_i = \delta(\boldsymbol{x_i}, \boldsymbol{y_i} | \mathcal{P} \equiv \sup\{\delta | \boldsymbol{x_i}, \delta \boldsymbol{y}_i) \in \mathcal{P}, \delta > 0, \tag{1}$$

where $\boldsymbol{x_i}$ is a vector of inputs and $\boldsymbol{y_i}$ is a vector of outputs for farm household i, and $\mathcal{P}$ is a production set defined by $\mathcal{P} = \{(x, y) | \boldsymbol{x} \text{ can produce } \boldsymbol{y}\}$. An overview of agricultural inputs is given in Table 1. Land is the major agricultural input; a missing land market means that the land input can be considered as exogenous. Labor is the second most important input. The survey does not contain data on labor input in days; I therefore use the number of adult males and females that are active on their own farm as a proxy for labor input. The value of equipment accounts for only large agricultural equipment, mainly plows and carts, which can be considered semi-fixed. However, an endogeneity problem may arise for variable inputs. In order to correct for this possible bias, I replaced the input variable with a predicted value obtained by running a regression using a set of instruments. Beyond the exogenous variables included in the production frontier, primary identifying instruments include the average age of household members and household asset holdings represented by the number of houses in the compound. Tests of identifying instrumental variables for regression estimates of the production function have not rejected the assumption of validity of the instrumental variables.

Table 1. Descriptive statistics for selected variables used in household-level production analysis

Farm characteristics (2006)	Mean	Standard deviation	Range
Land (ha)	5.16	4.90	0.1–70.13
Active adult women (number)	3.36	3.34	0–25
Active adult men (number)	3.34	2.90	0–27
Input cost (FCFA)[a]	34,286	49,420	216.67–493,616.70
Value of equipment (FCFA)	15,897	30,469	0–430,000
Value of output (FCFA)	240,239	179,076	7,188.23–1,182,325
Household characteristics (2006)			
Average age	21.98	8.24	6.58–80.5
Dependency ratio	1.48	0.87	0–6
Sex household head (male = 1)	0.95	0.22	0–1
Age household head	49.82	15.45	0–99
Ethnicity (Mossi = 1)	0.50	0.50	0–1
Religion (Muslim = 1)	0.51	0.50	0–1
N		1,696	

Source: Author's calculations.
Note: [a] FCFA 168 (Franc Communauté Financière Africaine) = US$1 in 2002 purchasing power parity (PPP) (World Bank 2005).

The boundary of $\mathcal{P}$ is sometimes referred to as the technology or production frontier and is given by the intersection of $\mathcal{P}$ and the closure of its complement. Farm households that are technically efficient operate somewhere along the production frontier defined by the boundary of $\mathcal{P}$.

The conditioning $f(\delta_i|\boldsymbol{z_i})$ operates through the following mechanism:

$$\delta_i = \psi(\boldsymbol{z_i}, \boldsymbol{\beta}) + \varepsilon_i \leq 1, \tag{2}$$

where farm household i is faced with environmental variables $\boldsymbol{z_i}$, drawn from $f(z)$; ψ is a smooth continuous function; $\boldsymbol{\beta}$ is a vector of parameters; and ε_i is a continuous, independent and identically distributed (iid), random variable, independent of z_i. ε_i in (2) is distributed $N(0, \sigma_\varepsilon^2)$ with right truncation at $1 - \psi(z_i, \boldsymbol{\beta})$ for each i. The estimator of δ_0 can be written in terms of the linear program

$$\hat{\delta}_i = \delta\left(\boldsymbol{x}_i, \boldsymbol{y}_i \middle| \hat{\mathcal{P}}\right) = \max\{\theta > 0 | \theta \boldsymbol{y}_i \leq \boldsymbol{Yq}, \boldsymbol{x}_i \geq \boldsymbol{Xq}, \boldsymbol{i}'\boldsymbol{q} = 1, \boldsymbol{q} \in \mathbb{R}_+^{\boldsymbol{p}+\boldsymbol{q}}\}. \tag{3}$$

In the second stage, estimated technical efficiency scores are regressed on environmental factors including human capital variables:

$$\hat{\delta}_i = \boldsymbol{z}_i\boldsymbol{\beta} + \zeta_i \geq 1, \tag{4}$$

where

$$\boldsymbol{z}_i = f\left(\boldsymbol{I}_{ij}\right) \qquad j = S_m, S_f, B_m, B_f, \tag{5}$$

where j refers to the type of human capital: S for years of schooling of males and females and B for body mass index of males and females (BMI: weight in kilograms divided by height in meters squared) as an indicator of adult nutritional status and current health (Strauss and Thomas 1998; Schultz 2003). The formation of these two types of human capital of adult household members is modeled as a function of local public services, relevant conditions, and the endowment of the parents of the individual. Following Schultz (2003), instruments for the human capital inputs that are assumed to affect only the demand for human capital and identify the technical efficiency equation include these: (1) community health infrastructure, presence of a secondary school and permanent market in the village, and year-round accessibility of the village; (2) utilities: connection of community to the electricity grid; (3) education level of the father and mother of the individual and whether they are employed in agriculture; and (4) eight community-level food prices.[1]

An often-used approach in the literature is to analyze the determinants of efficiency using a Tobit regression, considered appropriate since the dependent variable, the calculated efficiency scores from the DEA analysis, is censored at 1. However, recent contributions (Simar and Wilson 2007) have emphasized two possible problems associated with applying a Tobit model in this context. First, the efficiency scores are not independent observations since the calculation of the efficiency score for one farm household necessarily involves all other farm households in the sample. As a consequence, the error term will be serially correlated and standard inference is not valid. The second problem is that the efficiency scores are likely to be biased in finite samples. I therefore apply the double bootstrap procedure as developed by Simar and Wilson (2007), which consists of the following steps: (1) standard DEA efficiency point estimates are calculated; (2) these estimates are integrated in a bootstrap procedure that is similar to the smoothed bootstrap procedure of Simar and Wilson (1998)); (3) the bootstrap procedure produces bias-corrected efficiency estimates; (4) the bias-corrected efficiency estimates are used in a parametric bootstrap on the truncated maximum likelihood; (5) standard errors are thus created for the parameters of the regression; (6) confidence intervals are then constructed for the regression parameters as well as for the efficiency scores. To be in line with these authors, I set the number of replications for the first bootstrap equal to 100 and the number of bootstrap replications for the second bootstrap equal to 2,000.

[1]Sorghum, millet, maize, local rice, imported rice, wandzou, groundnut, and sesame

4. DATA AND STUDY AREA

Burkina Faso is a poor, landlocked country situated in the West African semiarid tropics. With a population of around 15.2 million people, Burkina Faso is one of the most densely populated countries of the West African Sahel (World Bank 2009). To achieve development, emphasis has long been put on the agricultural sector because economic growth and improvement in standard of living are thought to be difficult to achieve without the sector due to its importance in employment and export revenue (Asenso-Okyere, Benneh, and Tims 1997). During the period from 2000 to 2006, the country's economy experienced GDP growth of around six percent. The agricultural sector, which forms the main source of subsistence for the majority of the population, has been an important engine of this growth. Agriculture in Burkina Faso is generally extensive and practiced in family exploitations, dominated by small landholdings of between three and six hectares. Rainfed agriculture, which is subject to climatic variation, is prominent. Notwithstanding the important role of agriculture in GDP growth, strong performance of the sector is mainly due to land expansion. Generally, agricultural productivity has not increased; even in the cotton sector, productivity has remained relatively low. In Burkina Faso, GDP per capita grew around 2.5 percent between 1990 and 2006, and stood at around US$517 in 2009 (World Bank 2009).

Despite the good levels of growth recorded by the Burkina Faso economy, the results of the three priority surveys conducted in 1994, 1998, and 2003 reveal an increase in poverty. Based on an absolute poverty threshold estimated at 82,672 FCFA in 2003, the proportion of the poor increased from 45.3 percent to 46.4 percent between 1998 and 2003. In fact, if Burkina Faso were to stay on the current agricultural growth path, it would not halve poverty by 2015 and thus would fail to meet MDG 1. Although urban poverty is on the increase, poverty remains a largely a rural phenomenon. Promotion of the basic social sectors (basic education and basic health, including reproductive health, clean drinking water, nutrition, hygiene, and sanitation) has always been the cornerstone of Burkina Faso's development strategy. In fact, around 16 to 19 percent of national resources and official development assistance are devoted to these services (Burkina Faso, Ministry of Economy and Development 2004). However, the country continues to suffer from a low level of human capital development that limits labor productivity, particularly in the agricultural sector, the source of employment and incomes of nearly 80 percent of the labor force.

As part of activities aiming to promote rural development, since 2004, the Deuxième Programme National de Gestion des Terroirs (Second National Land Management Program, or PNGT 2) has undertaken socioeconomic studies with the overall objective of evaluating progress in the livelihoods of rural households following a number of interventions. These studies are based on field surveys that cover the national territory. The surveys constitute a three-year panel on living conditions of 2,000 households, with data collected in 2004, 2005, and 2006. Households included in the panel were drawn from 60 villages and all 45 provinces of Burkina. The villages were drawn according to probability proportional to their size. The random drawing of the sample and the coverage of all provinces ensures the representativeness of the data at the national level. Data include household characteristics, education, health, income-generating activities, asset holdings, and expenses, as well as community characteristics.

A land market does not exist in rural Burkina Faso. Data from the surveys show that land is generally cultivated on a hereditary basis and that most households do not hold a title for their land. While theory predicts that better property rights on land can increase investment through increased security, enhanced trade opportunities, and increased collateral value of land, the presence and size of these effects depend crucially on whether those rights are properly enforced. In rural Africa land markets often barely function and are generally quite thin (Lanjouw, Quiznon, and Sparrow 2001). In Burkina Faso commercial land market transactions were found to be extremely rare (Ouedraogo et al. 1996). The lack of commercial land market transactions implies that land cannot function as collateral for credit. In terms of land quality, soils tend to be sandy and to a lesser extent clayey. Only about 30 percent of households surveyed had access to animal traction. Inorganic fertilizer was applied by only a third of households, whereas the application of compost was more common.

On average the number of adult males and females active on the farm was about equal. Hired labor was not extensively used. A missing market for labor is characteristic of rural areas lacking a large landless class and with homogeneous factor endowments (de Janvry, Fafchamps, and Sadoulet 1991). In Burkina Faso, there appears to be a cultural barrier to offering one's own labor for a wage because it is thought to be a sign of inability to sustain production in one's own fields. Exchange labor in the form of work parties is slightly more common, but it is limited to a few crops with particular patterns of seasonality (Wouterse and Taylor 2008).

Table 2 shows that education, in number of years of formal education received by the individual, was lower for females than for males in all age categories. For BMI, on average there was no significant difference between males and females. However, if we consider the distribution across age categories, we find that women had higher BMIs in the lower age categories and lower BMIs as they got older, compared to males.

Table 2. BMI and years of education for adult males and females

Females	15–19	20–29	30–39	40–49
Education (years)	2.56 (3.29)[a]	1.68 (3.21)	0.84 (2.17)	0.49 (1.63)
BMI (Wt/[Ht*Ht])	20.43 (3.41)	22.20 (2.94)	22.38 (2.96)	22.18 (3.28)
N	327	542	330	243
Males	15–19	20–29	30–39	40–49
Education (years)	3.93 (3.38)	3.44 (3.97)	2.53 (3.78)	1.77 (3.14)
BMI (Wt/[Ht*Ht])	19.93 (3.45)	21.99 (2.74)	23.10 (2.74)	22.40 (2.91)
N	447	624	300	203

Source: Author's calculations.
Note: [a] Standard deviation in parentheses.

Table 3 shows that households were, in almost all cases, headed by a married male. Generally, the father of individuals working in agriculture was or had been active in agriculture; for the mother this was less so. Fathers of individuals working in agriculture had received about half a year of formal education, mothers almost none. In about 30 percent of the communities to which the individuals belonged, there was a clinic, in almost 60 percent a permanent market. A secondary school was present in only about 5 percent of communities. Connection to the electrical grid was particularly low, with only 1 percent of communities connected.

Table 3. Descriptive statistics for selected variables used in the individual-level human capital analysis

	Mean	Standard deviation	Range
Individual characteristics (2006)			
Age	27.43	9.41	16–49
Age household head	51.53	14.91	16–99
Sex household head (male = 1)	0.98	0.14	0–1
Marital status household head (married = 1)	0.96	0.20	0–1
Formal education father (years)	0.47	1.86	0–16
Formal education mother (years)	0.10	0.83	0–12
Father active in agriculture	0.93	0.25	0–1
Mother active in agriculture	0.69	0.46	0–1
Community characteristics (2004)			
Clinic (yes = 1)	0.29	0.45	0–1
Permanent market (yes = 1)	0.58	0.49	0–1
Secondary school (yes = 1)	0.05	0.01	0–1
Year-round accessibility (yes = 1)	0.30	0.46	0–1
Electrical grid (yes = 1)	0.01	0.10	0–1
N		3,020	

Source: Author's calculations.

5. ESTIMATION RESULTS

The results of the OLS regressions of determinants of human capital accumulation are given in Table 4. We are primarily interested in how government and household investments influence the formation of reproducible human capital.

Table 4. OLS regression of determinants of human capital inputs

	Education		BMI	
	Male	Female	Female	Male
Individual level				
Age	-0.11 (0.05)**[a]	-0.22 (0.05)**	0.51 (0.06)**	0.71 (0.01)**
Age squared	0.00 (0.00)	0.00 (0.00)**	-0.01 (0.00)**	-0.01 (0.00)**
Age household head	-0.01 (0.01)*	-0.00 (0.01)	-0.00 (0.01)	0.00 (0.01)
Sex household head (male = 1)	0.50 (0.63)	-1.36 (0.60)**	-0.51 (0.44)	-0.29 (0.60)
Marital status household head (married = 1)	-0.04 (0.40)	0.73 (0.34)**	0.78 (0.39)**	1.37 (0.39)**
Formal education father (years)	0.24 (0.04)**	0.27 (0.07)**	0.01 (0.05)	0.04 (0.04)
Formal education mother (years)	0.28 (0.11)**	0.44 (0.12)**	0.08 (0.13)	-0.00 (0.07)
Father in agriculture (yes = 1)	-0.03 (0.40)	0.14 (0.29)	0.90 (0.41)**	0.41 (0.31)
Mother in agriculture (yes = 1)	0.57 (0.26)**	0.42 (0.24)*	-0.09 (0.30)	0.32 (0.24)
Community level				
Clinic (yes = 1)	1.25 (0.34)**	1.48 (0.33)**	0.80 (0.31)**	1.00 (0.28)**
Permanent market (yes = 1)	0.48 (0.32)	0.13 (0.33)	-0.02 (0.30)	-0.09 (0.25)
Secondary school (yes = 1)	2.44 (0.50)**	2.95 (0.51)**	0.12 (0.56)	0.94 (0.40)**
Year-round accessibility (yes = 1)	1.08 (0.29)**	0.72 (0.24)**	-0.08 (0.28)	-1.01 (0.24)**
Electrical grid (yes = 1)	4.75 (0.81)**	4.33 (0.75)**	2.15 (0.88)**	0.56 (0.80)
R-squared	0.26	0.36	0.17	0.23
Number of observations	1,574	1,446	1,446	1,574

Source: Author's calculations.
Notes: * Significance at 10%, ** Significance at 5%;
[a] Robust standard errors in parentheses
Regional controls are not reported
Prices included in regressions (for sorghum, millet, maize, local rice, imported rice, wandzou, groundnut, and sesame) are not reported

Age is negatively related to years of formal education received, with younger people being better educated. A concave relationship exists between age of the individual and BMI, with the latter increasing over a certain age but decreasing as individuals get older. For both males and females, BMI is positively related to the marital status of the household head. Although for developed countries a relationship attributed to social problems has been established between single-parent status and childhood obesity (Huffman, Kanikireddy, and Patel 2010), studies from developing countries tend to show that single-parent status is associated with significantly higher prevalence of food insecurity, hunger, and severe hunger (Isanaka et al. 2007). Similar to findings of, for example, Tansel (1997) for Côte d'Ivoire, schooling of both parents is a crucial determinant for the level of education of males as well as females.

In terms of community services, the presence of a clinic in the community is positively related to years of education as well as to the body mass index of males and females. Community health infrastructure and access to medical care are expected to influence the prevalence of diseases and affect net nutritional status as proxied by BMI (Schultz 2003). Year-round accessibility of the community is positively associated with years of education. In cases where the secondary school is located outside the community, good year-round accessibility of the community is likely to play an important role in the possibility of attending school. Simultaneously, access to electricity facilitates and improves the delivery of social and business services from a wide range of village-level infrastructure such as schools, financial institutions, and farming machinery (Kirubi et al. 2009). Technical efficiency estimates are given in Table 5.

Table 5. Truncated regression of determinants of bias-corrected technical efficiency

	Bias-corrected estimates	Original estimates	Bootstrapped confidence interval	
Sex household head	0.130 (0.049)**	0.101 (0.037)**	0.1036	0.1566
Dependency ratio	-0.014 (0.010)	-0.013 (0.008)*	-0.0197	-0.0089
Religion (Muslim = 1)	0.002 (0.017)	0.006 (0.013)	-0.0074	0.0108
Ethnicity (Mossi = 1)	-0.051 (0.021)**	-0.076 (0.015)**	-0.0610	-0.0393
Average age	-0.003 (0.005)	-0.010 (0.004)**	-0.0057	-0.0000
Average age squared	0.000 (0.000)	0.000 (0.000)**	0.0000	0.0001
Household size	0.006 (0.001)**	0.007 (0.001)**	0.0049	0.0064
Predicted BMI men	-0.015 (0.016)	-0.008 (0.012)	-0.0236	-0.0069
Predicted BMI women	0.037 (0.022)*	0.025 (0.017)	0.0257	0.0496
Predicted years of education men	-0.076 (0.025)**	-0.008 (0.012)**	-0.0891	-0.0631
Predicted years of education women	0.059 (0.022)**	0.051 (0.017)**	0.0475	0.0703
Technical efficiency	0.39	0.55		
Number of observations	1,692	1,692		
Truncated observations	148	238		

Source: Author's estimations.
Notes: [a] Robust standard error in parentheses
*Significance at 5% level, **Significance at 10% level
Regional controls not reported.

Overall, the results suggest that substantial shortfalls in production efficiency exist. As mentioned, possible sources of inefficiency relate to managerial ability, endowments of human and physical capital, and access to financial capital. To identify sources of inefficiency, the technical efficiency estimates were regressed on the set of explanatory variables given in Table 1 as well as on predicted values of BMI and years of education for men and women. The estimation results of the truncated regression on the technical efficiency estimates are reported in Table 5. The results clearly illustrate the negative role of gender in technical efficiency, with female-headed households being less efficient. For the Ethiopian highlands, Holden, Shiferaw, and Pender (2001) found that female-headed households achieved much lower land productivity than did male-headed households. This finding was attributed to less availability of male labor and equipment in female-headed households. The findings here are similar of those by Bindlish, Evenson, and Gbetibouo (1993) for Burkina Faso, which show that female-headed households are less productive than those headed by men in most crops, with total values of output that are about 15 percent lower. Bindlish, Evenson, and Gbetibouo (1993) emphasize that fewer farm households are headed by women in Burkina Faso and that a woman comes under the authority of another male family member when her husband is away. In terms of the endowment of physical capital, the larger the household, the higher the technical efficiency. In the absence of a labor market, larger households are likely to be better able to meet their labor needs.

An interesting contrast is uncovered in the relation between schooling and technical efficiency. There is a positive relation between years of education of females and efficiency, and a negative relation between technical efficiency and the education of males. As shown in Table 2, males tend to have spent more years in school and thus are likely to have spent less time in the field learning traditional farming methods from the household head; they may even have developed negative attitudes toward farm labor (Weir 1999). A study by Appleton and Balihuta (1996), using data for Uganda, found that education—particularly secondary education—was associated with a reallocation of labor from the farm to nonfarm self-employment and wage employment. Using evidence from a large number of countries, the existence of higher rates of return on investments in the education of women has been established (Psacharopoulos 1985). One interpretation of this finding is that marginal returns on education among relatively low-educated females, typically affected by supply-side innovations, tend to be relatively high, reflecting women's high marginal costs of schooling rather than low ability that limits their return to education (Schultz 1999).

BMI of females is associated with higher technical efficiency, whereas no relationship exists between BMI of males and efficiency. Using cross-section data on hoe-cultivating farm households in Sierra Leone, Strauss (1986) found that ''effective family labor,'' which is a function of actual labor and per capita daily calorie intake, was a significant input in production. Croppenstedt and Muller (2000) showed for Ethiopia that nutrition status affected agricultural productivity. Bhargava (1997) used a panel of Rwandan households to analyze determinants of time allocation. Poor nutritional status was found to hamper the capacity of adults to undertake subsistence tasks. While poor health is associated with reduced labor supply, the fact that farm profits are not affected does not imply that the farmer's own productivity was unaffected but instead implies availability of labor that could substitute for the farmer during the time of illness (Strauss and Thomas 1998). All of these results strongly suggest that body mass is a proxy for strength or aerobic capacity, which are productive assets in the labor market of men, and possibly women, when working in more menial jobs. One explanation for this finding is that women are overrepresented in particular labor-intensive stages of the agricultural production process, such as weeding (Foster and Rosenzweig 1996). In Burkina Faso, where male migration is common, it has been demonstrated that in response to the absence of male labor, women disproportionately increase their weeding effort (Wouterse 2010).

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