Farmers' Social Expenditures and Agricultural Productivity A state variables approach

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Abstract:

With increasingly large shares of public expenditures going toward social sectors in agriculture-based economies, the issue becomes how to design a budget allocation scheme that maximizes agricultural productivity-enhancing effects of social expenditures. This study examines the impact of various subtypes of household health spending on agricultural labor productivity using data from 505 households in five Rwandan districts. Our findings confirm that change in agricultural productivity can be driven by change in marginal productivity of inputs induced by households' health status. The latter are significantly impacted by households' own social expenditures. This then suggests that there is a way to bundle social expenditures in order to compensate for the shortage of resources allocated to agriculture and therefore to harness their productivity-enhancing potential.

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Introduction

Rwanda’s recent development progress has been outstanding. Following the 1994 genocide, the country managed to translate its newfound political stability into social and economic progress. Indicators of primary school enrollment, literacy, life expectancy, child immunization, and access to improved sanitation have gone up while child and maternal mortality rates and the prevalence of chronic diseases such as the Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome (HIV/AIDS) have gone down. Today, Rwanda’s long-term annual economic growth target of 8 percent is well within reach, as real gross domestic product (GDP) grew at an annual rate of 7.8 percent between 2003 and 2010 (IMF 2012). Furthermore, Rwanda has been able to translate its economic progress into poverty and hunger reduction. The proportion of Rwandans living below the national poverty line fell from 56.7 percent in 2005–2006 to 44.9 percent in 2010–2011 (NISR 2012b). Meanwhile, the prevalence of undernourishment among the general population declined from 53 percent in 1997 to 32 percent in 2008 (World Bank 2012). While the recent progress is commendable, proportions of the poor and hungry are still high and as a result Rwanda will fall short of meeting the first Millennium Development Goal (MDG 1). Achieving MDG 1 or substantially reducing poverty and hunger will require consolidating recent social gains and ensuring that growth is inclusive, nutrition-sensitive, and pro-poor.

Raising agricultural productivity growth is central to accelerating overall economic growth and alleviating poverty in Rwanda (Diao et al. 2007, 2012). Over 90 percent of Rwandans depend on agriculture for their subsistence and economic livelihood while the sector contributes over 36 percent of GDP. Yet, agriculture is increasingly competing for attention and scarce resources with social sectors such as health and education. Health, for example, has received a great deal of attention in Africa and Rwanda in particular given the devastation caused by HIV/AIDS, malaria, and tuberculosis (TB). Global and domestic resources have been scaled up to combat these diseases. For example, the Global Fund to Fight AIDS, Tuberculosis and Malaria founded in 2002 had by 2008 approved grants amounting to US$7.2 billion to fight the three diseases. In Rwanda, the Global Fund supported a health systems strengthening project to enhance financial access to health insurance for the poorest of the poor in order to comprehensively combat AIDS, TB, and malaria. The project is attributed with drastically increasing the poor’s access to *mutuelles de* *santé*—a mutual/community health insurance scheme—reaching approximately 1.6 million Rwandans (Kalk et al. 2010). In 2003, the United States government launched the President's Emergency Plan for AIDS Relief (PEPFAR) and by 2009 it had allocated about US$6.5 billion to fight HIV/AIDS and other chronic illnesses. According to PEPFAR (2013), Rwanda received US$394.4 million from FY 2009 to FY 2011 to support comprehensive HIV/AIDS prevention, treatment, and care programs. And in 2012, Rwanda was one of the first few countries to receive direct budget support from PEPFAR to help address the three chronic diseases (Farmer et al. 2013). Therefore, in recent years, Rwanda has seen its total health expenditures, from public, private, and donor sources, increase substantially. For example, Rwanda's total health expenditures more than doubled from US$142.1 million in 2003 to US$307.3 million in 2006 (Health Systems 20/20 2008). Furthermore, a disproportionately high share of Rwanda's government budget goes to health. For example, in 2007, health accounted for 9.6 percent of Rwanda's total government expenditures, compared to a 3.9 percent share for agriculture (MINECOFIN 2012).

Despite the attention to health, the Rwandan government recognizes the important role played by agriculture. As part of the Comprehensive Africa Agriculture Development Programme (CAADP) implementation agenda, Rwanda has committed to raise investments in the sector to at least 10 percent of its national budget and to achieve an annual agricultural growth rate of 8 percent—higher than the CAADP target of 6 percent. In its agriculture sector strategy—the Strategic Plan for the Transformation of Agriculture in Rwanda: Phase III—the government has also committed to sustainably raise agricultural productivity and competitiveness in order to ensure food security and fight poverty (MINAGRI 2013). Moreover, the country's Economic Development and Poverty Reduction Strategy underscores agriculture as a key sector for broadening growth and poverty reduction efforts (MINECOFIN 2007).

Nonetheless, the bias toward social sectors like health is likely to continue particularly given pressing social needs (Badiane and Ulimwengu 2009). Thus, with increasingly large shares of investments going toward social sectors and emergencies in agriculture-based economies, a central challenge is how the investments can be allocated such that they also contribute to agricultural productivity growth. Previous studies have often only examined the impact of health outcomes or investments as a whole on agricultural growth without disaggregating health by its subcomponents. Therefore, of particular interest to this study is the relative contribution of subtypes of health spending to agricultural labor productivity. And given the sizeable contribution of private health spending to total health spending in Rwanda, the objective of this study is to examine how subtypes of households' health expenditures impact agricultural labor productivity in Rwanda. Private health spending made up 28 percent of Rwanda's total health expenditures in 2006. Furthermore, household health spending on healthcare was by far the largest portion of private health spending as out-of-pocket spending made up 23 percent of total health spending. Meanwhile, *mutuelles* made up 5 percent of total health expenditures (Kalk et al. 2010) and they are largely financed by households who made up 70 percent of their financing in 2006 (Health Systems 20/20 2008). Thus, this study examines the impact of various subtypes of household health spending on agricultural labor productivity using data from 505 households in five Rwandan districts.

The following section reviews empirical evidence on the impact of health outcomes and investments on agricultural productivity growth and briefly presents the primary data collection process and descriptive statistics. This is followed by a summary of empirical and analytical frameworks used in the analysis and a description of the empirical approach and results of the estimation. Overall conclusions are discussed in the last section.

Health and Agricultural Productivity

Besides being critical to each other, investments in health and agriculture are both important for poverty reduction. Poor health can lead to loss of labor, which in turn reduces agricultural output and incomes and thus increases vulnerability to poverty. Meanwhile, particularly in poor agrarian economies, agriculture affects availability of nutritious food, farmers' ability to afford health services, and time available for addressing health needs, while certain farming practices can impact farmers' health (Hawkes and Ruel 2006; Asenso-Okeyere et al. 2011). Given the bidirectional interactions between health and agriculture, studies have sought to empirically investigate the effect of health on agricultural productivity and vice versa.

Commonly used indicators of health outcomes include caloric intake, disease prevalence, probability of being sick, and days of sickness. Studies generally highlight the importance of good health for agricultural growth. For example, in their study on Uganda, Fan, Zhang, and Rao (2004) found that reduced days of sickness of farm laborers contributed positively and significantly to agricultural growth and increased rural wages. Meanwhile, Ulimwengu (2009) estimated the effect of health status, given as the probability of being sick, on agricultural efficiency using a stochastic frontier production function. Results showed that a 1 percent/unit increase in the probability of being sick among agricultural rural households in Ethiopia would significantly decrease agricultural efficiency by 2.1 percent. The same study also investigated the effect of agriculture on health. In particular, an increase in farming assets among agricultural households was found to significantly reduce the probability of being sick. And Strauss (1986) tested whether higher caloric intake enhanced family farm labor productivity among Sierra Leonean households. Study results found caloric intake to have a significant effect on labor productivity with a calorie-output elasticity of 0.34 at the sample mean.

Chronic diseases such as HIV/AIDS have been shown by studies to have a significant and negative impact on agricultural output through labor losses. Although HIV/AIDS prevalence rates have declined in Rwanda since the late 1990s, the impact of HIV/AIDS-related morbidity on agricultural activities remains important. Donovan and Bailey (2005) used Rwandan household survey data and a propensity score matching technique to assess the effects of prime-age morbidity and mortality on agricultural production between 1999–2000 and 2001–2002. They found that total production of bananas used to prepare beer (beer bananas) was significantly lower in households experiencing an illness than in households with no illness. Beer bananas are an important cash crop commonly processed by Rwandan women and as illness among women or the increased demands on women associated with taking care of someone ill rise, this is expected to reduce production. Nonetheless, among households with at least a member that was ill, total production of sweet potatoes was estimated to be significantly higher compared to that among households without an illness. This was attributed to the flexibility in the timing of labor for sweet potato production whereby planting could take place outside the main planting period while harvesting could be done over time.

Malaria is a leading cause of morbidity in much of Africa including Rwanda and affects mostly children. In 2010, 81 percent of malaria cases and 91 percent of deaths are estimated to have occurred in Africa, with children under five years of age and pregnant women being the most severely affected (WHO 2011). Malaria has been shown to impact agricultural production through reduced labor because of nonattendance by those that are sick or taking care of the sick, which in turn can negatively affect adoption of labor intensive technologies (Asenso-Okyere et al. 2009). Studies have estimated that malaria attacks can typically result in the loss of four working days and additional days of reduced capacity (Asenso-Okyere et al. 2011).

Other studies have examined how spending on health affects agricultural productivity via its effect on health outcomes. Researchers have, nonetheless, warned against automatically arguing that increases in public health spending lead to improved health status as this depends on the composition of the spending across health inputs; the effectiveness of health services created by the spending; market impact on consumer demand for health services; and the effectiveness of the health inputs on health (Filmer, Hammer, and Pritchett 2000). Fan, Zhang, and Rao (2004), in their study on Uganda, highlighted some of the challenges of capturing the effect of public health spending due to data limitations and inefficiencies in Uganda's health system. Their study found health investments to generate returns to agricultural output and poverty reduction, although they were the lowest among other types of investments such as those on agricultural research and development, education, and road construction and maintenance.

In addition to the relative contribution of social investments to agricultural productivity growth likely being different across sectors, relative contributions of different types of a particular social sector investment are also likely to be different. A study by Allen, Badiane, and Ulimwengu (2012) estimated the impact of Tanzanian district-level public health spending (development vs. salaries) on the marginal productivities of agricultural outputs. In particular, the study used a structural equation model to estimate the effects of development and salary health expenditures on health outcomes and consequently of health outcomes on marginal productivities of agricultural inputs. Study results showed that only per capita government health expenditures on salaries had a significant and negative impact on farmers' health status up to approximately 53,510 Tanzanian shillings per capita. Beyond that amount, increased health salary expenditures improved health outcomes. In addition, the study estimated a significant and positive association between improvements in health outcomes and the productivity agricultural land and labor; with elasticities of 0.09 and 0.44, respectively.

Badiane and Ulimwengu (2013) underscored the importance of different types of Ugandan household health expenses to health status and agricultural efficiency. Their study used a structural equation model to estimate the impact of different types of household health expenditures on health status defined by malaria incidence, and that of malaria incidence on agricultural efficiency. Estimation results showed that a 1 percent increase in consultation, medicinal, and hospitalization expenditures is expected to reduce malaria incidence by 3.6 percent, 2.0 percent, and 2.1 percent, respectively, which in turn decreases agricultural inefficiency by 0.11 percent, 0.06 percent, and 0.06 percent, respectively. The study revealed that policies to help Ugandan households deal with consultation costs, for example through subsidies, will generate large returns in terms of reduced malaria incidence and improved agricultural efficiency.

This study analyzes the relationship between households' health expenditures, health status, and agricultural labor productivity in Rwanda. The approach to evaluate this relationship is novel in that it implements a structural equation model in the form of a latent variable approach that helps to deal with the difficulty in measuring household overall health status. The latent variable approach allows the inclusion of more than one indicator to capture health status. Moreover, the analysis accounts for technological heterogeneity at the district level by implementing a generalized mixed linear model to estimate the production function. We are unaware of studies that have attempted to do this in Rwanda. The analysis is particularly useful in Rwanda, where household health spending makes up a large share of total health spending.

Data and Descriptive Statistics

Data

From November to December 2010, 505 household questionnaires were administered in six randomly selected Rwandan districts, including Burera in North province, Nyagatare in East province, Nyabihu in West province, Nyaruguru in South province, and Gasabo and Nyarugenge in the city of Kigali (see Figure 1). The questionnaire gathered data covering a 12 month period on, inter alia: household characteristics; agricultural production (crop output and input, crop sales, equipment, and livestock); health facility access, incidents, and expenditures; education facilities, participation, and expenditures; agricultural technical assistance; social protection; and household income and consumption.

[Insert Figure 1 here]

Household Head Characteristics

Demographic characteristics are those of household heads only. However, information on all other variables, including on production and health, is from all sampled household members. Almost three-quarters (72 percent) of sampled household heads are male and their average age is 43 years. The majority of them (84 percent) reported farming as their principal occupation while only 11.9 percent reported farming as a secondary occupation. Meanwhile, 61 percent of household heads have been to primary school and 71 percent can read and write.

Health Status and Expenses

Almost three-quarters (73.3 percent) of households reported having at least one household member that experienced a health incident. And out of all household members, only 32.7 percent of the members experienced a health incident. Malaria is the most common health incident among sampled households as it affected 30.5 percent of them (see Table 2 for summary statistics). Other commonly occurring health incidents are intestinal problems, upper respiratory problems, and wounds, which affected 23.8 percent, 15.4 percent, and 6.3 percent of households, respectively. On average, households lost approximately 24 days of agricultural labor and six days of school attendance due to infirmity. The number of agricultural days lost can potentially devastate agricultural activities given that farming is the primary occupation for most households.

[Insert Table 1 here]

The proportion of Rwandans enrolled in a community-based health insurance scheme (*mutuelles de santé*) grew from 44 percent in 2006 to 91 percent in 2010 (Rwanda, Ministry of Health 2012). It is therefore not surprising that health insurance makes up the single largest household health expenditure at 27.7 percent (see Figure 2). Mutuelles reportedly receive half of their funding from annual premiums of less than US$2 per person, while the other half comes from international donors (Emery 2013). However, in a country with an average annual GDP per capita of US$644 and an average sampled household size of about five, premiums of US$2 for each household member can quickly become insurmountable. Other large-share expenses are costs of medicines/drugs, hospitalizations, and transportation to a health facility that make up 16.3 percent, 9.6 percent, and 8.9 percent, respectively, of total household expenses. Almost all sampled households reported having access to health services that provide child vaccinations (95 percent) and mosquito nets (97.8 percent). It is expected that each of these services makes up less than 1 percent of health expense given that the majority of households likely receive the services free of charge or for a very small fee or as part of social safety net programs. The category 'other health expenses' made up a large share of household expenditures (32.6 percent) and includes expenditures on other items.

[Insert Figure 2 here]

Comparing average household expenditures with health status reveals that households that did not experience malaria spent more money on each of the top five health expenditure items than those that experienced the disease (see Figure 3). This could be because households that spend more money on "other" health expenditures, health insurance, medicines, and transportation to a health facility will likely pay more for preventative measures against malaria and will thus not experience the disease. A similar story can be told for average expenses among households that experienced or did not experience intestinal problems. However, the cost of transportation to a health facility is higher among households that experience intestinal problems possibly due to more trips to seek treatment. For upper respiratory problems and wounds, costs tend to be higher among households that experienced these health incidents than those that did not, possibly due to the higher cost of treating these ailments than preventing them. Differences in means of average health expenditures between households experiencing or not experiencing a health incident are not significant across most types of health incidents. However, there is a significant difference between means of other health expenditures for households experiencing and not experiencing wounds. In particular, it is expected that households experiencing wounds spend more money on other health expenditures.

[Insert Figure 3 here]

Health Status and Agricultural Productivity

Landholdings are very small among sampled households as the average cropping land size per household was estimated at 0.5 hectare. Crops grown most widely by sampled households include (in descending order) bush beans, maize, climbing beans, sorghum, plantains, sweet potatoes, Irish potatoes, and soft cassava. Household labor is an important asset in crop production; among the most commonly grown crops, the average household person days per plot per year ranges from 20 for climbing beans to three for soft cassava. A small proportion of hired labor is also used to supplement household labor, ranging from 12 person days for maize to two person days for soft cassava. The average total value of agricultural crop production was estimated at RWF59,948 per household. This is low as the average ratio of crop harvest to sales among the top eight crops is 3.2, indicating that farmers sell far less than what they harvest.

We compare average labor and land productivities for the above crops across households experiencing or not experiencing the four main health incidents (malaria, intestinal problems, upper respiratory problems, and wounds). In general, households with no health incident perform better than those that experienced a health incident (see Figures 4 and 5). However, the differences in means of the labor and land productivities for households with and without a health incident are not statistically significant.

[Insert Figure 4 here]

[Insert Figure 5 here]

On average, crops such as beans, sorghum, and maize require more person days per plot in a year compared to less labor-intensive root tubers like cassava and plantains (see Figure 6). In cases where households reported experiencing malaria and intestinal problems as the main health incidents, production of these crops used less labor per plot compared to households that did not experience malaria or intestinal problems as the main health incident.

[Insert Figure 6 here]

Analytical Framework

Descriptive results discussed in the previous section are not conclusive as they do not account for farmers' behavior as economic agents. Therefore, we implement the traditional agricultural household model which describes the mechanisms through which health investments can promote agricultural productivity. Following Pitt and Rosenzweig (1986), we use an agricultural household model defined as follows:

$$U = U(H, Y, Y^p, l) \qquad (1)$$

where the utility function (U) is defined over the health state (H), the amount of produced food commodity (Y), the market purchased food commodity (Y^p), as well as leisure (l). In this framework, each household produces health by combining the levels of Y and Y^p with a health input (Z) as well as the farmer's work time (l_f) and a random variable μ, which we assume is not influenced by the household's actions. Therefore, the health production function is given by:

$$H = h\left(Y, Y^p, Z, l_f\right) + \mu \qquad h_1, h_2, h_3 > 0; h_4 < 0 \qquad (2)$$

Equation 2 states that health status (H) is a function of home-produced and market-purchased food commodities, as well as health input and farmer's work time. Marginal changes of health status with respect to both food commodities and health input are positive.

An agricultural commodity is produced according to a conventional production technology, while accounting for how a farmer's health status may affect production levels. First, farmers' health can affect the quality of farm labor supplied, and the effective level of labor is modified from the amount of time allocated to farming based on the farmer's health status:

$$L = \theta\left(l_f, H\right) \quad \theta_1, \theta_2 > 0. \qquad (3)$$

where θ_1 and θ_2 are marginal effects of labor supply (L) with respect to farmer's work time (l_f) and health status (H).

Along with labor supplied by the farmer, labor can be purchased from the labor market at a wage (W). Hired labor produces σ units of labor in efficiency adjusted terms, so that the agricultural labor input in constant efficiency units is $L = L_f + \sigma L_H$, where L_H denotes hired labor. The market price of an efficiency unit of labor is $\omega = W/\sigma$. We assume that farmer-supplied labor can be perfectly substituted with hired labor and that any level of desired hired labor (at the needed times) can be purchased in the market at the efficiency wage, ω.

An increase in the farmer's health status will serve to produce more healthy time, so that additional healthy days are available for leisure (l) or work time (l_f):

$$l_f + l = \Omega(H), \qquad \Omega' > 0. \tag{4}$$

The farm produces output according to a production function that includes the ability of the farmer's health to impact the level of production:

$$Y = \Gamma(L; H). \tag{5}$$

The farm household's income constraint is given by:

$$p_y Y + p_{y^p} Y^p + p_z Z = \pi + \omega\theta(\Omega(H) - l, H) = I. \tag{6}$$

Here p_y, p_{y^p}, p_z are the market prices for the commodities $Y$and Y^p and health inputs Z, π is the farm profit, and I stands for the farm household income.

As pointed by McNamara et al. (2010), the above-described agricultural household framework points out two key relationships. First, an exogenous increase in health status increases utility directly through the health argument but also indirectly through the effective increase in healthy time available to the farmer. Hence, the impact on full income or potential income is clearly positive (Pitt and Rosenzweig 1986). However, unless health directly influences the production function or changes the family labor supply enough that the family switches from net buyer to net seller of labor, health has no impact on farm profit or productivity. In addition, Pitt and Rosenzweig (1986, 158) point out that even though the farmer's profits are "unaffected by the healthiness of the environment, potential output to society is affected (hired labor time can be released for use in other productive pursuits)."

Second, the importance of well-functioning input and output markets is critical. Indeed, where perfect input and output markets exist, the farm profits are independent of the specific health status of the farmer as the farmer can perfectly hire in agricultural labor and sell out any excess household labor.

Empirical Estimation and Results

We implement an estimation procedure that involves two stages. First, the estimation of health production as a function of households' expenses as well as community and household characteristics. Second, the estimation of the agricultural production function using a state variable approach where the predicted first-stage health status is used as the state variable.

To efficiently estimate the health production function, Baldacci et al. (2003) suggest modeling health status using a latent variable approach in the form of a general covariance structure model:

$$H = \vartheta H + \Gamma M + \zeta; \tag{7}$$

where ϑ are coefficients for the endogenous latent variables (H) and Γ are parameters of the exogenous latent variables (M), with ζ specified as random disturbances. After estimating Equation 7, the expected value of (H) is used as state (s) in the production function presented below.

Following Mundlak et al. (1997), each farm chooses a production technology $Y_j(X)$ with production techniques (j) where X is a vector of constrained (k) and unconstrained (v) inputs so that $Y_j(X) \ni v, k$. Depending on the choice of j, each farm selects the optimal level of inputs (X) for each technique (j) according to the assumption of profit maximization. However, as the production function is conditional on the state variables (s), any changes in s will imply changes in the optimal level of inputs (x^*) as well as the chosen technology $Y(x^*,s)$. It then follows that the production function $Y_j(X, s)$ assumes that the slope (β) and intercept *(Γ)* are both determined by *(s)*, as shown in Equation 8, where the dependent variable *(Y)* represents agricultural production (Mundlak et al. 1997).

$$ln\, Y = \Gamma\,(s) + \beta(s, x) + \varepsilon \quad (8)$$

Assuming heterogeneity in production technologies across locations, our empirical model takes the following form:

$$Y_i = \beta_0 + \sum_l \beta_{il} x_{il} + \varepsilon_i \quad (9)$$

$$\beta_{il} = \gamma_{0l} + \gamma_l s_{hd} + u_{il} \quad (10)$$

The system of Equations 9 and 10 is estimated using the generalized mixed linear approach developed by Verbeke and Molenberghs (2000). This is a two-stage estimation procedure; in the first stage estimates for the production function are generated for each district. The second stage explains the variation in these estimated parameters using exogenous covariates, in this case farmer's health status.

Results

Estimation of Health Function

Following Baldacci et al. (2003), we combine several symptoms as indicators of health status. Indeed, health status is not observed but rather inferred from several proxies. In addition, a single indicator, such as in logit or probit models, cannot fully capture health status. Hence, unlike previous studies, we do not use a single binary variables approach but opt for simultaneous use of all relevant proxies (disease symptoms) to capture health status. The underlying assumption is that health status is more accurately determined through multiple proxies rather than single indicators which are prone to biased estimates. Table 3 reports summary statistics of variables involved in the estimation of the health production function. The fitness statistics reported in Table 4 suggest that the model accurately fits the data.

As stated above, we use all diseases concurrently to estimate health status; however, to avoid multicollinearity between symptoms, at least one loading parameter is set to one (see Table 5, lower section). We also control for other factors such as education attainment and education expenditures, households attributes (gender and main activity), and distance to the nearest health facility.

As expected, results reported in Table 5 indicate that all health symptoms contribute significantly to the overall household heath status, thus justifying our use of multiple health indicators. With respect to expenditures, an increase in expenditures for health insurance reduces the number of household members affected by diseases; in other words, health insurance improves health status. As mentioned before, health insurance makes up the single largest household health expenditure at 27.7 percent. For all other health expenditures, the results suggest the existence of a minimum amount from which health expenses start improving farmers' health. This result is consistent with finding by Badiane and Ulimwengu (2013) in Uganda. The provision of health services involves certain cost; hence, accessibility to health benefits requires a fee to be paid either by the household or a given sponsor. It follows that whenever the fee is lower than the cost, health services are either inexistent or of poor quality.

[Insert Table 2 here]

[Insert Table 3 here]

[Insert Table 4 here]

Estimation of Production Function

In this section, we discuss the estimation results (see Table 6) of Equations 9 and 10 where all inputs and outputs are logged values and therefore estimates can be interpreted as elasticities. The results show that only land and capital elasticities are significant and positive across diseases, while labor elasticity is significant only for malaria. This confirms the preeminence of malaria as the main disease in Rwanda; 30.5 percent of sampled households were affected by malaria. It is also worth noting the nonlinear relationship between capital and agricultural production; in other words, a minimum stock of capital is requires to significantly increase production. As in Dethier and Effenberger (2011) and Badiane and Ulimwengu (2013), the high value of land elasticity supports the claim that agricultural growth in Sub-Saharan Africa has often been driven by land expansion. In Rwanda, land elasticity varies across diseases.

We use a metric developed by Fulginiti and Perrin (1993) to compute the elasticity of production with respect to health status. The metric is derived from Equations 9 and 10, where both *y* and *s* are in log form as:

$$\frac{\partial y}{\partial s} = \frac{\partial y}{\partial \beta}\frac{\partial \beta}{\partial s} = \sum_l \gamma_l x_l + \gamma_{0l} \qquad (11)$$

As expected, the elasticity of agricultural production with respect to health status is negative and varies between -0.061 and -0.034; it is the lowest for upper respiratory problems compared to the other diseases. Hence, since an increase in expenditure for health insurance is expected to improve households' health status by decreasing the number of people affected by diseases, it can be inferred that health insurance will improve overall agricultural productivity. Figure 7 presents production elasticities with respect to households' health insurance and education expenditures.

Our results confirm that improving farmer's human capital through investments in health and education is more likely to increase overall production. However, to be effective such investment strategy should account for differences across diseases and types of expenditures. As shown in Figure 7, the effect of health insurance is higher compared to education. Similarly, households' health expenditures have much more effect on malaria than other diseases.

[Insert Table 5 here]

[Insert Figure 6 here]

In addition to the production elasticity with respect to health, following Fulginiti and Perrin (1993), we use the pair-wise bias ($B_{l,i,S}$), defined as the logarithm of the change in the ratios of marginal products of two given inputs *l* and *i*, evaluated as

$$B_{l,i,S} = \partial\left\{\log {\partial y}/{\partial x_l} - \log {\partial y}/{\partial x_i}\right\}\Big/{\partial s} = \partial \log MRS_{i,l}\big/{\partial s}, \qquad (12)$$

where $MRS_{i,l}$ is the marginal rate of substitution between inputs i and l , and s represents the state variable.

In the case of a Cobb-Douglas production function, the pair-wise bias is given by

$$B_{n,i,S} = {}^{\gamma_l}/_{\beta_l} - {}^{\gamma_i}/_{\beta_i}. \qquad (13)$$

It follows that the net bias effect of health with respect to input *l* equals

$$B_{l,S} = \sum_{i=1}^{n} \beta_i \, B_{n,i,S} = ({}^{\gamma_l}/_{\beta_l}) \sum_{i=1}^{n} \beta_i \; - \; \sum_{i=1}^{n} \gamma_i. \qquad (14)$$

As pointed out by Fulginiti and Perrin (1993), a zero pair-wise bias parameter value will imply neutrality, while a positive (negative) value will indicate inputs-using (inputs-saving) technological change from a decrease in health impediment. Estimates of net bias parameters in Table 7 indicate that in the case of Rwanda, health status induces technical change that increases the cost shares of labor and capital and reduces that of land.

[Insert Table 6 here]

The net bias effects confirm that not accounting for health impediment leads to biased estimates of marginal productivity of agricultural inputs.

Conclusions

The main purpose of the paper is to assess the impact of health expenditures on agricultural productivity through labor productivity while accounting for other factors. However, since health expenditures impact productivity through health outcomes, we first estimated the health production function whose results are used to estimate the production function. The relationship between the two components of the empirical framework yields a mixed linear specification which allows for endogenous marginal productivity of inputs and heterogeneous production technology.

Overall, our findings confirm that shifts in agricultural productivity can be driven by changes in marginal productivity of inputs induced by households' health status. Estimates from health production suggest that health outcomes can be significantly impacted by households' own health expenditures. Indeed, an increase in expenditures for health insurance improves household overall health status. For other health expenditures, our findings suggest that a minimum level of expenditure is required before health expenses start improving farmers' health. This calls for government intervention to supplement households' own health expenditures.

The findings also confirm the variation in effects across the types of health impediments but also across particular agricultural inputs. The results show that only land and capital elasticities are significant and positive across all diseases; whereas labor elasticity is significant only for malaria. Heterogeneity in the effects of health symptoms suggests a need for careful targeting of social expenditures in order to fully harness their growth-enhancing potential.

Tables and Figures

Table 1—Descriptive statistics of sampled households

Variable	Obs	Mean	Std. Dev.
Household Head Variables			
Age of household head	504	43.105	13.72373
Marital status (1=married, 0=otherwise)	505	0.727	0.4460788
Gender (1=male, 0=otherwise)	505	0.729	0.4450648
Farming is primary occupation (1= farmer, 0= otherwise)	505	0.842	0.3654925
Farming is secondary occupation (1= farmer, 0= otherwise)	329	0.119	0.3237401
Primary school			
Education (Read and write)			
Total number of household members	505	4.84	1.954158
Health Variables			
Malaria (1= yes, 0= no)	505	0.305	0.461
Intestinal problems (1= yes, 0= no)	505	0.238	0.426
Upper respiratory problems (1= yes, 0= no)	505	0.154	0.362
Wounds (1= yes, 0= no)	505	0.063	0.244
Days of agric labor lost due to the illness	505	23.81	55.66
Days of school lost due to illness	505	6.44	35.65
Amount spent on treatment (RWF)	505	11,126.80	52,155.69
number of household members that have a bed net			
Access to a government clinic/health center(1= yes, 0= no)	505	0.96	0.20
Access to a government hospital (1= yes, 0= no)	505	0.83	0.38
Access village health worker/dispensary (1= yes, 0= no)	505	0.97	0.16
Access to childhood vaccinations (1= yes, 0= no)	505	0.95	0.22
Access to family planning resources (1= yes, 0= no)	505	0.93	0.25
Access to mosquito control (1= yes, 0= no)	505	0.98	0.15
Access to pharmacy (1= yes, 0= no)	503	0.44	0.50
Child vaccinations expenditures (RWF)	505	1.188119	16.32307
Medical consultations expenditures (RWF)	504	338.91	1,927.90
Hospitalizations expenditures (RWF)	505	1,512.08	16,197.73
Medicines/drugs expenditures (RWF)	505	2,564.81	13,855.31
Bed nets expenditures (RWF)	505	142.28	645.64
Medical exams expenditures (RWF)	505	274.51	2,498.55
Transportation to hospital/clinic expenditures (RWF)	505	1,409.21	6,354.48
Health insurance expenditures (RWF)	505	4,371.49	2,986.47
Other health expenditures (RWF)	505	5,144.23	35,906.94
Total health expenditures (RWF)	505	17,012.50	64,084.88
Agricultural Variables			
Total agricultural value of (crop) sold production (RWF)	505	59,947.57	139,132.20

Nonagricultural income	378	255,384.60	397,836.10
Livestock income	157	195,681.10	1,323,428.00
Land owned including all plots (ha)	505	0.51	1.07

Source: Authors using survey data.

Table 2—Summary statistics

Variable	Obs	Mean	STD	Min.	Max.
Malaria	505	0.42	0.78	0.0	7.0
Intestinal problems	505	0.30	0.59	0.0	3.0
Wounds	505	0.07	0.28	0.0	3.0
Upper respiratory problems	505	0.18	0.47	0.0	3.0
Log of health expenditures	505	8.56	1.96	-2.3	13.8
Log of health expenditures squared	505	77.14	22.99	5.3	189.5
Log of health insurance expenditures	505	7.38	3.11	-2.3	10.6
Household size	505	4.84	1.95	1.0	12.0
Log of education expenditures	505	4.49	4.86	-2.3	11.7
Education (1 if completed primary school, 0 otherwise)	504	0.28	0.45	0.0	1.0
Age (years)	504	43.11	13.72	18.0	95.0
Marital status (1 if married, 0 otherwise)	505	0.73	0.45	0.0	1.0
Gender (1 if female)	505	1.27	0.45	1.0	2.0
Farming activity (1 if farmer, 0 otherwise)	505	0.84	0.37	0.0	1.0
Distance to the nearest health facility (Km)	488	22.77	29.02	1.0	120.0
Log of production	505	11.46	1.45	-2.3	14.8
Log of land	505	-0.40	0.98	-2.3	3.4
Log of labor	505	4.68	1.10	-2.3	7.6
Log of capital	505	9.05	1.58	-2.3	14.7
Log of capital squared	505	84.44	28.98	5.3	217.2

Source: Authors.

Table 3—Overall goodness of fit

	R-squared	mc	mc^2
Wounds	0.916259	0.957214	0.916259
Intestinal problems	0.916162	0.957164	0.916162
Malaria	0.916163	0.957164	0.916163
Upper respiratory problems	0.916158	0.957161	0.916158

Source: Authors.

Notes: mc = correlation between dependent variables and its prediction;
mc^2 = Bentler-Raykov squared multiple correlation coefficient.

Table 4—Estimation results for health production

	Upper respiratory problems		Wounds		Intestinal problems		Malaria	
	Coef.	STD	Coef.	STD	Coef.	STD	Coef.	STD
Log of other health expenditures	*0.025*	*0.013*	*0.017*	*0.008*	0.029	0.015	0.045	0.024
Log of other health expenditures squared	-0.001	0.001	0.000	0.001	-0.001	0.001	-0.001	0.002
Log of health insurance expenditures	*-0.010*	*0.004*	*-0.006*	*0.003*	-0.011	0.006	*-0.017*	*0.009*
Household size	**0.043**	**0.011**	**0.029**	**0.007**	**0.051**	**0.013**	**0.078**	**0.018**
Log of education expenditures	*-0.008*	*0.003*	*-0.005*	*0.002*	*-0.009*	*0.004*	**-0.015**	**0.005**
Education (1 if completed primary school, 0 otherwise)	0.044	0.025	0.029	0.017	0.051	0.029	0.079	0.045
Age (years)	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.002
Marital status (1 if married, 0 otherwise)	0.064	0.041	0.042	0.026	0.075	0.048	0.115	0.076
Gender (1 if female)	0.057	0.041	0.038	0.027	0.067	0.046	0.103	0.072
Farming activity (1 if farmer, 0 otherwise)	-0.028	0.031	-0.018	0.020	-0.032	0.035	-0.050	0.054
Distance to the nearest health facility (Km)	0.000	0.000	0.000	0.000	-0.001	0.000	-0.001	0.001
Districts specific effects	yes		yes		yes		yes	
Measurement Model /Health Status Indicators								
Malaria	**1.829**	**0.558**	**2.792**	**0.859**	**1.566**	**0.461**	1.000	
Intestinal problems	**1.168**	**0.375**	**1.783**	**0.553**	1.000		**0.639**	**0.188**
Wounds	**0.655**	**0.184**	1.000		**0.561**	**0.174**	**0.358**	**0.110**
Upper respiratory problems	1.000		**1.527**	**0.429**	**0.856**	**0.275**	**0.547**	**0.167**
Variance								
Malaria	**0.573**	**0.039**	**0.573**	**0.039**	**0.573**	**0.039**	**0.573**	**0.039**
Intestinal problems	**0.335**	**0.022**	**0.335**	**0.022**	**0.335**	**0.022**	**0.335**	**0.022**
Wounds	**0.078**	**0.005**	**0.078**	**0.005**	**0.078**	**0.005**	**0.078**	**0.005**
Upper respiratory problems	**0.207**	**0.014**	**0.207**	**0.014**	**0.207**	**0.014**	**0.207**	**0.014**
Health	**0.001**	**0.004**	**0.000**	**0.002**	**0.001**	**0.005**	**0.004**	**0.013**

Source: Authors.

Note: Bold, italicized, and underlined text indicates significant at 1 percent, 5 percent, and 10 percent, respectively.

Table 5—Estimation results for the production function

	Upper respiratory problems		Wounds		Malaria		Intestinal problems	
	Coef.	STD	Coef.	STD	Coef.	STD	Coef.	STD
Land	**0.633**	**0.207**	**0.751**	**0.275**	**0.434**	**0.113**	**0.583**	**0.183**
Labor	0.187	0.218	0.063	0.284	**0.385**	**0.134**	0.241	0.197
Capital	*0.502*	*0.255*	0.417	0.279	**0.645**	**0.219**	*0.534*	*0.244*
Capital squared	**-0.037**	**0.011**	**-0.037**	**0.011**	**-0.037**	**0.011**	**-0.037**	**0.011**
Land*Health	<u>0.314</u>	<u>0.179</u>	<u>0.317</u>	<u>0.185</u>	<u>0.317</u>	<u>0.183</u>	<u>0.319</u>	<u>0.184</u>
Labor*Health	<u>-0.312</u>	<u>0.176</u>	<u>-0.320</u>	<u>0.183</u>	<u>-0.315</u>	<u>0.180</u>	<u>-0.313</u>	<u>0.182</u>
Capital*Health	*-0.223*	*0.094*	*-0.222*	*0.096*	*-0.223*	*0.095*	*-0.226*	*0.096*
Health	**3.568**	**0.989**	**3.578**	**0.996**	**3.561**	**0.994**	**3.581**	**0.997**
Intercept	**9.423**	**1.870**	**10.746**	**2.209**	**7.135**	**1.317**	**8.827**	**1.720**
Production elasticity with respect to health	-0.034		-0.061		-0.059		-0.061	
#Obs.	505		505		505		505	
Wald test $\chi^2(8)$	130.0		130.1		129.8		130.0	
restricted-likelihood	-754.3		-754.1		-754.2		-754.1	

Source: Authors.

Note: Bold, italicized, and underlined text indicates significant at 1 percent, 5 percent, and 10 percent, respectively.

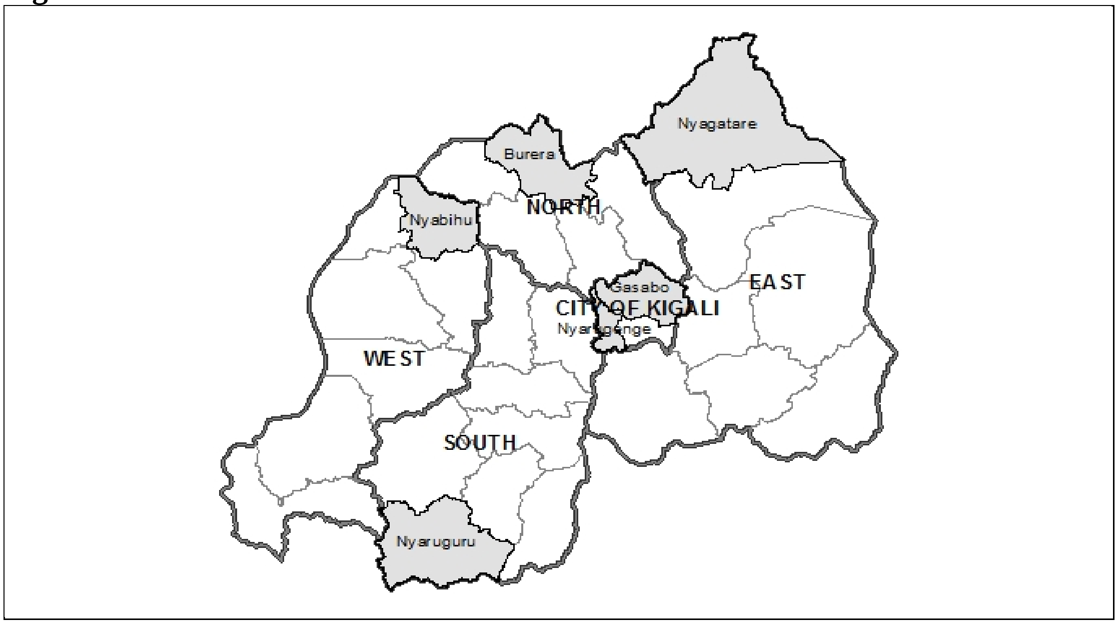
Table 6—Net bias effect of change in health status

	Upper respiratory problems	Wounds	Malaria	Intestinal problems
$\sum_{i=1}^{n} \beta_i$	0.987	0.896	1.129	1.023
$\sum_{i=1}^{n} \gamma_i$	-0.221	-0.225	-0.221	-0.220
Land	0.711	0.603	1.046	0.780
Labor	-4.793	-4.327	-0.703	-1.109
Capital	-1.096	-2.197	-0.591	-0.941

Source: Authors.

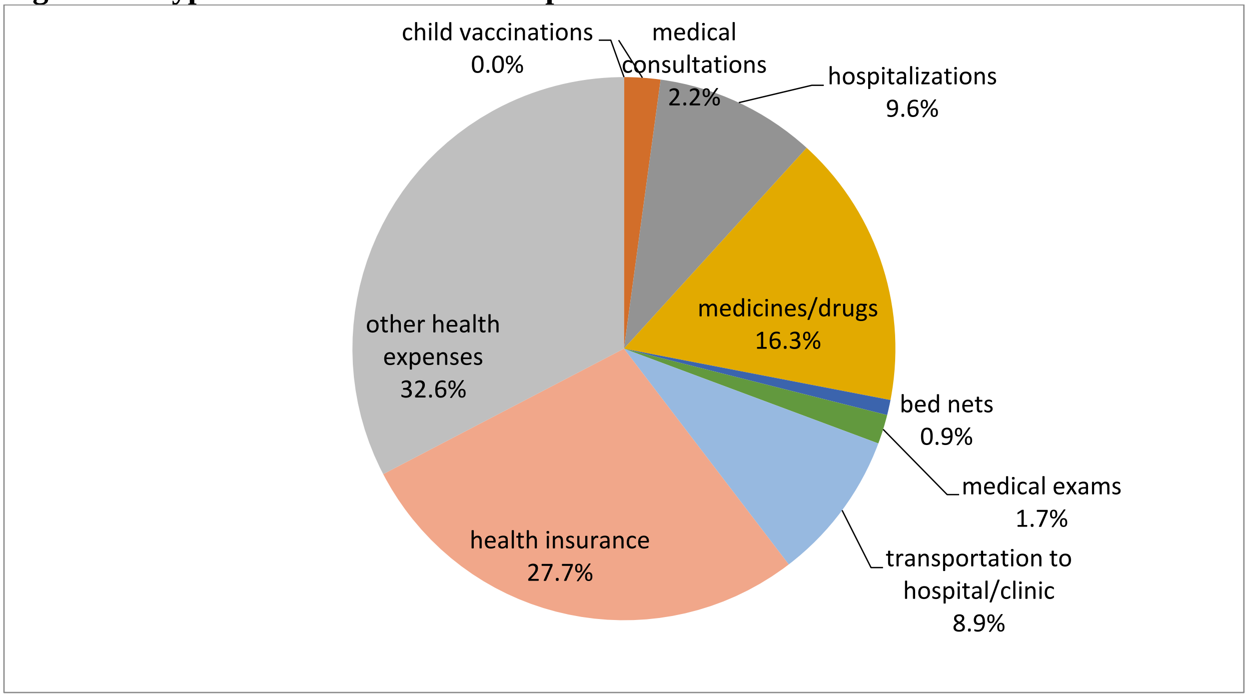
Note: The effects are estimated at the average for capital.

Figure 1—Selected Rwandan districts



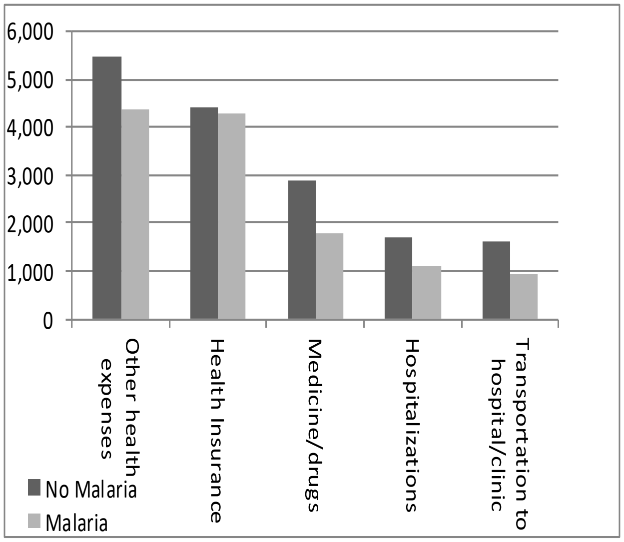
Source: Authors using spatial data from Rwanda MINITRACO-CGIS/NUR 2006.

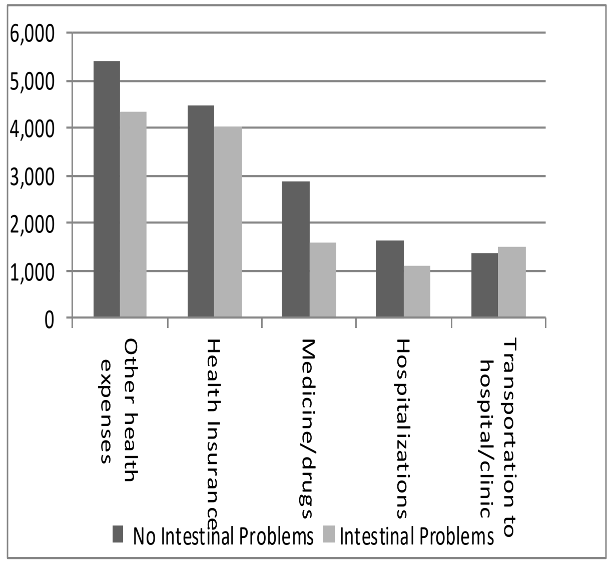
Figure 2—Types of household health expenditures

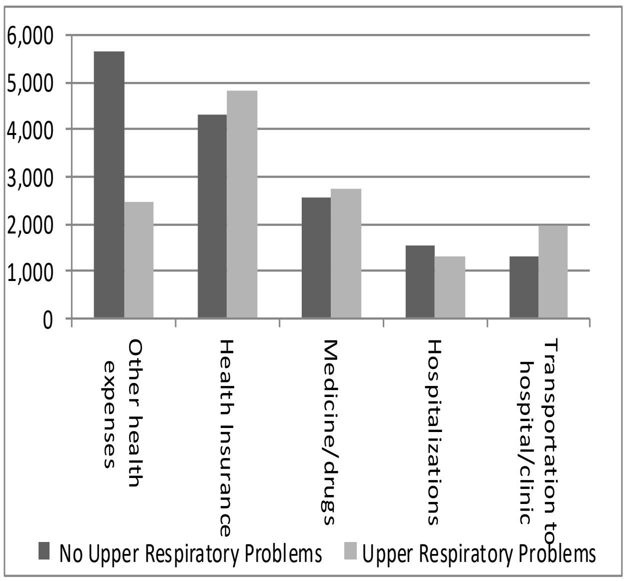


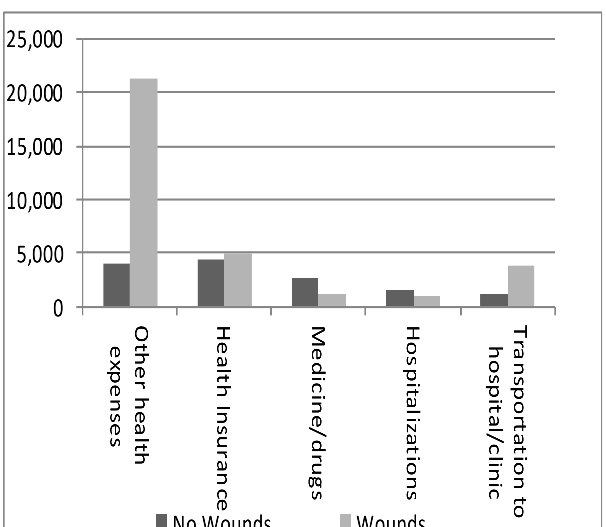
Source: Authors using survey data.

Figure 3—Average household health expenditures (in Rwandan francs) and health status


6,000
5,000
4,000
3,000
2,000
1,000
0
Other health expenses
Health Insurance
Medicine/drugs
Hospitalizations
Transportation to hospital/clinic
No Malaria
Malaria

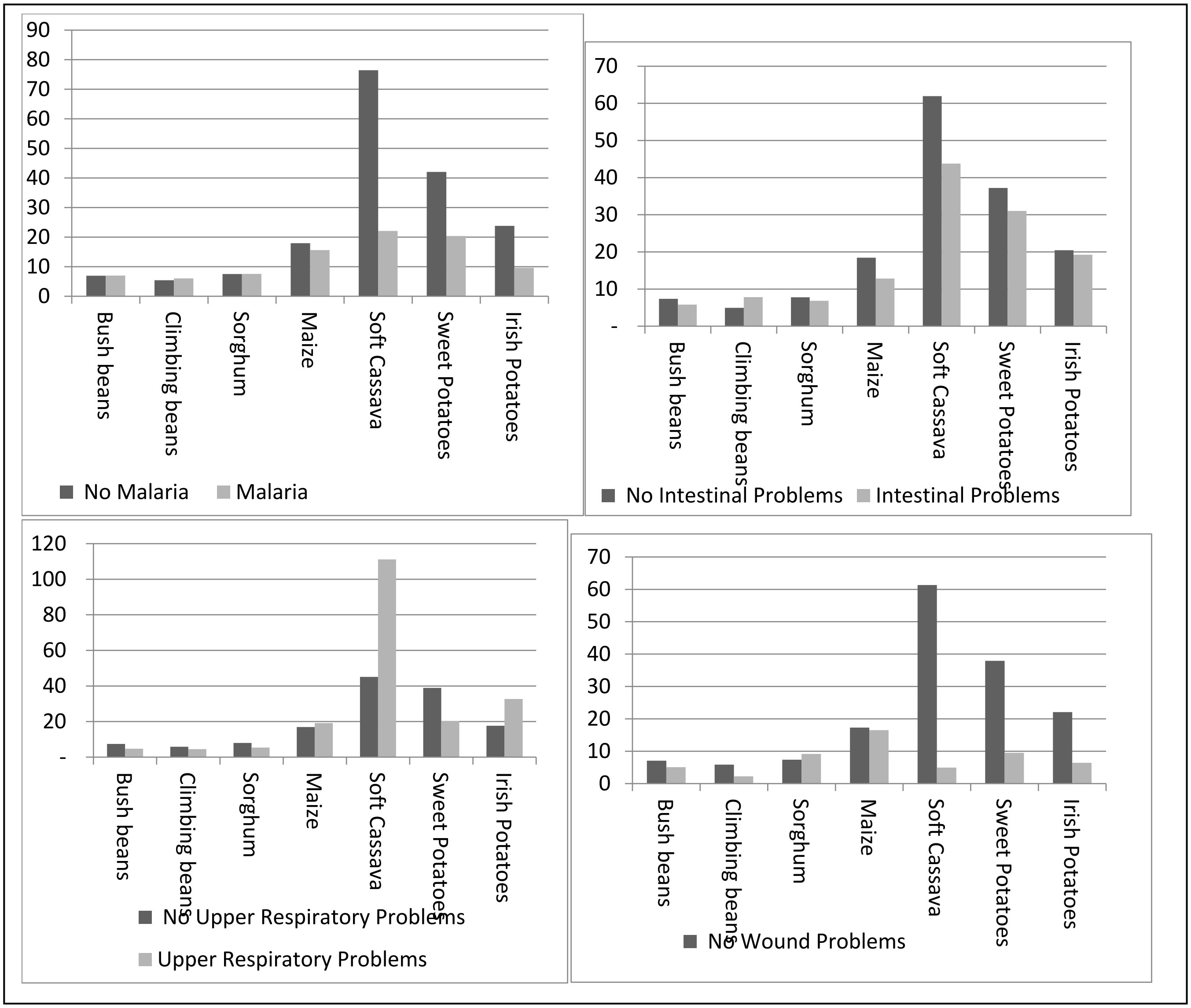

6,000
5,000
4,000
3,000
2,000
1,000
0
Other health expenses
Health Insurance
Medicine/drugs
Hospitalizations
Transportation to hospital/clinic
No Intestinal Problems
Intestinal Problems


6,000
5,000
4,000
3,000
2,000
1,000
0
Other health expenses
Health Insurance
Medicine/drugs
Hospitalizations
Transportation to hospital/clinic
No Upper Respiratory Problems
Upper Respiratory Problems


25,000
20,000
15,000
10,000
5,000
0
Other health expenses
Health Insurance
Medicine/drugs
Hospitalizations
Transportation to hospital/clinic
No Wounds
Wounds

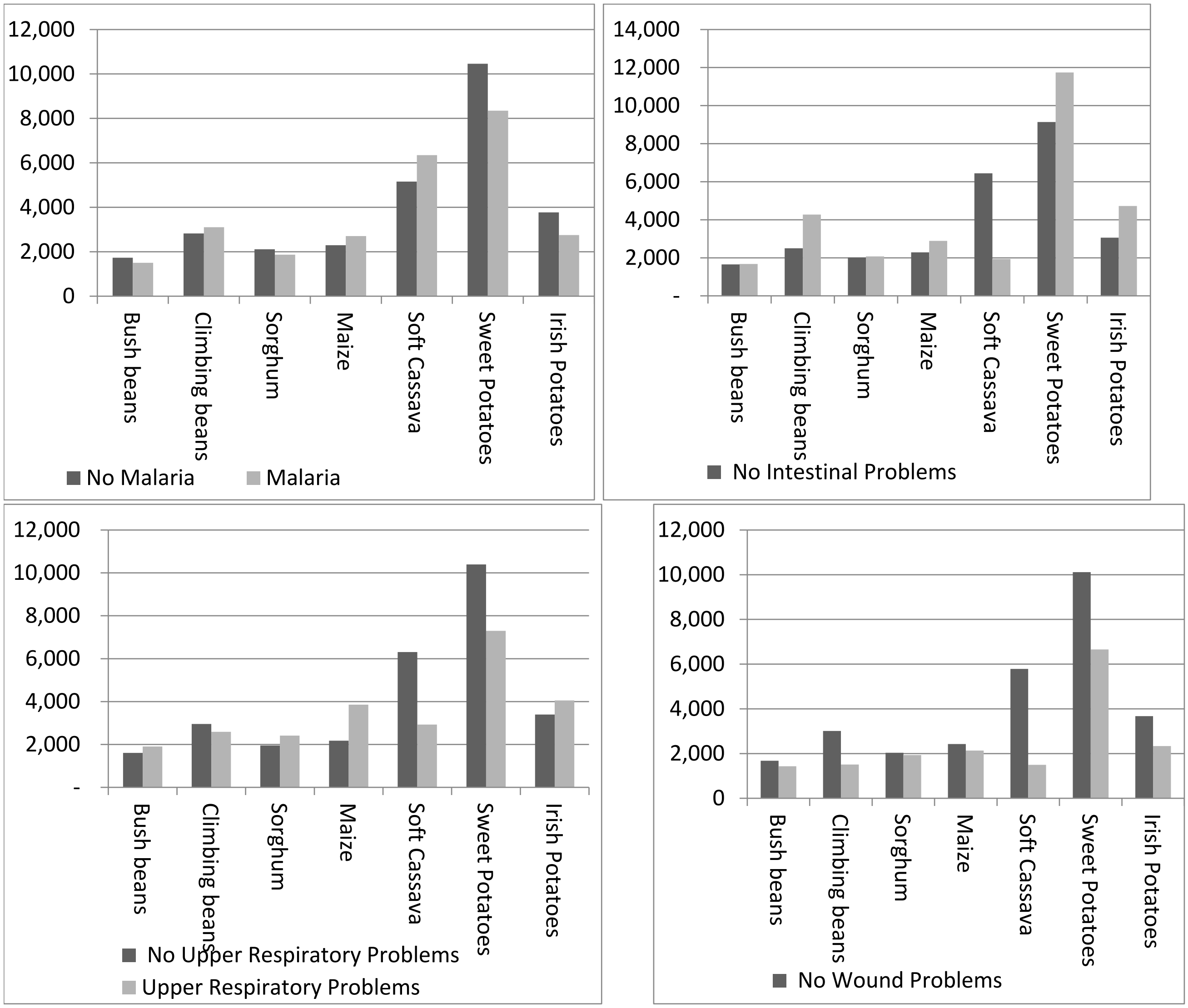
Source: Authors using primary survey data.

Figure 4—Labor productivity (kg/total annual person days per plot) and health incidents



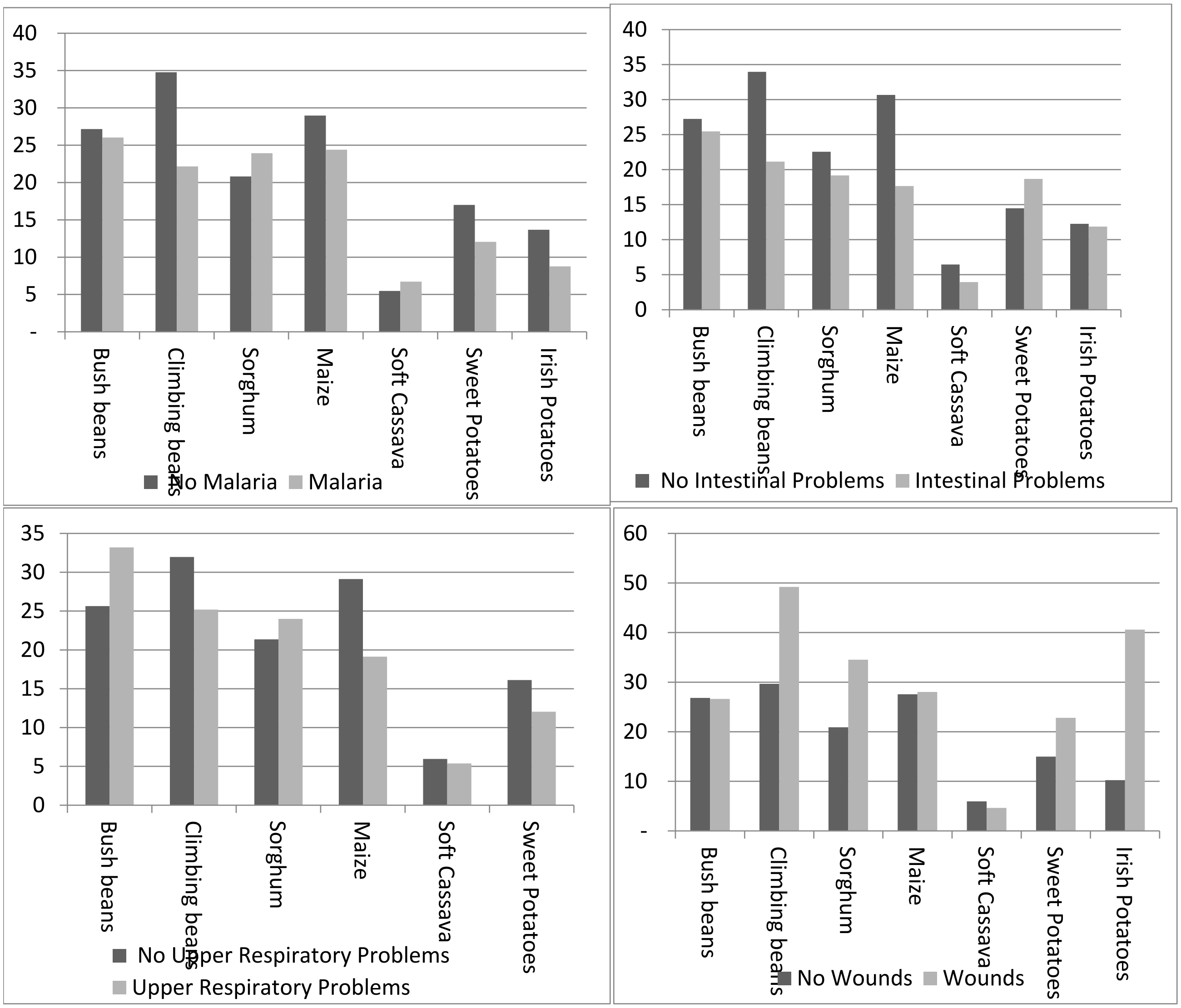
Source: Authors using primary survey data.

Figure 5—Land productivity (kg/ha) and health incidents



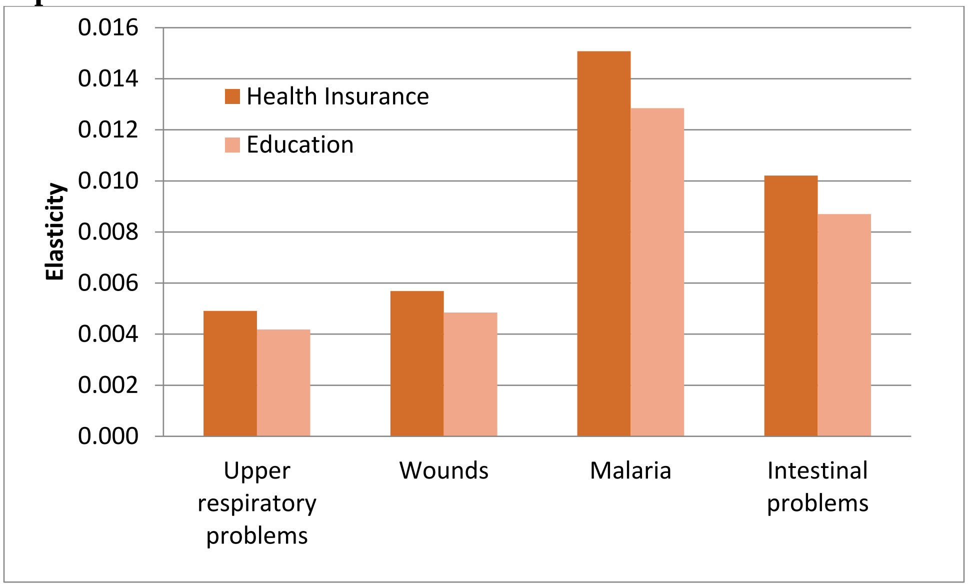
Source: Authors using primary survey data.

Figure 6—Labor supply (total annual person days per plot) and health incidents



Source: Authors using primary survey data.

Figure 7—Production elasticity for 15 percent increase in health insurance and education expenditures



Source: Authors.

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