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Do Health Investments Improve Agricultural Productivity?

Lessons from Agricultural Household and Health Research

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ABSTRACT

Determining the causality between health measures and both income and labor productivity remains an ongoing challenge for economists. This review paper aims to answer the question: Does improved population health lead to higher rates of agricultural growth? In attempting to answer this question, we survey the empirical literature at micro and macro levels concerning the link between health investments and agricultural productivity. The evidence from some micro-level studies suggests that inexpensive health interventions can have a very large impact on labor productivity. The macro-level evidence at the country and global level, however, is mixed at best and in some cases suggests that health care interventions have no impact on income, much less on agricultural productivity. At both micro and macro levels, the literature does not provide a clear-cut answer to the question under investigation. Overall, the review reveals a great deal of heterogeneity in terms of estimation methods, definition and measurement of health variables, choice of economic outcomes, single-equation versus multiple-equation approach, and static versus dynamic approach. The actual magnitude of estimated elasticities is difficult to assess in part due to estimation bias caused by the endogeneity of health outcomes. We also found significant gaps in the literature; for example, very little attention is given to demand for health inputs by rural populations and farmers.

Keywords: health, agriculture, growth, productivity, investment, nutrition

1. INTRODUCTION

The link between health and both income and labor productivity has been long studied by labor economists and development economists. The significant and positive correlation that observers clearly see between measures of health status and of income and work performance has motivated much of the research. Nonetheless, determining the causal link between health measures and a country's income and labor productivity remains an ongoing challenge for economists (see, for example, recent research by Liu et al. 2008). The variety of health measures and health interventions researchers can investigate compounds the dimensions of the topic, and methodological difficulties, such as isolating truly causal impacts in observational studies, have complicated the issue. Despite the number of studies focusing on the links between health status and economic outcomes, including income and labor productivity, very few studies exist that focus on the contribution of improvements in health to agricultural growth. This is particularly true of studies examining the impact of health shocks or health investment in developing countries characterized by multiple agricultural activities undertaken by a single family with off-farm opportunities also available. To understand the current research literature and to outline areas where future research might make a contribution, this essay provides a review of the health and agricultural productivity literature from the vantage point of agriculture in developing countries, especially in Sub-Saharan Africa.

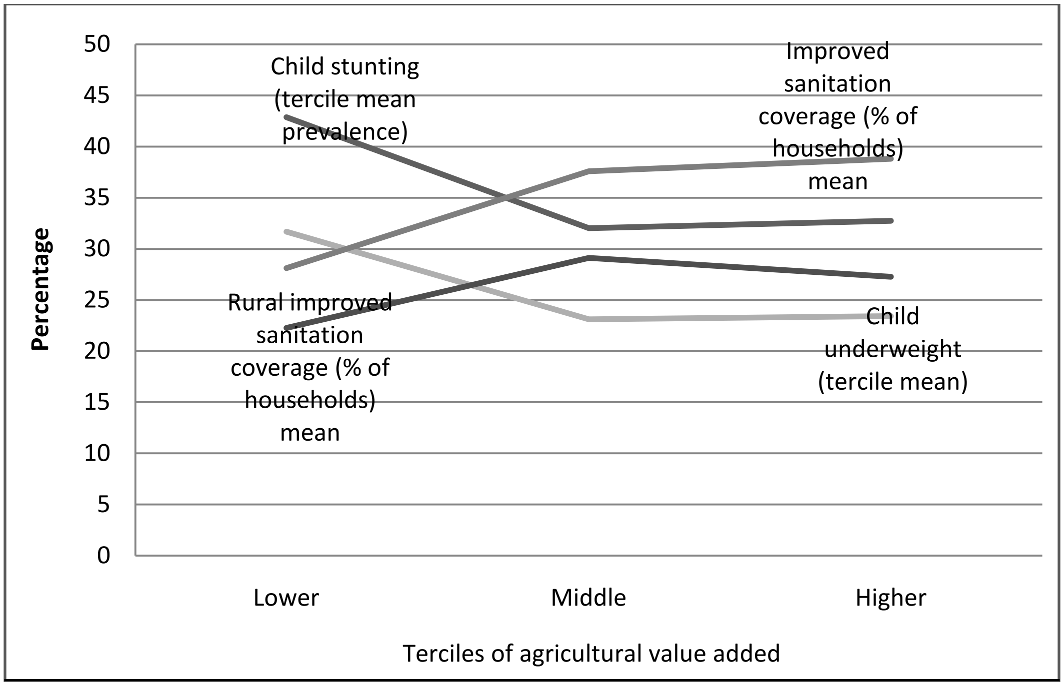
The strong association between good health and economic prosperity is easily appreciated and appears in the context of agricultural productivity as well as in contexts such as income, wages, and other wealth measures. As Figure 1 illustrates, a positive relationship exists between higher levels of agricultural value added and a number of health status and health input measures in countries in Sub-Saharan Africa for the period 1960 to 2006. In this graph, observations of agricultural value added by country for specific years are sorted into lower, middle, and higher terciles, and the health status and health input measures are reported for each tercile.

For all the measures displayed here (child stunting prevalence, child underweight prevalence, percent of overall households with improved sanitation, percent of rural households with improved sanitation), we observe a distinct gradient between higher levels of agricultural value added and better health status or health system measures. For example, levels of child stunting drop from about 43 percent in the lower tercile to roughly 32–33 percent in the middle and higher terciles. For specific health or health system variables the mean can be as much as four times greater in the higher tercile than in the lower one. For access to physicians, for example, the mean at the lower tercile is 0.05 physicians per 1,000 people while for the higher tercile the mean is 0.19 physicians per 1,000 people. Simple descriptive statistical relationships such as these motivate much of the interest in exploring the link between health and agricultural productivity growth.

While the link can be easily seen in descriptive statistics, disentangling the precise nature of the connection between health and agricultural productivity and whether the connection is causal is another matter altogether. Economists Thomas and Frankenberg write, "A positive correlation between health and economic prosperity has been widely documented, but the extent to which this reflects a causal effect of health on economic outcomes is very controversial" (2002, 106). They point out that the causality is likely to run in both directions.

While Thomas and Frankenberg (2002) write about the general variable of economic well-being, a similar observation can be made for the link between health and increase in agricultural productivity. Does better health lead to higher rates of agricultural growth? Possibly yes, and it is also likely that higher levels of agricultural growth lead to higher levels of health. In addressing the question of the link between health and agricultural growth, it is also necessary to understand the likely size of the link and the impact of complementary investments in other forms of human capital, such as education, or investments in physical infrastructure, such as rural roads, on both health and agriculture.

Figure 1. Health status and sanitation in relation to agricultural value added, Sub-Saharan Africa 1960–2006



Source: Authors' analysis of World Development Indicator data.

The importance of health in promoting economic development has been forcefully stated by the Commission on Macroeconomics and Health (2001). However, economists and development policy analysts debate the Commission's contentions and evidence, and the overall evidence of the impact of poor health on economic development appears to be mixed. For instance, in discussing the relative importance of education and dietary energy supply on economic growth, Huffman and Orazem state, "education as measured by the literacy rate is a more important determinant of growth than dietary energy supply" (2007, p. 2327). Similarly, studies that attempt to explain inter-country differences in economic growth and productivity rates have suggested that education, trade openness, savings, inflation, and the initial level of income are the key explanatory variables (Barro 1996; Barro and Sala-i-Martin 1995).

This review paper aims to answer the question: Does improved population health lead to higher rates of agricultural growth? In answering this question we address whether any found effect is likely to be large or small and whether the reverse causal effect is likely to be statistically significant. In Section 2, we review the economic theory of the agricultural household and summarize the conclusions from this model. Then, in Section 3, we survey the empirical literature at the microeconomic level concerning the link between health investments and agricultural productivity. In Section 4, in order to address the concern of aggregation as a possible source of bias, we turn to the macroeconomic evidence concerning the health and agricultural growth link. Section 5 examines the importance of indirect means to promote health improvements and agricultural growth simultaneously, such as education and infrastructure investments. In Section 6, we briefly review the evidence of reverse causality from the direction of agricultural growth to improved health status of populations. We conclude the essay with summary observations about the knowledge gaps in this area of agricultural economics and health systems research.

2. THE ROLE OF HEALTH IN THE AGRICULTURAL HOUSEHOLD MODEL

An economic model of the household allows a discussion of the mechanisms through which health investments can promote agricultural growth as well as an analysis of the conditions necessary for health investments to actually improve either labor productivity of rural households or agricultural productivity measured by yields. To highlight these possible mechanisms, we review the agricultural household model developed by Pitt and Rosenzweig (1986), wherein health plays a distinct role not only in yielding utility but also in influencing the level of agricultural production:

$$U = U(H, X^c, Y, l). \tag{1}$$

Here the utility function (U) is defined over the health state (H), the amount of produced food commodity (Xc), the market-purchased food commodity (Y), and leisure (l). The household produces health by combining the levels of Xc and Y with a health input (Z), the farmer's work time (lf), and a random variable (μ), which we assume is not influenced by the household's actions. Therefore the health production function is

$$H = h(X^c, Y, Z, l_f) + \mu \qquad h_1, h_2, h_3 > 0;\ \ h_4 < 0. \tag{2}$$

This health production function relates changes in the home-produced food commodity consumed and the market-purchased food commodity, as well as the health input and labor supplied, with health status. We assume that the marginal contributions of both food commodities and the health input to health status are positive and we assume that additional labor supplied has a negative incremental effect on health status. Note that health goods could include medical services, such as primary care or hospital care, as well as self-administered treatments and preventive measures, such as insecticide-treated bed nets, condoms, or over-the-counter medications. In addition, we do not assume that all households know the technology for producing improvements in health status equally well, and we assume that the health technology may change over time due to new medicines or treatments.

The agricultural commodity is produced according to a conventional production technology, with the additional consideration of how the farmer's health status may affect production levels. First, a farmer's health can affect the quality of labor he or she allocates to farming activities; it follows that the actual level of labor supplied by the farmer is modified (increased or decreased) by his or her health status:

$$L_f = \theta(l_f, H) \qquad \theta_1, \theta_2 > 0. \tag{3}$$

Along with labor supplied by the farmer, labor can be purchased from the labor market per unit of time (W). Hired labor produces σ units of labor in efficiency-adjusted terms, so that the agricultural labor input in constant efficiency units is

$$L = L_f + \sigma L_H\,. \tag{4}$$

Here, LH denotes hired labor. The market price of an efficiency unit of labor is

$$\omega = W / \sigma\,. \tag{5}$$

The total labor costs of farm production equal Lω. We assume that the labor supplied by the farmer 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 for farm labor (lf):

$$l_f + l = \Omega(H), \qquad \Omega' > 0. \tag{6}$$

Note that we can model the impact of the hired laborer's health on the market's labor supply, but since the farmer pays a wage based on the efficiency units of labor provided, the laborer's health has no effect on the farmer's hiring decision. Thus if σ varies with health, the market wage will also adjust and the farmer will always be able to secure the necessary level of labor at the efficiency wage.

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

$$X = \Gamma(L; H). \tag{7}$$

The farm household's income constraint is

$$p_x X^c + p_y Y + p_z Z = \pi + \omega L_f = \pi + \omega\theta(\Omega(H) - l, H) = I. \tag{8}$$

Here are the market prices for the commodities X, Y, and Z. Variable ω is the market wage in efficiency-adjusted terms for labor, and I is the income of the farm household. Farm profits are denoted by π and the profit function is

$$\pi = p_x X - \omega L. \tag{9}$$

With perfect markets (labor is inelastically supplied and effective or actual units of labor are a perfect substitute for family labor) the farmer maximizes profits by using labor until the marginal product of labor is equal to the wage. Farmers with a low level of their own labor supply relative to their land endowment will hire in labor at the wage ω. Farmers with a high level of their own labor relative to their land endowment will hire out labor at the wage W. Depending on the gap between ω and W, some farmers will neither hire in nor hire out labor. Except for the situation where a household is switching from hiring in to hiring out labor, the model is separable and the profit-maximizing decision does not depend on the farm family's own labor supply.

The framework of this model points out several key relationships. First, an exogenous increase in health status, perhaps working through the variable μ as an improvement in environmental health, increases utility directly through the health argument but also indirectly through the effective increase in healthy time available to the farmer. As Pitt and Rosenzweig (1986) pointed out, the impact on full income or potential income is clearly positive. 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, because we do not know the allocation of healthy time between additional labor employed on the farm and additional healthy leisure time, it is not possible to sign definitively the impact of increased health on income. Additionally, Pitt and Rosenzweig state 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)" (1986, 158). This puts the attention on the overall labor market and forces the analyst to deal with questions such as the value of a marginal unit of labor in an economy, the peak labor demand in tropical agriculture at times of planting and harvesting, and the level of unemployment and underemployment in an economy. It suggests that if few alternatives for employment exist, the benefit to society of the potential contribution to output of additional healthy labor may be small in the aggregate. Thus, although the separable household model suggests that health that leads to increases in effective family labor supply will have little impact on profits or productivity, marketwide impacts or large shifts in the supply of labor can clearly change the profit-maximizing decision. Health improves utility and is likely to improve income, but it may not influence productivity at all.

Second, the importance of well-functioning input and output markets (an assumption of no missing or broken-down markets) is highlighted in this framework. Essentially, in this framework, where perfect input and output markets exist, the farm profits are independent of the specific health status of the farmer. This is because the farmer can hire in agricultural labor and can sell out any excess household labor perfectly in these markets. However, in the case where such smooth substitutability is not present, we can expect health levels to influence farm production decisions and agricultural performance. A question for this literature review concerns the evidence regarding the nature of missing input and output markets, because the answer to this question may have implications for how health improvements influence agriculture.

A third point the theoretical model raises is a concern with units and carefully defined variables. For example, Pitt and Rosenzweig (1986) take care to define their labor input variable in terms of a standard unit of efficiency. Taking this framework to the field might imply measurements of labor in quality-adjusted terms (see for example Bell, Burriel-Llombart, and Jones 2005) that simply are not available. Otherwise, researchers may simply assume the agricultural labor market works with perfect efficiency. Similar issues of measuring health status and agricultural output may also arise.

To sum up, the theoretical model of the household put forward by Pitt and Rosenzweig (1986) has served as the basis for an economic literature that continues to this day. Most empirical implementations of agricultural household models on the impact of health follow more or less the framework these writers introduced. Indeed, extending traditional agricultural household models, Pitt and Rosenzweig developed a comprehensive framework to evaluate the impact of change in health on productivity, labor supply, and farmers' income. Extension of these variables involves incorporation of a health variable into the utility function and introduction of an explicit production technology for health. Based on this extended framework, change in farmers' health affects productivity only if input markets are perfect and there is no missing market for any of the consumed commodities or inputs in health production. However, no prediction is offered on farmers' actual income because the effect of health environment on the level of farmers' work time depends on the properties of unknown utility function as well as health production and local labor market characteristics, likewise not always known. In addition, the model offers no predictions for the directions of the effects of food price changes on health without complete knowledge of household preferences and health technology.

3. EMPIRICAL FINDINGS USING THE AGRICULTURAL HOUSEHOLD PRODUCTION MODEL

Most micro-level empirical studies on the link between health conditions and agricultural productivity follow more or less the framework introduced by Pitt and Rosenzweig (1986) and the wage-efficiency hypothesis. It follows that the link between health and agricultural productivity at household level is much more complex than suggested in most of the empirical studies in this area. In agricultural communities, poor health reduces income and productivity, further decreasing people's ability to address poor health and inhibiting economic development (Hawkes and Ruel 2006a).

This section reviews studies of the relationship between health variables (body mass index [BMI] or calorie intake) and labor supply, health and wages, or health and labor productivity (Pitt and Rosenzweig 1986; Strauss 1986; Deolalikar 1988; Antle and Pingali 1994; Berhman, Foster, and Rosenzweig 1997; Croppenstedt and Muller 2000; Ayalew 2003; Ajani and Ugwu 2008). Several studies looked at the impact of specific diseases, such as schistosomiasis (Audibert and Etard 2003), onchocercal skin disease (Kim, Tandon, and Hailu 1997), intestinal helminth infections and anemia (Gilgen, Mascie-Taylor, and Rosetta 2001), and HIV/AIDS (Fox et al. 2004). Apart from Berhman, Foster, and Rosenzweig (1997), the majority of studies followed a static approach, although several used panel (Deolalikar 1988; Ayalew 2003) or longitudinal data (Audibert and Etard 2003; Fox et al. 2004).

Empirical findings on the relationship between health conditions and wages, profit, or income are at best difficult to generalize (see Table 1). Pitt and Rosenzweig (1986) could not reject the separability hypothesis between farm production and consumption decisions. In other words, a farmer's illness does significantly reduce his or her labor supply even though it does not reduce farm profits. Deolalikar (1988) found that neither market wages nor farm output was observed to be responsive to changes in the daily energy intake of workers; however, both were highly elastic in relation to weight for height. The study by Kim, Tandon, and Hailu (1997) revealed that daily wages were 10 to 15 percent lower among employees at a coffee plantation in southwest Ethiopia exhibiting problems related to onchocercal skin disease (OSD). They also found that relatively older (35 and up), permanent, male employees had the biggest OSD-related loss in terms of diminished earnings and labor supply. Also in Ethiopia, Croppenstedt and Muller (2000) estimated a significant wage–BMI elasticity of 3.0 only for males. Differentiating between food for work (FFW) participants and nonparticipants, Ayalew (2003) found that a one percent increase in calorie intake led to a 3.5 percent and a 0.4 percent increase in the wages of FFW participants and nonparticipants respectively. Ajani and Ugwu (2008) examined the impact of health conditions on farmers' productivity in north-central Nigeria and found that a one percent improvement in a farmer's health condition led to a 31 percent increase in efficiency.

Departing from the traditional static framework, Behrman, Foster, and Rosenzweig (1997) used a stochastic dynamic multistage agricultural household model to estimate the calorie response to different components of income in Pakistan. Their results suggest that income–calorie relationship depends on the production stage, the form of income, the liquidity of assets, and the extent to which income is anticipated. In the planting stage, for households owning less than 1.5 acres of land, for each increase in household per capita consumption of 100 calories, harvest income increased by 34 rupees per acre cultivated. The same increase in per capita calories for households owning at least 1.5 acres of land induced a profit increase of only 22 rupees per acre. In the planting stage, wage–calorie elasticity was 0.61, but income increases in the food-abundant harvest stage had only small effects on calorie consumption.

Findings on the link between health conditions and output productivity also vary but tend to be more consistent than the results on the relationship between health conditions and wages, profit, or income (see Table 2). In Sierra Leone, Strauss (1986) estimated an output-elasticity of calories of 0.34 at the sample mean of average calorie intake, 0.49 at an average daily energy intake of 1,500 kilocalories, and 0.12 at a daily energy intake of 4,500 kilocalories. However, additional calories above a daily intake of 5,200 kilocalories were found to have a negative impact on effective labor. Using combined production and health data from a farm-level survey in two rice-producing regions of the Philippines, Antle and Pingali (1994) found that pesticide use had a negative effect on farmer health, while farmer health had a significant positive effect on productivity. They estimated a cost–health elasticity for rice production of 13.8 percent in the Laguna region and 36.3 percent in the Nueva Ecija region.

Audibert and Etard (2003) examined the evidence from a quasi-experimental design in an irrigated rice-growing site in central Mali affected by schistosomiasis. Unlike Pitt and Rosenzweig (1986), Audibert and Etard assumed imperfect substitution between family members and hired labor because of the cost of hired labor and the low agricultural yield. They observed an increase of 26 percent in production per person-day of family labor in the experimental group relative to the control group. The originality of their study is that they captured households' substitution behavior. Their study shows a case in which households preferred to utilize the additional time available to them through health improvement for leisure activities or for cultivating crops other than those grown as part of existing agricultural projects.

In Kenya, Fox et al. (2004) found that HIV-positive piece-rate tea workers plucked between 4.11 and 7.93 kilograms per day less than they plucked prior to the termination time. HIV-positive workers used between 9.2 and 11.0 more sick leave days, between 6.4 and 8.3 more annual leave days, and between 19.9 and 11.8 more casual leave days, and they spent between 19.2 and 21.8 more days doing less-strenuous tasks in their two years before termination than did non–HIV-positive pluckers. Tea pluckers who were terminated for AIDS-related causes earned 16.0 percent less in their second year before termination and 17.7 percent less in the year before termination.

Gilgen, Mascie-Taylor, and Rosetta (2001) used a randomized clinical intervention trial to investigate the effect of iron supplementation and anthelmintic treatment on the labor productivity of adult female tea pluckers in Bangladesh. Four groups were formed: group 1 received iron supplementation weekly, group 2 received anthelmintic treatment at the beginning and halfway through the trial (week 12), group 3 received the same iron supplementation as group 1 and the same anthelmintic treatment as group 2, and group 4 was a control group that received placebos. They found no significant difference in labor productivity among the four intervention groups over the trial period. Still, lower hemoglobin values (< 120 grams per liter of blood) and anemia were both associated with lower labor productivity and more days sick and absent.

Recently, Loureiro (2009), Ulimwengu (2009), and Badiane and Ulimwengu (2009) employed stochastic frontier regression techniques to assess the impact of farmers' health status on agricultural productivity in Spain, Ethiopia, and Uganda respectively. In each case, the authors found a significant and positive relationship between measures of health and agricultural technical efficiency.

The review of empirical findings on the link between health and agriculture at the micro level reveals a rather heterogeneous body of literature. Differences include estimation methods, health and nutrition variables, production versus cost function, and static versus dynamic approaches. In most cases, wage equations were estimated, assuming perfect competition, wherein labor productivity is equated to wages. Theoretically, unless markets are complete and efficient, the household consumption decision cannot be separated from the production decision (Dwayne 1992); in most empirical studies the separability between farmers' consumption and production decisions is often assumed but not tested. In addition, explicit health production is not always specified. Most of these studies are mute on the role of prices. Moreover, apart from Audibert and Etard (2003), none of the studies reviewed attempted to evaluate the possible substitution in labor supply and time allocation induced by a change in household health status.

Another key issue is that of the actual magnitude of estimated elasticities. Methodologically, these elasticities are prone to estimation bias, often caused by endogeneity resulting from the two-way causality between health and agriculture that many studies overlook. As Hawkes and Ruel (2006b) pointed out, poor health reduces producers' ability to innovate, experiment with different farming practices, and capitalize on farm-specific knowledge. On the other hand, agricultural income influences households' ability to purchase health-related goods and services that determine their overall health status (Hawkes and Ruel 2006a).

Table 1. Health effects on wage, profit, or income

Author(s)	Health variable(s)	Elasticity	Estimation methods
Deolalikar (1988)	Calorie intake [ns] Weight for height	-0.06 (FE) -0.06 (RE) 0.66 (FE) 0.28 (RE)	Fixed and random effects models with a semilog model
Kim, Tandon, and Hailu (1997)	Onchocercal skin disease (OSD): binary variable (0 and 1)	i) severe OSD -0.159 (all) -0.136 (ages 15–35) ii) no OSD 0.185 (all) -0.936 (ages 15–35)	Ordinary least square
Behrman, Foster, and Rosenzweig (1997)	Calorie intake	i) <1.5 acres 0.34 ii) >=1.5 acres 0.22	Stochastic dynamic multistage agricultural household model
Croppenstedt and Muller (2000)	BMI Height	2.7 (all) [ns] 3.0 (males) 2.2 (all) [ns] 3.6 (males)	Two-step Heckman procedure with a semilog model

Source: Authors' compilation.
Notes: BMI: body mass index; FE: fixed effect; RE: random effect; ns: not significant.

Table 2. Health effects on agricultural output or yield

Author(s)	Health variable(s)	Elasticity	Estimation methods
Deolalikar (1988)	Calorie intake Weight for height	0.07 (FE) ns 1.89 (RE) 1.32 (FE) 1.89 (RE)	Fixed and random effects models with a log-linear Cobb-Douglas
Strauss (1986)	Calorie intake	0.33	Nonlinear two-stage least square
Croppenstedt and Muller (2000)	Weight for height	1.90–2.26	Maximum likelihood with Cobb-Douglas Stochastic Frontier Production Function
Ayalew (2003)	Calorie intake	1.47 (IV) 0.55 (FE) 0.21 (RE) ns	Instrumental variables Fixed and random effects models with a log-linear Cobb-Douglas
Audibert and Etard (2003)	Schistosomiasis treatment: binary (0 and 1)	difference between the two groups because of treatment: 0.07 kg/ha (paddy) 0.26 kg/ha/person-day	Generalized linear mixed models for longitudinal data
Fox et al. (2004)	HIV/AIDS infection: binary (0 and 1)	7.1 kg less tea leaf per plucking day	Nonparametric

Source: Authors' compilation.
Notes: FE: fixed effect; RE: random effect; ns: not significant; IV: instrumental variables; kg: kilogram; ha: hectare.

4. ADVANCING ECONOMIC RESEARCH ON HEALTH AND AGRICULTURAL GROWTH: METHODOLOGICAL ISSUES

Measures of Health and Health Care

The most obvious problem in addressing the impact of health care on agricultural development is the divide between health and health care. As pointed out by Strauss and Thomas (1998), there are many potential indicators of health, and they may have different effects on productivity. Filmer, Hammer, and Pritchett (2000) noted that health care spending has only a small impact on health care outcomes such as mortality. Therefore, it is dangerous to assume that health care spending will increase agricultural productivity. Most macro-level studies avoid the issue by measuring the impact of improved health on income, not the impact of increased spending. The question then becomes how to measure health. Some papers examine infant mortality, others examine life expectancy, and others examine adult survival rates. In addition, there is some question as to whether mortality is as important as morbidity in this context. Some papers have attempted to look at the impact of health care on income and on agricultural sector income. Acemoglu and Johnson (2007) looked at the impact of increases in life expectancy on income, but they instrumented for life expectancy with major advances in health technology. Therefore, their test was really a test of the impact of exogenous health care improvements on income. Fan, Hazell, and Thorat (2000) and Zhang and Fan (2004) used spending on health care infrastructure as a measure of health care. In addition, we need to consider that spending on health care is an endogenous choice. If we expect health care spending to improve health, it must be the case that public expenditure is not simply crowding out private expenditure. Indeed, many aspects of health care are largely private goods and therefore would respond inelastically to public provision. People will buy more private goods if the price declines due to government subsidy, but the increase in demand is not necessarily proportional to government spending. In the poorest countries in the world, however, there is little debate on the role of public expenditure in health. Gollin and Zimmerman (2007) developed a model of the impact of malaria on long-run economic growth. Although preventing a malaria infection has positive externalities, it also has a very large private good component. However, the dynamic model of malaria shows that in some poor countries, incomes are so low that the cost of prevention exceeds the benefit. Thus, there are multiple equilibria, with some counties experiencing high incomes and high prevention and others experiencing low prevention and low incomes. Such traps are generally considered fertile ground for outside intervention. For a recent review on the link between malaria and agriculture, see Asenso-Okyere et al. (2009).

Methodology

That income and health are interrelated is beyond question. Higher-income countries have better health, and as incomes grow, health improves. Huffman and Orazem (2007) outlined the evidence for agricultural-led growth as a standard development model through history. According to this standard account, increases in productivity in the agricultural sector release resources (primarily labor and low-cost food) for use in the nascent industrial sector. The process of increased productivity has always been accompanied by increases in the human capital of labor in the agricultural sector. Huffman and Orazem (2007) argued that educational human capital has a greater causal impact on agricultural productivity than health. Nonetheless, this process has always been accompanied by increased health.

Therefore, any macro-level growth or income regression that includes measures of health (usually life expectancy) will show a positive coefficient. However, these regressions cannot establish causality. Health may be determined by income, or income and health may be simultaneously determined by a third input (such as education). Even if we examine health spending, not health itself, it is possible that income drives expenditure; health might be a luxury made affordable only by increases in government budgets.

Authors have taken multiple approaches to address the shortcoming of the standard regression format. These include modeling the impact of health in a framework that explicitly models the other forces acting on income simultaneously (Bloom, Canning, and Sevilla 2004; Fan, Hazell, and Thorat

2000; Zhang and Fan, 2004; Fan, Zhang, and Zhang 2002), model calibration (Gollin and Zimmerman 2007), lagged effects (Fan, Hazell, and Thorat 2000; Zhang and Fan 2004; Fan, Zhang, and Zhang 2002), and instrumental variables (Acemoglu and Johnson, 2007).

In general, the value of these approaches is in the eye of the beholder. In the macroeconomics literature, structural models and models with lagged effects are quite common. In addition, exercises relying on calibrated growth models continue to exert important influence. The advantage of these models and approaches is their feasibility. Country-level panel data on health and income are readily available, and in some countries region-level panel data on health and income are also available. Where data on the underlying mechanisms are absent, models can be calibrated using parameters from microstudies and overall patterns from macrostudies.

In the microeconomics literature, structural models and reduced-form regressions using lagged endogenous variables as instruments are less popular. Increasingly, papers in the applied microeconomics literature rely on quasi-experiments and plausibly exogenous instruments such as those used in Jayachandran and Lleras-Muney (2008) and Acemoglu and Johnson (2007) respectively. The ability of these methods to convincingly isolate causality is one of their strongest points. However, quasi-experiments and exogenous instruments are hard to find. Thus, in general, this literature is forced to look at data from limited countries and time periods, or to use narrow (though strong) instruments. A study by Acemoglu and Johnson (2007) offers a good example of what we call a narrow but strong instrument. This study used the expansion of health technology (antibiotics and vaccines) in the 1930s and 1940s as an instrument for life expectancy. The first stage impact is reasonably strong, but by definition the researchers were studying the impact of antibiotics and vaccines on economic growth, not the impact of health or even of health care on economic growth. Except for the fact that the revolution in such medicines did reduce tuberculosis-related deaths, most of the impact of this exogenous change in health care was concentrated on the very young. This narrow view of health care necessarily restricts its possible impact. Similarly, Jayachandran and Lleras-Muney (2008) were required to take a narrow view in their study of the link between decreased maternal mortality and girls' education. They examined the double difference between girls and boys in areas with large maternal mortality and girls and boys in areas with low maternal mortality and found a very small but significant increase in schooling. However, since the benefits of the educational program were confined to girls in areas with large maternal mortality, this methodology is not really a study of the general equilibrium effects of health improvements.

Thus in general there is a tradeoff between the microeconomists' desire for identification and the macroeconomists' desire to measure the broadest possible impacts, even when both study the same issues with the same data.

The Impact of Health and Health Care on Growth in the Agricultural Sector

Given the issues outlined above, it should not be surprising that studies of the impact of health care produce lower estimates of gains in income and economic growth than do studies of the impact of health. In addition, well-identified studies offer lower estimates of the gains than do broader studies. Here we summarize some of the results from a few representative papers in this field (the list is not exhaustive). Bloom, Canning, and Sevilla (2004) took a production function approach and estimated the impact of increases in physical capital, labor, and human capital on income growth. They assumed that total factor productivity was determined by a country-level trend, and they modeled human capital as being a function of education, experience, and health. They did not attempt to measure health care or expenditures on health care. They found that health was an important component of growth in income. They did not directly address the agricultural sector, and many of the assumptions they made are not particularly conducive to an understanding of agricultural sector growth: in particular, assumptions about labor force participation, the independence of human capital, and total factor productivity. In the agricultural sector, changes in labor force participation are central to the transformation from traditional to modern agriculture, and we suspect more agricultural economists would be eager to measure the link between total factor productivity and human capital.

Acemoglu and Johnson (2007) used much the same data as Bloom, Canning, and Sevilla (2004), but they instrumented for health using the boom in health technology. They found that health care increased life expectancy and eventually income but that the increase in population that accompanied the change in life expectancy left per capita income unchanged. In other words, a health care revolution fails to ignite overall growth. This is a strong negative result, but as discussed above, it covers a relatively narrow definition of health, not one we would expect to have the largest impact on human capital accumulation. Bhargava et al. (2001) examined similar data but focused on the adult survival rate and, not surprisingly, found a stronger impact of health on income.

Fan, Hazell, and Thorat (2000) and Zhang and Fan (2004) examined data from India and China respectively and found that health care expenditures had no impact on rural gross domestic product (GDP), agricultural GDP, or rural poverty. On the other hand, expenditures on roads, education, and agricultural research and development had strong positive impacts.

As discussed above, the fact that public health care spending does not improve income does not mean that health itself does not improve income. However, if we consistently find that health care spending is ineffective but health is effective, it suggests that we have not resolved the causal problem—it is much more likely that health is improving because incomes are improving.

There is reason to believe that health care spending is necessary but not sufficient to cause health to improve. Investment in facilities, medicines, and doctors may have little direct payoff if it is not associated with improvements in education or transportation. However, investments in transportation or education by themselves would not lead to improvements in health. The fact that these investments are tied to each other makes it difficult to measure the direct impact of health investments.

For example, there is every reason to believe that spending on roads directly increases the value of public health facilities. Klemick, Leonard, and Masatu (2007) showed that in rural Tanzania improvements in roads had a larger impact on health care access than improvements in health facilities because travel costs were one of the major impediments to health care access. 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 non-project villages (Hettige 2006). Travel time to health services was three times lower in project sites, and households were more likely to travel to medical facilities by bicycle or automotive transport than by foot. Households in non-project villages were twice as likely to use traditional healers or stay home in a medical emergency instead of seeking care at a modern facility. Travel times to hospitals and pharmacies declined significantly in Vietnamese villages with rural road projects relative to control villages (van de Walle and Cratty 2002). Visits to health facilities doubled in Moroccan villages after rural roads were paved (World Bank 1996). Improved road infrastructure can also boost staff attendance at rural facilities, improving health care availability through another channel (Hettige 2006).

Thus, whether health increases productivity or not, improvements in education, research and development, and transportation appear to have positive marginal impacts on productivity, maybe because they also increase health, maybe because they increase income.

5. MACRO-LEVEL AND GENERAL EQUILIBRIUM EFFECTS: HEALTH AND ECONOMIC GROWTH, HEALTH AND AGRICULTURAL PRODUCTIVITY

The evidence from some micro-level studies suggests that inexpensive health interventions can have a very large impact on labor productivity. For example, Basta et al. (1979) studied Indonesian rubber workers given 100 milligrams of iron a day for 60 days. Not only did their work effort improve during the intervention, but the increased earnings and nutritional intake enabled the workers to permanently increase their caloric intake, blood iron levels, and income. This is a remarkable transformation for an intervention with almost no cost. Many health interventions have been shown to have immediate impacts on health and thereby on labor productivity, suggesting that the overall impact of health interventions must be very large. Similarly, Hoddinott et al. (2008) found that boys who participated in a randomized nutrition intervention during conception and in their first two years of life earned wages as adults that were 50 percent higher than those of nonparticipants.

Much has been made of the possibility of a micro-level health poverty trap. If the wage rate reflects productivity and the worker has a low enough caloric intake that changes in calories will affect productivity, then it is possible to have two equilibria. In the first, the worker earns a high wage and consumes sufficient calories. In the second, the worker earns a low wage and consumes insufficient calories, leading to low productivity and a low wage. This possibility is attractive because a one-time intervention (such as the iron supplement mentioned above) can move the worker from the low equilibrium to the high equilibrium.

This health poverty trap has proven to be a very attractive concept at the macro level as well because it suggests that a sufficiently large intervention in the economies of poor countries will permanently eliminate country-level poverty and, importantly, that anything short of this sufficient level is doomed to failure. Evidence for the existence of such traps at either the micro or the macro level, however, is thin at best.

The evidence at the macro (country and global) level is likewise mixed at best and in some cases suggests that health care interventions have no impact on income, much less agricultural productivity. In this section, we review this macro-level evidence, paying close attention to differences in methodology and definitions. In particular, there is no consensus as to the appropriate lag to expect between an improvement in health care and an improvement in income or productivity. Whereas the microstudies show improvements within weeks, some macrostudies expect the maximum impact of a health intervention to occur 40 years later. Thus, we begin with an overview of the possible general equilibrium effects over the intermediate term, long term, and very long term. Second, we turn to the measures of economic growth used in the literature, examining their applicability to the agricultural sector. Third, we look at the measures and proxies used for health and health care, tying these to the potential gains outlined in the discussion of the general equilibrium impacts of health care. Fourth, we look at the various methods used to identify the impact of health care programs, including lagged variables, simultaneous equations, and instrumental variables. To conclude this section, we summarize the evidence for a link between health and agricultural productivity and for a link between health care and agricultural productivity.

General Equilibrium and Long-term Effects of Health Care Improvements

Microstudies of health and agricultural productivity focus, necessarily, on the immediate and intermediate impacts of health improvements. Thus, as discussed in the previous sections, healthy people can work longer hours and can engage in new activities once they realize that the health gains are relatively permanent. On the other hand, the macro-level analyses of health and health care focus on the long-run and very long-run impacts of health care measures. Here we will think of long-run impacts as being one-generational—that is, changes in the decisions made and outcomes experienced by individuals once they realize that their expected lifetime health experience has changed. Very long-run impacts will be intergenerational decisions—that is, changes in the decisions made by parents once they realize that their children's (and potential children's) expected lifetime health experience has changed.

Long-run Impacts of Health Care Improvements

As we have noted, improvements in health care increase the productivity of labor, especially if healthy people switch from low-productivity jobs to high-productivity jobs as their health improves. In addition, since the standard Mincerian regression shows strong returns on experience, we should expect incomes to grow simply because people live longer and therefore have, on average, greater workplace experience, even if there are no other changes in human capital (Schultz 1997; Bloom, Canning, and Sevilla 2004). Improvements in health experienced during childhood can have a lasting impact on the level and rate of depreciation of human capital. Healthy children have better cognitive abilities and grow into taller and generally healthier adults. In particular, there is strong evidence that economic growth in early industrialized countries was associated with significantly increased caloric intake, which produced greater height and body mass index (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 on further investments in human capital. This is particularly true of increases in life expectancy; people who expect to live longer earn their returns on education over a longer period of time. Jayachandran and Lleras-Muney (2008) reported that decreases in maternal mortality led Sri Lankan girls to stay in school longer; the reduced probability of dying in childbirth increased the returns on schooling by increasing life expectancy for girls. Although it is rare to be able to identify such effects in an empirical study, one would expect this effect to be strong for both genders and over a broad range of human development experiences.

Very Long-run Impacts of Health Care Improvements

The process of long-run economic growth is associated with decreased fertility and increased investment in the human capital of children—a choice to move from quantity to quality. Thus, there is a potentially important role for health care in this process. If one of the long-run impacts of improved health is an increase in human capital investment and thus the quality of children, then the very long-run impact will be a decreased fertility rate.

Although improved health may be part of this process, it is not clear that health can, by itself, set such a process in motion. Whereas one of the long-run impacts of improved health is increased human capital investment, another impact is an increase in population growth and potentially an increase in fertility. In a Becker quality-quantity model (Becker and Nigel 1976), increased childhood survival, for example, was equivalent to reducing the cost of quantity because a woman would experience fewer pregnancies per surviving child. Thus, not only would a decline in infant mortality increase the number of surviving children, but average fertility would possibly increase. Bleakley (2007) pointed out that the coefficients estimated by Acemoglu and Johnson (2007) were evidence of exactly this impact. Immediately following an exogenous decrease in infant mortality, the birthrate in low-income countries increases, staying above its previous level for somewhere between 10 and 20 years. After this point, it declines below its previous level, but because the population has increased, the total number of births remains above its historical level for about 40 years. Thus, in the very long run, there are two competing pressures on fertility. Whereas families are likely to choose lower fertility when they can invest in the quality of their children (through education, for example), they may continue to choose quantity if the cost of quality remains high. This suggests that improvements in health care may have more positive long-run impacts when they are paired with improvements in other forms of human capital, such as education, than by themselves, a point to which we will return below.

Measures of Economic Growth and Their Application to Agriculture

Most studies of the link between health and economic growth focus on overall growth, not on growth in the agricultural sector. Given the need for a long time series and the paucity of high-quality data on the agricultural sector for most countries, this is largely unavoidable. Thus, most studies focus on gross domestic product (GDP) and GDP per capita. To the degree that improvements in the agricultural sector are necessary to produce growth in GDP for the poorest countries in the world, GDP may not be a poor proxy for agricultural sector productivity. Nonetheless, the modeling choices often made reflect a bias toward the industrial sector rather than the agricultural sector. For example, Bloom, Canning, and Sevilla (2004) modeled the impact of human capital after controlling for labor inputs and assumed that the labor input is zero for people who are not in the labor market. In a rural economy, it would be much more difficult to measure labor inputs using such an assumption. Huffman and Orazem (2007) pointed out that female labor force participation changes significantly over the course of modernization. In poor, rural societies, female labor force participation is almost 100 percent, albeit in non-wage, agricultural activities. As the rural sector develops, women participate less and less in the market. However, they return to the urban or industrial labor market in the later stages of development. The proportion of women in agricultural production and postharvest activities ranges from 20 percent to 70 percent (GreenFacts, 2008) women's involvement is increasing in many developing countries, particularly with the rise of export-oriented irrigated farming, which is associated with a growing demand for female labor, including migrant workers. Thus, in the rural sector, labor force participation is an indicator of economic development and potentially of health, and it is not clear that its impact should be modeled separately from improvements in health care.

6. CONCLUDING REMARKS

This review reveals a great deal of heterogeneity in terms of estimation methods, definition and measurement of health variables, choice of economic outcomes, single-equation versus multiple-equation methodology, and static versus dynamic approaches. The actual magnitude of estimated elasticities is difficult to assess in part due to estimation bias caused by the endogeneity of health outcomes. Most of the studies fail to account for the cost of investment (especially at farmer level) in achieving the level of health required for sustainable agricultural productivity. Not factoring out the cost of health investment makes it difficult to assess the net magnitude of estimated marginal impact of change in health on agricultural productivity, wage, or income.

The evidence at the macro (country and global) level, however, is mixed at best and in some cases suggests that health care interventions have no impact on income, much less agricultural productivity. If the poorest countries of the world follow the development path of most industrialized economies, increases in the productivity of the agricultural sector will precede those of the industrial sector. In such a case, it would be preferable to study the impact of health in the agricultural sector by looking for evidence that health helps to jump-start the development process.

The literature at both macro and micro levels presents some significant gaps. Hence, very little attention is given to demand for health inputs by rural populations and farmers. This includes the issues of dynamics, externalities, and information gaps that might lead to the observed low levels of demand. More research is needed to understand consumer perceptions and understanding of health risks and health phenomena. Benchmarking the productivity effects of health by various health instruments such as prevention (immunization, screening, and so on), health protection (water sanitation, precautions against specific diseases, and so on), positive health education (training farmers in the use of pesticides, and so on) is also a policy-relevant research agenda. What specific crops or groups of crops yield the highest productivity impact from health investments? Research-based responses to this question should help improve policy interventions. Finally, investments in improved data, particularly longitudinal comprehensive surveys with good measures of health status and agricultural productivity, are likely to improve our understanding of the topic.

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