Social Services, Water Access, and Agricultural Productivity in Sub-Saharan Africa

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Summary

In sub-Saharan Africa, public resource allocation in social service sectors can be particular important in that low levels of development can make private services inaccessible for much of the population. In addition, short-term social services needs often compete with longer-term growth enhancing investments for limited government funds. However, the analysis and understanding of the agricultural productivity effects from the provision of social services has been severely limited by data constraints and the need to control for a variety of related factors. Given the importance of agriculture for rural incomes, a better understanding of the effects on agricultural productivity from the provision of a variety of social services is important for allocating spending that will not only support short-term needs but also longer-term growth in rural areas.

Despite the limited data availability, previous analyses have been conducted regarding the role of public expenditures on rural poverty. Often, this is limited to one sector or overall rural incomes rather than agricultural productivity. In addition, these analyses often assume homogeneous production technology and do not account for climatic variations driving production. Expanding on the work that has been done previously, we analyze multiple expenditure sectors, allowing heterogeneity in the underlying socio-economic and agro-climatic environment. This research estimates the impact of public expenditures on agricultural productivity across countries of sub-Saharan Africa and then, specifically in the case of Tanzania. Furthermore, given the limited funding available for the water sector in Tanzania, it looks specifically at water constraints at the household level and how this may constrain agricultural productivity.

In an effort to estimate the impacts of public expenditures on agricultural productivity, the first part of the analysis explores the existing data for sub-Saharan

Africa, using a cross-country regression framework. It exploits multiple analytical options while including a newly-compiled dataset on annual precipitation for agricultural land. While our conclusions are substantially limited by the data constraints, this analysis conducts an efficiency analysis for the group of sub-Saharan African countries using health and educational outcomes as indicators of social service availability. It also implements a latent variable structural equation framework for a subset of countries, allowing not only for country-specific heterogeneity but also more direct estimation of the role of social service expenditures covering multiple sectors. Overall, the results provide evidence that public service expenditures (especially on health and education) can influence input productivity and efficiency in agriculture. Country-specific heterogeneity and climate-related variables appear to be a significant consideration for agricultural production in sub-Saharan Africa that should not be ignored.

In the remaining sections, we focus on Tanzania in particular. We begin with an investigation of the impacts of district-level health and education expenditures on marginal productivities of agricultural inputs and overall production. The results of our latent variable, covariance structural model confirm the significance of government social expenditures in human capital formation as measured through health and education indicators. The results also show the effects of these health and educational outcomes on agricultural productivity. We find that the marginal productivities of inputs (labor in particular) respond significantly and positively to health and education outcomes, especially when health and education are considered jointly. The impacts also seem to be a function of the type of health constraint, with short-term health factors such as malaria and diarrhea impacting productivity of seeds and fertilizer. In contrast, longer-term health problems (i.e., chronic diseases) appear to have greater impacts on labor quality and land productivity. The results also suggest that there is a minimum level of expenditures per capita needed to see an impact on educational or health outcomes. The results confirm the importance of considering intra-country heterogeneity as well as climate-related constraints, as the results demonstrate that annual precipitation has a significant impact on production for all specifications.

For the final part of the research, we focus on the water sector in Tanzania, given that public spending in this sector is very limited. For this analysis, we rely upon primary household survey data collected in four regions of Tanzania to investigate the impact of drinking water access on agricultural productivity at the household level. As in many parts of sub-Saharan Africa, a lack of sufficient and safe drinking water is a health constraint in rural Tanzania. Although the water sector has been prioritized in poverty-reduction efforts, water collection time has been overlooked in many studies addressing productivity and incomes. Using a production function approach, we estimate the impact of drinking water collection times on agricultural labor availability, labor productivity, and yields. The results show that additional time required to access drinking water significantly reduces household labor productivity and yields for households that have to spend more than the median time (20 minutes) collecting water. In these households, the time needed to collect water appears to serve as a more significant constraint to labor productivity than the quality of the water at the source. This effect remains consistent even after controlling for heterogeneity among households, crop diversity, and districts. The relative importance of other productive inputs also changes with increased time needed for water collection. Our results support further consideration of the time required for water collection when planning rural development initiatives.

Overall, this research has highlighted the important data limitations and the confounding constraints that can hinder analysis of the impacts of public expenditures on agricultural productivity. In order for governments to efficiently target limited funds, a more comprehensive understanding of the direct and indirect impacts of these expenditures on farm-level decisions and constraints will be necessary. Further data sharing among agencies and working across ministries is needed in order to o meet common goals for long-term growth while addressing more immediate social needs. The findings here suggest that social expenditures can also positively impact agricultural productivity and these impacts should be further explored in making funding decisions.

In addition to emphasizing the need for additional data, this research has other important policy implications. It points to the importance of providing sufficient levels of expenditures in order to influence health and education outcomes and the importance of recognizing context-specific needs given the heterogeneity between countries even within a country. In addition, this research has provided strong evidence of the importance of water-related constraints (both precipitation and household access to water) that seem to support not only consideration of these constraints but also funding of measures that may reduce vulnerability.

Zusammenfassung

Die Verteilung der staatlichen Mittel zur Finanzierung von Sozialleistungen ist besonders wichtig in Sub-Sahara Afrika, da die immer noch hohen Armutsraten dazu führen, dass private Anbieter für einen großen Teil der Bevölkerung nicht bezahlbar sind. Zusätzlich stehen kurzfristigen Sozialausgaben dabei auch in Konkurrenz zu Investitionen die langfristig das Wachstum verbessern. Dennoch sind Analysen und das Verstehen landwirtschaftlicher Produktivitätseffekte durch staatlich bereitgestellte Sozialleistungen stark begrenzt durch Datenprobleme und die Notwendigkeit, für eine Vielzahl von damit verbundenen Faktoren zu kontrollieren. Da speziell im ruralen Raum der landwirtschaftliche Sektor eine wichtige Einkommensquelle darstellt, ist es wichtig, dass die Wirkungen der staatlichen Ausgaben für Sozialleistungen auf die landwirtschaftliche Produktivität besser verstanden werden. Die Mittelverteilung kann dabei nicht nur kurzfristige Bedürfnisse im Bereich Gesundheit und Bildung erfüllen, sondern auch zu langfristigem Wachstum führen.

Trotz der begrenzten Datenverfügbarkeit, wurden schon in der Vergangenheit Analysen zur Rolle von Staatsausgaben für die rurale Armut durchgeführt. Oft sind diese begrenzt auf einen Sektor, beziehen alle ruralen Einkommen ein und fokussieren sich nicht auf die landwirtschaftliche Produktivität. Zusätzlich, werden oft homogene Produktionstechnologien vorausgesetzt und klimatische Unterschiede, die die Produktion beeinflussen, werden nicht beachtet. Auf diesen früheren Untersuchungen aufbauend, untersuchen wir verschiedene Sektoren und lassen eine Heterogenität der zugrundeliegenden sozio-ökonomischen und klimatischen Umwelt zu. Diese Studie schätzt erst den Einfluss von Staatsausgaben auf die landwirtschaftliche Produktivität länderübergreifend in Sub-Sahara Afrika. Danach ist nur Tansania im Fokus der Analyse zur Wirkung von Sozialleistungen auf die landwirtschaftliche Produktivität. Weiterhin

wird in der abschließenden Untersuchung, die sich auch ausschließlich auf Tansania bezieht, der Einfluss der Wasserversorgung der Haushalte auf die landwirtschaftliche Produktivität analysiert.

Um den Einfluss der Staatsausgaben auf die landwirtschaftliche Produktivität zu schätzen, werden im ersten Teil der Analyse bestehende Haushaltsdaten für Sub-Sahara Afrika im Rahmen einer länderübergreifenden Regression untersucht. Es werden verschiedene analytische Möglichkeiten und außerdem ein neu zusammengesetzter Datensatz zu jährlichem Niederschlag auf dem Land genutzt. Obwohl Datenrestriktionen die Analyse und die möglichen Rückschlüsse aus dieser beträchtlich einschränken, wird eine Effizienzanalyse für die Länder in Sub-Sahara Afrika durchgeführt, in der Gesundheits- und Bildungsresultate die Indikatoren für die Verfügbarkeit von Sozialleistungen sind. Es wird außerdem ein Strukturgleichungsmodell mit latenten Variablen für eine Teilgruppe von Ländern implementiert, wo sowohl für länderspezifische Heterogenität kontrolliert wird als auch eine direktere Schätzung der Rolle der staatlichen Sozialleistungsausgaben durchgeführt wird, die verschiedene Sektoren abdeckt. Generell, unterstützen die Ergebnisse die Hypothese, dass Staatsausgaben für Leistungen gerade im Bereich Gesundheit und Bildung die Produktivität der Inputs und die Effizienz in der Landwirtschaft beeinflussen. Länderspezifische Heterogenität und Variablen, die mit dem Klima zusammenhängen, sind wichtige Faktoren für die landwirtschaftliche Produktion in Sub-Sahara Afrika, die in solchen Schätzungen nicht vernachlässigt werden sollten.

In den verbleibenden Teilen konzentriert sich die Analyse auf Tansania im Speziellen. Es werden die Effekte von Gesundheits- und Bildungsausgaben auf Distriktebene auf die Grenzproduktivitäten von landwirtschaftlichen Inputs und die gesamten Produktion untersucht. Die Ergebnisse des Strukturgleichungsmodels mit latenter Variable bestätigen die signifikante Wirkung von staatlichen Sozialausgaben für die Humankapitalbildung, gemessen mit Gesundheits- und Bildungsindikatoren. Die Ergebnisse zeigen auch Effekte von Gesundheits- und Bildungsresultaten auf die landwirtschaftliche Produktivität. Die Grenzproduktivität der Inputs, besonders Arbeit, reagiert signifikant und positiv auf Gesundheits- und Bildungserfolg, speziell wenn Gesundheit und Bildung gleichzeitig betrachtet werden. Die Einflüsse scheinen auch von der Wahl des Gesundheitsindikators abhängig zu sein, wobei kurzfristige Gesundheitsfaktoren wie Malaria und Durchfall die Produktivität von Saatgut und Dünger beeinflussen. In Gegensatz dazu haben langfristige Gesundheitsprobleme (z.B. chronische Krankheiten) scheinbar einen größeren Einfluss auf Arbeitsqualität und Landproduktivität. Die Ergebnisse weisen darauf hin, dass es ein Mindestniveau von Pro-Kopf-Ausgaben gibt, um zu einem Einfluss auf Bildung und Gesundheit zu führen. Es wird bestätigt, dass es wichtig ist, sowohl die Heterogenität innerhalb eines Landes als auch die klimatischen Besonderheiten mit einzubeziehen. Die Ergebnisse zeigen, dass der jährliche Niederschlag einen signifikanten Einfluss auf die Produktion in allen Modelspezifikationen hat.

Für den letzten Teil dieser Studie, konzentrieren wir uns auf den Wassersektor in Tansania, angesichts der Tatsache, dass öffentliche Ausgaben in diesem Sektor sehr begrenzt sind. Für diese Analyse nutzen wir Primärdaten auf Haushaltsebene, die in vier Regionen Tansanias gesammelt wurden, um den Einfluss von Zugang zu Trinkwasser auf die Produktivität des Haushalts in der Landwirtschaft zu untersuchen. Wie in den meisten Regionen von Sub-Sahara Afrika sind auch im ländlichen Tansania die Verfügbarkeit von Wasser und die Qualität des Trinkwassers wichtige Determinanten für den Gesundheitszustand der Bevölkerung. Obwohl Wasser im Zentrum der armutsreduzierenden Bemühungen steht, wurde die Zeit, die für das Wasserholen benötigt wird, in vielen Studien zu Produktivität und Einkommen vernachlässigt. Mit einem Produktionsfunktionsansatz schätzen wir den Einfluss von der für das Wasserholen benötigten Zeit auf die Verfügbarkeit und Produktivität von landwirtschaftlicher Arbeitskraft, und die Erträge. Die Ergebnisse zeigen, dass zusätzliche Zeit, die fürs Wasserholen benötigt wird, signifikant die Arbeitsproduktivität des Haushalts und die Erträge verringert, wenn die Haushalte mehr als den Median (20 Minuten) zum Wasserholen benötigen. In diesen Haushalten hat die Zeit, die fuer das Wasserholen benötigt wird, augenscheinlich einen größeren Einfluss auf die Arbeitsproduktivität als die Qualität des Wassers selbst. Dieser Effekt bleibt auch bestehen, wenn für Heterogenität zwischen Haushalten, Anbaupflanzen und Distrikte kontrolliert wird. Die relative Wichtigkeit anderer produktiver Inputs verändert sich auch, umso höher die Zeit ist, die für das Wasserholen benötigt wird. Folglich ist es wichtig, die Zeit für das Wasserholen zu beachten, wenn ländliche Entwicklungsprojekte geplant werden.

Insgesamt hat diese Studie hervorgehoben, dass Einschränkungen wegen Datenproblemen und aus anderen Gründen, die Wirkungsanalyse von öffentlichen Ausgaben auf die landwirtschaftliche Produktivität behindern können. Damit Regierungen ihre beschränkten Mittel effizient und gezielt einsetzen, ist es notwendig ein vollständigeres Verständnis für die direkten und indirekten Effekte zu haben, die Staatsausgaben auf die Entscheidungen der Landwirte haben und welche Einschränkungen existieren. Daten sollten zwischen verschiedenen Akteuren geteilt werden und Ministerien eng zusammenarbeiten, damit gemeinsame Ziele erreicht werden, die zu langfristigem Wachstum führen und gleichzeitig wichtige unmittelbare soziale Bedürfnisse erfüllen. Unsere Ergebnisse machen deutlich, dass Sozialausgaben in unseren Daten positive Wirkungen auf die landwirtschaftliche Produktivität haben. Diese

Wirkungen müssen weiter untersucht werden, um hilfreiche Entscheidungshilfen für die zukünftige Mittelvergabe zu liefern.

Zusätzlich zur Verdeutlichung des weiteren Forschungsbedarfs hat diese Untersuchung auch politische Implikationen. Sie zeigt die Wichtigkeit eines Mindestniveaus von staatlichen Ausgaben, damit der Gesundheitszustand und die Bildung beeinflusst werden können. Außerdem ist es auch wichtig kontextspezifische Bedürfnisse zu beachten, angesichts der Heterogenität zwischen Ländern oder sogar innerhalb von Ländern zu beachten. Zusätzlich ist in dieser Untersuchung die Wichtigkeit von wasserbedingten Beschränkungen (Regen und der Zugang zu Wasser) verdeutlicht worden. Der Zugang zu Wasser muss somit weiter in den Fokus rücken und Maßnahmen finanziert werden, die diese Probleme reduzieren können.

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Abbreviations

CIA	Central Intelligence Agency
DEA	Data Envelopment Analysis
DPT	Diphtheria, Pertussis, and Tetanus
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
HDI	Human Development Index
HIV	Human Immunodeficiency Virus
IFPRI	International Food Policy Research Institute
IMR	Infant Mortality Rate
MOHSW	Ministry of Health and Social Welfare (Tanzania)
NBS	National Bureau of Statistics (Tanzania)
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Association
OLS	Ordinary Least Squares
RE	Random Effects
REPOA	Research on Poverty Alleviation
SEM	Structural Equation Model
SFA	Stochastic Frontier Analysis
TFP	Total Factor Productivity
TB	Tuberculosis
TSH	Tanzania Shillings
UN	United Nations
WDI	World Development Indicator

1. General Introduction

Agricultural productivity in many countries of sub-Saharan Africa is limited when compared to other regions of the world. Growth in agricultural productivity and incomes has been limited partly due to climate-related constraints, lack of assets such as land, constraints to health and education (World Bank, 2008), infrastructure (UN HABITAT, 2011) and economic policies that have not fostered sustainable growth in many countries (Ndulu et al., 2007). In general, when compared to other regions, the public sector in sub-Saharan Africa provides less overall infrastructure than developing countries in South Asia, Latin America, or the Middle East and North Africa, creating a challenge for economic development and poverty reduction there (UN HABITAT, 2011). Increased public investment and more efficient public allocation are considered necessary for economic growth in this region (Fosu et al., 2012).

The lack of public services[1] can limit growth in multiple ways. For example, insufficient levels of infrastructure for transportation and communications can greatly reduce access to markets, substantially limiting income and economic opportunities, both on- and off-farm (UN HABITAT, 2011). Inadequate provision of health or educational services can also limit economic opportunities and incomes. For example, health problems and associated costs incurred have been found to impair farmers' willingness and ability (financially or physically) to incorporate new technologies, as well as lead to a loss of productivity due to the time needed to care for sick family members (Asenso-Okyere et al., 2011; Drimie, 2002). Likewise, public investments in education have also been shown boost economic competitiveness (Ndulu et al., 2007). Any factor that influences the agricultural sector can greatly impact the overall economy of rural areas. It is estimated that a one percent increase in overall yields (value-added per acre) could

[1] Throughout the text, "public expenditures" is used to describe generally, government spending on social or economic sectors, while the term "social services expenditures" is used to describe more specific social expenditures (i.e., health and education spending).

reduce the number of people living under US$1 per day by more than six million (of which 95 percent in Africa and Asia) (Thirtle et al., 2003). Therefore, it is important to understand these constraints in rural areas and the most effective methods for addressing them through government support programs.

1.1 Social Services and Agricultural Productivity in sub-Saharan Africa

In general, analysis of public investment needs for sub-Saharan Africa is very limited (Fosu et al., 2012) although it is a region where social service provision can be particularly important. Public resource allocation in a number of social service sectors is often necessary due to market failures and low levels of development (Mogues et al., 2011). For farmers in developing countries, public-sector provision for these short-term or ongoing social needs is crucial as they often do not have the resources or options that would allow them to reduce their risk of (and vulnerability to) health shocks. Given that poor households may be very dependent on public services, public spending on health may play a more important role in the lives of the poor and in low-income countries (Gupta et al., 2003). However, efforts to accelerate long-term economic development in much of Africa can be hindered by the need to use scarce resources to address the immediate symptoms of poverty rather than making investments that could increase production and incomes (Badiane & Ulimwengu, 2009).

Factors such as climate change and output and input price volatility will affect agricultural productivity and incomes, especially in sub-Saharan Africa (UNCTAD, 2012). These may shift both short-term and long-term constraints substantially, making it increasingly important to understand the mechanisms through which short-term assistance can be achieved without compromising more long-term growth or sustainability. This research strives to identify social services expenditures that have significant impacts on agricultural productivity in sub-Saharan Africa, given the importance of agricultural production for rural livelihoods. Such research is important in helping resource-constrained, agriculture-based economies allocate public resources most efficiently and effectively to meet both short-term poverty reduction and longer-term growth objectives.

1.2 Problem Statement

As mentioned, there are a number of socioeconomic, political, and environmental constraints that contribute to the slow growth of agricultural productivity in sub-Saharan Africa (Ehui & Pender, 2005), and efforts to increase public investments have often not had the desired effect on poverty (Anderson et al., 2006). This can be due to corruption, insufficiency of funds, improper targeting, or a number of other reasons. Changes in the broader economic structure will likely be needed to result in changes to agricultural productivity in many African countries (Morgan & Solarz, 1994). Despite the challenges, there have been indications that positive changes are possible. When implemented properly, policy changes that enhance availability and quality of infrastructure services for the poor can have a significant effect on health, education, and incomes of rural populations (Calderón & Servén, 2004). Pro-poor expenditures (such as public health spending) can have an impact on welfare, especially in areas with low levels of development (Gomanee et al., 2003). Positive changes in welfare can lead to not only short-term benefits, but also longer-term growth in agricultural productivity and incomes.

There have been multiple empirical analyses of the effects of public spending on overall economic growth. The literature on this topic documents the complexity inherent in understanding the relationship between government spending and economic growth, including endogeneity, heterogeneity across countries, and the inexact estimates of public services, growth, and savings (Barro, 1990). For agriculture specifically, there has been limited analysis regarding the effect of public expenditures on agricultural productivity; from the analyses that do exist, the effect is not clear (Reinikka & Svensson, 2002).

Many of the previous analyses regarding the impact of particular types of social services have also looked at the sectors in relative isolation. For example, previous research has found that one year of education is associated with a 3 to 14 percent increase in wages and productivity in sub-Saharan Africa (Appleton, 2000). The impact of increased health on rural incomes has also been established (Strauss & Thomas, 1998). These programs often have complementary effects. In Ethiopia, for example, it was found that social transfers alone had little impact on poverty levels, but that transfers in combination with agricultural support had greater impacts on food security and overall income in these areas (Gilligan et al., 2008).

Unfortunately, programs to increase social service availability often compete for limited central government funds. The optimal allocation of expenditures across subtypes of services has not been analyzed in detail despite the need for investments in short-term poverty alleviation that do not compromise agricultural productivity over the longer term (Badiane & Ulimwengu, 2009). The biggest constraint hindering this understanding of the impact of expenditures on productivity is a lack of sufficient data. Of course, the extent of data that exists varies between regions and particular conclusions for sub-Saharan Africa are more limited in the literature than for other regions such as Asia or Latin America. In addition, while public spending data could be considered the most direct measurement of public expenditures in particular types of social services, it can be an imprecise measure for use in evaluating the effect of infrastructure on poverty in cross-country analysis (UN HABITAT, 2011). The analysis that follows uses the most comprehensive available data and builds upon the studies that do exist for the assessment of the poverty and growth impacts of agricultural research and infrastructure investments in Asia (e.g., Fan et al., 2002).

Focusing on Tanzania in particular, the majority of the poor population there is located in rural areas and dependent upon agriculture for their livelihood, as in many sub-Saharan African countries. In Tanzania, around 80 percent of people are employed in agriculture (Cleaver et al., 2005). Unfortunately, Tanzania appears to have very low poverty-growth elasticity over time, and economic growth has not translated into a steep decline in poverty (Pauw & Thurlow, 2010). The government has striven to address poverty through investments in various social services including public health and education, agricultural extension, and infrastructure, and while it appears some positive changes in health and education indicators have taken place, there are still challenges in terms of staff, funds, and infrastructure as well as large differences between rural and urban areas (REPOA, 2006).

As with many other sub-Saharan African countries, water access also remains an important household-level constraint in Tanzania. Although Tanzania has the highest natural water storage capacity in Africa, nearly 80 percent of the population is extremely vulnerable to climatic variation (van den Berg et al., 2009). Water-related constraints can have significant impacts on incomes and food security, impacting households' decisions both on- and off-farm. Access to water has been shown to stabilize incomes, increase efficiency of other inputs, and open up production alternatives (such as into higher-value products) (Namara et al., 2010; Crow et al., 2012). Water use at the household level includes drinking, sanitation, bathing, and cooking as well as hand-delivered irrigation and livestock watering, affecting income directly in addition to contributing to increased education and health possibilities (Moriarty et al., 2004). In rural Tanzania, in particular, water is primarily used for domestic consumption, with most households dependent on canals fed by rivers (Aikaeli, 2010). This highlights the importance of surface water for not only agriculture but also household water needs.

1.3 Objectives of the Study

Building on the knowledge gained from prior analyses, this project will contribute to a better understanding of the mechanisms through which social services impact productivity and its' potential to enhance overall growth. Even with constant spending amounts, it is the aim that the information attained would assist in achieving greater impacts to income and improved cooperation between agriculture and social service ministries. Given the uniqueness of African agriculture and the diversity of government structures within the continent, this research focuses only on the lesser-developed countries of sub-Saharan Africa. The research first focuses on regional, country-level data before moving to more specific expenditures and indicators for Tanzania in particular.

The specific objectives of this study are as follows:

1. Analyze the data that exists for sub-Saharan Africa regarding social service expenditures and health and education indicators and use this to analyze the role that these may play in cross-country agricultural productivity differentials.
2. Focusing on Tanzania in particular, estimate the importance of health and education spending on health and education indicators and how this may impact the variation in agricultural productivity across districts.
3. Given the limited funding for and the importance of water in particular for rural households in Tanzania (as it was consistently labeled as the biggest

constraint faced), analyze the role of water access for household labor productivity and yields.

1.4 Outline of the dissertation

The remaining chapters of this dissertation expand upon the topic of social services and productivity for sub-Saharan Africa using a variety of datasets and methodological approaches. Chapter 2 provides an overview of the data limitations for sub-Saharan Africa and presents a stochastic frontier analysis to estimate the impacts of social services on agricultural production efficiency in sub-Saharan Africa. Using a structural equation approach and a subset of countries for which government expenditure data has been recently made available for a range of sectors, it also provides an analysis of the impacts of these expenditures on productivity.

The remainder of the analysis focuses on Tanzania as a case study, to allow a more detailed analysis. Chapter 3 uses recently available production data and a structural equation. This model includes latent variable estimations to evaluate the impact of government expenditures on health and education outcomes as well as the related impacts on overall agricultural productivity and input productivity at the district level. Chapter 4 briefly describes a household survey conducted in Tanzania in 2010-2011 (covering 498 households) and relies upon this data as well as a household level production function to analyze the impacts of water access constraints in particular given the limited funding for these types of projects in the region. Finally, Chapter 5 presents overall conclusions and policy implications that result from the research.

2. Cross Country Productivity and Social Services

2.1 Introduction

Cross-country studies evaluating the impacts from infrastructure and public services often focus on impacts in terms of Gross Domestic Product (GDP) or social indicators such as the Human Development Index (HDI) or Infant Mortality Rate (IMR) rather than agricultural productivity. In sub-Saharan Africa, where most of the population is employed in agriculture, understanding the impacts of particular spending decisions and associated outcomes on agricultural production may help leverage resources in ways that can better address the needs of rural economies.

In general, for sub-Saharan Africa, the effects of particular government expenditures on productivity remain unclear due to a lack of comprehensive analyses. MacNamara et al. (2010) document, for example, the mixed results from the provision of health services on labor productivity in Africa. However, it is unclear if these mixed results are due to the lack of a causal link or more a product of improper targeting, insufficient funds, or incomplete or inadequate analysis. Even the relatively direct evaluation of the impacts of aggregate education and health spending on social indicators has produced mixed results, at least partially due to inefficient distribution of funds (Gupta et al., 2002; Mosley et al., 2004). Adding the additional component of how these indicators may affect production can further complicate the analysis.

Given the complexity and data constraints for sub-Saharan Africa, we exploit multiple analytical options to estimate the role of social services in input efficiency for agricultural production. We also control for climatic conditions using a newly-compiled dataset on annual precipitation for agricultural land. The chapter is outlined as follows: Section 2.2 provides an overview of the previous cross-country analyses; Section 2.3 includes the methodological and empirical background for both empirical approaches taken with the data; Section 2.4 gives an overview of the data used, Section 2.5 provides the efficiency estimation results; Section 2.6 provides the structural equation results, and Section 2.7 discussions the conclusions and brief policy implications.

2.2. Methodological Background

Analysis of productivity growth across countries is well-established in the literature. The first study of its type (Bhattacharjee, 1955) relied upon FAO data from 22 countries for which sufficient data was available. However, many other cross-country productivity analyses are not able to include many African countries given the lack of data available for this region over time. In addition, most of these analyses do not account for public expenditures or social services, focusing only on physical inputs and outputs from a production perspective. A thorough review of general agricultural productivity research specifically for sub-Saharan Africa can be seen in Block (2010).

As shown in the productivity literature, factors such as fertilizer, labor, land, and mechanization (i.e. use of tractors or animals) remain crucial inputs for agricultural production. However the roles of these inputs and climatic conditions can vary substantially between regions. For example, O'Gorman and Pandey (2010) note that in the developing world, inequality in agricultural labor productivity has become more pronounced over the past 40 years (partially attributed to improved seed varieties). Farmers in countries of sub-Saharan Africa are, in general, not as well-equipped as farmers in other regions to respond to (or control for) instability in factors of production such as rainfall or market prices in inputs or outputs. Biophysical conditions such as soil quality and precipitation can also have indirect impacts to production due to their influence on historical agricultural production systems and infrastructure. Complicating the understanding of productivity constraints, these impacts are not always straightforward. For example, some studies show that land quality is an important component of variation in agricultural productivity in Africa (Wiebe, 2003); others show that it is not a significant determinant (Thirtle et al., 2003).

The role of particular types of public expenditures on agricultural production is also context-specific. For example, in Latin America, agricultural productivity was seen to increase from the provision of social services and public goods in rural areas (Allcott et al., 2006) while in Indonesia, public spending on irrigation had a positive impact and fertilizer subsidies had a negative impact (Armas et al., 2010). There are also complementary effects from multiple social services that can be difficult to capture and underlying political structures can determine impacts to a large extent. For example, institutional factors including political and civil liberties have been shown to be significant determinants of agricultural productivity in sub-Saharan Africa for 1960 to 1999 (Fulginiti et al., 2004). Likewise, while infrastructure is an important constraint to consider, the data on infrastructure in Africa and how it has changed over the last 30 years is very limited (Estache et al., 2005).

Of the studies that have captured multiple types of expenditures, some location-specific effects have been documented. For example, agricultural research was found to have significant productivity effects in India, China, Uganda, and Thailand (similar to the results seen for road infrastructure in Uganda and India) (Mogues et al., 2011).

Using a simultaneous structural approach, Fan, Hazell, and Haque (2000) and Fan, Hazell, and Thorat (2000) analyzed the impact of government spending on growth and poverty in India. They found that public expenditures reduce rural poverty through effects on total factor productivity and incomes. The authors later modified their approach by adding variables such as urban growth, institutions, and policies (Fan et al., 2002). Likewise, Fan and Zhang (2008) used a panel of data for Uganda and estimate productivity and poverty as a result of public investments and education and health indicators, finding the largest impacts from spending in agricultural research and extension, followed by roads and education spending; no significant results were found for health spending. In moving forward with our analysis for sub-Saharan Africa, we build upon this previous empirical work.

2.3 Empirical Strategy

Given the data constraints, we implement a variety of empirical approaches, relying upon both Stochastic Frontier Analysis (SFA) and Structural Equation Modeling (SEM). These empirical frameworks and the literature that they build upon are discussed in more detail in the following sections. Although social services and related constraints are likely to have broader economic impacts, this analysis focuses on the impacts on agricultural output and efficiency in agricultural input use.

2.3.1 Efficiency Analysis

We assume that infrastructure and other types of public expenditures often affect agricultural productivity indirectly (through their impacts on the effectiveness of productive inputs, including labor). Effectiveness of inputs in agricultural production can be measured through the efficiency of these production systems. Unlike typical production functions, efficiency analysis allows a relaxation of the assumption that all countries are producing in a technically efficient manner and allows evaluation of the impact of infrastructure on agricultural output and efficiency of input use (Kumbhakar & Lovell, 2000). Farrell (1957) defined technical efficiency as the ability to produce the largest possible output using the given inputs. Producers will fall below this optimum level of production due to inefficiency which can be related to both economic and physical constraints. When people are healthier, they are likely to have a higher quality of labor inputs; when infrastructure is available, farmers are likely to be able to get higher quality seeds and fertilizer; land inputs may also become more efficient due to soil conservation or water capture techniques. Allowing a range of efficiencies in agricultural production would seem to be especially important in developing countries where there is still a large range of production technologies and severe health constraints. For example, indicators of health were found to significantly impact agricultural efficiency in Ethiopia (Ulimwengu, 2009).

The estimation of production efficiency is generally done using both parametric (stochastic frontier analysis (SFA)) and nonparametric approaches (Data Envelopment Analysis (DEA)). Stochastic production frontiers (used in SFA), as proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977), allow for random country-specific production shocks and have been implemented in many different settings but require specification of a functional form. Non-parametric approaches do not require specification of functional form, but are less robust when there is measurement error (Saradifis, 2002) and do not allow for unobserved variables (van Biesebroeck, 2007). Previous longitudinal productivity studies have found that SFA performs better than DEA and the use of flexible functional forms (e.g., translog), can address some of the limitations imposed by the functional form (Headey et al., 2010). Given the need to account for country-specific heterogeneity and measurement errors in the data, we estimate a stochastic frontier model, including both an inefficiency term and a stochastic error term. For a panel dataset, the general model is defined as shown in Equation 2.1 (Battese & Coelli, 1995):

$$Y_{it} = f(x_{it};\beta)\exp(V_{it} - U_{it}) \tag{2.1}$$

Here, Y_{it} represents the net production for the country (i) in the year (t) of observation and $f(x_{\mathrm{it}}\beta)$ is the function of production inputs for each country's agricultural production, (V_{it}) represents the stochastic error and U_{it} is a non-negative random variable representing technical inefficiency. The explanatory variables of technical efficiency (U_{it}) can be represented by Equation 2.2 in which W_{it} is a random variable that depends upon the distributional assumptions and $z_{it}\delta$ is a set of explanatory variables for inefficiency and their coefficients (Battese & Coelli, 1995).

$$U_{it} = z_{it}\delta + W_{it} \qquad (2.2)$$

These functions can be estimated using maximum likelihood methods with distributional assumptions on the inefficiency term as half-normal, truncated normal, or gamma distributions. The overall estimations of technical efficiencies (and their ranking among producers) has been shown to not be greatly affected by the selection of the inefficiency distribution (Chakraborty et al., 2001). In our case, we estimate U_{it} ~ (μ_{it}, σ_{it}), assuming a truncated-normal distribution of the inefficiency term (truncated below zero), as is done in many previous analyses (Battese & Coelli, 1995). It should also be noted that time-invariant models can underestimate efficiency by confusing it with firm-level heterogeneity (Abdulai & Tietje, 2007). Due to time-specific and country-specific heterogeneity, this analysis does not pool the data and allows the panel structure to remain intact, with time controls for changes in technical efficiency and productive structure, as estimated by Battese & Coelli (1995).

2.3.2 Structural Equation Approach

Calculating efficiency in production can provide important information about production constraints, but like all empirical specifications, it has limitations. As noted previously, the models require either specification of a restrictive functional form or can be very sensitive to measurement error (in the case of nonparametric approaches)

(Saradifis, 2002). Frontier analysis can also ignore important farm-level differences between technology and production possibilities by assuming a homogeneous production frontier for all households (Mundlak, 1988).

Addressing the research question in a second way, we move to the structural equation framework, which is able to evaluate the multiple channels through which government expenditures can affect agricultural productivity. It can also account for endogeneity and possible interactions between variables. While empirically appealing, the framework of Fan, Hazell, and Haque (2000) and Fan, Hazell, and Thorat (2000), discussed earlier, is limited in its ability to identify the underlining economic behavior that may drive the results as well as indirect impacts through other agricultural inputs. Using data for a subset of countries (discussed in the following section) and building on this structural modeling framework, we include fixed effects allowing for heterogeneity between countries and latent variables in an attempt to better explain the link between social expenditures and social outcomes and their impacts on marginal productivities.

Government expenditures on social services are expected to have direct effects on agricultural production but also indirect effects through decisions regarding inputs and technology. The wide variation in the estimation results of agricultural production functions may be partially due to the exclusion of factors representing the political, economic, or physical environment (“states”), which have both direct and indirect effects on farm production and decisions (Mundlak et al., 2008). To try to capture both direct and indirect effects, the framework developed by Mundlak et al. (1997) is used to model farmers’ decision processes. To implement this approach, input elasticities are calculated from fitting a production function that is simultaneously determined by both observed inputs and state variables (Fulginiti & Perrin, 1993).

Following Mundlak et al. (1997), each farm chooses a technology subject to its constraints under the prevailing socioeconomic environment and jointly determined with the variable inputs. A production function $F_j(X)$ is estimated for all production techniques (*j*) where *X* is a vector of constrained (*k*) and unconstrained (*v*) inputs so that $F_j(X) \ni v, k$ (Mundlak et al., 1997). 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 this 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 *F(x*,s).* Therefore, the production function $F_j(X, s)$ assumes that the slope (β) and intercept *(Γ)* are both determined by *(s)*, as shown in Equation 2.3, where the dependent variable *(y)* is estimated as value-added per worker in their example and *u* represents the stochastic component (Mundlak et al., 1997).

$$ln\, y = \Gamma\,(s) + \beta(s, x)\ln x + u \qquad (2.3)$$

In addition, recognizing the importance of allowing for heterogeneity described in Mundlak (1988), we further assume that production technologies are heterogeneous across countries. Our empirical implementation of this approach is outlined in more detail in the following sections, which address the issue of heterogeneity, the endogeneity of technology and inputs, and the challenges of finding appropriate social outcome variables. For this specification, a two-stage, generalized mixed linear model (Verbeke & Molenberghs, 2000) is used to estimate equation *(2.4)*. The first stage summarizes a vector of country-specific regression coefficients and the second stage links these estimates to exogenous covariates through multivariate regression techniques. More explicitly, Y_{i} is the $\mathrm{n_i}$ −dimensional vector of repeated measurements of production for the country (i):

$$\mathrm{Y_i} = \mathrm{X_i}\beta_{\mathrm{i}} + \varepsilon_{\mathrm{i}} \qquad (2.4)$$

in which X_i is a (n_i*q) matrix of exogenous variables, β_i to represent the q-dimensional vector of regression coefficients, and $\varepsilon_i$as the residual components. This uses the normal assumptions for ε_i in that it is independently distributed normal with a mean of zero and a covariance matrix $\sigma^2 I_{n_i}$ (where $I_{n_i}$is a ni-dimensional identity matrix) (Verbeke & Molenberghs, 2000).

In the second stage, the following is used to capture heterogeneity between countries:

$$\beta_i = Z_i \gamma + b_i \qquad (2.5)$$

Equations (*2.4*) and (*2.5*) are combined to yield the generalized mixed effects model (which mixes both the fixed-effect (γ) and the random, country-specific effect (b_i):

$$Y_i = K_i \gamma + X_i b_i + \varepsilon_i \qquad (2.6)$$

where $K_i = X_i Z_i$ is a $(n_i * p)$matrix of exogenous covariates. Following Laird and Ware (1982), a linear mixed effects model satisfies the following conditions: b_i~N(0,D), $\varepsilon_i \sim N(0, \sum_i)$, and $b_1, \ldots . b_N, \varepsilon_1, \ldots \varepsilon_N$ are independent. The empirical implementation process and the data used follows.

2.4 Data and Summary Statistics

For both models, we rely upon the same agricultural dataset for inputs and outputs. As mentioned, the dependent variable for our models is the net value of production for all agricultural crops in thousands of international dollars[2] from FAO (FAO, 2011). The data used as inputs for agricultural production are the commonly used agricultural inputs including the following collected from FAO for the period 1961 to 2010: labor (thousands of people employed in agriculture); land (thousands of hectares in

[22] International dollars are hypothetical and held at constant purchasing power parity (PPP) for the USD in 2004.

agricultural crop production); livestock (head of cattle or other livestock); fertilizer (consumption in tons); and tractors (tractors used in the country). The percentage of irrigated crop land was also calculated using FAO data (FAO, 2011). To control for heterogeneity in the importance of agriculture in the economy and climatic differences, we include the percent of land in agriculture and alternatively, the agro-ecological zone as shifter variables in the translog specification. Unlike many estimations of production, we also include the amount of precipitation (millimeters per year) on agricultural land. This data was obtained using climate data from the University of East Anglia and adjusted for agricultural land using data from IFPRI's Harvest Choice project (You et al., 2009; Williams & Breneman, 2009).

The variables included to account for inefficiency were informed by the existing literature to try to capture the differences in social services expenditures across countries that could influence the ability to use agricultural inputs efficiently. We make the assumption that overall health and survival to an advanced adult age could be a sufficient indicator of ability to work in agriculture and therefore, we use annual life expectancy rates to account for the quality of labor (World Bank, 2010). As done by Fulginiti et al. (2004), to account for political stability and institutional strength, we include a variable for the number of years since independence (Central Intelligence Agency (CIA), 2009). The rates of immunization for diphtheria, pertussis (whooping cough), and tetanus (in combination and referred to DPT) (as a percentage of children aged 12-23 months old) were used as a proxy for health provisions (World Bank, 2011).

Other variables were compiled from the WDI (e.g., pupil-teacher ratio for primary and secondary schools, the net enrollment rate in primary schools, literacy rates, health and education spending as a percentage of GDP, domestic credit to the private sector as a percentage of GDP, net overseas development assistance, prevalence of malaria, TB, and HIV, and access to water and sanitation) as well as the world governance indicators (Kaufmann et al., 2009) and freedom indicators (Freedom House, 2011). All variables considered are summarized in Table A.1. Many of the variables were not sufficiently observed to draw conclusions and were not included in the final model. They are listed in the Appendix as background for model specification.

Table 2. 1-Summary Statistics

Characteristics of the Variables						
Variable	**Units**	**Obs**	**Mean**	**Std. Dev**	**Min**	**Max**
Countries		43				
Year		22			1980	2002
Production	value (2004/06) (1000 Int$)	948	1,339,921	2,284,168	7136	2.04E+07
Labor	people in agri (1000s)	948	3,057	3,677	33	25595
Fertilizer	tons consumed	948	26,726	53,379	0	461000
Tractors	agri tractors used	948	3,111	4,436	1	24000
Land	production area (1000 ha)	948	20,977	24,251	65	133824
Livestock	oxen equivalents	947	3,663,390	5,727,351	3360	3.99E+07
Inefficiency variables						
Life expectancy	life expect at birth	948	51.0	6.7	26.4	69.26
Independence	years since independence	948	50.38	201.26	0	1993
Percent Ag Land	% of land in agriculture	925	46.02	19.69	7.9374	91.16
Irrigated	% of ag land irrigated	917	0.59	0.89	0.002	4.48
Precipitation	mm year on ag land	938	1098	562.8	182	2818
Land quality	crop land quality index	838	88.13	21.75	38	128
Immunization	% children DPT immun	804	53.98	25.41	1	99

Source: Author's estimations.

2.5 Empirical Specification of Efficiency in Production and Results

Using this data, the specification and results of the SFA model are shown below. We first estimate the following, normalized by the sample means:

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln(Labor_{it}) + \beta_2 \ln(Fertilizer_{it}) + \beta_3 \ln(Tractors_{it}) + \beta_4 \ln(Land_{it}) + \\ \beta_5 \ln(Livestock_{it}) + \beta_6 \ln(precipitation_{it}) + \beta_7 \ln(irrigation_{it}) + \beta_8 \ln(agland_{it}) + \beta_9 (time) + V_{it} + U_{it} \quad (2.7)$$

in which inefficiency is estimated by the following base equation

$$U_{it} = \delta_0 + \delta_1 (LifeExpect_{it}) + \delta_2 (immunization_{it}) + \delta_3 (Independ_{it}) + \delta_4 (time) + W_{it} \quad (2.8)$$

This specification allows the *X* variables to represent traditional inputs into production and the Z variables to represent observed heterogeneity that is not related to the production structure (Greene, 2005). While much of the data is available for additional years, the models in Equations *(2.7)* and *(2.8)* are estimated for the period of 1980 to 2002 given missing data before 1980 and the lack of information on the use of fertilizer after 2002. A total of 39 sub-Saharan African countries are included partially due to incomplete information, but also because our estimates for the frontier are likely to be more robust across similar production units. Because of this, South Africa and Mauritius were excluded given their higher level of development than other countries in sub-Saharan Africa. Nigeria's production was also seen to be much higher than all other countries (by a factor of 10); it was dropped from analysis to avoid biasing the frontier. Not all variables are observed in all years and some countries are measured in more years than others leading to many dropped observations. For example, Eritrea and Ethiopia were not observed before 1993 and Liberia and Sierra Leone had many missing years. Given this, all models were run with and without these countries for comparison purposes. The results were similar so these countries were included in the final model.

In order to estimate a stochastic frontier model, assumptions regarding the functional form are necessary. It was found that a flexible functional form that allows cross-elasticities and non-linear effects in the variable inputs (i.e., Translog) fits better than the Cobb-Douglas specification according to the Likelihood Ratio test. Therefore, we estimate the Translog model as:

$$\ln Y_t = \alpha_0 + \sum \beta_i (\ln X_{it}) + \frac{1}{2} \sum_i \sum_j \beta_{ij} (\ln X_{it} \ln X_{jt}) + V_{it} - U_{it} \tag{2.9}$$

Here, *Y* represents the net agricultural crop production and the *X* variables represent agricultural inputs, discussed previously. The percentage of land in agriculture is used as a control variable for relative importance of agriculture in the country and therefore, only included as a shifter variable. All variables are logged and the differences from the sample means are used in the estimations. The model is estimated with the econometric package *frontier* for R (Coelli & Henningsen, 2011; R Core Development Team, 2011). In general, many observations are dropped due to missing values especially if the model is extended back to 1961 and the models with this data do not seem to fit the data very well in that gamma is very small and the efficiency levels do not seem realistic in a few cases. We also estimated the production frontier with other variables as well (see previous discussion of variable options), but given missing values, we are limited on the conclusions that can be drawn.

The results in Table 2.2 show most inputs are significant and positive both directly and through joint effects with other inputs. The results show that precipitation has a quadratic relationship with production. Production may decline after too much rainfall is received if the ability to store this excess is limited. This nonlinear and significant relationship between climatic variables and agricultural productivity has been documented in the literature (Maddison et al., 2006; Gommes, 1999). The results (also consistent across specifications) show that irrigation is not significant, which is not surprising in sub-Saharan Africa, where irrigation levels are very low. The percent of land that is in agriculture is also a significant control variable for intra-country differentials in production strategies.

Table 2. 2-Annual Specification, 1980-2002

Production Value	Coefficient	SE			
Constant	0.232***	0.051		**Coefficient**	**SE**
Labor	0.560***	0.044	Tractors^2	0.015	0.018
Fertilizer	0.182***	0.015	Tractors*Land	0.193***	0.016
Tractors	0.123***	0.023	Tractors*Livestock	-0.216***	0.019
Land	0.088**	0.033	Tractors*Precipitaiton	0.058*	0.023
Livestock	-0.035	0.028	Tractors*Irrigation	0.010	0.008
Precipitation	0.317***	0.054	Land^2	-0.252***	0.051
Irrigation	-0.002	0.023	Land*Livestock	0.349***	0.034
Labor^2	0.102	0.058	Land*Precipitation	0.109*	0.045
Labor*Fertilizer	-0.008	0.011	Land*Irrigation	-0.011	0.018
Labor*Tractors	-0.004	0.017	Livestock^2	-0.255***	0.040
Labor*Land	-0.325***	0.030	Livestock*Precipitation	-0.580***	0.054
Labor*Livestock	0.173***	0.035	Livestock*Irrigation	0.069***	0.016
Labor*Precipitation	0.446***	0.058	Precipitation^2	-0.739***	0.107
Labor*Irrigation	-0.188***	0.018	Precip*Irrigation	0.069**	0.023
Fertilizer^2	0.019***	0.004	Irrigation^2	0.012	0.011
Fertilizer*Tractors	0.004	0.005	Percentage Ag Land	0.067***	0.018
Fertilizer *Land	0.031***	0.008	Time	0.010***	0.002
Fertilizer *Livestock	-0.026**	0.009			
Fertilizer *Precipitation	0.030	0.017			
Fertilizer *Irrigation	0.036***	0.005			
Inefficiency	**Coefficient**	**SE**			
Life Expectancy	-0.057***	0.005			
Immunizations	0.011***	0.002	Log Likelihood	-9.501	
Time	0.005	0.007	Cross Sections	39	
Independence	0.000***	0.000	Time Periods	23	
σ^2	0.197***	0.015	N	755	
γ	0.972***	0.012	mean eff	0.719	

Source: Author’s estimations; *p<0.10, **p<0.05,***p<0.001

From the results, it appears that inefficiency could be a significant contributor to cross-country differentials in yearly productivity and input productivity. It also seems (consistent across model specifications) that life expectancy is significantly and negatively associated with inefficiency, showing that increases in health likely increase efficiency in agricultural production. While immunization rates seem to have the opposite effect, it could be that these are not a good representation of rural health outcomes as these are national statistics. The independence variable is also significant across specifications, possibly capturing a portion of the cross-country heterogeneity in political structures. Average efficiency estimates by country for these annual estimations are included in Table 2.3. Here, a score of 1 represents full efficiency and 0 representing total inefficiency when compared to the joint production frontier (i.e., a score of 0.5 implies that a country could produce the same output using 50 percent fewer inputs if the production systems were fully efficient). However, some of these countries do not fit our expectations in terms of production efficiency which could be the result of a few confounding factors. For example, Ethiopia and Eritrea's efficiency scores could be due to the limited years of data while other countries (Sudan, for example) may be suffering from significant issues in terms of data quality. Ultimately, the data constraints and the results highlight the difficulty in cross-country analysis for sub-Saharan Africa.

Table 2. 3- Efficiency Estimates (from Table 2.2)

Country	Efficiency	Country	Efficiency
Benin	0.929	Kenya	0.789
Ivory Coast	0.916	Maurtania	0.755
Cameroon	0.889	Central African Republic	0.726
Sudan	0.875	Lesotho	0.699
Namibia	0.873	Senegal	0.671
Chad	0.868	Tanzania	0.654
Gabon	0.864	Burkina Faso	0.647
Mali	0.856	Sierra Leone	0.640
Togo	0.841	Mozambique	0.602
Madagascar	0.839	Guinea	0.573
Somalia	0.838	Liberia	0.536
Ghana	0.836	Rwanda	0.534
Uganda	0.833	Gambia	0.525
Cape Verde	0.831	Burundi	0.517
Botswana	0.830	Malawi	0.470
Swaziland	0.825	Ethiopia	0.402
Congo	0.817	Eritrea	0.360
Zimbabwe	0.801	Angola	0.348
Niger	0.796	Zambia	0.295

*Source: Authors' estimations; *p<0.10, **p<0.05,***p<0.001*

The lack of a substantial panel of data is a common problem in estimating the impacts of infrastructure and other social services on productivity in Africa (Block, 2010). For example, annual data that is collected is insufficient to account for educational indicators. In an effort to expand this analysis, the frontiers are also estimated using five-year averages so that educational variables can be included. Other SFA analyses have found that country means over intervals were "better behaved" than yearly data (Greene, 2005). Again, all variables are log-transformed. However, five-year averages did not seem to fit in our case (gamma was equal to 1.00, which is not appropriate). One set of these results are included in the Appendix (Table A.2). Averages of other variables (e.g., access to drinking water, sanitation, health spending, governance indicators and freedom indices) were attempted but none of these variables proved to be a significant determinant of inefficiency.

The sensitivity of the results to different empirical strategies illustrates the challenge of obtaining robust results using cross-country data. For this reason, multiple imputation has been used in developing country analysis and can be preferred to listwise deletion (removing observations that contain any missing values) (Daniels & von der Ruhr, 2003; Tavits, 2008). Listwise deletion can make it particularly difficult to draw conclusions across the sample. Of bigger concern is the fact that dropping all observations with a missing predictor leads to biased and inefficient results (Honaker & King, 2010). In a final attempt to account for the role of educational expenditures on efficiency in agriculture, we take advantage of a recently available dataset (CANA dataset) that relies upon multiple imputation for the pupil/teacher ratio (Castellacci & Natera, 2011). This pupil/teacher ratio may be a relevant indicator for expenditures in education. As shown in Table 2.4, it is not clear that this data is appropriate for our purposes given how drastically it changes other estimation results, such as the influence of land and irrigation, from all the other models that were attempted, but it still appears that inefficiency is an important component for variability in agricultural production across countries in sub-Saharan Africa.

Table 2. 4-Annual Estimations using CANA Education Dataset

Production Value	Coefficient	SE
Constant	0.216***	0.065
Labor	0.514***	0.046
Fertilizer	0.160***	0.021
Tractors	0.105**	0.033
Land	0.044	0.042
Livestock	-0.057	0.045
Precipitation	0.029	0.073
Irrigation	0.213***	0.030
Labor^2	0.300***	0.071
Labor*Fertilizer	-0.019	0.014
Labor*Tractors	0.015	0.022
Labor*Land	-0.330***	0.032
Labor*Livestock	0.034	0.049
Labor*Precip	0.292	0.080
Labor*Irrigation	0.230***	0.021
Fertilizer^2	0.014**	0.005
Fertilizer*Tractors	0.007	0.008
Fertilizer *Land	0.039**	0.014
Fertilizer *Livestock	-0.023	0.014
Fertilizer *Precip	0.058	0.030
Fertilizer *Irrigation	0.041***	0.007

	Coefficient	SE
Tractors^2	-0.037	0.023
Tractors*Land	0.265***	0.038
Tractors*Livestock	-0.231***	0.028
Tractors*Precip	0.024	0.032
Tractors*Irrigation	0.102***	0.014
Land^2	-0.293***	0.072
Land*Livestock	0.101*	0.041
Land*Precip	0.133	0.068
Land*Irrigation	0.141***	0.029
Livestock^2	0.095	0.061
Livestock*Precip	-0.570***	0.077
Livestock*Irrig	-0.075	0.039
Precipitation^2	-0.853***	0.144
Precip*Irrigation	0.109***	0.027
Irrigation^2	0.125***	0.020
Percentage Ag Land	0.099***	0.019
Time	0.018***	0.003

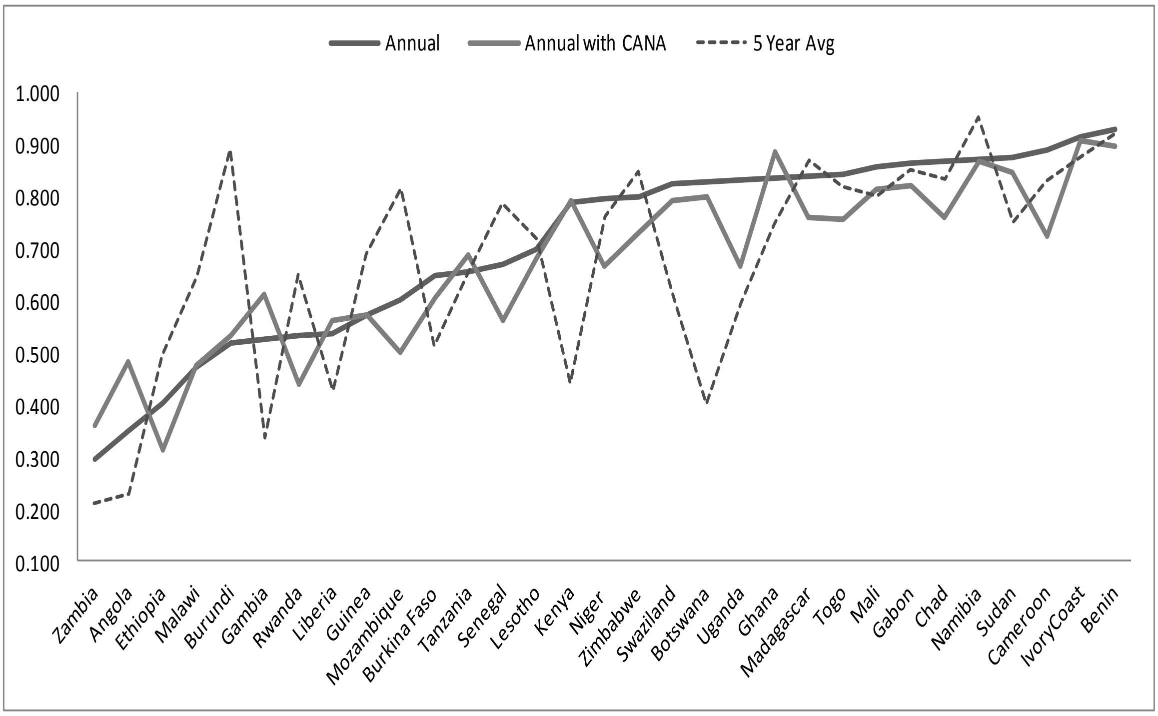
Inefficiency	Coefficient	SE
Life Expectancy	-0.035***	0.006
Immunizations	0.005***	0.001
Pupils/Teachers	-0.008***	0.001
Time	0.005	0.005
Independence	0.000***	0.000
σ^2	0.078***	0.013
γ	0.901***	0.071

Log Likelihood	47.820
Cross Sections	33
Time Periods	23
N	639
mean eff	0.680

*Source: Author's estimations; *p<0.10, **p<0.05,***p<0.001*

To evaluate how efficiency estimates may change between model specifications, the comparisons of mean efficiencies by country for the models using annual data (with and without education considered) and five-year averages and can be seen in Figure 2.1, highlighting the importance of considering missing observations in the dataset and estimations using listwise deletion.

Figure 2. 1-Average efficiencies by model, 1980–2002



Source: Author's estimation

2.6 Empirical Specification of Public Expenditures as Latent Variable and Results

As seen in the previous section, using existing data on yearly education indicators results in a large variation in results. Therefore, we move to the use of a complementary dataset and the structural equation framework, focusing more on health and education expenditures rather than health or education indicators solely. For this analysis, we use a select set of countries for which social expenditure data is available through IFPRI from 1980 to 2006 (Botswana, Burkina Faso, Cameroon, Cote d'Ivoire, Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Togo, Uganda, Zambia, and Zimbabwe) (Malaiyandi, 2010). For these countries and range of years used in our analysis (1980-2002), the public expenditures per capita are shown in Table 2.5.

Table 2. 5-Per Capita Expenditures in International Dollars, 1980-2002

Sector	Obs	Mean	Std Dev	Min	Max
Education	309	82,462	134,343	321	887,766
Health	309	26,363	33,754	150	272,229
Agriculture	309	27,421	37,197	537	209,698
Transportation	309	27,928	38,764	25	208,253
Social Services	309	18,389	34,082	26	240,838

Source: SPEED Data International (2000) from Malaiyandi, 2010

As mentioned in the previous specification, we assume aggregate production is a function of the commonly-used inputs including labor, land, animal power, tractors, fertilizer, and irrigation as well as constraints in the natural environment (such as precipitation). Following from Mundlak (1988), we assume that production technologies are heterogeneous across countries and that input decisions are jointly made with production choices, depending on state variables (i.e., social services or support). These state variables affect production both directly and indirectly (through the impact on other inputs) and are considered endogenous (Mundlak, 1988). Empirically, state variables for health, education, agriculture, transportation, and other public services are estimated as a function of government expenditures on health while controlling for country-level *(i)* fixed effects. These estimated state variables are then used to estimate marginal productivities of inputs (β_{il}) using the following production function for the state variables considered in our case (spending on health, education, social services, transportation, and agriculture). The estimates for health are explained in more detail below:

$$Y_i = \beta_{0i} + \sum_{iL} \beta_{il} x_{il} + \beta_i p_i + \varepsilon_i \qquad (2.10)$$

$$\beta_i = \gamma_{0l} + \gamma_{1i}\hat{s}_h + \gamma_{2i}S_{ed} + \gamma_{3i}S_{tr} + \gamma_{4i}S_{soc} + \gamma_{5i}S_{ag} + u_i \qquad (2.11)$$

where y: output; x: agricultural inputs (described in the previous section); p: precipitation over the agricultural year and ε, u: iid error terms.

Other studies have noted the complications in estimating impacts to the overall health of a population due to related factors that are difficult to disentangle as well as the issues in capturing overall health using only a few indicators (Jack, 1999). Based on this, Baldacci et al. (2003) argue that using proxies for unobservable social outcomes does not efficiently estimate the impacts of expenditures and suggest estimating a latent variable and associated covariances to explain the relationship between public expenditures and this unobservable health outcome. The authors find that estimates of government spending elasticities are higher under this approach than under traditional specifications (Baldacci et al., 2003). Therefore, for the health indicators (the only indicators for which we have a sufficient panel of data to implement this approach, as mentioned earlier), a general covariance structure model is estimated as:

$$S = \Lambda M + \delta \qquad (2.12)$$

where Λ is the matrix of covariances between the latent (unobserved) variable M and the observed social variables (S). In the case of two observable variables (S_1 and S_2) for each country (i), assuming exogenous latent variables (M) and endogeneous latent variables (N) are uncorrelated with the error terms, which can be written as:

$$s_{1i} = \Lambda_x M + \delta \text{ and } s_{2i} = \Lambda_y N + \varepsilon \qquad (2.13)$$

with the structural equation model (Baldacci et al., 2003; StataCorp, 2011) specified as:

$$N = \vartheta N + \Gamma M + \zeta \qquad (2.14)$$

The variable ϑ is the vector of regression coefficients for the endogenous latent variables (N) and Γ are parameters of the exogenous latent variables (M) with respect to (N), with ζ specified as random disturbances (Baldacci et al., 2003). The results of this first-stage are shown in Table 2.6. The results show that health expenditures per capita are a significant determinant of health outcomes, as it is measured here (using immunizations and life expectancy).

Table 2. 6-Latent variable estimation for health

Variables	Coefficients
Health Outcome	
Health Expenditures/capita	2.331***
Health Indicators	
Life Expectancy	1
Immunizations	5.591***
Variances	
Health	0.945
Life Expectancy	26.20***
Immunizations	340.85***
Log Likelihood	-3000.5
N	336

*Source: Authors' estimations; *p<0.10, **p<0.05,***p<0.001*

Using the results from the structural model and the two-stage approach, the agricultural output (y_i) for country (i) is conditioned on state variables (s) that may not be properly captured through input quantities (x) alone. The results of these state variable approaches (with and without the consideration of a latent variable for health) are shown in Table 2.7 and compared to the model without state variable consideration.

The results again confirm the significance of precipitation for production, even after controlling for country-level fixed effects. The results document the importance of social expenditures in not only directly impacting production but also indirectly (through joint effects with other agricultural inputs). The results also show that particular public expenditures are complementary (e.g. agricultural spending and transportation spending or social spending and health spending). The results confirm the impact of using a latent variable approach to estimate health rather than using indicators, supporting the idea that measuring these outcomes in a population may be more appropriate through the use of a combined variable rather than a single measure of expenditures or one particular health indicator.

Table 2.7-Production and Government Expenditures

Variables	No State	Health	Education	Transport-ation	Social	Agri-culture	Educ& Health	Agri& Transport	Education& Transport	Social& Health	Health Latent Var
Land	0.45	0.522	0.49	0.469	0.626	0.439	0.48	0.409	0.471	0.626	0.58
Labor	0.630**	0.502*	0.536**	0.558*	0.666***	0.519*	0.510*	0.507*	0.526*	0.626***	0.646**
Animals	0.455*	0.504*	0.437	0.465*	0.276	0.583**	0.476*	0.574*	0.423	0.292	0.43
Precipitation	0.146***	0.145***	0.142***	0.157***	0.139***	0.144***	0.140***	0.148***	0.147***	0.134***	0.142***
Health expenditures		-21.95*					-13.7			-16.76	-0.11
Land*Health		2.475**					2.295*			2.205*	0.01
Labor*Health		0.690*					0.586			0.793**	0
Animals*Health		-0.501					-0.907			-0.738	-0.001
Education expenditures			-12.86*				-6.897		-13.89*		
Land*Education			0.855				0.185		0.99		
Labor* Education			0.42				0.325		0.446		
Animals* Education			0.123				0.214		0.09		
Tranportation Expend				-6.258				-9.647	-2.55		
Land*Transport				-0.977				-1.880*	-1.2		
Labor*Transport				-0.796*				-0.978*	-0.981*		
Animals*Transport				1.536*				2.490**	1.509*		
Social Expend					-37.32***					-31.95**	
Land*Social					-6.184**					-7.715**	
Labor*Social					-2.726**					-3.364**	
Animals*Social					8.208***					9.215***	
Agriculture Expend						8.984		11.02			
Land*Agriculture						1.557		2.601**			
Labor* Agriculture						1.153*		1.336**			
Animals* Agriculture						-2.310**		-3.272***			
constant	-3.370*	-3.708*	-2.695	-3.156*	-2.743	-4.106**	-2.932	-3.592*	-2.263	-2.623	-4.275*
CountryFE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	373	360	360	360	360	360	360	360	360	360	373

*Source: Author's estimations; *p<0.05, **p<0.01, ***p<0.001*

Regardless of the model specification, the inclusion of a state variable induces a shift in the size and significance of input elasticities, especially for labor. This is particularly true when health expenditures are considered, but also holds for education. To further interpret the significance of the results in Table 2.7, we use metrics developed by Fulginiti and Perrin (1993), relying upon the elasticity of production with respect to states variables and evaluated as $\frac{\partial y}{\partial z} = \frac{\partial y}{\partial \beta}\frac{\partial \beta}{\partial z} = \sum_l \gamma_{ls} x_l + b_s$ where both y and z are in log form. Using the estimates presented in Table 2.5 and following from Fulginiti and Perrin (1993), the elasticity of productivity for particular inputs is estimated with respect to the state variables and the significant results are presented in Table 2.8.

Table 2. 8-Marginal productivity of significant inputs by specification

Input	No State	Health	Education	Transport	Social	Agriculture	Latent health
land	0.22	2.30	1.08	-1.14	-5.52	1.75	0.32
labor	0.46	1.03	0.85	-0.36	-2.16	1.76	0.43
animal	0.75	0.24	0.83	2.45	8.55	-1.47	0.70

Source: Author's estimations

From Table 2.8, it is clear that the estimates of marginal productivity change significantly based on the model specification. Although the impact of public expenditures on marginal productivities varies between specifications, it is apparent that consideration of the health and education expenditures (both with and without the structural equation approach) changes the estimates. As a result, elasticities that do not account for these differences may be biased, underestimated or inaccurate.

2.7 Conclusions

This research has attempted to develop the discussion regarding the impacts of public expenditures on agricultural production rather than economic development in general, which is a particularly important consideration in rural economies. Our attempts to use the data available have provided multiple examples of how data constraints can limit this type of analysis for sub-Saharan Africa. The results have suggested that ignoring the missing data and estimating using only the available data may lead to biased results. Despite the limited data, using multiple empirical approaches, the results have provided evidence that country-specific heterogeneity is a significant consideration for agricultural production and efficiency in sub-Saharan Africa. Both approaches document the significance of climate-related variables in productivity estimations, even after controlling for differences between countries.

In addition, the results provide evidence that certain types of social services can influence agricultural production efficiency. The estimates of both production efficiencies and marginal productivities are very dependent the model chosen and how we account for the underlying structure of the socio-economic systems. The results point to the importance of considering these underlying structures when planning policy interventions in rural economies.

Specifically, the results using a subset of countries for which detailed expenditure data was available provides empirical support for the impact of social expenditures on agricultural productivity directly and through the ability to use productive inputs most efficiently. The results also document the difficulty in measuring health outcomes using limited indicators of health. Regardless of this difficultly and even after empirically controlling for it with a latent variable approach, the results confirm the impacts of health expenditures on particular health outcomes.

The results further suggest that these health outcomes impact both overall productivity and marginal productivities. We note that the coefficients on labor change substantially when expenditures are accounted for in the model, and this is especially the case for health expenditures. This suggests that the productivity of agricultural inputs is at least partially dependent on social constraints. There also seem to be important complementarities between multiple types of public expenditures that significantly impact agricultural productivity. Overall, the results call for better data on public service expenditures so that the relationships between labor, health, and government provisions can be better understood. Chapter 3 will take advantage of more detailed social services expenditure data and health indicators for Tanzania to look at these relationships in more detail across a particular country.

3. Government Expenditures, Social Outcomes, and Marginal Productivity of Agricultural Inputs[3]

3.1 Introduction

As mentioned in the research overview and supported by the results in Chapter 2, health problems detract directly from the quantity of labor available for agriculture (due to time spent sick), but can also lower the quality of agricultural labor as workers may not be as productive due to illness. For example, in Ethiopia, the likelihood of adoption of new agricultural technology was greatly reduced by time spent sick or caring for sick household members (Ersado et al., 2004). This can impact productivity, both in the short- and long-term. Health issues and constraints, particularly malaria, but also unsafe drinking water and undernourishment, have been found to have a negative and significant impact on Total Factor Productivity (TFP), particularly in Africa (Cole & Neumayer, 2006; Strauss & Thomas, 1998) and have been shown to lead to a shift in cropping patterns (Asenso-Okyere et al., 2009).

Furthermore, health constraints have been shown to impact productivity. However, studies that analyze the impact of public health *expenditures* are not as widespread and often focus on particular sectors and outcomes rather than multiple sectors of spending (Benin et al., 2009). Many of the studies that have been done evaluate differences in income effects across countries (Dollar & Kraay, 2002; Fan & Rao, 2003) or evaluate only the impacts of expenditures on mortality or morbidity (see Anyanwu & Erhijakpor, 2007 and Benin et al., 2009 for detailed reviews). This can miss important linkages, as it has been suggested that the relationship between health conditions and *productivity* can be more consistent than those between health conditions and *income* (McNamara et al., 2010).

[3] Author acknowledges contribution of Ousmane Badiane and John Ulimwengu of IFPRI.

Estimating the impacts of particular expenditures on productivity can be complicated by endogeneity (Headey et al., 2010) and data constraints. For example, previous studies note that while health capital *indicators* can increase growth rates in Africa by 22 to 30 percent, results have been mixed when looking at health care *expenditures* and outcomes (Anyanwu & Erhijakpor, 2007). An increase in health spending of 1 percent of GDP can be associated with an increase in 0.6 percentage points in under-five child survival, especially in low-income countries (Baldacci et al., 2004).

In addition to the impacts from health constraints, agricultural productivity can be impacted through educational expenditures and services. Baldacci et al. (2004) found that an increase in education spending by 1 percent of the country's Gross Domestic Product (GDP) can be linked to an average of an additional 3 years of schooling. Unlike with health, however, the effects on agricultural productivity from increased education are not always straightforward. An increase in secondary education may open up opportunities into non-agricultural activities that can provide more income, and therefore, may not necessarily improve agricultural productivity. However, an increase in primary education or vocational training may increase the pool of informed labor force that, in turn, can influence on-farm decision-making. In this way, additional education can lead to an increase in the efficiency of agricultural inputs (Phillips & Marble, 1986).

This chapter is outlined as follows: Section 3.2 provides the methodological background for the approach used here; Section 3.3 provides an overview of government expenditures and agricultural productivity in Tanzania; Section 3.4 includes the empirical background; Section 3.5 provides a discussion of the data used; and Section 3.6 provides empirical results, together with additional tests of the modeling framework. The final section presents conclusions and resulting policy implications.

3.2. Methodological Background and Approach

A few different methods have been used in an attempt to empirically estimate the impacts of health and education on productivity. They include augmenting the human capital portion of the production function or/and allowing changes to labor efficiency (Teal, 2011), using social indicators as determinants of an unobservable latent variable (Baldacci et al., 2003), and estimating government expenditures as direct determinants of agricultural growth and poverty (Fan et al., 2002). Despite data constraints, these studies have found that government expenditures in sectors such as agricultural research and development, irrigation, education, and infrastructure have contributed to agricultural productivity growth as well as reduced rural inequality and poverty in China and India (Fan, Hazell, & Haque, 2000 and Fan, Hazell, & Thorat, 2000) and in Uganda (Fan & Zhang, 2008). Redistribution of taxes to education and health was also found to reduce poverty and inequality in Thailand (Warr, 2003).

Studies that evaluate the impacts of expenditures on agricultural productivity have not been conducted for Tanzania at the district level. Using detailed data recently made available, we expand empirically on the previous estimation methods. As with previous attempts to model the relationship between public expenditures on social services and productivity, we are limited by the data as we do not have utilization of social services, how these expenditures were allocated at the local level, or a panel of data allowing sufficiently lagged values that may be needed to witness full impacts. However, we are able to draw some relevant conclusions regarding the role of expenditures in agricultural productivity in Tanzania using district-level expenditures as well as household-level social indicators. Specifically, we analyze the role of particular components of health and education expenditures on indicators of health and education as well as their impacts on the marginal productivity of labor and other inputs for rural households in Tanzania.

This research, in addition to using the most recently available agricultural production data for Tanzania[4], is novel in that it implements a covariance structural model to account for the underlying socio-economic environment and the difficulty in capturing the overall health of a population. It also looks specifically at funding for personal salaries and overall development expenditures, two categories thought to be less subject to leakages in some cases. This can be interesting from a policy perspective. For example, previous studies have found that the expenditures on social services and public goods can have a greater impact on agricultural incomes than nonsocial subsidies (Allcott et al., 2006). The analysis also evaluates particular health constraints (e.g. malaria, diarrhea, long-term diseases). In addition, unlike many previous approaches, it allows for technological heterogeneity at the district level by implementing a mixed linear model. As spending on public services may be determined by the population of interest (and therefore endogenous) (Benin et al., 2009), capturing heterogeneity in the underlying socio-economic environment is important for drawing relevant conclusions. Previous results have shown large variation in the impacts of educational expenditures across regions in Vietnam, for example (Fan et al., 2004) and we would expect that this may even be more significant in a country as large and economically diverse as Tanzania.

3.3 Social Expenditures and Agricultural Production in Tanzania

Although data disaggregated by the type of social service provided is not available, we are able to analyze the impact of particular categories of expenditures on

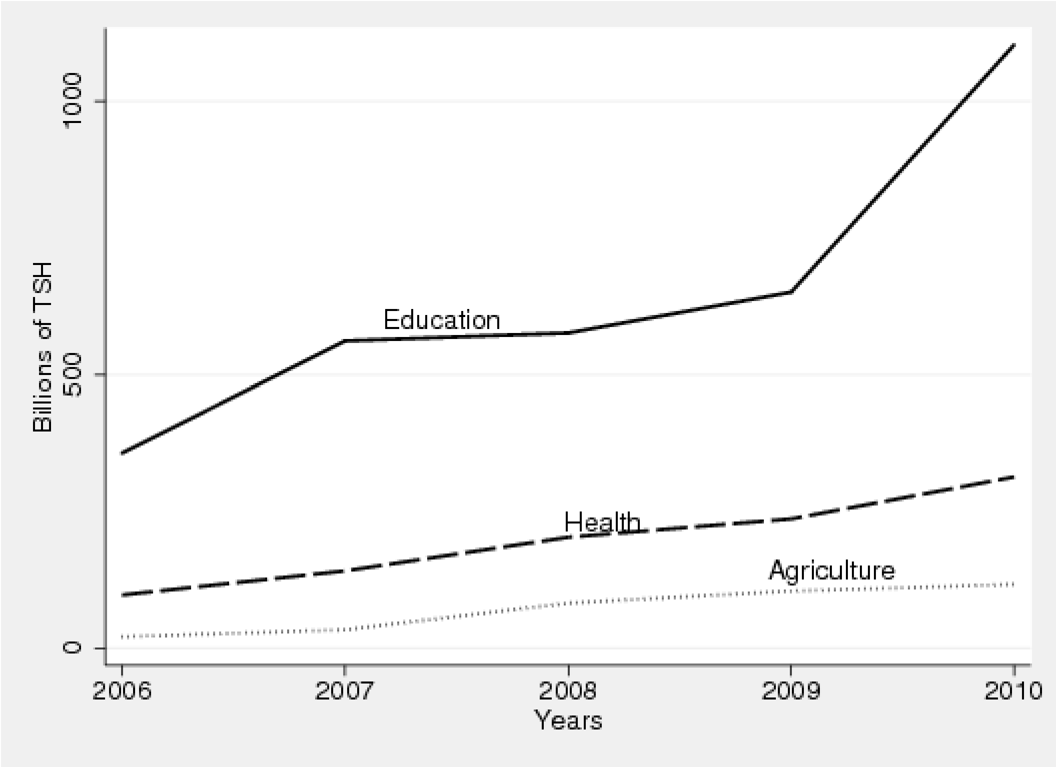
[4] The National Bureau of Statistics of the United Republic of Tanzania provided data from the 2008 agricultural census and advance data for the 2008 household budget survey for this study, for which the authors are grateful.

social outcomes and agricultural productivity at district-level. This type of analysis for one country rather than across very heterogeneous countries may allow a better understanding of the impacts of particular social expenditures on social outcomes and agricultural productivity. The heterogeneity even within a country is particularly important to consider for countries that have transferred expenditures to lower levels of government (Gupta et al., 2002), as in Tanzania.

Tanzania includes 21 administrative regions and 133 councils (district and municipal) with 10,342 villages (MOHSW, 2009). Local Government Authorities (LGAs) at the district-level are responsible for delivering public health services, primary education, agricultural extension, water supply systems, and local road maintenance (Republic of Tanzania, 2006). This transfer of responsibilities to LGAs has contributed to higher-quality health services (Denmark, Ministry of Foreign Affairs, 2007). For example, the Primary Health Care Service Development Programme increased primary health service provisions through staff and supply increases and upgraded facilities (MOHSW, 2009). The Centre for Research on Poverty Alleviation (REPOA), a Tanzanian nongovernmental organization (NGO), noted that according to data from censuses and Demographic and Health Surveys, from 1978 to 2005, infant mortality was reduced from 137 per 1,000 live births to 68, with similar reductions in under-five mortality, partially as a result of prevention and treatment of malaria, increased Vitamin A supplementation, immunization, and better nutrition (REPOA, 2006). In terms of education initiatives, the Primary Education Development Plan 2002–2006 abolished primary school fees, increased teachers by 50 percent, and built more than 41,000 new classrooms (Mamdani et al., 2009).

Figure 3.1 shows national spending (in millions of Tanzanian shillings (TSH) on health and education at the district level, where it is apparent that education spending has been a priority in the last few years.

Figure 3. 1-Tanzania Health and Education Spending, District Level



Source: Local Government Finance Working Group, 2011.

There have been a few analyses that have addressed the impact of government services on rural incomes in Tanzania. In particular, Fan et al. (2005) estimated the role of expenditures by estimating access to capital and infrastructure as a determinant of household welfare and then, linking expenditures to access variables. Likewise, Jung and Thorbecke (2003) used a national general equilibrium model for 1992 and found that educational expenditures especially benefit the poorest in Tanzania, dependent on meeting a certain level of expenditures. However, these analyses were limited by the data available at the time and the impact focused on overall poverty rather than agricultural productivity. Temu et al. (2005) conducted a regional analysis for Tanzania, linking access to infrastructure and services, inputs, and other fixed factors to farm-level production. Taking this idea further with more recent datasets and further disaggregation, we use household-level agricultural production and indicators of health and education outcomes as well as public expenditure data at the district level to investigate the possible impacts of public expenditures on health and education indicators, and through this, on agricultural productivity.

3.4 Empirical Strategy

In an extensive review of the empirical work on public expenditures and poverty, Paternostro et al. (2007) note that despite the analyses of the linkages between expenditures and growth or poverty, there are empirical gaps when it comes to setting spending priorities for rural development policies. They argue that a useful conceptual framework is lacking and empirical validation (due to both the dynamic nature of this analysis and data constraints) limits the ability to identify appropriate public policies to address poverty (Paternostro et al., 2007). The empirical challenges can play as large of a role in this knowledge gap as the lack of sufficient data. The effects of infrastructure, for example, have been found to be smaller when the endogeneity of investments is considered, which is likely not efficiently eliminated using a fixed effects model (Pinstrip-Anderson & Shimokawa, 2008).

Despite these constraints to estimation, several studies have explicitly modeled the relationship between health and agricultural productivity by incorporating a health variable into the utility function (Pitt & Rosenzweig, 1986) or modeling public expenditures and productivity using a system of equations (Benin et al., 2009). Others have used stochastic frontier analysis (SFA) to estimate the relationship between agricultural efficiency and health measures or farmer education (Ulimwengu, 2009;

Phillips & Marble, 1986). As mentioned, these models can be limited and in this case as well, we build upon Mundlak et al.'s (1997) analysis using this data specific to Tanzania. As the state variable approach has been outlined in the previous chapter, this chapter will focus only on the components that have been adapted for this dataset and for this particular research question. Our empirical strategy takes into account district heterogeneity to examine the effect of district-level education and health expenditures on health outcomes, and then uses a covariance structural model to estimate elasticities for agricultural productivity.

3.4.1 Consideration of District Heterogeneity

As in the cross-country analysis in Chapter 2, we follow Mundlak et al. (1997), specifying the aggregated agricultural output (Y_i) for household (*i)* conditioned on state variables *(S)* for each district *(d)*, capturing district-level constraints through input quantities (*x)* alone. To account for heterogeneity among districts, we use a two-stage estimation of the production function in which the first stage estimates the production function for each district and the second stage explains the variation in these estimated parameters using exogenous covariates (following Verbeke & Molenberghs, 2000). In their framework, Y_i is defined as the n_i-dimensional vector of repeated measurements of production for the household *(i)*, satisfying the following linear relationship:

$$Y_i = x_i\beta_i + \varepsilon_i \qquad (3.1)$$

Here, $x_i$is an (n_i*q) matrix of exogenous variables, β_i is the q-dimensional vector of unknown individual-specific regression coefficients, and ε_i represents the residual components. This uses the normal assumptions for ε_i: iid~N($\sigma^2 I_{n_i}$), where $I_{n_i}$is a n_i-dimensional identity matrix (Verbeke & Molenberghs, 2000). The second stage uses a matrix of exogenous covariates (Z_i) to explain this observed heterogeneity between districts with respect to their specific (unknown) regression coefficients (β_i) as shown in equation *(3.2)* where the residual, $b_i \sim N(0, D)$:

$$\beta_i = Z_i \gamma + b_i \qquad (3.2)$$

Equations *(3.1)* and *(3.2)* are combined to yield the generalized mixed-effects model (allowing both the fixed-effect (γ) and the random, individual-specific effect (b_i)):

$$Y_i = K_i \gamma + x_i b_i + \varepsilon_i \qquad (3.3)$$

In Equation *(3.3)*, $K_i = x_i Z_i$ and is a $(n_i * p)$ matrix of exogenous covariates. This builds upon the assumptions that the model satisfies the following conditions: b_i~N(0,D), $\varepsilon_i \sim N(0, \sum_i)$, and $b_1, \dots . b_N, \varepsilon_1, \dots \varepsilon_N$ are independent (Laird & Ware, 1982).

3.4.2 Social Expenditures and Social Outcomes

As mentioned in Chapter 2, to generate efficient estimates of the impacts of expenditures on social outcomes, Baldacci et al. (2003) suggest modeling social outcomes as partially determined by the institutional and individual environment using a latent variable approach. These social indicator variables (S) can then be used as state variables in our specification of agricultural production, outlined in more detail below. We first estimate the state variables (measures of health and education status) as functions of district-level government expenditures for health and education while controlling for household characteristics and district fixed effects as follows:

$$S_{id} = f(z_{id}, g_d) \qquad (3.4)$$

where *i* and *d* represent the household identifier and district location, respectively, and *S*: (*education, health*), *z*: household member characteristics, and g:district-level government expenditures on education and health. These district-level expected values of health

$(\hat{S}_{hd})$ and education $(\hat{S}_{ed})$ outcomes are then plugged into equation *(3.6)* to estimate marginal productivities of each input (l) as (β_{il}) from the following production function where p is total precipitation, discussed in more detail in the following section:

$$Y_i = \beta_0 + \sum_l \beta_{il} x_{il} + \beta_d p_d + \varepsilon_i \quad (3.5)$$

$$\beta_{il} = \gamma_{0l} + \gamma_{1l}\hat{S}_{hd} + \gamma_{2l}\hat{S}_{ed} + u_{il} \quad (3.6)$$

3.5 Data and Summary Statistics

For this analysis, we rely upon agricultural production data from the 2007/08 Agricultural Census, a nationally representative survey covering 52,594 households in Tanzania for the agricultural year that ran from October 1, 2007 to September 30, 2008 (National Bureau of Statistics, 2010). Given the variety of crops produced in Tanzania, weighted production is calculated as in Equation *(3.7):*

$$Y_i = \sum_{c=1}^{n} (y_{ic} \cdot a_{ic}) \quad (3.7)$$

Here, Y_i is the aggregate production amount (in kilograms) for household (i), y_{ic} is the production of crop c, and $a_{ic}$is the share of land allocated to crop c. In our case, value measurements were not possible given a lack of disaggregated price data. This also limits our ability to control for input endogeneity that has long been recognized to bias estimates (Marschak & Andrews, 1944). The endogeneity of inputs in a cross-section is often addressed using prices as instrumental variables but this is dependent upon variation in prices (Mundlak, 2001). As the underlying technology likely represents the main driver of outputs rather than prices (Mundlak, 2001), we assume that the endogeneity that is not accounted for is not greatly affecting our results. Despite this, we focus more on the effect from consideration of state variables (i.e., underlying technology and socio-economic conditions) and the heterogeneity within a country rather than the levels of the coefficients on the inputs.

We assume that aggregate agricultural output as defined here is a function of typical agricultural inputs (chemical and physical) and constraints in the natural environment (such as precipitation). For inputs, we include labor (the number of working-age household members), the use of animals for traction, the amount spent on seeds, the quantity of chemical fertilizer used in kilograms, and the size of land planted in acres. Precipitation data are also included to control for weather variations. These data are satellite-collected daily precipitation (in millimeters per day) that has been averaged over the district observation points from the Climate Prediction Center of the US National Weather Service (NOAA, 2010). These are the most accurate data available for these purposes, and have been calculated as precipitation amounts for the agricultural year. The specification was also done using a measurement of organic fertilizers, but inorganic fertilizers proved to be a better determinant of productivity differentials. This is not surprising given the relatively low levels of inorganic fertilizer use on small-scale farms.

In addition to the agricultural variables, data is taken from the 2008 Household Budget Survey (National Bureau of Statistics, 2011). This data is used to control for the rural location of households (the population of interest) and households headed by females (as we would expect that female-headed households might have different levels of access to public services in education) (UN Economic Commission for Africa, 2008). For implementation of the latent-variable approach, the numbers of household members not affected by malaria, diarrhea, or long-term illness within the household over the past month were used as health indicators. These illnesses are in line with the most documented illnesses in this dataset as well as in previous studies for Tanzania (Koestle, 2002). Education indicators included the number of household members who have completed secondary school, those who are literate in English, and those who are literate in Swahili. While accounting for adult education would have been interesting, this variable was not observed in enough households and data on professional and vocational training was not available. The summary statistics for these household-level variables are presented in Table 3.1.

Table 3. 1-Tanzania Health and Education Spending, District Level

Production	**N**	**mean**	**std dev**	**min**	**max**
production (area-weighted kg)	51534	1011	2956	0	224653
labor	52594	2.1	1.4	0	19
land (acres)	51534	3.9	5.1	0	160
fert (kg)	51534	586	10245	0	900950
animals	52594	0.25	0.43	0	1
seeds (tsh)	51534	30692	62025	0	3710010
animals	52594	0.25	0.43	0	1
Annual precipitation (mm)	42363	844	250	452	2115
Tobit Regressions (individuals)					
female	37938	0.52	0.50	0	1
rural	37938	0.35	0.48	0	1
No sickness	37896	0.78	0.41	0	1
No malaria	37938	0.86	0.35	0	1
years of education	37826	5.37	4.24	0	20
Latent Variables Equations (households)					
completed secondary	10972	0.14	0.44	0	5
English literacy	10972	0.07	0.42	0	9
Swahili literacy	10972	2.15	1.83	0	19
No malaria	10972	0.48	0.85	0	11
No fever	10972	0.53	0.93	0	11
No diarrhea	10972	0.72	1.07	0	13
No long term health problems	10972	0.69	1.06	0	14

Source: Author's calculation from NBS 2010 and 2011

Data on district expenditures for a range of expenditure categories is compiled and available online from the National Bureau of Statistics (Local Government Finance Working Group, 2011). In Tanzania, past research has estimated that 57 percent of the "other charges" category for education is being diverted away from the intended purposes and 88 percent of these charges are diverted in health (Sundet, 2004). Therefore, we analyze categories of these expenditures that are likely to include fewer leakages (personal salaries and development grants). Unfortunately, expenditure data for agriculture, roads, and other types of social expenditures were missing for a large majority of the sample. Still, ours is one of the few analyses that analyze particular categories of expenditures rather than aggregates for education and health.

We calculated the mean of expenditures for 2005 and 2006 to capture lagged effects (as much as possible given data limitations). This average allows a more consistent representation of district expenditures than using only one year. As districts vary greatly in size, we calculated the expenditures per capita[5] at a district-level using population data from the Population Census for 2002/03, the most recent compiled source of population data for Tanzania (National Bureau of Statistics, 2006). Although in the estimations, we use billions of TSH per capita for scaling purposes and interpretation, Table 3.2 presents the amounts in TSH per capita.

Table 3. 2-District Expenditures (TSH) per Capita, Avg 2005/06

Expenditure Category	Mean	Standard Deviation
Education Personal Salaries	22,841	48,400
Education Development Grants	6,357	15,013
Education Total Spending	34,482	72,574
Health Personal Salaries	5,179	9,559
Health Development Grants	1,719	4,180
Health Total Spending	9,893	22,657

Source: Local Government Finance Working Group 2011

3.6. Results

3.6.1. Estimation of Social Outcomes

As mentioned previously, indicators of health and education outcomes often used in traditional approaches may not be appropriate proxies given that the health of a population is difficult to accurately measure. We first specify tobit models to estimate our expected state variables for health and education (aggregated to the district-level)

[5] On October 30, 2011, TSH 1,724.35 = $1 (OANDA, 2011).

using both development and personal salary expenditures in the education and health sectors. The results were shown to vary with the choice of indicator, supporting the use of a latent-variable approach as discussed earlier and as per Baldacci et al. (2003). Therefore the latent variables approach was implemented using the structural equation model specified in Equation *(3.5)*. These results are presented in Tables 3.3 and 3.4 for health and education, respectively. The models, as specified, fit a measure of "good" health and the "stock" of education at the household level. Indicators of household health status include the numbers of household members without the common illnesses of malaria and diarrhea, but also long-term illnesses. These longer-term diseases have been found to have negative effects on income and livelihoods in Tanzania (Koestle, 2002; Adhvaryu & Beegle, 2010).

As shown in Table 3.3, all of the indicators are positively and significantly correlated with the health status variables. Results also suggest a quadratic relationship between health status and expenditures on salaries in the health sector.[6] These results suggest the existence of a minimum amount from which health expenses start improving farmers' health status in all types of illness. For example, at the household level, this minimum for long-term health is estimated at TSH 53,510 per capita (approximately US$31[7] per capita per year).

[6] The maximum/minimum is the value of x that solve $\frac{dy}{dx} = 0$.
In this specification (y=a+bx+cx*x), the solution is given by $x = -\frac{b}{2c}$.
[7] All dollar amounts are in US dollars. On October 30, 2011, TSH 1,724.35 = $1 (OANDA, 2011).

Table 3. 3-Health Expenditures and Health Outcomes

Variables	No Long-Term Illness	No Malaria	No Diarrhea
Health Development/capita	5.454	4.063	5.5473
Health Development/capita²	-143.48	-110.00	-150.00
Health Salaries/capita	-14.100***	-10.637***	-14.519***
Health Salaries/capita²	135.294**	102.239**	139.555***
Rural	0.174***	0.136***	0.186***
Health Indicators			
Member without long-term health problems	1.00	1.291***	0.946***
Members without fever	0.775***	0.845***	0.619***
Members without malaria	0.654***	1.000	0.733***
Members without diarrhea	1.057***	1.3648***	1.000
Variances			
Health	0.978***	0.586***	1.091***
Without long-term health problems	0.095***	0.094***	0.094***
Without fever	0.283***	0.282***	0.282***
Without malaria	0.261***	0.259***	0.259***
Without diarrhea	0.003*	0.003*	0.003***
chi²(21)=	1701.05	1715.69	1715.69
Log Likelihood	16106.8	168892.7	168892.7
N	9725	9846	9846

*Source: Authors' estimations; *p<0.10, **p<0.05, ***p<0.01*

With respect to education, the number of household members with secondary education, those with literacy in Swahili, and those with literacy in English were used as indicators of the household stock of education. Unfortunately, as mentioned, information on vocational training is not available and therefore, the following analysis is focused on secondary education. In his review of public expenditure and education outcomes in Africa, Al-Samarrai (2003) concluded that increased resources for education alone are unlikely to be sufficient for achieving education goals and that the composition of resources and the institutions that govern the use of these resources are crucial. As shown in Table 3.4, both English literacy and literacy in Swahili are significant determinants of our education indicator (secondary education); while English literacy is positively associated with the stock of education, literacy in Swahili has a reducing effect on the stock of education. This may be due to the fact that completion of secondary education (constrained to be equal to the stock of education in our setting) requires knowledge of English. Unlike health, both salary and development expenditures in education significantly affect the stock of education, but in different ways. Indeed, while development expenditures require a minimum amount (TSH 285,034 per capita per year—or approximately US$165) from which a positive effect can be observed, there seems to be a maximum amount (TSH 281,163 per capita per year—or US$163) of personal salary expenditures beyond which no positive effect is observed.

Table 3.4-Education Expenditures and Education Outcome

Variables	**Secondary Education**
Education Salaries/capita	1.615***
Education Salaries/capita²	-2.872**
Education Development/capita	-2.156***
Education Development/capita²	3.783*
Rural	-0.122***
Male Household Head	-0.032***
Education Indicators	
Completed Secondary	1.00
English Literacy	0.412***
Swahili Literacy	-0.304**
Variances	
Education	0.06***
Completed Secondary	0.132***
English Literacy	0.167***
Swahili Literacy	3.215***
chi²(12)=	222.94
Log Likelihood	75690
N	9819

*Source: Authors' estimations; *p<0.10, **p<0.05, ***p<0.01*

3.6.2. Estimation of Production Function

Moving onto the estimation of the production function (without the consideration of state variables), Ordinary Least Squares (OLS) estimates, with and without precipitation are compared to random effects (RE) estimates. All inputs and outputs are logged values and estimates can be interpreted as elasticities. The results reported in Table 3.5 show that all input elasticities are significant and positive. Compared with other inputs, elasticity of production with respect to land and seeds are the highest, ranging from 0.445 to 0.577 for land and from 0.466 to 0.522 for seeds. The value of land elasticity seems to support the idea that agricultural growth in sub-Saharan Africa has often been driven by land expansion (Dethier & Effenberger, 2011). The elasticity with respect to labor is modest and only significant when we account for precipitation and district heterogeneity.

Precipitation appears to have a nonlinear relationship with production as too much precipitation in one area during a season can be detrimental to crop production. The results suggest a tipping point of 638.5 millimeters of precipitation[8] when using the RE model and 777.2 millimeters with the OLS specification, beyond which additional precipitation begins to decrease agricultural production. This nonlinear and significant relationship between climatic variables and agricultural productivity has been documented in the literature (Maddison et al., 2006; Gommes, 1999). The results here highlight the necessity of controlling for agro-climatic conditions as well as other sources of heterogeneity when estimating input elasticities.

[8] Tipping point is the value of rainfall/temperature for which agricultural production reaches its maximum level. It is the value of x that solve $\frac{dy}{dx} = 0$. In our specification (lny=a+blnx+clnx*lnx), the solution is given by $x = e^{\frac{-b}{2c}}$.

Table 3. 5-Production Estimation

Variable	OLS	OLS with Precip	RE Model
Land	0.577***	0.520***	0.445***
	(0.011)	(0.012)	(0.030)
Labor	-0.015	0.050***	0.074**
	(0.013)	(0.015)	(0.032)
Seeds	0.522***	0.499***	0.466***
	(0.003)	(0.004)	(0.008)
Fertilizer	0.020***	0.014***	0.042***
	(0.002)	(0.003)	(0.008)
Animals	0.206***	0.182***	0.118***
	(0.009)	(0.010)	(0.020)
Precipitation		19.621***	25.165***
		(0.685)	(2.568)
Precipitation²		-1.474***	-1.948***
		(0.051)	(0.190)
Constant	0.094***	-64.80***	-80.219***
	(0.027)	(2.310)	(8.661)
Obs.	51174	41313	41313
Groups			113
Adj R^2	0.562	0.521	
Chi^2/F	13110.7	6424.9	9396.7
Log Likelihood			66050.3

*Source: Authors' estimations; std errors in parentheses, *p<0.10, **p<0.05, ***p<0.01*

3.6.3. Social Indicators and Productivity

Moving forward with the inclusion of state variables as discussed previously and following Equation *(3.3)*, the agricultural production function at the household level was estimated using a generalized mixed linear model, for which the results are presented in Table 3.6. This incorporates the expected values of education and health measures estimated from Equation *(3.4)*, with the intercepts and indirect effects for health and education. To allow for comparison, the results without state variables (the RE model from Table 3.5) are also presented.

The results in Tables 3.6 demonstrate the impact of the inclusion of social outcomes on the magnitude and significance of input elasticities, both separately and when interacted with state variables. They appear to provide evidence that education (secondary education) significantly impacts the productivity of inputs both directly and indirectly as complements to other inputs (e.g., seeds and land). For health, similarly, it appears that all indicators have direct and indirect effects on productivity. These results are significant even after controlling for district-level heterogeneity and precipitation variation. The results suggest that there are differences between the impacts based on the type of health constraint; compared to long-term diseases and diarrhea, malaria has a greater impact on productivity for all inputs other than animals.

We also analyze the interactions of health and education indicators as there may be some complementarities. Others have found a positive association between health capital and education capital in developing countries (Baldacci et al., 2008). To analyze the presence of this interaction, Table 3.7 provides interaction between health and education variables. The results confirm (when compared to Table 3.6) that when the interaction between education and health is considered, the role of education and health in productivity changes. The marginal productivity of inputs (especially labor) also changes when both education and health variables are considered and this is especially the case with malaria. These results will be tested further using additional metrics in the following discussion.

Table 3. 6-Production Estimation with and without State Variables

Variable	No State	Secondary Education	Long -Term Health	Diarrhea	Malaria
Land	0.445***	0.425***	0.436***	0.435***	0.433***
	(14.96)	(13.06)	(14.54)	(14.42)	(14.28)
Labor	0.0742**	0.0858**	0.0925***	0.0929***	0.093***
	(2.30)	(2.50)	(-2.85)	(2.85)	(2.84)
Seeds	0.466***	0.481***	0.469***	0.470***	0.471***
	(58.56)	(56.92)	(59.88)	(59.78)	(59.72)
Fertilizer	0.042***	0.046***	0.045***	0.045***	0.046***
	(5.47)	(5.52)	(5.85)	(5.88)	(5.89)
Animals	0.118***	0.126***	0.115***	0.114***	0.116***
	(6.01)	(4.99)	(4.84)	(4.76)	(4.78)
Precipitation	25.16***	25.85***	27.36***	27.38***	27.41***
	(9.80)	(10.21)	(-10.81)	(10.81)	(10.83)
Precipitation²	-1.948***	-1.987***	-2.091***	-2.092***	-2.095***
	(-10.25)	(-10.61)	(-11.16)	(-11.17)	(-11.18)
Education Intercept		-11.61***			
		(-14.38)			
Land*Education		-1.512**			
		(-2.22)			
Labor*Education		-0.235			
		(-0.33)			
Seeds*Education		1.114***			
		(6.38)			
Fertilizer*Education		0.225			
		(1.29)			
Animals*Education		0.591			
		(1.01)			
Health Intercept			4.425***	4.192***	5.964***
			(14.33)	(14.30)	(14.45)
Land*Health			0.699**	0.661	0.945**
			(2.43)	(2.42)	(2.47)
Labor*Health			-0.0387	-0.048	-0.055
			(-0.13)	(-0.17)	(-0.14)
Seeds*Health			-0.432***	-0.407***	-0.583***
			(-6.16)	(-6.14)	(-6.25)
Fertilizer*Health			-0.163**	-0.157*	-0.219**
			(-2.32)	(-2.36)	(-2.34)
Animals*Health			-0.065	-0.056	-0.113
			(-0.22)	(-0.20)	(-0.30)
Constant	-80.22***	-83.24***	-88.61***	-88.67***	-88.77***
	(-9.26)	(-9.75)	(-10.37)	(-10.38)	(-10.39)
District FE	YES	YES	YES	YES	YES
N	41313	41313	41313	41313	41313
Log Likelihood	-66050	-65938	-65942	-65943	-65939
Wald Chi²	9397	9999	10280	10267	10268

*Authors' estimations; *p<0.10, ***p<0.05, ***p<0.01; t stats in parens for Tables3.6&3.7*

Table 3. 7-Interactions between Health and Education

Variable	No State	Long-Term Health & Education	Diarrhea & Education	Malaria & Education
Land	0.445***	0.433***	0.432***	0.432***
	(14.96)	(-12.61)	(12.74)	(12.85)
Labor	0.0742**	0.0806**	0.0814**	0.082*
	(2.30)	(2.23)	(2.28)	(2.30)
Seeds	0.466***	0.475***	0.476***	0.476***
	(58.56)	(-53.7)	(54.50)	(54.83)
Fertilizer	0.0421***	0.0401***	0.0408***	0.0412***
	(5.47)	(-4.64)	(4.78)	(4.88)
Animals	0.118***	0.134***	0.1323***	0.1312***
	(6.01)	(-5.13)	(5.10)	(5.07)
Precipitation	25.16***	26.64***	26.644***	26.712***
	(9.80)	(-10.5)	(10.50)	(10.53)
Precipitation²	-1.948***	-2.040***	-2.041***	-2.046***
	(-10.25)	(-10.87)	(-10.87)	(-10.90)
Education Intercept		-5.958***	-6.051***	-5.560***
		(-3.47)	(-3.58)	(-3.20)
Land*Education		0.46	-0.607	-0.439
		(-0.73)	(-0.42)	(-0.29)
Labor*Education		-0.347	-0.971	-1.036
		(-0.58)	(-0.70)	(-0.72)
Seeds*Education		-0.274	0.518	0.454
		(-1.99)	(1.57)	(1.34)
Fertilizer*Education		-0.315	-0.427	-0.455
		(-2.26)	(-1.29)	(-1.33)
Animals*Education		0.969*	2.463*	2.347
		(-1.43)	(1.77)	(1.64)
Health Intercept		2.438***	2.287***	3.481***
		(-3.71)	(3.72)	(3.91)
Land*Health		-0.542	0.409	0.677
		(-0.37)	(0.69)	(0.79)
Labor*Health		-0.971	-0.33	-0.499
		(-0.69)	(-0.60)	(-0.62)
Seeds*Health		0.489*	-0.248*	-0.385*
		(-1.45)	(-1.95)	(-2.09)
Fertilizer*Health		-0.435*	-0.297**	-0.432*
		(-1.28)	(-2.30)	(-2.31)
Animals*Health		2.396	0.958	1.223
		(-1.74)	(1.46)	(1.32)
Constant	-80.22***	-86.10***	-86.11***	-86.35***
	(-9.26)	(-10.06)	(-10.06)	(-10.08)
District FE	YES	YES	YES	YES
N	41313	41313	41313	41313
Log Likelihood	-66050	-65928	-65928	-65925
Wald Chi²	9397	10188	10183	10188

3.6.4. Additional Metrics for Interpretation

To further interpret the results in Tables 3.6 and 3.7, we employ a series of metrics developed by Fulginiti and Perrin (1993). The first metric is the average production elasticities with respect to inputs which correspond to Equation *(3.5)* and is shown in Table 3.8. These elasticities simply compile the results from Tables 3.6 and 3.7 and are reported for only those districts in which they were significant for each model specification. As mentioned previously, the focus is on secondary education due to a lack of information on vocational training. As can be seen in Table 3.8, labor elasticity changes substantially when health and education are considered. It is estimated at 0.053 (with education), 0.064 (with long-term health), and 0.066 (with both education and malaria considered) compared to the baseline of 0.031 (with no state variables considered). In addition, land productivity is positive and significant; but its value varies between 0.459 (with no state variable included) and 0.423 (when malaria alone is included). The results show that there is bias if one does not account for health and education outcomes, either individually or combined.

Table 3. 8-Marginal Productivity of Inputs

Model	Land	Labor	Seeds	Fertilizer	Animal
No State	0.459	**0.031**	0.468	0.042	0.137
Education Alone	0.451	0.053	0.472	0.042	0.137
Health Alone					
No Long Term Disease	0.440	**0.064**	0.471	0.044	0.124
No Diarrhea	0.423	0.052	0.481	0.048	0.133
No Malaria	0.423	0.052	0.481	0.048	0.133
Education & Health Combined					
Education & No Long Term Health	0.431	0.061	0.475	0.044	0.116
Education & No Diarrhea	0.435	0.062	0.475	0.045	0.114
Education & No Malaria	0.425	**0.066**	0.478	0.473	0.111

Source: Authors' estimations; Square roots of variances for all elasticities presented are less than 0.005

The second metric from Fulginiti and Perrin (1993), is the elasticity of production with respect to state variables (health and education) and evaluated from Equations *(3.5)* and *(3.6)* where both *y* and *s* are in log form as:

$$\frac{\partial y}{\partial s} = \frac{\partial y}{\partial \beta}\frac{\partial \beta}{\partial s} = \sum_l \gamma_{ls} x_l + b_s \qquad (3.7)$$

The results are shown in Table 3.9, with components of Equation (*3.7)* broken out individually. The metric of interest (average production elasticities with respect to states) is estimated at -3.24 with respect to education, 5.31 with respect to the presence of a long-term disease, 0.13 with respect to diarrhea, and 0.16 with respect to malaria. This suggests that while increased health would be an advantage for agricultural production, increasing household stock of education (here secondary education) may decrease overall agricultural production as an increase in secondary education may open up opportunities into nonagricultural activities and thereby reduce available labor for farming activities.

Table 3. 9-Production Elasticities & Marginal Productivity of Inputs

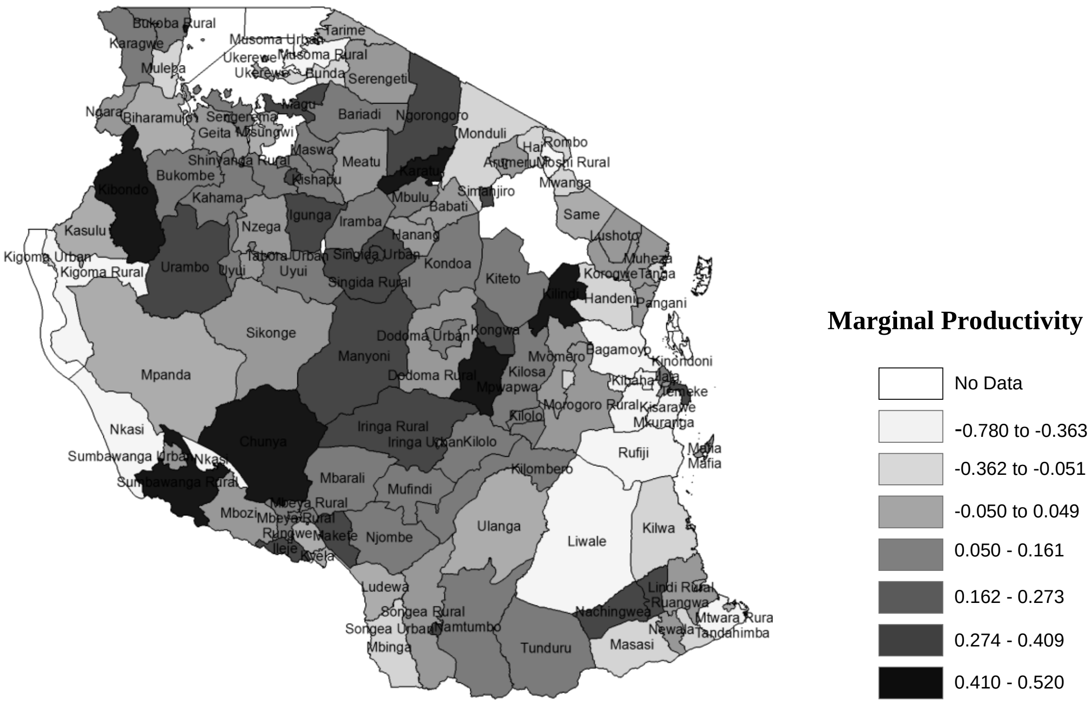
	Elasticities of Marginal Productivity of Inputs with Respect to States						**State own-elasticities**	**Elasticity of production with respect to states**
	Total Elasticitiy (sum of MPs)	**Land**	**Labor**	**Seeds**	**Fertilizer**	**Animals**		
Secondary Education	0.2	-1.5	-0.2	1.1	0.2	0.6	-11.6	-3.24
No Long-term disease	0.9	-0.5	-1.0	0.5	-0.4	2.4	2.4	5.31
No Diarrhea	0.5	0.4	-0.3	-0.2	-0.3	1.0	2.3	0.13
No Malaria	0.6	0.7	-0.5	-0.4	-0.4	1.2	3.5	0.16

Source: Author's calculations

Total elasticities (summed across all inputs) are positive as overall production increases but there are significant differences in individual estimates and not all individual estimates are significant (as shown in Tables 3.6 and 3.7). These findings highlight the need for careful targeting in the implementation of social programs aimed at improving agricultural productivity. The variation in significance of the impacts associated with social variables among districts could indicate diversity in production technology across Tanzania.

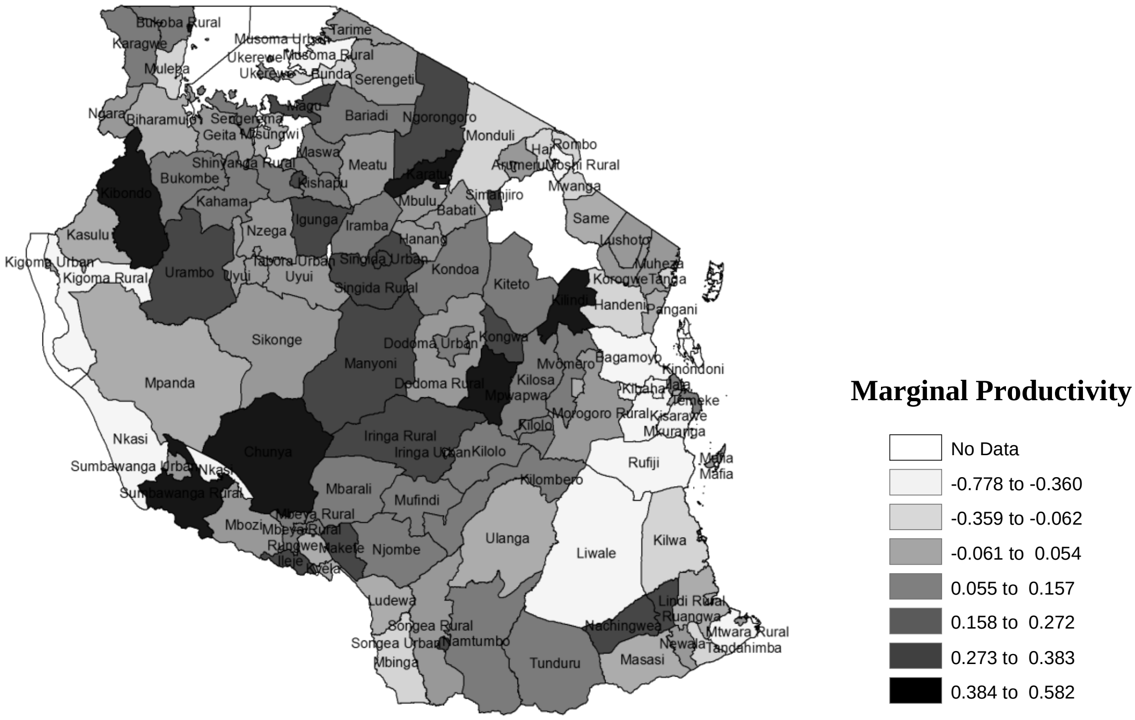
This heterogeneity among marginal productivities can be seen through the geographical distribution of labor productivity with respect to states, shown in Figure 3.2 for long-term health, Figure 3.3 for education, and Figure 3.4 when both are considered. Additional figures showing district heterogeneity in marginal productivities for land and labor (with education and health both separately and combined) are included in the Appendix (Figure A.1-Figure A.3). The comparison among Figures 3.2 to 3.4, for example, show the variation not only throughout the country but the impact of the state variable considered. This diversity highlights the shortcomings of the homogeneous technology assumption, and at least in the case of Tanzania, policy recommendations based on national averages are likely to miss the target in many districts.

Figure 3. 2-Marginal Productivity of Labor (Long-Term Health as State variable)



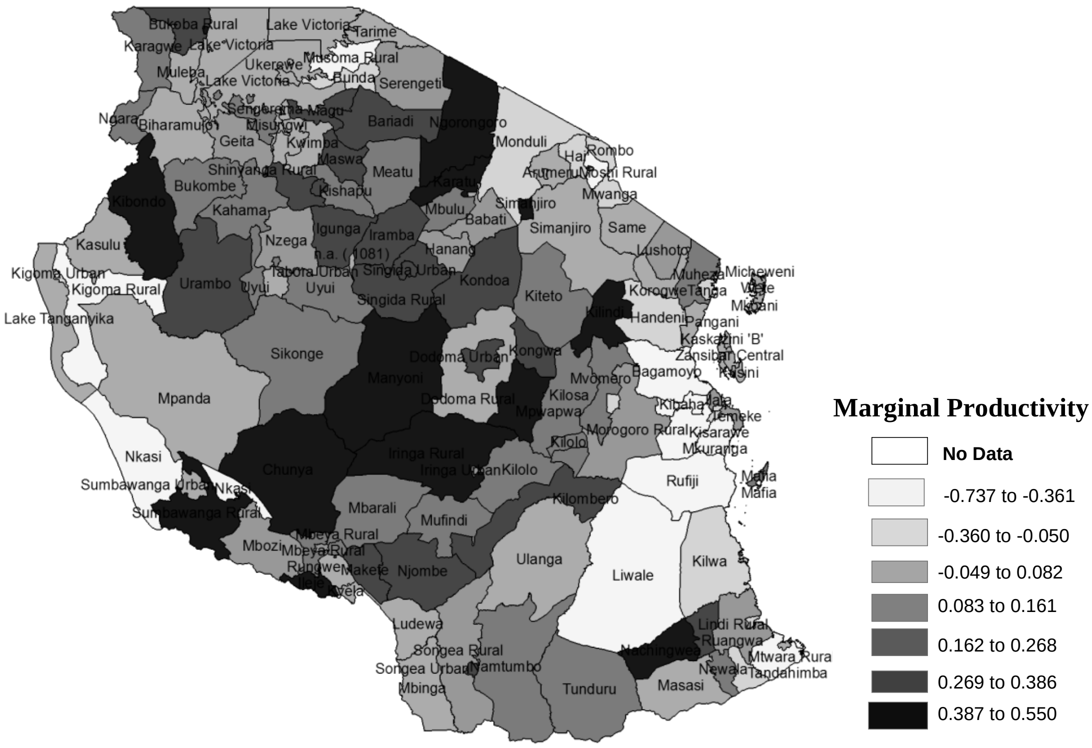
Source: Author's calculation

Figure 3. 3-Marginal Productivity of Labor (Education as State variable)



Source: Author's calculation

Figure 3. 4-Marginal Productivity of Labor (Education and Health as State Variables)



Source: Author's calculation

3.7 Conclusions

Combining the most recent nationally-representative data on agricultural production and household characteristics available for Tanzania, we evaluate the impact of specific sub-components of health and education expenditures at the district-level on human capital and marginal productivity of agricultural inputs at the household level. This research allows more detailed analysis than many studies in that it analyzes the heterogeneity within one country, accounting for district-level expenditures and heterogeneity of production and climate. It also analyzes unique types of government expenditures and health constraints to the extent possible and their direct and indirect effects on agricultural productivity. This relies upon the combination of a generalized mixed-effects model (to capture heterogeneity) and a covariance structure that accounts for not only the underlying socio-economic environment driving farm-level decisions but also imperfect measurements of health and educational outcomes.

The results of the analysis confirm the significance of government social expenditures in human capital formation as measured through health and education indicators. Building upon this knowledge, we also show that these health and education indicators significantly impact agricultural productivity both directly and indirectly. The results show variation in effects across types of diseases as well as combined effects of both education and health across input productivities. Overall production elasticities respond positively to the absence of long-term disease and to a greater extent than to malaria or diarrhea. In terms of educational indicators, overall production elasticities respond negatively to an increase in secondary education, which may indicate a focus on off-farm sources of income. For particular inputs, the marginal productivity of land and labor are most affected by long-term disease incidence while seeds and fertilizer productivity is more affected by malaria and diarrhea. These results may highlight the difference in the short-term health factors that impact immediate on-farm investments and the longer-term health constraints which may be a sign of limited investments to restructure agricultural production. This result points to not only the complexity in measuring important health outcomes but also suggests that the return to additional investment in malaria prevention on agricultural productivity of labor in Tanzania might be higher compared to similar interventions on other diseases.

The results also point to the importance of controlling for heterogeneity across sub-national entities as well as the overwhelming importance of precipitation as a constraint to agricultural production. The findings highlight the effects of different types of social expenditures (i.e., health expenditures and education expenditures) as well as between expenditure allocations (i.e., development expenditures and staff salary expenditures). In particular, we find a minimum level of expenses on health salaries from which farmers' health status improves across all types of illness. Likewise, our results show that there is a minimum level of expenditures needed to see changes in the stock of education. This result is in line with what has been documented in other regions and calls for careful targeting of social spending to achieve expected educational outcomes.

Overall, our findings have shown that the level of productivity resulting from the use of various agricultural inputs is affected by changes in social outcomes and that these changes can be impacted by government expenditures in these sectors. They also highlight the existence of estimation bias when marginal productivities of inputs are assumed to be constant across locations or farming households. Geographical distribution of marginal productivities of inputs with respect to these state variables, even after controlling for district fixed effects and variation in precipitation, seem to confirm technology heterogeneity across districts. Ignoring this heterogeneity when implementing social or agricultural programs could result in inefficient use of limited government resources. Keeping in mind this heterogeneity within Tanzania, Chapter 4 moves to household level production in a particular region of the country, analyzing the impact from one particular constraint in public services (water access at the household level).

4. Household Water Constraints and Agricultural Labor Productivity in Tanzania[9]

4.1 Introduction

As mentioned previously, the water sector in Tanzania does not receive a high share of government funding despite the fact that water access is a significant constraint to households in rural Tanzania. Water-related constraints can have significant impacts on incomes and food security, impacting households' decisions both on- and off-farm. The time required for collecting drinking water can influence the choice of supply source for a household. This was shown empirically in Benin, for example, where the choice to use an unimproved water source was often the result of distance to improved water sources (Ruben & Zintl, 2011). Distance to a water source, regardless of the quality of the water, can also impact the household in other ways. Increased time needed for water collection can decrease the labor time available for farming and affect the use of other inputs (Hoddinott, 1997; Croppenstadt & Muller, 2000). It may also mean that households are storing more water at the household level, possibly increasing exposure to pollutants from improper handling or storage (Zwane & Kremer, 2007; Ruben & Zintl, 2011).

Furthermore, water collection times can influence water usage within the household. In addition to limiting water consumption, households may change sanitation practices as a water-saving strategy, which can negatively impact health. The health impacts of bacteria, viruses, and parasites in surface water tend to increase substantially due to a lack of sufficient water for washing and hygiene (Zwane & Kremer, 2007). In fact, the quantity of water available was found to be a more robust indicator of health than quality, largely due to limitations on sanitation rather than consumption (Esrey et al., 1991; Madulu, 2003; Fewtrell et al., 2005).

[9] Author acknowledges contribution of Andrew Temu of Sokoine University and Matin Qaim of Göttingen Universität.

For Tanzania specifically, water access has been recognized as one of the most important components needed for achievement of the nationally recognized social and economic development goals (Tanzania, United Republic, 2002). However, public expenditures on water have been very low (3.7 percent of government spending in 2010) (Tanzania, United Republic, 2009). Under the National Water Policy of 1991, a target was set of providing clean and safe water within 400 meters of each household by 2002; more recent targets include a goal of providing 90 percent of the rural population in Tanzania with sustainable access to safe water by 2025 (Jiménez & Pérez-Foguet, 2010). As of 2007, over half of the rural households in Tanzania had to travel more than one kilometer to their drinking water source in the dry season (National Bureau of Statistics, Tanzania, 2009). Studies for rural Tanzania showed that poor access to water is a significant determinant of diarrhea and trachoma (a bacterial eye infection) (Tumwine et al., 2002; Baggaley et al., 2006).

There is a substantial body of literature looking at the linkages between drinking water access and health (e.g., Tumwine et al., 2002; Baggaley et al., 2006; Zwane & Kremer, 2007; Ruben & Zintl, 2011). There are also studies that analyze the influence of health on agricultural productivity and efficiency (e.g., Antle & Pingali, 1994; Ersado et al., 2004; Asenso-Okyere & Mekonnen, 2011). However, there is very little research looking at the direct impacts of household water access constraints on agricultural productivity. Given government budget constraints, understanding the spillovers of policies and expenditures in one sector on other sectors is important to design efficient policy strategies. This is especially important for spillovers on agriculture as the main source of income for the rural poor. We hypothesize that water access constraints have a negative impact on agricultural labor productivity. This hypothesis is tested for the case of Tanzania, using primary household survey data.

The chapter is organized as follows: Section 4.2 provides some background and presents the analytical approach; Section 4.3 gives an overview of the household survey and descriptive statistics; Section 4.4 presents the estimation results; and Section 4.5 concludes and discusses some policy implications.

4.2. Empirical Background and Approach

Many households in sub-Saharan Africa are faced with very large water collection times, which often disproportionately affect women (Boone et al., 2011; Subaiya & Cairncross, 2011). Existing research suggests that investing in water infrastructure to reduce collection times could contribute to poverty alleviation (Blackden & Wodon, 2006; Ruben & Zintl, 2011). But the underlying mechanisms are less clear, as they can be manifold (Ogilvie, 2010). One potential mechanism is through increased agricultural productivity, as was pointed out conceptually by Rosen & Vincent (1999). But empirical research in this direction remains rare. One study for Ethiopia found that time to access drinking water was a significant determinant of overall agricultural productivity, likely through health impacts or time that is diverted from agricultural activities (Croppenstedt & Muller, 2000). We are not aware of other research on this particular relationship.

4.2.1 Potential Mechanisms of Impact

In rural areas of Tanzania, most households are dependent on canals fed by rivers as their drinking water source. While some of this water is used for irrigation, most is used for domestic purposes (Aikaeli, 2010). Long distances to water can have wide-ranging effects, as was already mentioned above. Here, we measure drinking water access in terms of the time it takes to collect water rather than the distance. Given different infrastructure conditions, time is a better measure than distance (Boone et al., 2011). Moreover, time includes possible waiting times at the water source, which is important when looking at issues of labor time availability. We concentrate on the time to water during the dry season, '*kiangazi'*. Given the dependence on surface water for households in rural Tanzania, access to water in the dry season is often more limiting than in the wet season.[10]

We evaluate the role of water access for the *quantity* of household labor used in agriculture, capturing both direct effects (assuming that time spent gathering water could reduce time available to work on-farm) and indirect effects (assuming time spent sick due to lower access to water could reduce labor days available). Beyond labor quantity, water access may also affect the *quality* of household labor. When facing severe water access constraints, households may choose to limit water use for consumption and sanitation with negative health implications, as was discussed earlier. They may also store water for longer periods of time, which is often associated with declining water quality (Ruben & Zintl, 2011). Household members that suffer from infectious diseases may still work on their fields, but they may be physically weakened and thus less productive. We analyze this by looking at the impact of water access on household labor productivity. Finally, we measure the impact of water access on crop yields.

4.2.2 Estimation

We first evaluate the role of water access on the *quantity* of agricultural labor used by the household. Although water access could affect other household decisions, we focus on days of household labor used for crop production. We acknowledge that labor days is not a very precise measure, as the number of hours spent in the fields may vary somewhat. But we do not have more precise data available. We regress labor quantity on

[10]We also ran the estimation models with wet season collection times and average annual collection times with similar general results.

water access and several control variables. For better comparison across farms of different size, we divide household labor use by the land cultivated, measured in acres. All variables are log-transformed as follows:

$$ln\,\frac{Labor_i}{Land_i} = \alpha + \beta lnW_i + \gamma S_i + \delta ln\boldsymbol{T_i} + \rho ln\boldsymbol{H}_i + \tau\boldsymbol{D}_i + \varepsilon_i \qquad (4.1)$$

Here, W_i stands for water access in minutes of collection time for household *i*, S_i is a variable capturing the safety of the water source, $\boldsymbol{T_i}$ is a vector of variables for agricultural technology, and $\boldsymbol{H}_i$ is a vector of household control variables that are expected to influence labor use decisions. These variables are discussed in more detail below. Finally, a vector of district dummies $(\boldsymbol{D}_i)$ allows a control for differences in agroecological factors, including soil and climatic conditions, and possible unobserved regional heterogeneity. The Greek symbols are parameters to be estimated; ε_i is a random error term.

For the second part of our analysis, we anticipate that impacts of water access will show up in household labor effectiveness, or labor *quality*. As labor quality is not observed, we estimate this effect through agricultural labor productivity, partially determined by inputs and additional household-level constraints. Labor productivity is often particularly relevant for measuring welfare in rural areas (Wiebe, 2003). For the construction of the productivity variable we convert production output to a value measure using local prices. This is important, as farm households grow different crops of different weight and measured in different units. In addition, as the diversity of crops grown (e.g., cereals, tubers, tree crops) could affect the distribution of production value and the use of labor and other inputs, we employ a weighting procedure as follows:

$$Prod_i = \sum_{k=1}^{n}(v_k \cdot a_k) \qquad (4.2)$$

where $Prod_i$ is the production value of household *i*, and a and v are respectively the share of the farm area and the production value of crop *k*. Labor productivity is then calculated by dividing by the quantity of household labor used. For the impact analysis, we regress labor productivity on water access (W_i) and several control variables as follows:

$$ln\ \frac{Prod_i}{Labor_i} = \alpha + \beta ln\ W_i + \gamma S_i + \theta ln\ \boldsymbol{X}_i + \delta ln\ \boldsymbol{T}_i + \rho ln\ \boldsymbol{H}_i + \tau\ \boldsymbol{D_i} + \varepsilon_i \qquad (4.3)$$

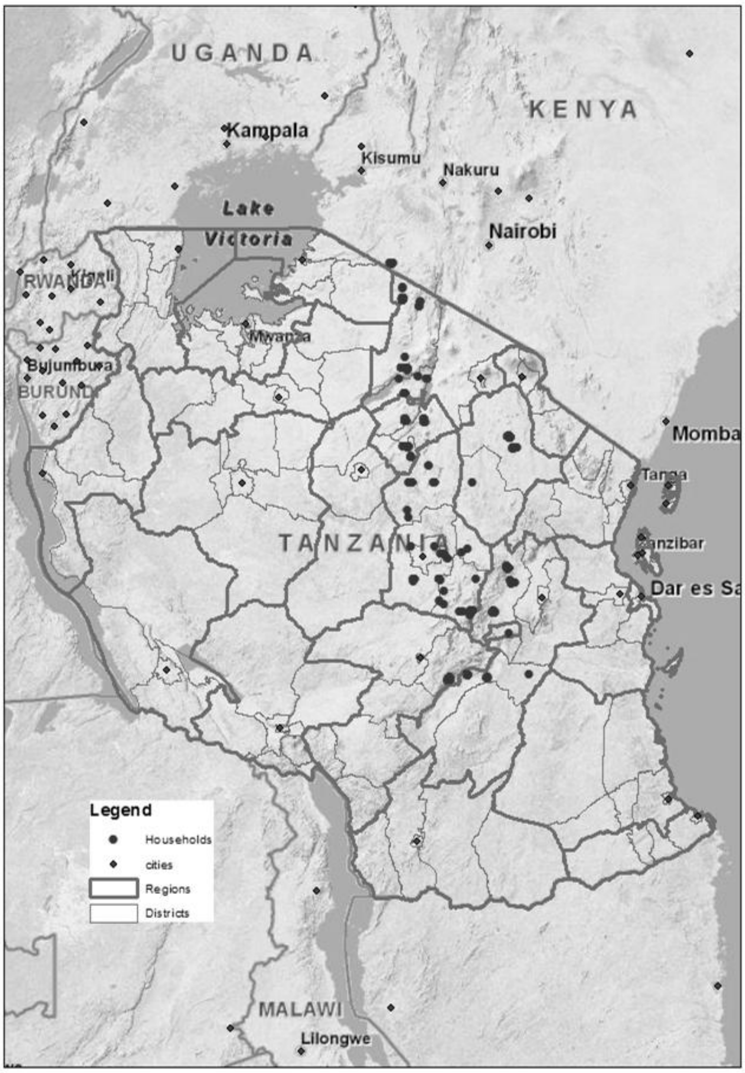
The variables are defined as above. In addition, we include other agricultural inputs ($\boldsymbol{X_i}$), which are expected to influence labor productivity.

4.3 Data and Descriptive Statistics

A household survey was conducted from November 2010 to January 2011 in central-east and central-north parts of Tanzania, covering household characteristics and agricultural production data for the previous 12 months. The districts selected included Kilosa and Kilombero in Morogoro region, Kondoa and Chamwino in Dodoma region, Ngorongoro and Karatu in Arusha region, and Babati and Simanjiro in Manyara region. These districts were selected using a clustering design to allow for a diversity of social programs while focusing on an area with similar production and weather patterns. This was particularly important given the diversity of agro-climatic conditions in Tanzania, which has led to different production environments and constraints (Fan et al., 2005). The area of analysis has bimodal precipitation (with short rains from October-December and long rains from March-May).

Two villages per district and households within those villages were randomly sampled, covering 75 percent of the available hamlets in each village. In total, 504 households were sampled in the 8 districts. The households sampled were mapped using GPS and the area of sampling is shown in Figure 4.2. The survey questionnaire was translated into Swahili, pretested for clarity, and interviews were done with the household head. Questions included information on household composition, water access, agricultural production (inputs and outputs), livestock ownership and trade, health facilities, communication and transportation, educational facilities and participation, credit access and social networks, as well as household income and consumption. While the sample is not representative of conditions in all rural areas of Tanzania, public spending patterns and water access conditions are typical for the country. In the regions sampled, government expenditures mirrored national-level expenditures for each sector, with less than 2 percent of the budget going to the water sector in 2006 (Tanzania, United Republic, 2009).

Figure 4. 1- Sampled Household Locations



Author: Summer Allen

For the households sampled, agriculture was the main occupation, with a majority having no secondary occupation. Descriptive statistics are shown in Table 4.1.[11] Farm sizes averaged 6 acres with most of this (85 percent) in staple crops (cereals, tubers, or pulses), primarily maize. At the farm level, less than 10 percent of land is irrigated and around 30 percent is planted with improved seeds. Almost 50 percent of the households belonged to at least one type of village-level group (farmer group, religious group, women's group etc.). The income variables at the bottom of the table suggest wide

[11]Out of the 504 households, six had incomplete data on selected variables and were not included in the analysis; these households were not outliers for other variables.

variability between households across all measures (10,000TSH = USD$6.84 in January 2011).

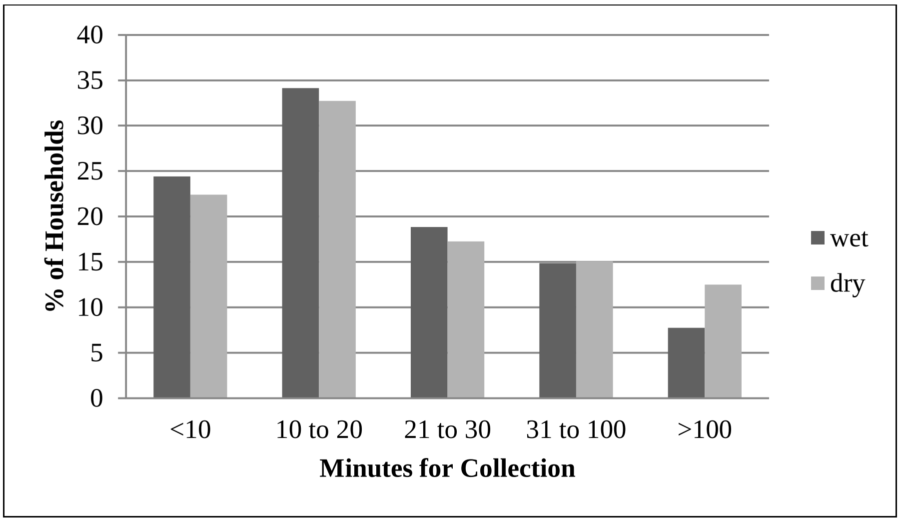
Table 4. 1- Descriptive Statistics of Sampled Households

	Full sample (*N=498)*		Less than 20 minutes (*N*=239)		At least 20 minutes (*N*=259)	
	Mean	SD	Mean	SD	Mean	SD
Household variables						
Household members	6.0	2.5	5.82	2.4	6.19*	2.63
Dependency ratio	1.01	0.78	1.00	0.73	1.03	0.82
Female headed (% of households)	12.6	-	14.2	-	11.2	-
Education of household head (years)	5.53	3.12	6.09	2.9	5.05***	3.19
Age household head (years)	45.6	19.2	46.6	16.7	44.7	21.3
Non-agricultural occupation (% of households)	33.2	-	35.8	-	31	-
Group membership (# of groups per household)	0.47	0.8	0.5	0.9	0.43	0.7
Safe water (% of households)	50.6	-	60.4	-	41.5***	-
No toilet (% of households)	11.2	-	6.2	-	15.8***	-
Minutes to road	21.8	34.8	23.3	40.2	20.3	28.9
Minutes for water (dry season)	45.2	82.4	8.6	4.7	78.7***	103.3
Labor days lost from sickness	22.3	45.3	22.6	38.2	22.1	51.2
Agricultural variables						
Land (acres)	6.19	7.3	5.71	7.16	6.6	8.3
Pesticides (‘000 TSH)	8.6	33.6	12.0	42.2	5.5**	22.6
Fertilizer (‘000 TSH)	5.8	26.8	8.2	31.5	3.6*	21.5
Traction animals (#)	1.29	2.4	0.93	1.8	1.63**	2.78
Household labor (days)	174.0	256.2	176.0	324.5	172.1	171.1
Hired labor (days)	64.7	123.0	59.7	90.4	62.3	146.8
Part in agricultural training (% of households)	6.2	-	8.8	-	4.6*	-
Part in farmer field schools (% of households)	10.4	-	12.1	-	8.8	-
Staples (% of farm)	85.2	23.2	88.0	20.5	82.6*	25.3
Cash crops (% of farm)	13.3	22.0	10.7	19.3	15.8**	24.0
Improved seeds (% of farm)	31.3	39.4	32.1	38.8	30.6	40.1
Irrigation (% of farm)	5.9	19.5	8.5	23.5	3.4**	14.6
Extension (# of visits per household)	0.42	0.55	0.42	0.54	0.41	0.57
Income variables						
Total prod value (‘000 TSH)	3,520	9,376	3,631	11,200	3,417	7,255
Labor productivity (‘000 TSH per day)	59.0	324.6	38.4	126.5	78.1	437.7
Weighted labor productivity (‘000 TSH per day)	27.3	149.7	18.9	62.9	34.9	198.5
Weighted yield (‘000 TSH per acre)	184.3	377.9	195.6	409.2	173.9	347.0

*Note: t-test results for difference in means between the two subsamples: *** p<0.01, ** p<0.05, * p<0.10*
Source: Author’s calculations based on survey data

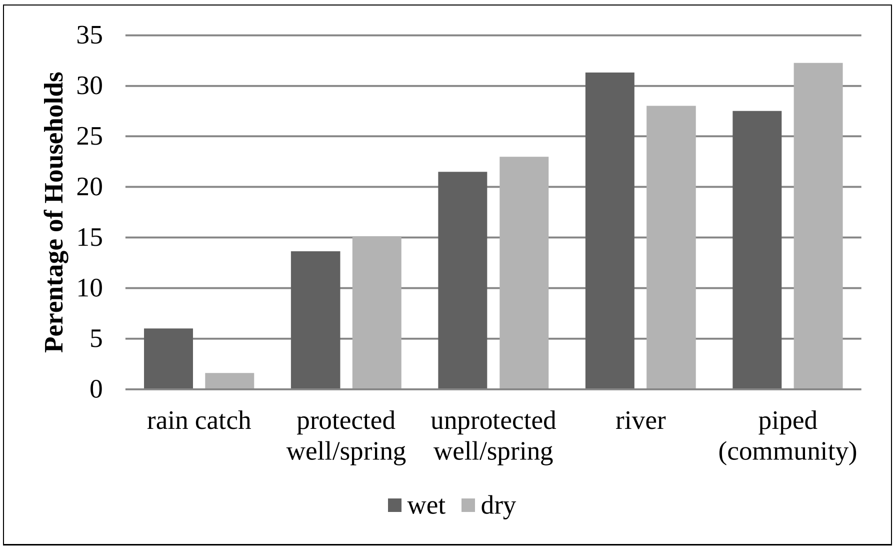
Looking at water availability and access specifically, households need 45 minutes to collect water during the dry season on average. Fifty percent of households are using some type of protected water source such as a protected well, spring, or water bought from a vendor or neighbor with a tap; we refer to such protected water sources as "safe water". Figure 4.2 shows the distribution of the time needed to collect water by season, whereas Figure 4.3 shows the water source by season. No household in the sample has in-home piped water. As can be seen, seasonal differences are not substantial, but during the wet season, more households use rain catchments and more than 30 percent collect their water directly from rivers.

Figure 4. 2- Water Collection Times by Season



Source: Author's calculations from the 2010/11 survey data

Figure 4. 3- Water Source by Season



Source: Author's calculations from the 2010/11 survey data

It is possible that households with limited water access are disadvantaged also in other ways that could affect their productivity. For example, households in villages with drinking water wells or more established water infrastructure could also have relatively better access to input and output markets and public support services, such as agricultural extension. To evaluate this, Table 4.1 breaks out the characteristics for households that spend less than the median time (20 minutes) collecting water and those that spend at least the median time collecting water in the dry season.[12]

Some of the differences between these two subsamples are statistically significant, such as irrigation, use of a protected water source, and the presence of a pit latrine. While irrigation is low in both groups, it is especially low among households far away from water sources. There are also some differences in terms of educational levels, input use, and types of crops grown. In the regression analysis, we will control for such differences to isolate the effects of water access. Interestingly, the differences in

[12] The median time required to collect water is 20 minutes. The reason why the two subsamples are not exactly of equal size is that several households stated collection times of 20 minutes.

household labor and labor productivity are not significant between the two subsamples. Further details are analyzed in the next section.

4.4. Results

4.4.1. Effects of Water on Household Labor Quantity

Table 4.2 presents the estimation of household labor quantity (Equation 4.1). In addition to water access, the model includes a dummy if safe water from a protected source is used (see above for definition). As agricultural technology variables we include a dummy for participation in agricultural training, the number of traction animals per acre, and the share of the farm area under staple crops (as opposed to horticultural and other crops). These variables may influence household labor use, and they were shown to differ between households with better and worse access to drinking water. We do not include hired labor use, as this may be jointly determined with household labor use and could thus lead to problems of endogeneity. The same holds true for other agricultural inputs such as fertilizer and pesticides.

To control for differences in household level characteristics we include a set of socio-demographic variables. Human and social capital can influence household labor use decisions on-farm and off-farm (Narayan, 1997). We use a dummy for female household heads, the dependency ratio (number of children to each adult in the household), and group membership (since shared labor may be used). We also include the education of the household head (in years), which is significantly different between household with better and worse access to water. We also tried to control for a few other variables, such as household size and age of the head. The major results remained unchanged, but as these are correlated with other variables in the model, the standard errors increased, so that we removed them in the final version. In the survey, we had also collected data on the incidence of illness. However, many diseases are not recorded as such, and they may also not always lead to lost labor days (farmers may still work in the field when sick).We found no correlation with household labor days. Other studies have discussed the inherent difficulty of measuring the impact of health indicators on output or labor lost (Pitt & Rosenzweig, 1986).

The results in the first column of Table 4.2, referring to the full sample, suggest that access to water does not influence household labor use significantly. Likewise, many of the other variables are not significant. The variables that are significant are traction animals and female household head. The number of traction animals per acre has a negative effect on household labor use, which is as expected. Agriculture in Tanzania is still widely limited to hand hoe cultivation (Fan et al., 2005), which is very labor intensive. Traction animals reduce the labor requirements for tillage operations in particular. Households with female heads use significantly more household labor for crop production. This effect is quite strong and may be related to fewer alternative income-earning opportunities for female-headed households. Women also tend to have lower access to inputs and technologies, which they may try to compensate by using more household labor.

Table 4. 2- Determinants of Household Labor per Acre

		Subsamples by water access	
Household Labor Days	Full sample	Less than 20 min	At least 20 min
Water access (minutes)	0.022	-0.004	-0.004
	(0.04)	(0.09)	(0.09)
Safe water (dummy)	-0.074	-0.16	-0.16
	(0.10)	(0.16)	(0.16)
Agricultural training (dummy)	-0.16	0.227	0.227
	(0.17)	(0.21)	(0.21)
Traction animals/acre	-0.042***	-0.025	-0.025
	(0.01)	(0.02)	(0.02)
Staples (% of land)	-0.011	0.171	0.171
	(0.02)	(0.19)	(0.19)
Non-agricultural occupation (dummy)	0.053	0.113	0.113
	(0.10)	(0.13)	(0.13)
Dependency ratio (adults/children)	0.010	-0.004	-0.004
	(0.02)	(0.02)	(0.02)
Education of household head (years)	0.018	0.026	0.026
	(0.01)	(0.02)	(0.02)
Female household head (dummy)	0.499***	0.571***	0.571***
	(0.11)	(0.14)	(0.14)
Group membership (# of groups)	-0.002	0.001	0.001
	(0.01)	(0.01)	(0.01)
District fixed effects	YES	YES	YES
Constant	2.500***	1.493	1.493
	(0.30)	(0.93)	(0.93)
Observations	502.00	240.00	240.00
R-squared	0.13	0.178	0.178

*Note: *** p<0.01, ** p<0.05, * p<0.10; robust standard errors in parentheses*

The second and third columns of Table 4.2 show separate regressions for households with water collection times below and equal or above the median time requirement. This disaggregation helps to identify possible effects that are not continuous. It also allows us to analyze whether water access has an influence on the effect of other determinants of household labor. The results show that the coefficients for water access remain insignificant. The other effects differ slightly in magnitude, but without changing the general results. Water access does not appear to be a significant determinant of household labor *quantity* when other household and regional differences are controlled for. We now move forward with our analysis of the impacts of water access on the *quality* of labor used.

4.4.2 Effects of Water Distance on Household Production and Household Labor Quality

Table 4.3 shows results of models where we regress household labor productivity on water access and control variables, as described in equation (4.3). Labor productivity is calculated for the farm as a whole, not per acre. Hence, the vector of agricultural inputs includes land cultivated measured in acres, next to hired labor measured in days, the number of traction animals, pesticides and fertilizers measured in value terms, and the percentage of land cultivated with improved seeds. We also control for the percentage of land irrigated, which could be correlated with water access, because water may be used domestically and for irrigation purposes (Ersado, 2005).

Household socio-demographic variables are the same as discussed above. In addition, we include road access, measured as the time required for reaching the next road, and a dummy for whether or not the household has a toilet (pit latrine). Toilet can be seen as a proxy for more general hygiene conditions that go beyond access to water and may also affect household labor productivity. We also tested other variables, especially those with significant differences between households with better and worse water access. These other variables had no significant coefficients in the estimation model and did not change the other results. The double-log functional form was tested against more flexible forms (such as the translog), but the goodness of fit did not improve.

The estimation results in the first column of Table 4.3 refer to the full sample. Water access does not have a significant effect on household labor productivity in this specification. Hired labor, the amount of land, the amount spent on pesticides, and the number of traction animals increase household labor productivity significantly. A female household head has a relatively large negative effect. This may be due to the same reasons that were already discussed above for household labor quantity. First, females often have lower access to information and technology, which may not be fully controlled for in the other covariates. Second, females may work more in their own fields because of their lower access to off-farm economic activities. Due to diminishing returns, using more labor on the farm can be associated with lower labor productivity.

However, while we see water access has a negative but insignificant effect on labor productivity, it could be that this elasticity is not constant. Based on this, we divide the sample into two subsamples with water collection times below the median of 20 minutes and equal or above that median value.

Table 4. 3-Area-Weighted Labor Productivity by Water Access

		Subsamples by water access	
Labor Productivity	Full Sample	Less than 20 min	At least 20 min
Minutes for water (dry)	-0.057	-0.106	-0.261**
	(0.05)	(0.13)	(0.12)
Irrigation (%)	-0.001	-0.004	-0.006
	(0.02)	(0.02)	(0.04)
Use safe water (dummy)	0.051	0.241	0.105
	(0.14)	(0.22)	(0.21)
No toilet (dummy)	0.169	-0.044	0.395
	(0.28)	(0.37)	(0.36)
Land (acres)	0.188**	-0.088	0.056
	(0.08)	(0.10)	(0.14)
Pesticides (TSH)	0.0170*	0.020*	-0.004
	(0.01)	(0.01)	(0.01)
Traction animals (#)	0.045***	0.041*	0.041*
	(0.01)	(0.02)	(0.02)
Hired labor (days)	0.044***	0.044***	0.055***
	(0.01)	(0.01)	(0.01)
Fertilizer (TSH)	0.005	-0.012	0.015
	(0.01)	(0.01)	(0.02)
Improved seeds (%)	0.003	0.015	-0.005
	(0.01)	(0.02)	(0.02)
Participate in agricultural training	0.143	-0.055	-0.209
	(0.17)	(0.28)	(0.36)
Dependency ratio	-0.014	-0.040	0.020
	(0.02)	(0.03)	(0.04)
Minutes to road	0.004	0.018	0.075
	(0.04)	(0.06)	(0.07)
Female household head (dummy)	-0.470***	-0.513**	-0.535**
	(0.15)	(0.23)	(0.27)
Education of household head (years)	-0.0113	-0.0254	-0.0108
	(0.01)	(0.02)	(0.02)
FIXED EFFECTS	DIST	DIST	DIST
Constant	8.709***	8.715***	9.127***
	(0.38)	(0.60)	(0.63)
Observations	498	239	259
R-squared	0.349	0.300	0.324

*Note: *** p<0.01, ** p<0.05, * p<0.10; (robust standard errors)*

All continuous variables are included in log form. The dependent variable is the log of household labor productivity, using a weighting procedure as described in equation (4.2).

Model estimates for these two subsamples are shown in the second and third columns of Table 4.3. Indeed, water access has a significantly negative effect for households with water collection times of at least 20 minutes, while this effect is not significant when collection times are shorter. For the more water-constrained households, a one percent increase in collection time reduces household labor productivity by 0.26 percent. This confirms our main hypothesis that water access constraints have a negative impact on agricultural labor productivity. Comparing the two subsample models we also find differences in the coefficient magnitudes and significance levels of a few other covariates, such as hired labor, pesticides, and female household head. These differences indicate that water access may determine household behavior and labor productivity through multiple mechanisms.

We carried out several robustness checks. As described in section 4.2, we considered labor productivity combined for all the crops grown on farms, weighting crops by their area share on the farm. We tested whether the weighting procedure has an effect on the results by running the same models without weighting. The general results did not change. We also ran the models only for cereal production with results presented in Table 4.4. We find similar relationships regarding the direct and indirect influence of water access, with differences between the households depending on water collection times. In particular, Table 4.4 shows that a one-percent increase in collection time reduces household labor productivity in cereals by 0.22 percent and that for these households, irrigation and traction animals pay a significant role in labor productivity. Hence, as concluded above, water access appears to play a role in determining household behavior and the main findings do not seem to be driven by the type of crops considered.

Table 4. 4-Cereal Labor Productivity by Water Access

Cereal Labor Productivity	Less than 20 min	At least 20 min
Minutes for water (dry)	-0.0395	-0.219*
	(0.16)	(0.12)
Participate in agricultural training	0.073	-0.030
	(0.30)	(0.42)
Irrigation (%)	0.003	0.211***
	(0.04)	(0.07)
Use safe water (dummy)	0.153	0.263
	(0.26)	(0.19)
No toilet (dummy)	-0.045	0.341
	(0.40)	(0.38)
Land (acres)	-0.046	0.028
	(0.12)	(0.13)
Pesticides (TSH)	0.004	-0.016
	(0.01)	(0.01)
Traction animals (#)	0.0319	0.062***
	(0.03)	(0.02)
Seeds (TSH)	0.009	-0.035***
	(0.02)	(0.01)
Hired labor (days)	0.058***	0.056***
	(0.02)	(0.01)
Fertilizer (TSH)	-0.005	0.016
	(0.02)	(0.02)
Dependency ratio	-0.025	0.020
	(0.04)	(0.04)
Minutes to road	0.083	0.004
	(0.10)	(0.06)
Female household head (dummy)	-0.608**	-0.561**
	(0.27)	(0.26)
Education of household head (years)	-0.025	-0.005
	(0.03)	(0.02)
FIXED EFFECTS	DIST	DIST
Constant	8.771***	11.62***
	(1.08)	(0.87)
Observations	231	250
R-squared	0.2	0.391

*Note: *** p<0.01, ** p<0.05, * p<0.10; standard errors in parentheses*

All continuous variables are included in log form. The dependent variable is the log of household labor productivity in cereal production.

Water access may also affect productivity in ways other than through labor. For example, it may influence decisions on how much water to use for irrigation (beyond the irrigated area share) or how much complementary inputs to apply. To analyze this, we look at the impact of water access on crop yield (production value per acre). The variables are log-transformed as previously and the results are shown in Table 4.5. In this case as well, water access has a significant and negative effect on yields in households that are more than the median distance from the water source. For these households, a one percent increase in water collection time decreases yield by 0.17 percent on average. Comparing the results across subsamples, we also see that more limited water access can impact the importance and production elasticity of household labor, hired labor, improved seeds, pesticides, and fertilizer.

The results of this analysis for both labor productivity and yield support our assumption that households with more limited water access are faced with very different constraints than households with relatively better access to water. These effects could be overlooked if only evaluating the direct effects of water access on labor hours or production outcomes.

Table 4. 5-Determinants of Yield by Water Access

Variables	Less than 20 min	At least 20 min
Water access (minutes)	-0.131	-0.169*
	(0.10)	(0.09)
Irrigation (%)	0.015	0.034
	(0.02)	(0.02)
Household labor (days/acre)	0.275***	-0.025
	(0.08)	(0.07)
Hired labor (days/acre)	0.029***	0.002
	(0.01)	(0.01)
Traction animals (number/acre)	0.023	0.014
	(0.02)	(0.02)
Pesticides (TSH/acre)	0.022**	0.004
	(0.01)	(0.01)
Fertilizer (TSH/acre)	0.010	0.030***
	(0.01)	(0.01)
Improved seeds (%)	0.013	0.019*
	(0.01)	(0.01)
Dependency ratio	-0.026	0.036*
	(0.02)	(0.02)
Road access (minutes)	0.059	0.043
	(0.05)	(0.05)
Education household head (years)	0.002	0.011
	(0.02)	(0.01)
Female household head (dummy)	-0.202	-0.127
	(0.20)	(0.18)
District fixed effects	YES	YES
Constant	11.10***	12.91***
	-0.52	-0.43
Observations	240	260
R-squared	0.394	0.47

*Note: *** p<0.01, ** p<0.05, * p<0.10; robust standard errors in parentheses. All continuous variables are included in log form. The dependent variable is the log of yield per acre in value terms.*

4.5 Conclusions

While previous research has analyzed linkages between drinking water access and health, and to some extent also between health and agriculture, there are hardly any studies that have examined the direct impact of drinking water access on agricultural productivity. We have addressed this gap, using survey data from agricultural households in Tanzania. Water access and the time required for collecting drinking water may influence the quantity of household labor available for crop production. This effect was not significant in the case analyzed here. Drinking water access may also affect the quality of household labor; access constraints may contribute to poor health, resulting in lower labor productivity. This hypothesis was confirmed for the sample households in Tanzania.

The time needed for water collection has no immediate productivity effect in households with relatively good water access, but it significantly decreases labor productivity for households that require more than the median time for water collection. For these more water-constrained households, doubling the time required for water collection reduces labor productivity by over 20 percent. This effect is net of differences in input use, types of crops grown, agroecological conditions, and socioeconomic factors. For these water-constrained households we also identified a negative effect of water collection time on crop yield. The yield elasticity with respect to drinking water access is larger than yield elasticities with respect to inputs such as fertilizer and pesticides. One could assume that this is due to irrigation that is correlated with water access. Yet, in the models we control for irrigation, so we conclude that the productivity effects are mainly due to poorer health in water-constrained households. Furthermore, water access seems to influence other input choices to some extent. These results suggest that there are important linkages between drinking water access and agricultural growth, which have often been overlooked in the past.

Previous studies have analyzed the impact of water quality on health, measuring quality at the water source (e.g., Tumwine et al., 2002). However, water quality at the source may not be the same as the quality of water actually consumed. With increased distance to water, it is likely that households are storing more at the household level, increasing opportunities for exposure to pathogens from handling or insufficient storage. And, in addition to quality, long distances to the water source may lead to water quantity constraints. Indeed, recent meta-analysis of studies on the impact of distance to water for health showed that water use tends to decrease with long water collection times (Subaiya & Cairncross, 2011). This is in line with our results. Our findings also support previous studies showing that the largest improvements in health come from a combination of hygiene education, sanitation, and increased quantity of water available (Hoddinott, 1997). Our findings also support the argument that strategies to promote economic development must include measures to increase access to water (Kumar et al, 2008).

Our study has a few limitations that should be pointed out. First, the data we collected on household labor quantity is not very precise. While we know the number of household labor days spent on different crops, labor days may vary in length. For instance, women that are busy with both household and cropping activities may spend fewer hours in the field, which may still have been captured as full labor days in the survey. For future research in this direction, more precise time measurements should be used. Second, while we collected data on the self-reported incidence of illness, we have realized that this is an imperfect measure of health status. Hence, we were unsuccessful in explicitly modeling the full causal chain from water access over health to productivity; this also remains a task for follow-up research. In spite of these limitations, our results are robust across multiple model specifications, providing substantial evidence that drinking water access is a significant constraint for agricultural productivity in Tanzania. Hence, improving water access for rural households should receive higher policy priority not only from a health but also from an agricultural perspective. More generally, a better understanding of how public expenditures in one sector can impact developments in other sectors is useful for efficient policy design.

5. Conclusion

The last decade has seen increased focus upon the impacts of social services on agricultural productivity and rural incomes in developing countries. However, there remain large gaps in understanding not only the expected impacts but the confounding factors that drive differences both between countries and within countries. These knowledge gaps are concerning given that many households in these countries are dependent upon public services and limited government funding must often be divided between efforts to meet short-term needs and more long-term growth strategies. Building upon the complementarities that exist between these goals is important but understanding the most efficient allocation of government expenditures for poverty reduction and long-term growth continues to be a difficult endeavor. Advancing this realm of research requires not only additional high quality data but the ability to account for and incorporate a variety of political and social structures, different time horizons, as well as multiple sectors that range from public health to road infrastructure.

This research has evaluated the impacts of particular types of social service expenditures on agricultural production in sub-Saharan Africa. Employing multiple empirical approaches and a variety of datasets at multiple scales, it has provided evidence that government expenditures in a variety of sectors (particularly health and education) can significantly impact the marginal productivity of agricultural inputs through impacts on health and education outcomes. It has also shown that particular health problems can lead to different limitations on productivity. Analyzing the role of one particular infrastructure constraint (water access) in Tanzania highlights the significant role of water availability in agricultural productivity at a household level. Overall, the results have confirmed that there are opportunities to promote health and education while supporting agricultural productivity but impacts will likely only be seen with more substantial investments. It calls for increased focus upon (and funding to promote) the complementarities that exist between the sectors.

5.1 Synopsis

Focusing on health and education services for sub-Saharan Africa, this research provided evidence of the large data constraints that exist in terms of social service expenditures and health and educational indicators for this region. Using the data available, it appears that inefficiency in input use may be partially driven by health and education factors as measured by the available indicators (e.g., life expectancy, immunizations, pupil/teacher ratio). In addition, the variation in the results for country-specific inefficiency points to the importance of considering the effects of missing data on overall estimations and provides caution against interpreting results for countries where missing data is prevalent. This analysis has also provided evidence that country-specific heterogeneity as well as climate-related variables remain significant considerations that should be taken when estimating agricultural production in sub-Saharan Africa.

Using a subset of countries for which a range of public expenditure data was available, we confirm the significance of expenditures as determinants of both overall productivity and marginal productivities for agricultural inputs including labor and land. Based on an empirical approach that considers the underlying economic environment, the results further confirm the difficulty in capturing overall health of a population and complementary effects that may exist between social service sectors. Of particular interest are the significant results of health expenditures and outcomes on the marginal productivity of labor inputs. These impacts remained even after controlling for differences between the countries and the significant effects of precipitation in all of the models.

Given the heterogeneity of political, economic, and social systems as well as agro-climatic constraints between countries of sub-Saharan Africa, we then focus the remaining analysis on intra-country heterogeneity in the case of Tanzania. Using recent district-level data on public health and educational expenditures, the analysis confirms the significance of these government expenditures for health and educational outcomes. It also supports the previous cross-country results in that increases in health and education significantly impact agricultural productivity (both overall and through changes in the marginal productivity of inputs). Interestingly, the analysis shows that long-term diseases are more limiting for production (and for the marginal productivity of labor and land) than more immediate health indicators such as malaria and diarrhea. However, the productivity of seeds and fertilizer appear to be most impacted by these more immediate health constraints. In summary, we find evidence that short-term health factors affect the use of more immediate on-farm investments while longer-term health constraints affect investments in the type of production undertaken.

The results also show that control variables for intra-country heterogeneity and climatic constraints are significant in all specifications and particular types of expenditure allocations result in different impacts. Among the relevant control variables employed in our analysis, the results consistently point to the importance of precipitation in agricultural productivity estimates. In addition to evaluating the role of the health and education sectors separately, we also evaluated the particular components of those expenditures (development funds versus personal salaries for staff). We also see that there is a minimum level of expenditures needed to be allocated to both education and health employee salaries for changes in the social indicators to become apparent, pointing to the importance of sufficient investments in these programs. There is also an upper limit for personal salary expenditures in education, beyond which there appear to be decreasing marginal returns.

Analyzing water-related constraints more specifically, the research relies upon household-level data from four regions of Tanzania. In a household survey undertaken in 498 households, household water access was overwhelmingly noted as the most limiting constraint to household production and incomes. Using data from these households, this constraint is analyzed further in an effort to better understand the limitations it imposes and the impact that public expenditures for water access may play in rural incomes. The households sampled are similar in most measurements (including water access) to rural households throughout Tanzania and provide evidence of the importance of water access for agricultural productivity there.

The results of this analysis show that even after controlling for cropping patterns, infrastructure, and differences across districts, the time needed to access water is a significant determinant of both agricultural labor productivity and yields. In addition, the location of the household in relation to the water source shifts other constraints to agricultural productivity, appearing to drive allocation of other inputs. For households that required more than 20 minutes for water collection in the dry season (the mean collection time), a doubling of water collection time would decrease labor productivity by 20 percent and yield value by at 20 to 30 percent. These impacts may be due to both time constraints but also health constraints that occur when water usage decreases due to limited access or water quality declines due to increased and improper storage at the household level. For households that require more than 20 minutes to collect water, this time appears to be a more significant constraint to labor productivity and yields than the quality of the water at the source, road access, or household structure.

The research summarized here has confirmed the importance of considering inter-country heterogeneity as well as intra-country heterogeneity in efforts to understand constraints on agricultural productivity. The analysis has also pointed to the importance of considering climate in agricultural production estimations and the importance of water access in rural communities. Using multiple empirical methods and datasets at the country, district, and household levels, the analysis has documented the importance of social service expenditures on agricultural productivity in sub-Saharan Africa. For Tanzania in particular, this research has confirmed the important role of health and education spending (and outcomes) on productivity. It has also confirmed the importance of water access for rural households.

5.2 Policy Implications

The results here suggest that public service expenditures (especially on health and education) influence input productivity and efficiency in agriculture. This research has also emphasized the data limitations and the confounding constraints that hinder analysis of these impacts. If governments hope to better target limited funds, a more comprehensive understanding of the direct and indirect impacts of these expenditures on farm-level decisions and constraints will be necessary. This speaks to the need for further data sharing among agencies so that the relationships between labor, health, and government provisions can be better understood. It also points to the value of working across ministries and emphasizes the need for targeting of social spending to achieve desired social outcomes, addressing immediate social needs while supporting long-term economic growth.

In addition to emphasizing the need for additional data, this research points to the importance of providing sufficient levels of expenditures in order to influence health and education outcomes and consequently, agricultural productivity. It provides evidence that there exist different optimum levels based on the funding type (e.g., development grants versus expenditures for staff salaries) and taking advantage of the optimum levels of funding would increase efficiency in national spending. The research also provides evidence that more immediate health constraints impact households in very different ways than long-term diseases and using this type of information allow a better understanding of the possible outcomes from targeted health interventions.

The results have also shown that there may be significant estimation bias when assumptions are made regarding rural households that may vary substantially (such as when marginal productivities are assumed to be constant countries or even within a country). It is important to consider this heterogeneity when planning expenditures to avoid waste and inefficient targeting. In addition, this research has provided strong evidence of the importance of water-related constraints (both precipitation and access to water) that seem to support not only consideration of these constraints but also funding of measures to reduce climatic vulnerability. The results suggest that ignoring water access times in favor of water quality interventions could miss an important constraint for rural households in Tanzania.

5.3 Limitations of the Study and Further Research

Findings from this study are intended to provide research-based evidence to guide the formulation, implementation, and monitoring of agricultural strategies and their connection to social programs. While this research has identified strong relationships between social service expenditures, health and education outcomes, and productivity, there are some limitations that should not be ignored. As noted, while the cross-country analysis suggests that health and education can impact production efficiency, the analysis is substantially limited by the data available. Looking at a subset of countries and a more detailed methodological framework for expenditures helps alleviate some of these concerns and supports our conclusions. We further avoid many of the data limitations by scaling down to Tanzania in particular. In this way, the analysis of expenditures by sector is able to control for many variables that have not been analyzed in previous studies (such as the underlying structure of the economy, the difficulty in measuring health at an aggregate level, and technological and climatic heterogeneity that exists within the country). However, due to the inability to gather robust price information across all crops, it is subject to possible endogeneity of inputs that may limit conclusions for particular components of the latent variable model for Tanzania.

This type of analysis could be improved by further disaggregating social expenditures by function or nature of targeted social issues. Such disaggregation would provide more clarity to policymakers in terms of appropriate and specific tools available for effective decision-making. Addition of a dynamic framework would also allow the capture of lagged effects in the relationship between social outcomes and social expenditures as well as between social outcomes and marginal productivities of agricultural inputs and possibly further analysis of sufficient levels of expenditures to see preferred outcomes. While using the most recent data available and novel empirical approaches in this context, the major limitation of the country-level study for Tanzania is the use of several datasets that were not necessarily designed to complement each other, thereby raising the risk of potential biases. To address this issue, the use of integrated household surveys where data on agriculture, budget, and social services are jointly collected would be useful.

Finally, our results regarding the importance of water access in Tanzania appear robust to multiple specifications and support the qualitative information gathered during household and community-level visits. Although the survey is not nationally-representative, household and production characteristics from the sample are similar to characteristics from national census data. In addition, while we are using very detailed agricultural production data, the survey was designed to collect information on a range of social services and household constraints, and for this reason, did not collect additional information that might have been useful to better understand water constraints such as the number of times water was collected or who was responsible for collecting water. Despite this, the results provide strong evidence of the importance of water as a significant constraint to agricultural productivity at the household level in Tanzania. Regardless of the challenges noted here, the results were achieved using novel approaches at multiple scales in an effort to address the research questions. They allow substantial room for discussion on the role of public expenditures in agricultural development and provide guidance for future research and data collection.

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APPENDIX A: ADDITIONAL TABLES AND FIGURES

Table A. 1-Variables Collected and Considered for Cross-Country Inefficiency

Variable	Units	Obs	Mean	Std. Dev	Min	Max
Credit	% of GDP (domestic credit)	940	14.8	12.5	1	180
Freedom	freedom (1=most free)	829	3.5	2.0	1	7
TB	TB incid per 100,000 people	756	288.5	168.5	42.0	1198
HIV Prevalence	% hiv prevalance (15-49 yrs)	710	5.1	6.6	0.1	28.9
Malaria	% of pop with malaria	580	0.11	0.11	0.00	0.94
Pupil/Teacher	pupil-teach ratio, primary	552	45.2	12.3	19.3	91.1
Net Enrollment Rate	% enrollment, primary	471	63.7	20.4	8.2	99.6
Radio	% HH with radio	450	50.2	15.8	0	91.9
IMR	mortality per 1,000 live births	418	106.9	36.6	24	252
Paved Roads	% total roads paved	406	20.1	16.2	0.8	78
Health Expend	% of GDP spen on health	211	2.4	1.5	0.2	9.6
Education Expend	% of GDP spend on educ	369	4.3	4.2	0.4	49.5
Physicians	# physicians/1000 people	250	0.1	0.1	0.0	0.572
Schooling	average years of school	180	4.2	2.0	0.8	9.6
Rural Sanitation	% rural with improved sanit	158	21.5	15.6	0	62
Rural Water	% rural with improved water	157	48.9	18.0	4	91
Literacy	adult literacy (%)	122	53.4	22.1	8.7	93
Women	% of women in nonag jobs	108	26.4	11.5	3.8	51.6

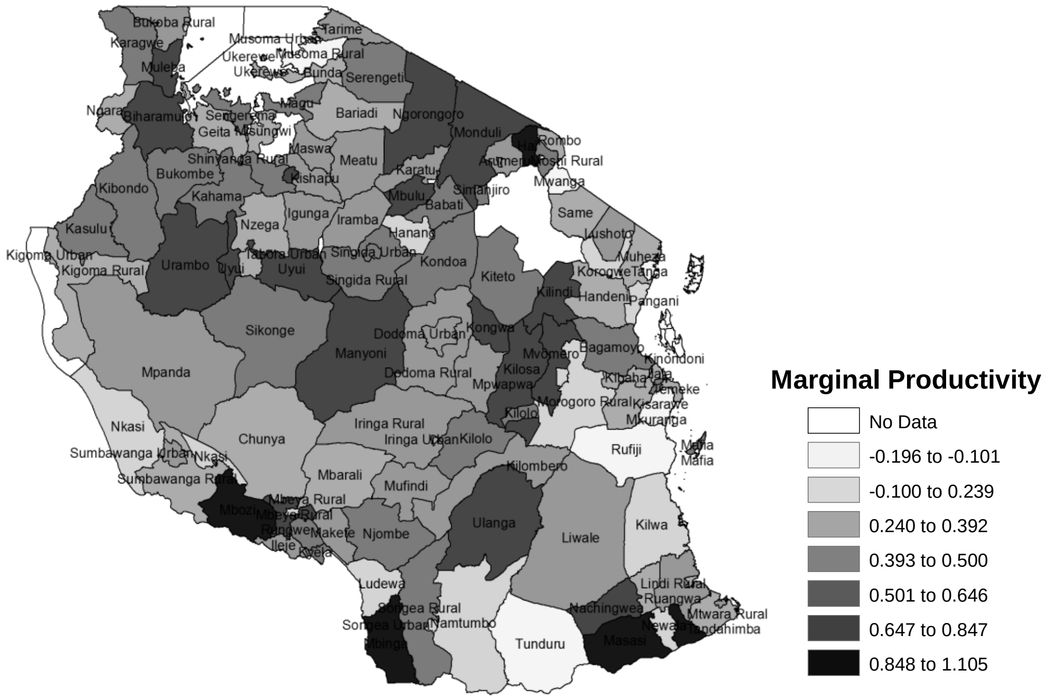
Table A. 2-Cross Country Stochastic Frontier, Five Year Averages

Production Value	**Coefficient**	**SE**		**Coefficient**	**SE**
Constant	-0.255	0.349			
Labor	0.346**	0.129	$Tractors^2$	0.002	0.040
Fertilizer	0.119*	0.057	Tractors*Land	0.315***	0.026
Tractors	0.285***	0.036	Tractors*Livestock	-0.243***	0.051
Land	0.104	0.107	Tractors*Precip	0.136*	0.054
Livestock	-0.073	0.075	Tractors*Irrigation	-0.010	0.017
Precipitation	0.179	0.151	$Land^2$	-0.353***	0.090
Irrigation	-0.141*	0.057	Land*Livestock	0.280***	0.055
$Labor^2$	-0.553***	0.088	Land*Precip	-0.141	0.127
Labor*Fertilizer	-0.022	0.029	Land*Irrigation	0.022	0.037
Labor*Tractors	-0.039	0.037	$Livestock^2$	-0.352***	0.031
Labor*Land	-0.081	0.047	Livestock*Precip	-0.433*	0.197
Labor*Livestock	0.467***	0.053	Livestock*Irrig	0.084**	0.030
Labor*Precip	0.813***	0.121	$Precipitation^2$	-1.109***	0.236
Labor*Irrigation	-0.335***	0.024	Precip*Irrigation	0.147**	0.047
$Fertilizer^2$	-0.022*	0.010	$Irrigation^2$	0.071***	0.013
Fertilizer*Tractors	0.038***	0.011	Percentage Ag Land	0.235**	0.076
Fertilizer *Land	-0.090***	0.025	Time	0.088***	0.009
Fertilizer *Livestock	0.030	0.022			
Fertilizer *Precip	-0.111**	0.039			
Fertilizer *Irrigation	0.015	0.010			
Inefficiency	**Coefficient**	**SE**	Log Likelihood	-28.515	
Immunizations	0.014***	0.003	Cross Sections	37	
Teach/Pupil Raio	-0.028***	0.004	Time Periods	6	
σ^2	0.484***	0.045	N	187	
γ	1.000***	0.000	Mean Efficiency	0.708	

*Source: Author's estimations; *** p<0.01, ** p<0.05, * p<0.10*

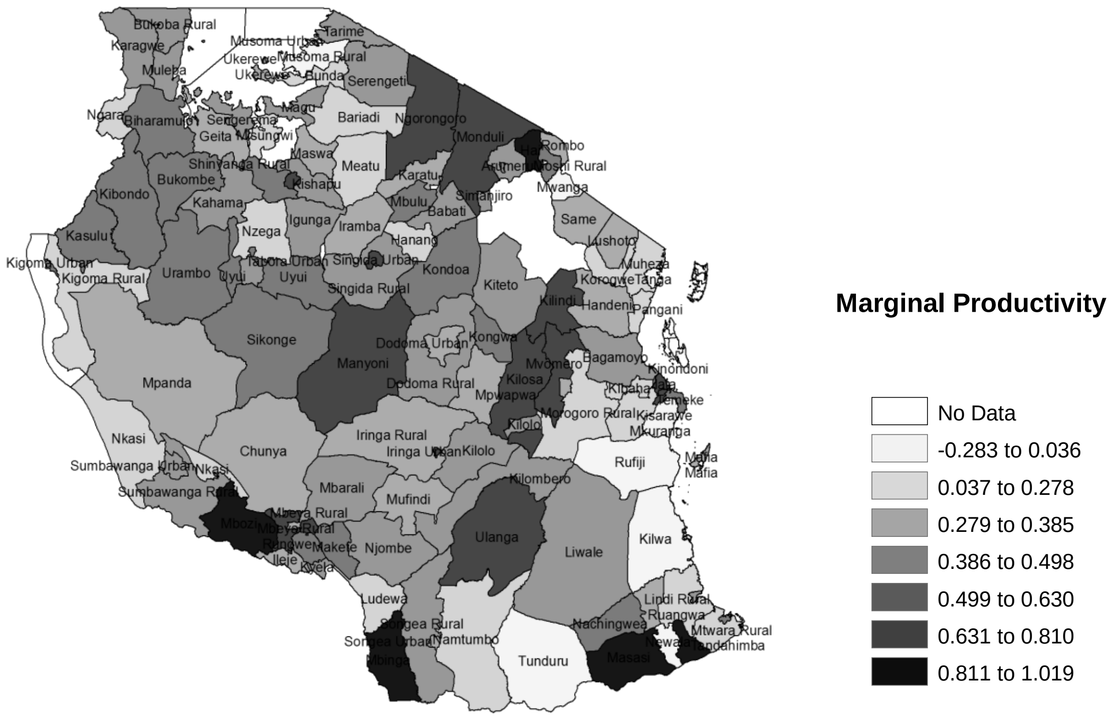
Appendix B: Survey Questionnaire

Figure A. 1-Marginal Productivity of Land (Education as State Variable)



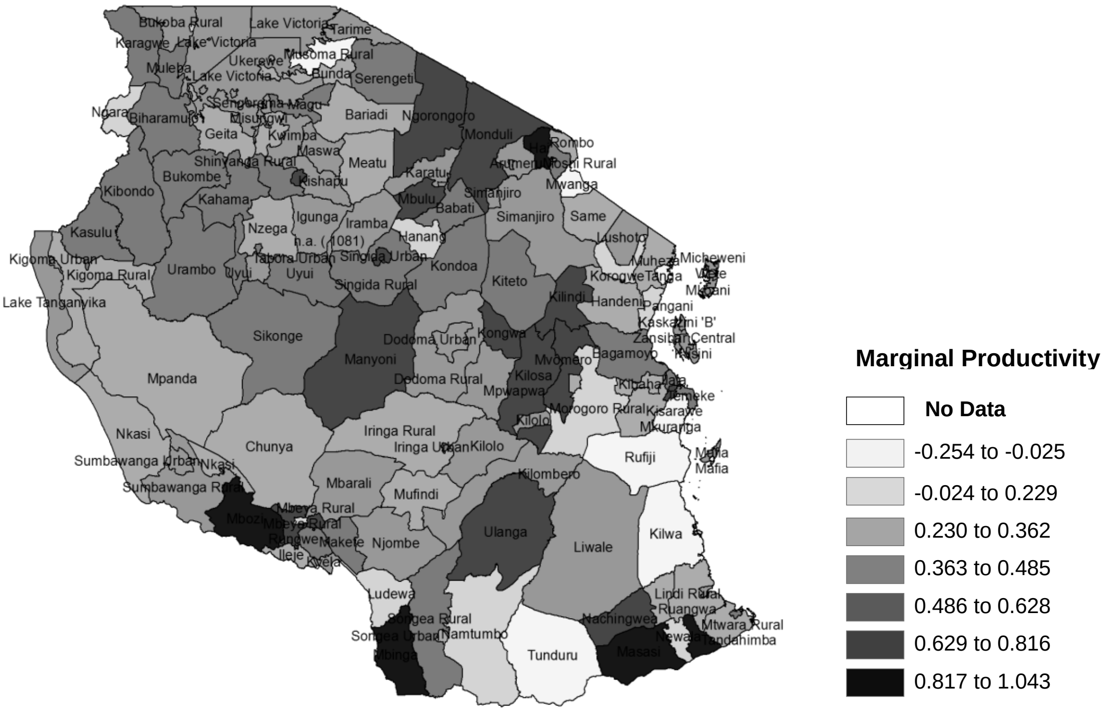
Source: Authors'calculations

Figure A. 2-Marginal Productivity of Land (Long-Term Health as State Variable)



Source: Authors'calculations

Figure A. 3-Marginal Productivity of Land (Health and Education as State Variables)



Source: Authors'calculations

Appendix B: Survey Questionnaire

LINKAGES BETWEEN SOCIAL SERVICES AND AGRICULTURAL GROWTH

HOUSEHOLD SURVEY
2010/2011

1. CONTACT INFORMATION

1. Questionnaire Number ________________________
2. Household ID Number ________________________
3. Region____________________________________
4. District ___________________________________
5. Division ___________________________________
6. Ward______________________________________
7. Village ___________________________________
8. Hamlet ___________________________________

9. GPS Location: Lat _______Long_______ Altitude______
11. Household Head ________________________________
12. Name of Respondent _____________________________
13. Phone Number __________________________________

	Date		
	Day	Month	Year
Interview Visit 1			
Interview Visit 2			
Field check			
Office check			
Data entry			
Enumerator Name			
Supervisor Name			

NOTE:
Code -77 if question is not applicable
Code -88 if the respondent did not want to answer
Code -99 if the respondent does not know the answer

2. GENERAL HOUSEHOLD INFORMATION (All questions to be completed by Household Head or other responsible party)

List household members (those whose food is supplied by the household head for more than six months per year).

A1	A2		A3	A4	A5	A6		A7	A8	A9a	A9b	A10a	A10b
Household Member ID	**Household Member Name**		**Relation-ship to HH head** (use codes below)	**If mother is in HH, which HH member?** (use codes)	**Sex** **1 Male** **2 Female**	**Age (use mos if <1 year)**		**Marital Status** 1 Married (monogamously) 2 Married (polygamously) 3 Single 4 Divorced/Separated 5 Widow (er)	**ID of the Spouse** - if married polygamously note the number of the first wife - if spouse doesn't live in the household, please code 99	**Main Occupation (use codes)**	**Secondary Occupations**	**Years of Education Successfully Completed**	**Literacy** 1 Read/Write Swahili 2 Read/Write English 3 Read/Write Another 4 Can't Read or Write
	Last Name	**Other Names**				**Years**	**Months**						
1			Head										
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													

Relationship to Household Head (A3)

1 Household Head
2 Spouse
3 Son/Daughter
4 Father/Mother
5 Sister/Brother
6 Daughter in Law
7 Nephew / Niece
8 Grandchildren
9 Grandparents
10 Adopted Child
11 Other

Main Occupation (A9a and A9b)

1 Agriculture on own farm (including bee-keeping and fishing)
2 Hunting and plant gathering
3 Agricultural wage labor (other people's farms)
4 Agricultural trading
5 Grain Milling
6 Other trading
7 Self-employed off farm (non-agri)
8 Other employment off farm (non-agri)
9 School
10 Children too young/not attend
11 Disability/Pension

Section 2- AGRICULTURAL PRODUCTION; PART A: CROP INPUT (Short Rains)

1. a. How much land do you own including all plots? Size ________acres b. How much of this owned land do you use in the short rains season? ______acres
   c. How much land do you borrow in the short rains season? Size _______acres d.) How much land do you rent in the short rains season? _________acres
2. What crops were grown in the last year on each plot?

Plot number	How big is this plot? (acres)	What crop (s) was planted on this plot during this season?	Was this crop inter-cropped with another?	% of Plot area Under this crop?	Was this crop irrigated?	Did you use improved seeds for this crop?	For the crop grown in this plot, how much did this household spend on…during this season?					How many person-days of household labor were used to grow and harvest the [crop] in this plot during season […]?	How many person-days of hired labor were used to grow and harvest the [crop] in this plot during season […]?	What was the average daily wage paid to these hired laborers? *(If payment in kind, note form and value equivalent)*	Where do most of your hired laborers for this crop come from?	How much was harvested from this plot during the season?		
		Crop code (see codes below)	1 Yes 0 No	%	1 Yes 0 No 2 by hand only	1 Yes 0 No	…seed and planting materials? Tsh	…fertilizer and manure? Tsh	…pesticides (including spraying services)? Tsh	…equip-ment repair? Tsh	…other non-labor operating expenses? Tsh			Tsh per day	1 Same village 2 Same ward 3 Other (specify)	Quantity	Unit 1 sack/bag 2 plastic bag 3 kilograms 4 metric tons 5 #head 6 tenga 7 batches 8 pishi 9 debe 10 fungu	Equivalent in KG for ONE Unit Measure
A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17a	A17b	A17c
1																		
2																		
3																		
4																		

<u>Note: For tree crops and crops grown throughout the year, record all information in the dry season.</u>

								701 Oranges	709 Lemon
101 Sugar Cane	108 Other-Cash Cro	206 Other Oil Seeds	306 Red Sorghum	404 Red Beans	503 Sweet potatoes	604 Eggplants	611 Mushroom	702 Mangoes	710 Papaya
102 Cotton	201 Soy beans	301 Yellow Maize	307 White Sorghum	405 Cow Peas	505 Irish/round potatoes	605 Lettuce	612 Turnip	703 Pineapples	711 Strawberries
103 Coffee	202 Ground nuts	302 White Maize	308 Other Cereals	406 Pigeon Peas	506 Other Roots and tubers	606 Cabbages	613 Garlic	704 Tangarines	712 Grape fruit
104 Cashew nut	203 Sunflower	303 Rice	401 Black beans	407 Other legumes	601 Tomatoe	607 Cauliflower	614 Other vegetab	705 Watermelon	713 Bananas
105 Tea	204 Coconut	304 Wheat	402 White Bean	501 Yams	602 Onions	608 Cumcumbe	701 Oranges	706 Grapes	714 Other Trees
106 Tobacco	205 Ufuta	305 Barley	403 Yellow Beans	502 Cassava	603 Carrots	609 Green Pepper		707 Lime	800 Fallow
107 Seeds						610 Spinach		708 Plum	801 Rented out

3. b. How much land do you use in the dry season? Size ________acres c. How much land do you borrow in the dry season? Size _______acres
d. How much land do you rent in the dry season? _________acres

4. What crops were grown in the last year on each plot?

Plot number	How big is this plot? (acres)	What crop (s) was planted on this plot during this season?	Was this crop inter-cropped with another?	% of Plot area Under this crop?	Was this crop irrigated?	Did you use improved seeds for this crop?	For the crop grown in this plot, how much did this household spend on…during this season?					How many person-days of household labor were used to grow and harvest the [crop] in this plot during season […]?	How many person-days of hired labor were used to grow and harvest the [crop] in this plot during season […]?	What was the average daily wage paid to these hired laborers? *(If payment in kind, note form and value equivalent)*	Where do most of your hired laborers for this crop come from?	How much was harvested from this plot during the season?		
		Crop code (see codes below)	1 Yes 0 No	%	1 Yes 0 No 2 by hand only	1 Yes 0 No	…seed and planting materials? Tsh	… fertilizer and manure? Tsh	…pesticides (including spraying services)? Tsh	…equip-ment repair? Tsh	…other non-labor operating expenses? Tsh			Tsh per day	1 Same village 2 Same ward 3 Other (specify)	Quantity	Unit 1 sack/bag 2 plastic bag 3 kilograms 4 metric tons 5 #head 6 tenga 7 batches 8 pishi 9 debe 10 fungu	Equivalent in KG for ONE Unit Measure
A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17a	A17b	A17c
1																		
2																		
3																		
4																		

<u>Note: For tree crops and crops grown throughout the year, record all information in the dry season.</u>

								701 Oranges	709 Lemon
101 Sugar Cane	108 Other-Cash Cro	206 Other Oil Seeds	306 Red Sorghum	404 Red Beans	503 Sweet potatoes	604 Eggplants	611 Mushroom	702 Mangoes	710 Papaya
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103 Coffee	202 Ground nuts	302 White Maize	308 Other Cereals	406 Pigeon Peas	506 Other Roots and tubers	606 Cabbages	613 Garlic	704 Tangarines	712 Grape fruit
104 Cashew nut	203 Sunflower	303 Rice	401 Black beans	407 Other legumes	601 Tomatoe	607 Cauliflower	614 Other vegetab	705 Watermelon	713 Bananas
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106 Tobacco	205 Ufuta	305 Barley	403 Yellow Beans	502 Cassava	603 Carrots	609 Green Pepper		707 Lime	800 Fallow
107 Seeds						610 Spinach		708 Plum	801 Rented out

5. b. How much land do you use in the long rains season? Size ________acres c. How much land do you borrow in the long rains season? Size _______acres
d. How much land do you rent in the long rains season? _________acres

6. What crops were grown in the last year on each plot?

Plot number	How big is this plot? (acres)	What crop (s) was planted on this plot during this season?	Was this crop inter-cropped with another?	% of Plot area Under this crop?	Was this crop irrigated?	Did you use improved seeds for this crop?	For the crop grown in this plot, how much did this household spend on…during this season?					How many person-days of household labor were used to grow and harvest the [crop] in this plot during season […]?	How many person-days of hired labor were used to grow and harvest the [crop] in this plot during season […]?	What was the average daily wage paid to these hired laborers? *(If payment in kind, note form and value equivalent)*	Where do most of your hired laborers for this crop come from?	How much was harvested from this plot during the season?		
		Crop code (see codes below)	1 Yes 0 No	%	1 Yes 0 No 2 by hand only	1 Yes 0 No	…seed and planting materials? Tsh	… fertilizer and manure? Tsh	…pesticides (including spraying services)? Tsh	…equip-ment repair? Tsh	…other non-labor operating expenses? Tsh			Tsh per day	1 Same village 2 Same ward 3 Other (specify)	Quantity	Unit 1 sack/bag 2 plastic bag 3 kilograms 4 metric tons 5 #head 6 tenga 7 batches 8 pishi 9 debe 10 fungu	Equivalent in KG for ONE Unit Measure
A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17a	A17b	A17c
1																		
2																		
3																		
4																		

Note: For tree crops and crops grown throughout the year, record all information in the dry season.

								701 Oranges	709 Lemon
101 Sugar Cane	108 Other-Cash Cro	206 Other Oil Seeds	306 Red Sorghum	404 Red Beans	503 Sweet potatoes	604 Eggplants	611 Mushroom	702 Mangoes	710 Papaya
102 Cotton	201 Soy beans	301 Yellow Maize	307 White Sorghum	405 Cow Peas	505 Irish/round potatoes	605 Lettuce	612 Turnip	703 Pineapples	711 Strawberries
103 Coffee	202 Ground nuts	302 White Maize	308 Other Cereals	406 Pigeon Peas	506 Other Roots and tubers	606 Cabbages	613 Garlic	704 Tangarines	712 Grape fruit
104 Cashew nut	203 Sunflower	303 Rice	401 Black beans	407 Other legumes	601 Tomatoe	607 Cauliflower	614 Other vegetab	705 Watermelon	713 Bananas
105 Tea	204 Coconut	304 Wheat	402 White Bean	501 Yams	602 Onions	608 Cumcumbe	701 Oranges	706 Grapes	714 Other Trees
106 Tobacco	205 Ufuta	305 Barley	403 Yellow Beans	502 Cassava	603 Carrots	609 Green Pepper		707 Lime	800 Fallow
107 Seeds						610 Spinach		708 Plum	801 Rented out

PART B: CROP OUTPUT

1. List production and crops sold over the last 12 months (or 3 seasons).

How much of the harvest from this plot was sold during the past year?						**How much was consumed in the household?**	
Season	What crops were sold during SEASON ...? *[Only Repeat Crops that were sold]* *(use crop codes)*	Quantity	**unit** 1 Bags/sack 2 Plastic Bags 3 Kilograms 4 Metric Tons 5 # Head 6 Tenga 7 Batches 8 Pishi	Equivalent in kg for ONE quantity unit	Selling Price per unit (Tsh)	Quantity	Units (see codes in B3b)
B1	B2a	B2b	B2c	B2d	B2e	B3a	B3b
Short Rains							
Dry Season							
Long Rains			-				

2. Please indicate if your household's production has changed in the past 2 years.

2. Please indicate if your household's production has changed in the past 2 years.	
Change (codes below)	**Reason** (see codes below)
B4a	B4b
01 No Change 02 Change in Crop Mix 03 Increase in Cultivated Area 04 Decrease in Cultivated Area 05 Decline in Production Amount	01 More Inputs Available 02 Price Changes at Market 03 More Water Available 04 Disease or Disability 05 Credit Available 06 New Crop Varieties 07 Increased Labor 08 Increased Off-farm 09 Increased Government Support 10 Climate Change/Less Rain 11: theft; 12: more rain 13: increased experience 14: lack of improved seeds 15: increased pesticides 16 increased family size 17 lack of / cost of inputs (includ. labor) 18 damage from animals 19 family problems 20 lack of education 21 change in production type 22 crop disease

3. In addition to the temporary labor documented above, how many permanent farm workers did you have **last year** and what was their monthly salaries?

A. Permanent Workers (number)	**B. How many months did they work?**	**C. Avg Monthly Salary for each (Tsh)**

PART C: AGRICULTURAL EQUIPMENT

What special agricultural equipment do you have and what is the value of these?

Equipment or tool	Do you have this? 1 Yes; 0 No	Value if sold (Tsh)	Equipment or Tool	Do you have this? 1 Yes; 0 No	Value if sold (Tsh)	Equipment or Tool	Do you have this? 1 Yes; 0 No	Value if sold Value
	C1	C2		C1	C2		C1	C2
1. Water pump			10. Tractor			19. Bicycles		
2. Borehole			11. Animal Plough			20. Motorcycles		
3. Water tank			12. Hand Hoe			21. Barn		
4. Drip irrigation system			13. Harvester			22. Trailer		
5. Special pipes			14. Processing Machines			23. Harrow		
6. Sprinkler			15. Machete, sicke, mow er			24. Axe		
7. Furrow irrigation (gravity-fed)			16. Ox cart			25. Rake/Spade		
8. Watering can			17. Wheelbarrow s			26. Other		
9. Truck			18. Sprayer for Pesticides					

PART D: LIVESTOCK

1. For the last 12 months, please give the total numbers of livestock or animal products sold or consumed and the revenue (when sold - using product codes on the right).

Type of Animal or Product	Qty in Stock Now	Qty Bought	Qty sold	Units (use codes)	Price Per Unit
D1	D2	D3	D4	D5a	D5b

01 cows
02 goats
03 sheep
04 chicken
05 pigs
06 donkeys
07 Rabbits
08 Ducks
09 Fish
10 Others

Products:
11 Honey
12 Eggs
13 Milk

Units: 1: kg; 2: pieces; 3: liters; 4: whole animal

2. Please give the total numbers of livestock that your household used for traction in the last 12 months (using product codes on the right)

Type of Animal	Qty	01 horses 02 donkeys 03 oxen 04 camels 05 others(specify)
D6a	D6b	

4. HEALTH FACILITES, STATUS, AND INFRASTRUCTURE

PART A: HEALTH FACILITIES

Health Facilities and Services	Is this facilility available in this village? 0 No 1 Yes (if No, go to question A9; if Yes, complete A3 to A8)	Does your household have access to it? 0 No 1 Yes	How long does it take to get to nearest…? Distance (km)	Time to travel there (minutes)	Mode of transport to get to nearest…? 1= foot 2=bicycle 3=car 4=bus 5= Other (specify)	If you don't use the service, why not? 1=Too expensive 2= Too far 3= Other (specify)	Quality of Service or Facility (for those who used it) 1= Good 2= Acceptable 3= Poor	Reason for Low Quality Ranking (use codes below)	If facility is not available in the village, do you use a facility elsewhere? 0 No 1 Yes	If not available in this village, how long does it take to get to nearest…? Distance to the nearest (km)	Time to travel there (hours)
A1	A2	A3	A4a	A4b	A5	A6	A7	A8	A9	A10a	A10b
1. Public Clinic or Health Center											
2. Private Clinic											
3. Dispensary											
4. Village Health Worker											
5. Childhood Vaccinations											
6. Nutritional Supplements											
7. Family Planning Resources											
8. Mosquito Control (nets, sprays repellents)											
9. Other Health Facilities (specify)											

Reason for Poor Quality of Services (A8)

1 Poorly trained doctors	5 Medicine needed not available
2 No doctor available	6 Other medical supplies not available
3 Wait time too long	7 Often not open
4 Too expensive	8 No running water available
	9 No incentive for health workers

PART B: HEALTH INCIDENTS 1. Please document health incidents that have affected your family in the past 12 months. Include the loss due to a caregiver's response.

Household Member ID (fill in from first table)	**Health Incident** (use codes below) list each separately)	**During which season were you sick?** 1 Planting 2 Growing 3 Harvesting 4 Off-season	**How many days of labor have you lost due to the illness?** (including the ill and the caretaking person)	**How did you deal with this loss?** (see codes below)	**How many days of school have you lost due to the illness?**	**Where did you go for treatment?**	**How much was spent for treatment? (if applicable)?** (Tsh)
B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**

Health Incident (B2)

01 Malaria
02 Diarrhea
03 Cough
04 Headache without Malaria
05 Measles
06 Parasitic disease/ Intestinal Worms
07 Sexually Transmitted Disease
08 Tetanus
09 Hypertension (Blood pressure)
10 Typhoid
11 Dysentery
12 Cholera
13 Ulcers/ Other intestinal
14 River Blindness
15 Trachoma
16 Other Vision disease
17 Meningitis
18 Asthma
20 Dental Infections/Problems
21 Skin/Scabies
22 Wounds
23 Anemia
24 Severe malnutrition
25 Pregnancy/childbirth complications
26 Fever
27 Pneumonia
28 Other disability/limb or joint problems
29 TB
30 Unspecified Illness
31 Diabetes
32 Ears or Throat Problem
33 Stomach Problems
34 Chronic Disease (cancer, etc)
35 Other (specify)

Adaptation (B5)

01 Did Nothing
02 Hired someone to help
03 Credit from family/friend/neighbo
04 Credit from formal sources
05 Government transfer
06 Ask household member to help
07 Other (specify)

Location of Treatment (B7)

01 No Treatment
02 Government Clinic
03 Government Hospital
04 Private Clinic/ Hospital
05 NGO Health Clinic/Hospital
06 Village Health Worker
07 Dispensary/Pharmacy
08 Traditional Doctor
09 Traditional birth attendant
10 Other

2. Document health expenditures at the household level in the past 12 months.

Health Expenditures	**Annual Expenses (Tsh)**
A. Vaccinations	
B. Bed Nets	
C. Medications	
D. Doctor Fees or Medical Care	
E. Transportation to Hospital or Clinics	
F. Supplements	
G. Enrollment in Community Health Fund	

PART C: HEALTH-RELATED INFRASTRUCTURE

1. a. How many household members have a bed net? [ ]

b. Do they use it? [ ]
1 = Yes
2 = No
3 = Sometimes

2. What is the household's main source of drinking water?

Water Supply	**Drinking Water Supply Source** (use codes)	**Distance** (in km)	**Costs for establishment and delivery** (Tsh)	**Time to Fetch Water each time** (in min)	**Source (use codes below)**	**Distance** (in km)	**Time to Fetch Water** (in min)	**Costs for establishment and delivery** (Tsh)
	C1a	C1b	C1c	C1d	C2a	C2b	C2c	C2d
1. Dry Season								
2. Wet Season								

01 Rain catchment tank
02 Public well (protected)
03 Public well (unprotected)
04 Vendor (Person selling water)
05 Piped (Tap) water on community supply
06 Piped (Tap) water on private supply
07 Private well (unprotected)
08 Private well (protected)
09 Spring (Protected)
10 Spring (not protected)
11 River, Dam, Lake, etc
12 Bottled Water
13 Buy water from neighbor on community supply
14 Other, specify

3. Please indicate the type of toilet your household has:

Toilet Facilities	**In your Home** (use codes)	**If not in your home, how far from home?** (km)	**What type of facility is this?** (codes)	**Time to the toilet** (in min)
	C3	C4a	C4b	C4c

01 No toilet/bush
02 Flush toilet
03 Pit latrine (traditional)
04 Improved pit latrine
05 Other type (specify)

PART D: COMMUNICATION AND TRANSPORTATION

1. Does your household have an electricity connection?
   1= Yes
   0 = No

2. Does your household own a telephone (including mobile)?
   1= Yes
   0 = No

3. If your household does not own a phone, how many minutes would it take you to reach the closest public phone?

4. How far are you from the closest all weather road by walking? (in minutes) (in kilometers)

5. How far are you from the closest tarmac road by walking? (in minutes) (in kilometers)

6. What is your occupancy status?
   1= Own house
   2 = Rent house 4= Borrowing
   3 =Leasing house 5 = Other

5. EDUCATIONAL OPPORTUNITIES and SOCIOECONOMICS

PART A: Educational Facilities Please indicate whether the following facilities are available in the village.

Educational Facilities	Is ….available in this village? 1 Yes 0 No	How many household members have used this facility, past and present ?	How long does it take you to get to facility?		Quality of Service or Facility 1 Good 2 Acceptable 3 Poor	If quality is poor, give a reason (codes below)	If facility is not available in the village, do you use a facility elsewhere? 1 Yes 0 No	If not available in the village, how long does it take you to get to the neares one?	
			Distance (in km)	Time (in minutes)				Distance (in km)	Time (in minutes)
	A1	**A2**	**A3a**	**A3b**	**A4**	**A5**	**A6**	**A7a**	**A7b**
1. Primary School									
2. Secondary School									
3. Advanced Secondary									
4. College									
5. Agricultural Vocational Training									
6. Non-agriculture Vocational Training (specify)									
7. Agricultural Extension Agents									
8. Farmer Field School									
9. Livestock Research Center									
10. Other (specify)									

Codes for Quality (A5)
01 Not enough trained staff
02 Building facilities inadequate (building only)
03 No drinking water available
04 No electricity available
05 Not enough books or educational materials
06 Toilet facilities not available
07 teachers don't teach
08 Not offered to most HH 09 Other

PART B: Education Participation: Describe expenses on education within the household for members that participated in educational activities in the last 12 months.

HH Member ID	Type of Education (use codes below)	If this household member participate? (only mark if applicable) 1 Yes 0 No	If no participation, why not?	Expenditures per Household Member for 12 months (Tsh)			Do you receive assistance for costs	If you receive partial assitance, what percentage is paid?	If you receive assistance, what is the source? 1Govt provide cash transfer 2 Govt provided transportation 3 NGOs 4 Family/Friends 5 Others
				Fees/ Tuition	Uniform/ Books/ Stationery	Travel Expenses			
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7a**	**B7b**	**B7c**
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									

Education Type (B1)	6 Agricultural Training	**Reason for Not Participating (B3)**	07 Too young
1 Primary School	7 Farmer Field School	01 Too far from house	08 Too old
2 Secondary School	8 Community-Sponsered Education	02 Too expensive	09 Few extension workers
3 Advanced Secondary	9 Nursery	03 No time	10 Failed
4 College	10 Livestock Training	04 Not sure of value	11 Waiting for results
5 Non-Agricultural Vocational Training	11 other	05 Disability	12 Not interested
		06 Illness	13 No information

6. INFORMATION ON CREDIT ACCESS, TECHNICAL ASSISTANCE, AND SOCIAL NETWORKS

PART A: CREDIT ACCESS

1. Did you apply for a loan or credit in the past 12 months?

   1 Yes
   2 No

2. If no, why didn't you apply?

   1 No need
   2 Lack of guarantee
   3 Too risky
   4 Too expensive
   5 Not Available
   6 No Enough Information

3. Document loan applications for the past 12 months and for which purpose they were used. *If no applications, go to Part B.*

Loan Applications	Did you receive a loan? 1 Yes 2 No	If Yes, what is the source? (use codes below)	If no loan received, why not? (use codes below)	Total Amount (Tsh) (include value estimate for credit given in the form of inputs)	For what purpose was the loan used? (see codes below)
A1	A2	A3	A4	A5	A6
a					
b					
c					

Reasons for Denial (A4)
1 Lack of endorsement or guarantee
2 Did not have necessary documents
3 Prior debt
4 Other (specify)

Credit Source (A3)
1 Input Salesmen
2 Buyer of Harvest
3 Private Bank
4 SACCOS
5 Microfinance Institutions
6 NGO
7 Family/friend
8 Govt entity
9 Production Group
10 Women's Group
11 Local Entrepren. Group (VIKOBA, etc)

Loan Use (A6)
1Purchase of seeds or fertilizer
2 Purchase of agric. Equipment
3 Storage
4 Irrigation or other infrastructure
5 Repairs to House
6 Medical Expenses
7 School Expenses
8 Marriage or Funeral
9 Bicycle
10 Household Daily Needs
11 Business Purposes (start-up, expansion)
12 Purchase Livestock
13 Others

PART B: Technical Assistance (*including any assistance related to development)*

1. Have you received technical farm assistance in the last 12 months? [ ]
   1 Yes
   0 No
2. If yes, how many times? [ ] (If none received, go to question 4).

3. Describe the source and cost of your technical assistance (each time received) over the past 12 months.

What type of services were received from provider? (see codes below)	**What was the source of the assistance?** (use codes below)	**Who was responsible for the technical assistance?** (use codes below)	**How much did you spend on technical assistance? (Tsh)**
B1	B2a	**B2b**	**B3**

Services Received:	Source:	Responsible Party:
1 New Crop Introduction	1 Extension Agents	1 Ministry of Agriculture
2 Soil Analysis	2 Livestock Center	2 District Government
3 Seeds	3 Veterinary Clinic	3 Non Governmental Org
4 Pest and Disease Control	4 Other Farmers	4 Producers Committee/Farmers Organization
5 Harvesting Techniques	5 College Students	5 University
6 Business Management	6 local microfinance institution	6 Independent
7 Marketing Techniques		7 Private Company
8 Packing/Selection		8 Other (specify)
9 Fertilizer		
10 Planting techniques		
11 livestock Vaccination		
12 Other livestock Services (insem)		

4. If you did not receive any technical assistance, why do you think this is?
   1 Not offered   3 Too expensive   5 Not needed   7 Not enough resources from government
   2 Not suitable   4 Don't trust providers   6 No information

PART C: SOCIAL NETWORKS

1. Are you a member of any group or an association? *(If no, please skip question 2)*

2. Document your household's group membership for the past 12 months.

To which groups do you belong? (use codes)	**How long have you been a member?** (years)	**Services Received from Group (**see codes below)
C1	C2	C3

<u>Group:</u>
1 Producer Group
2 Farmers COOP
3 Women's Group/Youth Group
4 Community Welfare Group
5 Church Association
6 Other (specify)
7 Entrepreneuship Group
8 SACCOS
9 others

<u>Services:</u>
1 Credit
2 Inputs
3 Training
4 Marketing
5 Welfare/Social Support
6 Business
7 Other non-farm activities
8 Nothing (yet)

PART D: SOCIAL ASSISTANCE

Are any of the following programs active in this village or ward?

Programs	Active in this village? 1 Yes 0 No	Active in this ward? 1 Yes 0 No	Name of Program and sponser, if active:	Are you participating? 1 Yes 0 No	If available and not participating, why not? (see codes below)
D1	D2	D3	D4	D5	D6
1. Hygiene Education					
2. Support to Female-Headed Households					
3. School Feeding Programs					
4. School Funding (uniforms, books, fees)					
5. Conditional Cash Transfers for Health					
6. Conditional Cash Transfers for Education					
7. Credit or Savings Programs					
8. Input Subsidies for Farmers					
9. Farmer Training and Extension					
10. Drinking Water Support					
11. Infrastructure Programs for Roads and Transport					
12. Family Planning Programs					
13. Distribution of Bed Nets					
14. Distribution of ARV drugs to dispensaries					
15. Immunization Programs					
16. Health insurance					
17. Other (Specify)					

Provider of Services (D4)
1 Government
2 NGO (external, maria stopes,etc)
3 International Org (WFP, World Vision, etc)
4 Community Group (SACCOS)
5 Private (including Church)
6 Microfinance institution (ex. VIKOBA)
7 Other (Specify)
(specify)

Reasons for Not Participtating (D6)
1 Don't see benefit
2 Not offered to this HH
3 Don't qualify
4 No information on time
5 Chose a different program
6 Too expensive
7 Too risky
8 Other

7. HOUSEHOLD INCOME AND CONSUMPTION
PART A: NON-AGRICULTURAL INCOME EARNED

1. Document the income earned by income earner in the first and secondary occupations.

HH Member ID	Income from main Non-Agricultural income (Tshs)	Income per month (Tshs)	Has income changed in past 5 years? 1 Yes 0 No	Reasons for these changes (See codes)
A1	A2	A3	A4	A5

Reason for Change in Income

1 Working more in off farm business
2 working more in others farms
3 Family size changes
4 change in health or disability
5 production changes
6 changes in cost of
7 Drought
8 Theft
9 Lack of inputs
10 temporary work
11 Decline in business

2. What was your household's income from the following sources during the past 12 months? (***include the income of all household members)?***

Income source	**Tsh. in past 12 months**	**Is this accounted for in Question 1?** 1 Yes 0 No
A6a	A6b	A6c
1. Income from machinery services for other farms (plowing etc.)		
2. Income from own **non-agricultural** businesses		
3. Wages for labor on other farms		
4. Wages and salaries for **non-agricultural** employment		
5. Pensions		
6. Remittances from family members/friends who do not live in the household		
7. Revenues from leasing out land		
8. Non-conditional Cash transfers from government or other group		
9. Conditional cash transfers (specify conditions):		
10. Non-agricultural business		
11. Sales of livestock		
12. Income from processing		

3. Document other sources of household goods:

Source	**Qty**	**Units** **1 kg** **2 meals** **3 buckets**	**Value (Tsh)**
A7a	A7b	A7c	A7d
1. Food for education			Per week:
2. Food for work			
3. Food stamps or transfer			
4. School-based food programs			Per day:
5. Other targeted programs (for women, children, elderly) Please Specify: ______________________			

PART B: CONSUMPTION

1. Please document household consumption for the last **7 days** (include consumption within and outside the home).

Food Products	Quantity (specify units)	Units	Tsh. Worth in past week
B1a	**B1b**	**B1c**	**B1d**
1. Millet			
2. Rice/Pilaf			
3. Maize			
4. Sorghum			
5. Cassava			
6. Nuts and Beans			
7. Milk, Cheese, Yoghurt, Eggs			
8. Fruits or Juices (banana, mango, etc)			
9. Vegetables (spinach, okra, tomatoes, eggplant, pumpkin, etc)			
10. Breads, Chapati			
11. Meat and Fish			
12. Food Consumed outside Home			
13. Chai/Tea or Coffee/Cocoa			
14. Sugar, Salt and Spices			
15. Soft drinks or other Non-alcoholic drinks			
16. Oils or Butter			
17. Cigarettes or Tobacco			
18. Alcohol (Beer or Wine)			

Units (B1c): 1 kg; 2 pieces 3 Liters 4 Bunch 5 Packet 6 Fungu 7 Grams 8 Debe 9 Cups 10 Plates/Meals 11 Sadolin 12 Kipanda 14 Other (write in name)

2. Please document household expenditures in the last **month:**

Monthly Expenditures	**Tsh. in past month**
B2a	**B2b**
Transportation	
1. Gas for own vehicle/maintenance	
2. Taxi or bus	
3. Bicycle	
4. Motorcycle	
5. Other transportation (Specify) ____________________________	
Communications	
6. Mobile phone	
7. Telephone	
8. Newspaper or Magazines	
9. Others (Specify)___________________________	
Personal and Home Needs	
10 Soap, razors, other personal products, haircuts, etc.	
11. Clothing, Shoes, Linens	
12. Firewood, Charcoal, Fuel for Cooking	
13. Cleaning products and home supplies	
14. Others (specify)____________________________	

3. Please document household expenditures in the last **year**:

Yearly Expenditures	**Tsh. in past year**
B3a	**B3b**
Lighting and Cooking	
1. Diesel (liters)	
2. Kerosene (liters)	
3. Lamp purchases	
Purchases	
4. Bicycle or motorbike (specify)	
5. Furniture or Appliances (specify)	
6. Cart	
7. Pots or Cooking Supplies	
8. Salary for help around the home	
9. Home Repair	
10. Toys or Children's Items (non-school related books,etc)	
Other Expenditures	
11. Social/Religious/Birth/Death/Dowry	
12. Government Taxes/Licenses	
13. Payments to organizations	
14. payments to School feeding program	
15. Electricity	
16. Others (specify)______________________________	

4. What is the biggest constraint to your household income? (Rank the following with 1 being of biggest concern):

A. Health Incidences	
B. Lack of Educational Resources for Children	
C. Lack of Market Access	
D. Inadequate Medical Care	
E. Rapid Price Changes for Agricultural Products	
F. Outmigration of youth	
G. Unpredictability of Weather	
H. Lack of Storage Facilities	
I. Lack of Farmer Training	
J. Government Taxes	
K. Theft	
L. Lack of Adequate Land	
M. Lack of Funds for Business	
N. Lack of Infrastructure/Transport	
O. Scarcity of Water	
P. Lack of machinery or improved seeds	
Q. Shortage of Vaccines and Drugs	
R. Electricity	
S. Communication	
T. Animals as Pests	
U. Land Tenure	
V. Livestock Diseases	
W. Lack of Food	

Thank you for your time and patience!