University of Sussex

Three Essays on Agriculture and Economic Development in Tanzania

Ani Rudra Silwal

Submitted for the degree of Doctor of Philosophy

University of Sussex

March 2016

Three Essays on Agriculture and Economic Development in Tanzania

Summary

One cannot study poverty in Tanzania without understanding the agricultural sector, which employs more than two-thirds of the population and accounts for nearly a quarter of national GDP. This thesis examines three themes that focus on the difficulties that rural Tanzanians face in achieving a reasonable livelihood: the adverse legacy of a failed historical policy, a difficult climate, and market failures.

The first empirical chapter examines the legacy of the villagization program that attempted to transform the predominantly agricultural and rural Tanzania. Between 1971 and 1973, the majority of rural residents were moved to villages planned by the government. This essay examines if the programs effects are persistent and have had a long-run legacy. It analyzes the impact of exposure to the program on various outcome measures from recent household surveys. The primary finding of this study is that households living in districts heavily exposed to the program have worse measures of various current outcomes.

The second empirical chapter examines the role of reliability of rainfall, which is important in Tanzania as agriculture is predominantly rain-fed and a small fraction of plots are irrigated. This chapter investigates if households cope with this major risk to income by re-allocating their labor supply between agriculture, wage labor, and self-employment activities. This chapter combines data on labor allocation of households within and outside of agriculture from the National Panel Survey with high-resolution satellite-based rainfall data not previously used in this literature. The primary finding of this study is that households allocate more family labor to agriculture in years of good rainfall and more labor to self-employment activities in years of poor rainfall.

Market failures are often cited as a rationale for policy recommendations and government interventions. The third chapter implements four tests of market failures suggested in the literature, all of which rely on the agricultural household model but differ in how market failures are manifested. The common finding of these tests is that market failures exist in agricultural factor markets in Tanzania, although significant heterogeneity exists. Markets are more likely to fail in rural areas, remote locations, and are more likely to affect female-headed households. Households are also more likely to face market failure when they try to supply labor to the market than when they try to hire labor from the market.

Acknowledgements

Undertaking this Ph.D. has been a challenging and fulfilling journey and I have many people to thank for helping get through it all. First of all, I am indebted to my supervisors Prof. Andy McKay and Prof. Barry Reilly for guiding me through this project.

I would like to thank my colleagues at Sussex for making my stay here more joyful than I had ever anticipated: Rashaad, Tsegay, Antonia, Nihar, Hector, Kalle, Farai, Pedro, Gustavo, Cecilia, Amrita, Marco, Edgar, Egidio, Eva Maria, Nouf, and Samantha. Shova and Lokendra, thank you for making me feel at home at Sussex.

My friends have been my second family and I am lucky to have their support: Ramu, Babita, Prabesh, Samagya, Utpal, Prakriti, Sameer, and Prerana.

At the World Bank, Kathleen Beegle was always my inspiration and support at various times. I am thankful to Dilip, Sonia, and Sanket for my time working with them in the Migration Unit. And Im grateful to George for encouraging me to go back to school.

My family has always been my bedrock at high and low tides. Arun, Suna, and Oscar in London were always the perfect escape from school. My didi and parents what else do I need to say other than how lucky I am to have you in my life? Sudeep dai, Bijana dijju, and Subrat: I am lucky to be a part of your family!

But most of all, I am thankful to my wife, Srijana. To put it simply, I would not have been able to finish my Ph.D. were it not for your love and support. To love is to let go - and you let go of me while we lived apart on two sides of the ocean for four years to finish this work. This thesis is dedicated to you.

Contents

List of Tables

List of Figures

Chapter 1

Introduction

A salient feature of economic development is that as countries become richer, agriculture plays a relatively smaller role in the economy (Alston and Pardey, 2014; Timmer, 2009). Many have argued that agriculture needs to be prioritized in the early stages of development because of its important linkages to economic growth and poverty reduction (Gollin et al., 2002; Christiaensen et al., 2011).[1] In Tanzania, as in many developing countries, agriculture is a major provider of food, employment, and export earnings. According to official statistics, the Tanzanian economy stagnated between independence in 1961 until the 1990s, but has seen rapid growth in the last 15 years. Yet despite the rapid economic growth, monetary poverty has not fallen significantly (Arndt et al., 2015). One cannot study poverty in Tanzania without understanding the agricultural sector, which employs more than two-thirds of the population and accounts for nearly a quarter of national GDP. Securing improvements in agriculture through, for example, removing the bottlenecks in this sector could help reduce poverty. This thesis examines three themes that focus on the difficulties that Tanzanians face in achieving a reasonable livelihood: a difficult climate, the adverse legacy of a failed historical policy, and market failures.

The first empirical chapter examines the legacy of the villagization program that attempted to transform the predominantly agricultural rural sector. After inde-

[1] Dercon and Gollin (2014) provide a summary of this literature that goes back to the Lewis (1954) model as well as the work of Johnston and Mellor (1961).

pendence, President Julius Nyerere embarked on a social transformation, a major component of which was to relocate its scattered population to concentrated and planned villages where people could live and work together. Between 1971 and 1973, the majority of rural residents were moved to villages planned by the government. However, Tanzania soon faced an economic crisis and the program was abandoned in the late 1970s. Scholars have documented the disastrous consequences of this program on rural livelihoods (Collier et al., 1986). This essay examines if the program's effects were persistent and have had a long-run legacy. In order to do so, it analyzes the impact of exposure to the program on various outcome measures from the Household Budget Survey, National Panel Survey, and the Tanzanian Census. The concern with this analysis is that villagization may have been implemented more heavily in areas that were more likely to be poor economic performers in the future. In order to address this potential endogeneity, I instrument the implementation of villagization at the district-level with sporadic droughts across Tanzania exploited by the government to force people into planned villages. I find that households living in districts that were heavily exposed to the program have worse measures of various outcomes. I finally suggest that a reason villagization adversely affected living standards was because agriculture was ignored households living in heavily villagized districts are still engaged predominantly in agriculture at the expense of self-employment or wage activities.

A major factor that makes it difficult to rely on agriculture as a means of livelihood is that households are often at the mercy of the natural environment. The second empirical chapter examines the role of one measure of the Tanzanian environment reliability of rainfall. Unreliable rainfall is a particularly important factor in Tanzania as agriculture is predominantly rain-fed and a small fraction of plots are irrigated.[2] This issue is also important in the context of climate change, one consequence of which is thought to be more variable rainfall (IPCC, 2007; Collier et al., 2008). How do households cope with this major risk to income? I examine

[2]According to the Household Budget Survey 2011/12, 6.6% of plots in mainland Tanzania are irrigated.

whether households diversify their livelihoods outside of agriculture so that they are less subject to rainfall shocks. Since labor is an important asset of poor households, understanding how it is used to manage risk may help us devise appropriate policies to address this issue. This study pays careful attention to the multiple activities in which households are engaged. This effort is aided by the use of the Tanzanian National Panel Survey, which collected rich data on labor allocation of households within and outside of agriculture. I combine this data with high-resolution satellite-based rainfall data not previously used in this literature. I find that households respond to rainfall shocks by participating in non-agricultural activities. In particular, I find they allocate more family labor to agriculture in years of good rainfall and more labor to self-employment activities, such as small-scale retail trade, in years of poor rainfall. I find that they do not use wage labor as a coping mechanism to respond to rainfall shocks, perhaps due to market imperfections.

The third empirical chapter examines the issue of market failures in agricultural factor markets in Tanzania. The efficacy of policies affecting rural households in countries like Tanzania depends much on how well markets work and market failures are often cited as a rationale for policy recommendations and government interventions. This chapter first attempts to quantify the extent of market participation in agricultural factor markets of in Tanzania. It then implements four tests of market failures suggested in the literature, in contrast to most studies in the literature that rely on a single method. All of the tests are based on the agricultural household model described in Singh et al. (1986) but differ in how market failures are manifested. The intuition of these tests is that if markets are working well, then household labor demand in production is uncorrelated with its endowment of labor and the shadow wage of household labor will be equal to the market wage. The common finding of these tests is that market failures exist in agricultural factor markets in Tanzania, although significant heterogeneity exists. Markets are more likely to fail in rural areas, remote locations, and are more likely to affect female-headed households. Households are also more likely to face market failure when they try to supply labor to the market than when they try to hire labor from the market.

The rest of the thesis is structured as follows. Chapter 2 briefly describes the Tanzanian context relevant for this thesis. Chapter 3 examines whether the consequences of Tanzania's villagization program on living standards are still being felt today. Chapter 4 examines whether households cope with rainfall shocks by diversifying their income-generation activities outside of agriculture. Chapter 5 examines how well markets function by implementing various tests of market failure. Chapter 6 summarizes the findings of this thesis before discussing the limitations of this work and suggesting potential avenues for further research.

Chapter 2

A brief background on Tanzania

The purpose of this chapter is to set the context for the empirical analysis conducted in this thesis. First it presents some basic facts about Tanzanian geography. Then it discusses in broad outline its recent history, focusing in particular on the last few decades. It then describes the structure of the Tanzanian economy and where the country currently stands in the process of economic development. It finally discusses how the rest of this thesis relates to the themes raised in this chapter.[1]

2.1 Geography

Tanzania is a country of 50.75 million people (in 2014) with an area of 0.95 million square kilometers located on the eastern coast of Africa between 1-11° S. Nearly four times the size of the UK and more than twice that of Germany, it is geographically diverse. It is divided roughly into two halves by the Great Rift Valley which runs vertically across the center. The north-eastern part of the country is mountainous and includes the tallest mountain in Africa, Kilimanjaro. The center of the country is a plateau, although mountains and lakes punctuate many parts of the country.

Tanzania's climate is tropical but has regional variation due to its topography.

[1] Tanzania has ignited much scholarly and political interest since independence. Coulson (2013) describes the Tanzania of the 1970s, in particular, the University of Dar es Salaam, as a maelstrom of ideas and debates among historians, political scientists, sociologists, and economists. For example, Joan Robinson spent a term there in the 1970s.

The central plateau gets as little as 500 mm of rainfall per year but the western and southern areas get up to 2,000 mm of rainfall per year. The northern part of the country has two rainfall seasons during October-December and March-May whereas the southern part of the country has a single rainfall season during November-April. Due to its size, Tanzania borders many countries: Kenya, Uganda, Rwanda, Burundi, DR Congo, Zambia, Malawi, and Mozambique (Figure 2.1) and has a coastline on its eastern side of about 1,400 kilometers with the Indian Ocean.

Figure 2.1: Map of Tanzania (Source: Google Maps)

2.2 Brief history

Tanzania's strategic location along the East African coast and its borders with many countries has also meant it has been an important center of trade in history. Tanzania's first contact with the rest of the world was perhaps through Arabic traders that settled in the Kilwa and Zanzibar islands to channel ivory, gold, and slaves from the interior of the country. Mainland Tanzania (then called Tanganyika) was ruled by the Germans as a part of German East Africa from 1884 until the end of the First World War, when it began to be administered by Great Britain under a League of Nations mandate. Tanganyika gained sovereign status in 1961, with Julius Nyerere as its first prime minister. It united with Zanzibar in 1964 to become the United Republic of Tanzania.

Julius Nyerere was a charismatic and widely-respected leader with a socialist vision for a new Tanzania, on which he elaborated in the Arusha Declaration in 1967. A major component of Nyerere's socialist vision (*ujamaa*) was to relocate its predominantly rural population to planned villages modeled after collective farms in China. Nyerere's vision was that people would not only live together in these villages but would also work together for the common good. The villagization drive was implemented primarily during 1973-75 and by the late-1970s, four-fifths of the population lived in government-designated villages. In the late-1970s, Tanzania faced a balance of payments crisis, on the one hand, and a war with Uganda, on the other. These two events, combined with external pressure amidst the poorly performing economy, led to Nyerere's resignation in 1985 and the beginning of the slow reversal of his policies. Under the Economic Recovery Program, led by the IMF and the World Bank, the state began to allow a bigger role for markets. This also meant deregulating the various state monopolies and price controls imposed by Nyerere's government. The liberalization program has been slow but remains ongoing.

2.3 Structure of the economy

Drawing inferences about Tanzanian economic activity is fraught with danger given problems with the underlying data. Jerven (2011) and Arndt et al. (2015) discuss at length the inconsistencies between different data sources that lead to different conclusions about the direction of the Tanzanian economy. Statistics on the Tanzanian economy usually cite the National Bureau of Statistics of Tanzania, World Bank's World Development Indicators, IMF's World Economic Outlook, or the Penn World Tables. Although the Tanzanian government is assumed to be the source of all official numbers, other entities often transform these data to harmonize them with their own databases. As a result of this, one is often left with different impressions of the state of the economy. A recent example of the fluid nature of macroeconomic statistics on Tanzania is the revision of its real GDP in October 2014. The GDP estimate was revised to incorporate the latest available information on the economy. A result of this was that Tanzania's nominal GDP in 2007 increased by 27.8% compared with previous estimates (National Bureau of Statistics, 2014b). The implication of this is that macroeconomic statistics should not be taken at face value but should instead be taken as indications of the actual magnitude and direction rather than providing precise estimates.

Despite concerns about the reliability of national account statistics, one thing that is consistent among various sources is the significant role of agriculture in the economy. According to the latest Household Budget Survey conducted in 2012, about three-quarters of the currently employed population aged 15 years or above reported their primary activity in the prior 12 months to be in agriculture.[2] This number appears higher than that reported in the 2012 Census, according to which, agriculture (including livestock and fishing) employs 65.4% of the employed population for the same age category (National Bureau of Statistics, 2014a).[3] This lower estimate may be due to the fact that the census was conducted on August 26, 2012, which falls outside of the agricultural seasons in Tanzania.

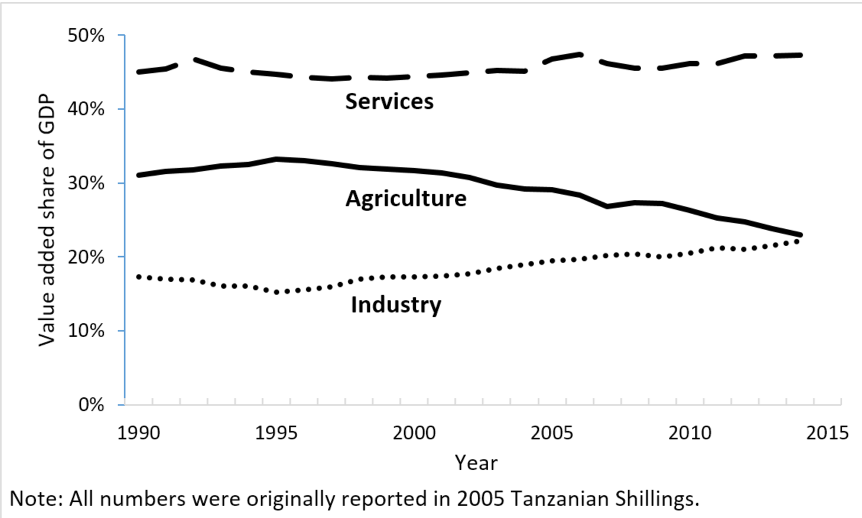
The share of agriculture in Tanzanian GDP is not only smaller than its employment share but has shrunk over time. Using the latest available data from the World Development Indicators, Figure 2.2 shows the sectoral shares of Tanzanian GDP between 1990 and 2014 in real Tanzanian Shillings. Agriculture constituted 31% in of national GDP in 1990. This share began to fall in the mid-1990s and stood

[2]This category includes fishing but it is unclear if it includes livestock (National Bureau of Statistics (2014a), Table 5.2). According to the HBS, 74.7% of Tanzanian mainland households owned or cultivated some land in the previous 12 months. The HBS was conducted between October 2011 and October 2012 and collected information on the primary activity of respondents in the prior 12 months.

[3]The relevant census question asked "What type of work did [NAME] do in the week preceding the census night?"

at 23% in 2014 (World Bank, 2015). The drop in agriculture's share in GDP has been absorbed almost entirely by the industrial sector. These numbers are somewhat at odds with those reported by Arndt et al. (2015), who find that the share of agriculture in the economy dropped from 45% in 1991 to 23% in 2012. This discrepancy is most likely due to the recent revision of GDP numbers by the Tanzanian government. Figure 2.2 uses the revised estimates that were made available after Arndt et al. (2015) was published. Despite disagreement on the magnitude of the drop, both Figure 2.2 and the numbers reported in Arndt et al. (2015) agree that the value-added share of agriculture in Tanzanian GDP is contracting.

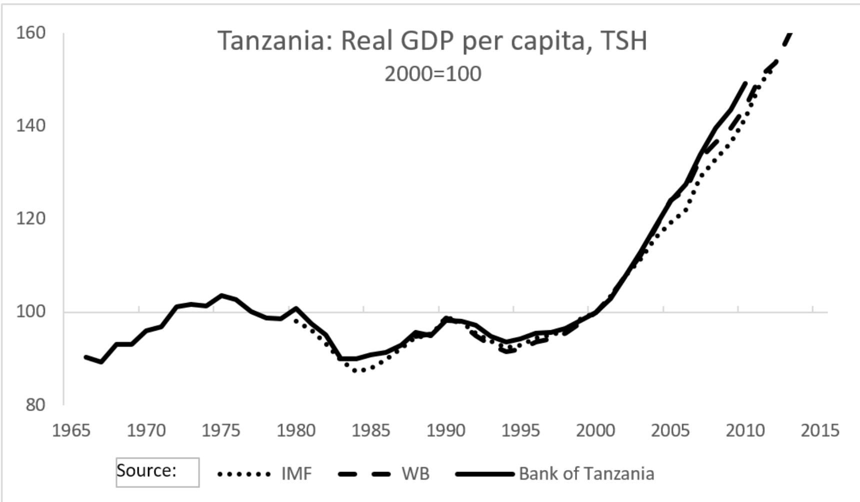
Figure 2.2: Sectoral shares of Tanzania's GDP for 1990-2014 (Source: World Bank (2015))



Obtaining an accurate picture of Tanzania's growth performance is difficult given the data problems described above. However, the best data currently available, presented in Figure 2.3, suggest that the Tanzanian economy has been growing rapidly since the late-1990s after several decades of stagnation. It grew at an average of 6.5% between 1999 and 2014 and its annual growth rate was never lower than 4.7% during this period. If the official statistics are correct, the Tanzanian economy has made impressive progress during the last fifteen years: GDP per capita growth is reported as 3.5% and the real per capita GDP in local currency in 2014 was 70% greater than 15 years earlier.

The GDP growth rates reported for Tanzania's neighbors Rwanda, Mozambique, Zambia, and Uganda were higher during the same period. But this does not detract from the fact that Tanzania's recent growth performance has been impressive, particularly in the context of its more anemic growth in the previous three decades. Figures 2.2 and 2.3 present the following puzzle: despite the rapid economic growth in the last 15 years, why has Tanzania's sectoral structure changed very little? In particular, why does agriculture still employ two-thirds of the adult working population? Another puzzle that remains unresolved is the source of this growth. However, a more important question these figures raise is: how, if at all, has the recent growth performance improved the living standards of Tanzanians? These questions are part of the motivation behind the research in this thesis.

Figure 2.3: Tanzania's real GDP per capita



An explanation of the discrepancy between the rapid economic growth and slow poverty reduction may be the data on consumer price inflation, which directly determine changes over time of living standards. Sandefur (2013) demonstrates how data from household surveys can be used to verify and correct the highly political and possibly incorrect consumer price indices. He finds that doing correcting for prices yields a more modest picture of both economic growth and poverty reduction.

2.4 Progress in living standards

Tanzania faced many challenges when it became independent in 1961. Its predominantly agrarian population of approximately nine million lived in a natural environment that was harsh and inhospitable. Much of the country faced nutrient-poor soil, irregular and poor rainfall, and prevalent disease (Iliffe, 1979). About 4% of the population lived in urban areas and only 16% of adults were thought to be literate in 1961 (Iliffe, 1979). Compared with its status five decades ago, Tanzania has made significant improvements in quality of life. Life expectancy has improved from 43.9 years in 1961 to 61.5 years in 2013. Infant mortality has fallen from 142.7 in 1961 to 36.4 per 1000 live births in 2013. Primary school enrolment has increased from 33.8% in 1970 (Edwards, 2012) to 84.5% in 2013 (World Bank, 2015). Adult literacy has increased from 16% in 1961 (Iliffe, 1979) to 67.8% in 2010 (World Bank, 2015). According to Bank of Tanzania (2011), its real GDP per capita in Tanzanian Shillings in 2010 was 65% greater than its level in 1966.

Despite the progress Tanzania has recently made, it is one of the poorest countries in the world and still faces many of the challenges it confronted five decades ago. According to the Tanzanian Household Budget Survey (HBS),[4] poverty in Tanzania fell from 38.6% in 1992 to 28.2% in 2012. Although this suggests a slow but steady progress in monetary living standards, it is surprising that this progress was not faster given the rapid economic growth in the last 15 years. Arndt et al. (2015) and Atkinson and Lugo (2010) argue that the somewhat inconsistent narratives presented by the national accounts data and the household surveys may be due to an improvement in non-monetary indicators. Arndt et al. (2015) show that Tanzania has seen steady progress between 1992 and 2012 in measures such as water supply, sanitation, shelter, education, and access to information.

Owens et al. (2011) and Lokina et al. (2011) suggest that the neglect of agriculture may be an explanation for why poverty in Tanzanian has not fallen in recent

[4]HBS is a widely-used source of data on living standards is the Household Budget Surveys (HBS), conducted every few years by the Tanzanian National Bureau of Statistics. These cross-sectional surveys were conducted in 1969, 1976/77, 1992, 2001, 2007, and 2011/12.

years. Owens et al. (2011) compare Tanzania's experience with that of Ghana, both of which experienced similar rates of economic growth but Ghana had more success in lowering poverty. This may be the consequence of a greater effort by Ghana in improving its agricultural sector. Lokina et al. (2011) find that the more modest decrease in poverty in Tanzania happened because households moved out of agriculture rather than the fact that agriculture had become more productive. They find that productivity growth in agriculture actually fell in the early 2000s and that adoption of modern inputs such as inorganic fertilizers and hybrid seeds did not increase.

2.5 Agriculture in Tanzania

Although the 2012 Census and HBS 2011/12 are not completely consistent in the sectoral shares of employment, both of these sources agree that agriculture is by far the largest employer in Tanzania. According to HBS 2011/12, agriculture is not only a rural activity but also an urban one: 88% of rural residents, 58% of urban areas other than Dar es Salaam, and 7% of residents of Dar es Salaam report this being their primary sector of employment. The average household owns 5.5 acres (2.2 hectares) of land. Agriculture is dominated by smallholders since 69% of households own less than six acres of land. This sector is also mostly traditional given the fact that 83% of households still use the hand hoe and less than 1% of households own a tractor, tractor plough, or tractor harrow.

The use of modern inputs is low: less than 10% of households report using each of irrigation, inorganic fertilizer, or pesticide. The main crops grown are maize (81% of households), beans (32%), paddy (21%), potatoes (21%), groundnuts (14%), cassava (13%), and bananas (10%). Livestock plays an important role in the rural economy since 51% of households report owning at least one livestock. Agricultural productivity is very low in Tanzania, compared with its neighboring countries (World Bank, 2015). Cereal yield in 2013 was 1,417 kg/hectares, which was among the lowest in the world and below that of most of its neighbors.[5]

2.6 Conclusion

One cannot study poverty in Tanzania without understanding the agricultural sector, which employs more than two-thirds of the population and accounts for nearly a quarter of national GDP. This thesis examines three themes that focus on the difficulties that Tanzanians face in achieving a reasonable livelihood: a difficult climate, the adverse legacy of a failed historical policy, and market failures. The first empirical chapter examines the legacy of the villagization program that attempted to transform the predominantly agricultural rural sector. The second empirical chapter examines the role of one measure of the Tanzanian environment reliability of rainfall. The third empirical chapter examines the issue of market failures in agricultural factor markets in Tanzania.

[5] Tanzania's cereal yield grew from an average of 765 kg/hectares in the 1960s to 1,387 kg/hectares in the first decade of the twentieth century. Despite this growth, its cereal yield has been below that of most of its neighbors during this period (World Bank, 2015).

Chapter 3

"To live in villages is an order": The long-term consequences of villagization in Tanzania [1]

3.1 Introduction

Various governments around the world attempted ambitious policies during the 20th century to transform the lives of their rural citizens by resettling them (Clarke et al., 1985).[2] While some of these projects have had the intended consequences, many more have resulted in chaos and disruption in the immediate aftermath of the policy and subsequently over the long run. Examining such policies is important because the past teaches us lessons on the expected and unexpected consequences of government policy. Another reason to examine major government policies is that differences in intra-country economic outcomes may be partly explained by historical circumstances.

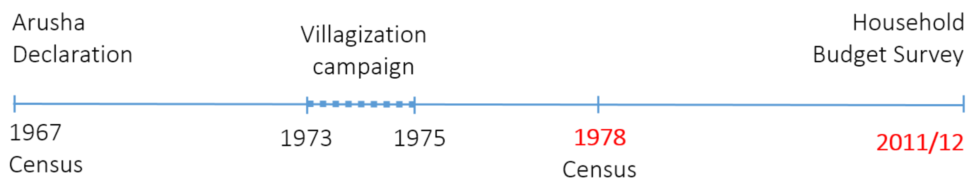
This paper examines the long-term consequences of a major attempt by the Tanzanian government in the 1970s to transform its predominantly-rural landscape

[1] "To live in villages is an order" is the title of a news article in The Daily News from November 7, 1973 (Coulson, 2013).

[2] The redistribution of the population through active policies (Clarke et al., 1985) took the form of communal settlements (Tanzania, Mozambique, Ethiopia), agricultural resettlement schemes (Nigeria, Sudan), and shifting of the national capital (Nigeria, Tanzania).

by relocating people from scattered settlements to planned, concentrated villages.[3] My research question is whether within-country differences in current economic outcomes in Tanzania can be explained partly by the exposure to the villagization program at the height of the program. Although the program was announced in 1967 as a part of the socialist vision of President Julius Nyerere elaborated in the Arusha Declaration, much of its implementation happened between 1973 and 1975 (Figure 3.1). The goal of the program was to re-organize rural areas with the idea that the formation of these villages would allow for scale economies and when combined with communal effort and social infrastructure projects, the lives of rural citizens would be uplifted. By the time the 1978 census was conducted, about 75% of Tanzanians were living in villages planned by the government. Collier et al. (1986) suggest that this is one of the largest interventions in the rural development policies of any country in history.

Figure 3.1: Timeline of study



This study is related to the broader literature on whether current economic outcomes can be partly explained by historical circumstances (see Nunn (2014) for a survey of this literature). Recent analysis of mass relocation programs broadly similar to the one in Tanzania show that these programs had negative consequences for wellbeing both in the short run, in Rwanda (Isaksson, 2013), and in the long run, in Mexico (Dell, 2012). Much of the literature on the villagization program in Tanzania was written in the 1980s when the near-collapse of the Tanzanian economy in the aftermath of the villagization program attracted much international attention (Collier et al., 1986; Bevan et al., 1988; Collier, 1988; Boesen et al., 1986). Interest in the program waned but a recent literature has begun to revisit this issue (Osafo-

[3]According to the 1967 Census of Tanzania, only 5.7% of the population lived in urban areas. Half of this population lived in Dar es Salaam, the capital city at the time.

Kwaako, 2012; Edwards, 2014; Schneider, 2014; Lofchie, 2014). This paper builds on and extends Osafo-Kwaako (2012), which finds that villagization led to higher levels of education and social capital (political awareness and community participation), but at the cost of lower levels of consumption in 2000.

I examine if the effects of villagization persist three decades after the program was abandoned. I find that exposure to villagization in the 1970s is associated with lower levels of various measures of current outcomes: household consumption, income, assets, and education levels. The measure of villagization that I use is the percentage of district population in the 1978 Census that lived in villages planned by the government. A concern with this analysis is that the intensity of villagization in a district may have been determined by unobservable characteristics that may also determine current outcomes. That would prevent us from making a causal statement about the impact of the program. I address this issue by instrumenting the intensity of villagization with droughts that occurred sporadically across Tanzania during 1973-75, when most of the program implementation happened. These droughts were exploited by government officials, who promised drought-relief conditional on people moving to government villages. I find that the economic activity that households are engaged in may be a mechanism that explains these findings: villagization may have had a persistent and negative impact on current outcomes by preventing people from moving out of subsistence agriculture. This paper also provides an example of how large government projects can be expedited by unpredicted weather events (Dell, 2012; Fenske and Kala, 2014), and how these policies could have unintended and persistent effects.

Section 2 describes the various stages of the villagization program in Tanzania. Section 3 describes the various datasets I use in this analysis and presents characteristics of the sample that I analyze. Section 4 explains the strategy used to identify the relationship between villagization and current outcomes. Section 5 presents the results of the analysis and some robustness checks. Section 6 discusses activity choice as a potential mechanism that may explain why villagization may have led to worse outcomes even three decades after the program was abandoned. The final section discusses the implications of these results.

3.2 Relevant literature

A number of countries implemented programs similar to the villagization one in the 20th century. For example, the Soviet Union embarked on a collectivization campaign during 1929-1932 that had disastrous consequences for agricultural production. Agricultural output in the Soviet Union in 1933 was 20% below the level in 1928 immediately before the collectivization campaign began (Holland, 1988). China also implemented a similar campaign during 1959-1961, a consequence of which was that grain output in 1961 and 1962 were 30% lower than the level in 1958 (Lin, 1990). The country also experienced famines in the immediate aftermath of the campaigns, which resulted in 30 million deaths. Mexico began implementing land reform in 1917 that were similar to the collectivization programs later implemented in the Soviet Union and China (World Bank, 2001). Rural Mexican households were organized into large farms called *ejidos*, which were owned by the government but gave cultivation rights to households.

Analyses of similar programs around the world suggest that they have had adverse effects in the short run and long run on various aspects of wellbeing. In her paper on the long-run consequences of a land-redistribution program in Mexico in the early-20th century, Dell (2012) uses a similar methodology to the one employed in this paper. She finds a strong correlation between sporadic droughts in Mexico, which aided insurgents in their demand for land reform, and the magnitude of state surface area that was eventually redistributed to communal *ejidos*. She finds that the *ejido* communities now are substantially poorer, more agricultural, and less industrial as they were burdened with restrictive land policies imposed by a political system steeped in clientelism.

Rwanda experienced a villagization program in the 1990s, when nearly 20% of the population was moved to imidugudu planned villages (Leeuwen, 2001). Isaksson

(2013) suggests that although a primary goal of the program was to allow households to economically diversify away from agriculture, imidugudu households differed very little in terms of diversification from non-Imidugudu households in 2005. Although the program may have succeeded in resolving the shortage of housing and facilitating reconciliation after the genocide, it had not made much headway in addressing the income portfolios of the program beneficiaries. Kondylis (2008) also examines the impact of displacement on agricultural production of households in Rwanda following the re-settlement program in the 1990s. She finds that the relocation to imidugudu areas did not increase agriculture output of households. Returnees to policy areas also had lower returns to seeds, suggesting that relocation had resulted in a loss of agricultural know-how. Ethiopia and Mozambique also experimented with villagization on a smaller scale (Clarke et al., 1985; Lorgen, 2000). Although nearly two million people in Mozambique and as many as twelve million people were villagized in Ethiopia in the 1980s, little evidence exists on the economic effects of these programs. Zimbabwe implemented a voluntary resettlement program (for about one percent of its population) who were granted agricultural land formerly owned by whites. Gunning et al. (2000) find that this program was immensely successful over a period of about 13 years. Based on analysis of a panel of about 400 resettled households, they find that resettled farmers experienced not only a large accumulation of assets but also higher returns to their assets over time.

This study builds on Osafo-Kwaako (2012), which may be the only recent study that directly examines the legacy of the villagization program in Tanzania. Using data from the 1988 census, he finds that the program contributed to higher levels of education in districts that were more exposed to the villagization program had higher levels. He also finds that districts more affected by the program had higher level of social capital (political awareness and community participation) and provision of primary schools in 2009. In addition to this, he finds that consumption in these districts was significantly lower in 2000. This study builds on and extends Osafo-Kwaako (2012) by emphasizing the economic consequences of the villagization program using the most recent data with alternative treatment measures (from two different sources of data), outcome measures (consumption, education, asset-ownership computed from the HBS, NPS, and Tanzanian censuses), and an improved identification strategy that uses a richer and more reliable instrument. This study also suggests over-reliance in agriculture as a plausible mechanism through which villagization may have led to lower outcomes.

3.3 Villagization in Tanzania

Rationale for establishing *ujamaa*[4] villages in Tanzania

Tanzania went through a massive transformation of its landscape and economy during the villagization program in the 1960s and 1970s. Over the span of a decade, the landscape was transformed from a land of dispersed, scattered dwellings into a country in which more than three-quarters of its population lived in planned, concentrated villages. This reorganization of the landscape originated from the socialist *ujamaa* vision of cooperative living and production that its leader Julius Nyerere laid out in the Arusha Declaration of 1967. The consequences of this policy are still not completely understood and are possibly still being experienced five decades later.

Most Tanzanians in the 1960s lived in scattered houses spread across the land for many reasons (Iliffe, 1979; McHenry, 1979). The soil in most of Tanzania is poor in nutrients and unsuitable for intensified cultivation. People adapted to this by spreading out thinly across the country to eke out a living through shifting cultivation and pastoralism. Wild animals were abundant and land was plentiful; agricultural development was delayed because people could survive on hunting and gathering. During the slave trade, there was deep distrust of other people as there

[4] "*Ujamaa*" literally means "familyhood" in Swahili. As a political philosophy, this was Nyerere's interpretation of socialism appropriate for the Tanzanian context. Nyerere asserted that while "doctrinaire socialism" was a response to a class-based society with laborers and capitalists, this was not applicable to Tanzania as it never had classes prior to colonization. *Ujamaa* was the version of socialism in which everyone in society was a member of the same greater family. The goal of *ujamaa* was to reverse the trend towards class differentiation that he saw emerging in Tanzania during colonization.

was a constant fear of being enslaved through slave raids. One way to lower the chances of being raided was to live as far away from others as possible. Finally, during colonization from the late nineteenth century, living in concentrated settlements meant that people would be more vulnerable to taxes and labor demands. The Germans, who ruled Tanzania from 1884 until 1918, attempted to set minimum village size in some parts of Tanzania, but to no avail. Tanzania was under British mandate from the end of World War I until 1961. During this period, the British attempted to implement various policies to encourage people to live in more concentrated areas but these policies also largely failed (McHenry, 1979).

Julius Nyerere, the first president of Tanzania after independence from Great Britain, had a clear vision about how Tanzanian society had to be organized in order to improve the lives of its citizens. In his independence speech in December 1961, he said:

> "*If we want to develop . . . The first and absolutely essential thing to do . . . is to begin living in proper villages . . . unless we do so we shall not be able to provide ourselves with the things we need to develop our land and to raise our standard of living.*" (cited in Coulson (2013)).

Nyerere laid out his vision of a socialist Tanzania in the Arusha Declaration in February 1967, in which agriculture was the cornerstone of development. Seven months later, he issued the paper "Socialism and Rural Development," in which he formally launched the villagization program. In this 30-page document, he argued that the only way to defeat poverty in Tanzania was to build rural agriculture, which employed the vast majority of the population at the time. He proposed the primary vehicle to build rural agriculture to be *ujamaa* villages, in which all Tanzanians would "live and work together for the good of all." The document lacked specific details about how *ujamaa* villages would be organized, but he argued that living and working in concentrated villages would not only allow for better provision of social services such as education, health and water supply but would also enable farmers to adopt modern methods of production such as tractors. A key feature of his proposal was the voluntary nature of the villages. He argued that people should be either persuaded or shown by example that living and working together will benefit them and provide "a more secure living."

Stage 1: Arusha Declaration and launch of villagization program (1967-1972)

Ujamaa villages took off very slowly. Only 180 villages had been established fifteen months after the announcement of the plan to move the entire rural Tanzania into *ujamaa* villages. Various reasons contributed to the slow take-off of this program. Nyerere's 30-page paper announcing the program had very few practical details on how the program was to be implemented. Even basic questions were unanswered such as "how many households should an *ujamaa* village have?" or "how close do people have to live to be called an *ujamaa* village?" There was no clear role for the government or the sole party in the country, Tanganyika African National Union (TANU), in the implementation of the program. In fact, the role of the government was intended to be minimal and limited to persuading and educating people about the benefits of *ujamaa* villages (Cliffe et al., 1975).

Nyerere announced two changes in 1969 that sped up the establishment of *ujamaa* villages (Coulson, 2013). First, the government issued a circular that ordered government departments to give spending priority to *ujamaa* villages. Second, Nyerere allowed a limited amount of force to be used to expedite the formation of villages although he had clearly hitherto ruled out the use of compulsion. By the end of 1970, almost 2,000 *ujamaa* villages had been established with close to half a million Tanzanians living in them. Since the government had not announced a clear demarcation of communal and private activities, private farming was prevalent in most villages (Cliffe et al., 1975). Most of this took the form of "block-farming," in which the communal land was split up into parcels that households cultivated privately and kept its proceeds. By the end of 1972 and five years after the announcement of the villagization program, only two million people had moved into some 5,500 *ujamaa* villages across the country, less than 15% of the population at the time (Coulson, 2013).

Stage 2: Acceleration of villagization program (1973-1975)

Nyerere was increasingly frustrated with the slow pace of movement into villagization and declared in November 1973 that "to live in villages is an order" and that everyone had to move to villages by the end of 1976 (McHenry, 1979; Coulson, 2013). Having realized that getting people to work together was going to be received with much more resistance than living together, he practically abandoned the policy of working together but emphasized the living together aspect of the policy going forward. Over the next three years, various relocation operations such as "Operation Sogeza", "Operation Dodoma", and "Operation Imparnati" were conducted throughout the country. Various organs of the government including the police, army, and TANU officials engaged in an all-out effort to move people to villages (Coulson, 2013). This often entailed showing up in rural areas in trucks and forcing people to pack their belongings before moving them to a nearby village. Most relocations only covered short distances and often were only a few miles away. But families had to leave all their belongings and their houses and move to a new place where they would re-establish themselves. The village sites were most often decided by party and government officials that had little local knowledge, but the primary criterion for site selection was that it had to be on or near an all-weather road (Coulson, 2013).

Force was often used in moving people to villages during this stage of villagization and included burning or tearing down of houses and other physical property. But few incidents were reported of physical violence being used against individuals for resisting a move to villages (Coulson, 2013; McHenry, 1979). The use of force distinguished this phase from the first stage of the villagization program. Opposition against the program was not significant and was limited to people hiding, fleeing, or bribing to delay their move to villages. Most Tanzanians complied with the villagization drive because of persuasion by party and government officials, incentives promised to them, and compulsion in the form of destruction of property (McHenry, 1979). The villagization drive of 1973-1976 turned out to be immensely successful. Approximately two million people were living in villages at the end of 1972. The implementation was declared to have been effectively implemented by the end of 1975 (Coulson, 2013). By February 1977, 13 million people, out of a population of 17 million, were living in about 8,000 villages across the country (Coulson, 2013).[5]

Although the drive to move people to villages was very successful, getting people to work together was not. Households resisted working in communal farms and the general trend was "block farming": communal land that was split into small parcels to be cultivated by individual households. By the end of the 1970s, a third of all villages practiced some form of communal farming but this contributed to less than 2.5% of national GDP, a very small fraction compared with nearly 40% for all of agriculture (McHenry, 1979). Communal farms were most often parcels of land that all households would contribute labor towards. The proceeds would be allocated towards community activities such as buying water pipes or building schools, and the rest would be shared among households. There was much more success at non-farming activities such as building schools, dispensaries, and water supply facilities. Communal farming did not generate much support, most often due to confusion over the rules for working together and distributing income from the communal farm (von Freyhold, 1979).

Aside from villagization, Tanzania also went through major changes in the economy (Ellis and Mdoe, 2003). Major productive institutions such as manufacturing industries, agricultural estates, and service sector enterprises were nationalized and operated through parastatal agencies that were indirectly operated by officials appointed by the government. The government introduced comprehensive controls on agricultural prices and markets through crop marketing agencies. In summary, the

[5]The precise number of people relocated has been debated in the literature. Thomas (1985) argues that although the 1978 Census reports that 13 million Tanzanians lived in villages, only 8-9 million were likely to have been relocated while the rest were simply labeled as official government villages and counted in official statistics. Lorgen (2000) suggests that the relocated population may have been as low as 5 million.

government control of economic activity increased sharply in the decade after the Arusha Declaration.

Stage 3: Stagnation and abandonment of villagization program (1976-1982)

The immediate impact of the villagization program was far more positive in the provision of public services than in agricultural production (Collier, 1988). Primary enrolment increased from 32% in 1965 to 87% in 1985. Access to safe water in rural areas increased from 9% in 1973 to 28% in 1985. Infant mortality fell from 139 in 1965 to 111 per 1000 live births by 1985.[6] However, this was accompanied by a sharp decline in incomes (Collier, 1988). Real per capita income in 1982/3 was between 41% and 51% [7] of the level in 1974/5 and between 55% and 68% of the level in 1969, with urban incomes faring worse (Bevan et al., 1988). An immediate impact of the villagization program was that the agricultural production dropped because of the disruption caused by the unprecedented scale of dislocation (Coulson, 2013; Kikula, 1997).

This dismal situation in agricultural output was only made worse by the war with Uganda from October 1978 to April 1979. Uganda invaded the Kagera region of Tanzania. Tanzania then retaliated by invading Uganda and eventually ousting the president, Idi Amin. The cost of this war for Tanzania was very heavy as the war absorbed scarce resources and was followed by shortages in food, fuel, and imported goods (Coulson, 2013). Agricultural exports, a major source of foreign exchange earnings at the time, were hit seriously. Tanzanian exports of cotton, sisal, and cashew nuts (commodities with the largest export volumes in 1970) declined by 55% , 59% , and 80% , respectively, between 1970 and 1982 (Edwards, 2014).[8] This contributed to a balance of payments crisis and the implementation of an IMF

---

[6] According to World Bank (2015), Tanzania's neighbors Kenya, Uganda, Mozambique, and Malawi also witnessed big increases in life expectancy and a drop in infant mortality during this period. Thus, it is hard to say how much of the progress in measures of human development can be attributed to villagization and Nyerere's other policies.

[7] The range captures the uncertainty in the inflation level in the late-1970s and early-1980s, which **?** argue was higher than the official level reported by the government.

[8] According to estimates in Biermann (1990), the decline in the value of exports of these commodities was also in a similar scale.

and World Bank's Structural Adjustment Program in the 1980s. The villagization program finally came to an end after the Local Government Finances Act of 1982 repealed the Villages and Ujamaa Villages Act of 1975. Nyerere voluntarily left power in 1985, after which the Structural Adjustment Program began a slow reversal of the policies that he had introduced.

3.4 Data and descriptive statistics

The goal of this study is to examine if villagization still has a legacy on the economic well-being of Tanzanian households. The nature of this study necessitates the use of data from a variety of sources and collected at different points in time. The measure of villagization I use is the intensity of villagization, which is the share of the district population living in planned (registered) villages in the 1978 population census. This census collected data on the precise location and population of all government-planned villages. According to this census, 13.7 out of 17.5 million Tanzanians, or 78.3% of the population were living in planned villages. The average intensity of villagization across the 94 districts in mainland Tanzania was 73%. Zanzibar is excluded from the analysis because the villagization program was not implemented there and it was largely governed as an independent state until the late 1980s (Shivji, 2008).[9] The primary dataset I use to examine current economic outcomes is the Tanzania Household Budget Survey (HBS) 2011-12. Conducted by the Tanzania National Bureau of Statistics, this survey is used to generate the official estimate of poverty. This is a representative survey of mainland Tanzania.[10] Interviews were conducted with 10,186 households, out of which 10,063 households were included in the estimation sample after dropping observations with missing values.

I also use data on current economic outcomes from the Tanzania National Panel

[9]Zanzibar is an important part of Tanzania and was merged with mainland Tanzania (previously called Tanganyika) to form the United Republic of Tanzania in 1964. According to the 1978 Census, Zanzibar accounted for 0.5 million (3.1%) of the Tanzanian population.

[10]HBS excludes Zanzibar, but this is not a concern for this paper as Zanzibar is excluded from all analysis.

Survey (NPS) undertaken as a part of the World Bank's Living Standards Measurement Survey - Integrated Surveys of Agriculture (LSMS-ISA) project. NPS is a comprehensive multi-topic and panel survey that interviewed 3,265 households in 2008/9, 3,924 households in 2010/11, and 5,011 households in 2012/13. The full sample included 10,117 observations pooled from three NPS waves after dropping observations with missing values. The second and third waves attempted to interview all individuals covered in the first round, even if they had moved to a different location or joined a new household. Of all the original respondents, 90% of individuals and 95% of households were also re-interviewed in the third wave. [11]

Table 3.1 provides descriptive statistics on the variables used in the analysis. The primary outcome measure I examine is the annual per capita consumption of HBS households. I also examine household per capita income of HBS households as an alternative outcome measure. I analyze these same variables and household assets using data from NPS to confirm my findings. I follow Filmer and Pritchett (2001) to aggregate asset variables into an index using Principal Component Analysis.[12]

Figure 3.2 presents results from a local polynomial regression of the log of household consumption in 2011/12 on the district-level measure of villagization in 1978.[13] It suggests a strong negative correlation between these two variables, although at this point it is unclear whether or not this relationship is robust to the inclusion of control variables. Finally, I use characteristics of Tanzanian districts to control for geographic differences prior to villagization using data collected primarily by Jensen and Mkama (1968), who were a part of the UN Resident Mission based in Dar es

[11] My second measure of villagization is taken from the community questionnaire of NPS. If an NPS community was formed during the villagization program it was asked how many new people moved into the community as a part of the program. The possible answers to this question were "a lot", "some", "very few", or "none". I use these two questions to categories all 349 communities into three categories: "old village, no new residents" (14.67%), "old village, some new residents" (13.92%), and "new village, all new residents" (71.41%).

[12] See Section 4.3 for further details on this method. My asset index is composed of 34 assets, which incorporate at least some of the following types of assets: housing quality, furniture, consumer durables, and productive assets. The following assets have the highest weights: television, lighting from electricity, high-quality floor, mobile telephone, iron, fridge, sofas, and air-conditioner.

[13] Local polynomial regression is a non-parametric technique for smoothing scatter plots. Instead of parametric regressions that estimate parameters for a pre-determined family of functions, this technique relaxes that assumption so that the estimated plot fits the data more accurately. I use the Epanechnikov kernel function to calculate the weighted local polynomial estimate.

Salaam at that time. These data mostly come from the 1967 Census and include the following variables: district government revenues, number of cattle heads per person, number of dispensaries per 1,000 people, birth rate, death rate, and primary school enrolment per head of population.

Table 3.1: Summary statistics

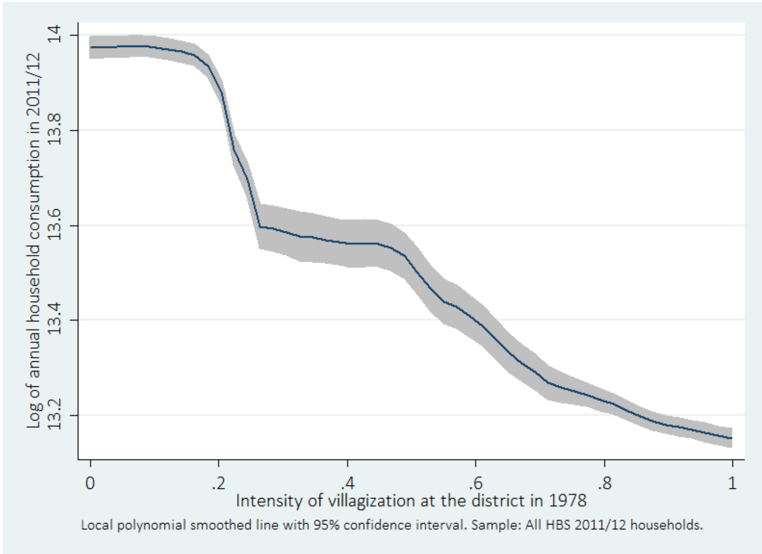
Variable	N	Mean	S.D.	Min	Max
Outcome variables					
Log of per capita household consumption, HBS	10,063	13.50	0.74	10.93	18.42
Log of per capita household consumption, NPS	10,117	13.30	0.79	10.38	16.73
Log of per capita household income, HBS	10,063	12.94	1.83	5.52	20.17
Log of per capita household income, NPS	10,117	13.82	1.33	6.21	18.14
Share of HH labor spent in the last 12 months in:					
Agricultural labor	10,117	0.46	0.42	0.00	1.00
Wage labor	10,117	0.27	0.38	0.00	1.00
Non-agricultural self-employment	10,117	0.25	0.35	0.00	1.00
Villagization variables					
Intensity of villagization in 1978	94	0.73	0.31	0.00	1.00
Villagization category in 1978:					
Old village, no new residents	10,117	0.14	0.34	0.00	1.00
Old village, some new residents	10,117	0.14	0.34	0.00	1.00
New village, all new residents	10,117	0.73	0.45	0.00	1.00
Control variables					
District government revenues (mn. TSH), 1967	94	1.94	1.85	0.00	8.22
Cattle heads per person, 1967	94	0.88	1.56	0.00	9.14
Dispensaries per 1,000 people, 1967	94	8.91	9.00	0.00	68.25
Birth rate, 1967	94	4.61	0.62	3.10	5.80
Death rate, 1967	94	2.26	0.53	1.10	3.30
Primary school enrolment per person, 1967	94	75.22	42.97	26.55	392.80
Share of district population in urban areas, 1967	94	0.05	0.11	0.00	1.00
Household size	10,063	4.60	2.88	1.00	42.00
Household dependency ratio	10,063	0.38	0.26	0.00	1.00
Household head is female	10,063	0.26	0.44	0.00	1.00
Household head is literate	10,063	0.85	0.36	0.00	1.00
Age of household head	10,063	43.84	14.81	14.00	97.00

Sources: Household Budget Survey 2011/12; National Panel Survey 2008/9 to 2012/13; Tanzania Census 1978; Jensen and Mkama (1968); Henin and Egero (1972); Tanzania Census 1967.

3.5 Methodology and identification strategy

Figure 3.1 outlines the timeline of this study, in which the outcome variables during 2011/12 are a function of the intensity of villagization measured during the 1978 census. The primary specification I estimate is expressed in equation 3.1 below. Let y_i be the log of household i's annual per capita consumption. The primary ex-

Figure 3.2: Local polynomial regression plot of current consumption on villagization in 1978



planatory variable is x_{1i}, which represents the household's exposure to villagization, measured as a share of household i's district population that lived in planned villages in the 1978 census (Figure 3.3).[14] X_{2i} is a vector of covariates measured in 1967, prior to villagization, that may also affect i's consumption during 2011-12. I also control for a vector of current household characteristics (X_{3i}) that may influence household consumption.

If households are randomly subjected to the villagization variable, we could estimate the marginal effect of villagization on current consumption by ordinary least squares estimation on the pooled data as:

$$y_i = \beta_0 + x_{1i}\beta_1 + x_{2i}\beta_2 + x_{3i}\beta_3 + \varepsilon_i \tag{3.1}$$

where observation $i = 1, 2, \ldots, N$ represents HBS households. β_1 is our primary coefficient of interest, and ε_i is an independently distributed error term. If districts in 1978 were not randomly subjected to villagization but were instead allocated due to unobservable factors such as remoteness or socio-political reasons that are correlated with current consumption, then the OLS coefficient of villagization is potentially

[14] Figure A.1 (page 127) presents the locations of all planned villages and urban areas that the author encoded using data from the 1978 Census.

biased. I control for district-level covariates in order to account for other factors that could also affect household consumption. Even with these controls, unobserved but time-varying district characteristics affecting household consumption could be a concern.

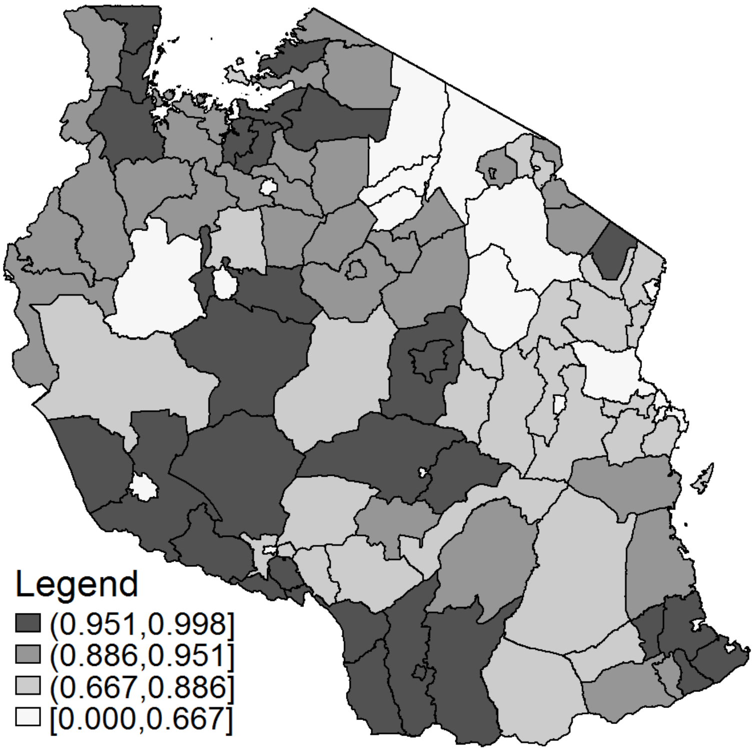
As noted above, I employ the instrumental variables (IV) technique to overcome this identification challenge by instrumenting villagization with sporadic droughts across Tanzania during 1973-75. I discuss the validity of this instrument in detail in the results section. I estimate the IV model using two-stage least squares, for which equation 3.1 is the second stage equation. The first-stage equation is:

$$x_{1i} = \alpha_0 + z_i\alpha_1 + x_{2i}\alpha_2 + x_{3i}\alpha_3 + \mu_i \tag{3.2}$$

where z_i is my instrument for the endogenous variable x_{1i}, μ_{1i} is the error term, which I assume to be normally distributed with zero mean and constant variance. The identification assumption is that the IV estimate of β_1 is an unbiased estimate of the marginal effect of villagization on household consumption if the relevance condition holds ($\alpha_1 \neq 0$) and the instrument is orthogonal to the error term in the second stage, i.e. $E(z'\varepsilon) = 0$.

I instrument the intensity of villagization in 1978 with sporadic droughts across Tanzania during 1973-75, the years when most of the villagization program was implemented across the country. Table 3.2 suggests that these were relatively dry years, with average rainfall across Tanzania being 0.26 standard deviations below the long-run average. In contrast, the periods 1970-72 and 1976-78 experienced rainfall very close to the long-run average. These droughts in certain parts of Tanzania are widely reported in the literature as forcing the government to import large quantities of grains to meet the shortfall in domestic production (von Freyhold, 1979; Coulson, 2013; Lofchie, 1978). Figure A.2 (page 128) shows that rainfall patterns across Tanzania were very different between 1973-75, 1970-72, and 1976-78. A commonly used argument and threat by government and party officials to move people into planned villages was that only those living in planned villages would receive drought

Figure 3.3: Share of district population living in planned villages in 1978 (Source: Tanzania Census 1978)



relief from the government. For example, von Freyhold (1979) says that droughts meant "a new pressure was created to persuade outsiders to join the villages. This took the form of distributing famine relief only to members of the Ujamaa village."[15] My instrumentation strategy improves upon a similar one adopted by Osafo-Kwaako (2012) but uses a much richer dataset on rainfall and a more accurate method to estimate district-level rainfall.[16]

I use station-level rainfall data from 279 stations across Tanzania and 53 stations near its borders with neighboring countries Zambia, Kenya, Malawi, Mozambique,

[15]The period between 1973-75 was not the only time when droughts were followed by announcements of villagization campaigns, although this is when these campaigns were intensified and scaled up. For example, Mascarenhas (1977) says that "[f]ollowing the drought of 1969, the government announced that a major resettlement operation would take place and people would have to live in planned villages."

[16]Osafo-Kwaako (2012) uses data from 108 rainfall stations across Tanzania and allocates a rainfall value from the nearest station to the entire district. I use data from 332 stations in Tanzania obtained from the Tanzania Meteorological Association. I spatially interpolate this data before taking district averages for analysis. Doing this is preferable to taking the value of rainfall from one specific location in the district (as Osafo-Kwaako (2012) does), given the geographic diversity of Tanzania.

Table 3.2: Summary statistics on instrument

Variable	N	Mean	S.D.	Min	Max
Mean rainfall in district, 1940-2000	94	1,026.42	182.14	699.72	1,392.27
SD of rainfall in district, 1940-2000	94	276.03	56.64	203.61	511.16
Z-score of rainfall during 1970-72	94	0.01	0.20	-0.63	0.40
Z-score of rainfall during 1973-75	94	-0.26	0.25	-0.82	0.23
Z-score of rainfall during 1976-78	94	0.01	0.21	-0.52	0.35

Sources: Tanzanian Meteorological Agency and Global Historical Climate Network database. Unit of observation is district.

Uganda, Burundi, and DR Congo.[17] Two-thirds of my station data were obtained from the Tanzanian Meteorological Agency, while the remainder were obtained from the Global Historical Climate Network database.[18] Although I have raw data on rainfall from nearly a thousand rainfall stations across Tanzania, I keep only those years with at least 11 months of reported data for any given station and rainfall stations that report at least 20 years of data between 1940 and 2000.[19]

3.6 Results and robustness checks

3.6.1 Validity of the instruments

A major concern in my analysis is that the intensity of villagization may have been associated with district characteristics prior to villagization that are also correlated with current outcomes. To address this question, I examine if systematic differences exist between districts by the intensity of villagization. Table 3.3 compares 1967 characteristics of districts grouped by intensity of villagization. The last two sets of columns contain differences between the districts grouped by the intensity of villagization. The results suggest that although there were differences across districts prior to villagization in many variables and that we need to address this fact in our analysis.

Although the results in Table 3.3 mitigate some concerns that districts with greater potential to be well-off in the future may have been subjected less to vil-

[17] I spatially interpolate data from rainfall stations by kriging, a method commonly used by geographers for this purpose (Earls and Dixon). I then take district averages of rainfall to calculate the z-score of rainfall for each district relative to the long-run mean for 1940-2000.

[18] http://www.ncdc.noaa.gov/ghcnm/v2.php

[19] This ensures that the annual data on stations are as complete and accurate as possible.

Table 3.3: Differences between districts prior to villagization

District characteristics	Intensity of villagization in 1978			Medium minus Low	High minus Medium	High minus Low
	Low	Medium	High			
	(1)	(2)	(3)	(4)	(5)	(6)
Share of district population in planned villages, 1978	0.37	0.88	0.97	0.50***	0.09***	0.59***
Area, '000 sq. km.	12.12	14.91	14.03	2.79	-0.88	1.91
Birth rate per 1000 people, 1967	44.59	45.72	48.29	1.13	2.57	3.70**
Death rate per 1000 people, 1967	21.72	22.31	24.13	0.59	1.82	2.41*
Dispensaries per 1000 people, 1967	9.53	9.03	8.22	-0.50	-0.82	-1.31
Primary school enrolment per 1000 people, 1967	81.39	72.04	71.52	-9.35	-0.52	-9.87
District government revenues (mn. Sh.), 1967	1.33	2.07	2.45	0.75*	0.38	1.12**
GDP, total (mn. Sh.), 1967	78.67	84.78	84.79	6.11	0.01	6.12
GDP, agriculture (mn. Sh.), 1967	23.62	34.89	33.50	11.27	-1.40	9.87
Cattle heads per person, 1967	0.92	0.83	0.88	-0.10	0.06	-0.04
GDP per inhabitant, Sh., 1967	570.72	360.15	316.53	-210.57	-43.63	-254.19*
Share of district population in urban areas, 1967	0.09	0.02	0.04	-0.07**	0.02	-0.06*
Mean annual rainfall during 1940-2000, mm	1054.41	1022.51	1005.95	-31.90	-16.56	-48.46
Std. dev. of rainfall during 1940-2000, mm	295.16	270.46	262.02	-24.69	-8.44	-33.14**
Number of districts	32	32	31			

* p < .10, ** p < .05, *** p < .01. Data sources: 1967 Census, 1978 Census, Jensen and Mkama (1968), Henin and Egero (1972).

lagization, the three groups of districts in Table 3.3 may have been systematically different in unobservable characteristics. I therefore instrument villagization in order to address this issue. Finally, a valid instrument should not directly affect the outcome variable but should do so only through the instrument. This can be crudely examined by including the instrument in the OLS model. Results of this specification are presented in Column 5 of Table 3.4, where we can see that the droughts during 1973-75 are not a significant predictor of consumption of HBS households in 2012/13 once the district villagization variable is included.

I instrument the district-level intensity of villagization with the district-level Z-score of rainfall during 1973-75 relative to the long-run rainfall for the district during 1940-2000. Table 3.2 suggests that rainfall during these years was 0.26 of a standard deviation below the long-run mean, while the rainfall during the three years before and after these years were much closer to the long-run mean. These were also the years when the villagization program was ramped up after Nyerere declared that "to move to villages is an order" (Coulson, 2013; McHenry, 1979; Boesen et al., 1986). Widespread droughts were reported to be a commonly-used excuse by officials to force people to move to planned villages.[20] Figure A.2 (page

[20]Households were often told that the government would not be able to provide drought relief

Table 3.4: Determinants of the log of household per capita consumption in HBS (1st stage IV results)

Instrument=>	(1) 1970-72	(2) 1973-75	(3) 1976-78	(4) 1970-72, 1973-75, 1976-78	(5) Reduced form model
Z-score of rainfall, 1970-72	-0.089			0.169	
	(0.236)			(0.195)	
Z-score of rainfall, 1973-75		-0.721***		-0.791***	0.146
		(0.234)		(0.235)	(0.138)
Z-score of rainfall, 1976-78			0.069	0.056	
			(0.207)	(0.162)	
Intensity of villagization in 1978					-0.354***
					(0.067)
Share of district population in urban areas, 1967	-0.462***	-0.416***	-0.457***	-0.402***	-0.162
	(0.166)	(0.133)	(0.164)	(0.128)	(0.111)
District government revenues (mn. Sh.), 1967	0.106***	0.117***	0.106***	0.117***	0.002
	(0.016)	(0.014)	(0.015)	(0.014)	(0.013)
Cattle heads per person in district, 1967	0.001	-0.008	0.001	-0.008	0.038***
	(0.016)	(0.014)	(0.016)	(0.015)	(0.013)
Dispensaries per person in district, 1967	-9.891**	-13.484***	-10.259**	-14.202***	2.164
	(4.111)	(3.458)	(4.129)	(3.300)	(2.661)
Birth rate per 10,000 pop. of district, 1967	0.100	0.152**	0.091	0.145**	-0.021
	(0.068)	(0.063)	(0.069)	(0.065)	(0.050)
Death rate per 10,000 pop. of district, 1967	-0.025	-0.079	-0.017	-0.075	-0.145**
	(0.087)	(0.088)	(0.088)	(0.091)	(0.073)
Primary school enrolment per person in district, 1967	-0.095	-0.564	0.046	-0.424	-0.333
	(0.903)	(0.748)	(0.911)	(0.850)	(0.444)
Mean annual rainfall in district ('000 mm), 1940-2000	0.226	0.287	0.238	0.323	-0.006
	(0.251)	(0.221)	(0.239)	(0.228)	(0.137)
SD of annual rainfall in district ('000 mm), 1940-2000	-1.878*	-1.240	-1.766*	-1.050	-1.090*
	(1.020)	(0.879)	(1.000)	(0.828)	(0.648)
Latitude of district centroid, degrees	-0.044	-0.084***	-0.055	-0.103***	0.028
	(0.041)	(0.031)	(0.038)	(0.038)	(0.026)
Longitude of district centroid, degrees	-0.019	-0.025	-0.013	-0.016	0.023
	(0.024)	(0.021)	(0.022)	(0.023)	(0.014)
Household size, 2011/12	0.002	0.001	0.002	0.001	-0.070***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.005)
Household dependency ratio, 2011/12	0.086***	0.070***	0.085***	0.067***	-0.780***
	(0.021)	(0.018)	(0.021)	(0.019)	(0.041)
Household head is female, 2011/12	-0.024***	-0.020***	-0.024***	-0.018**	-0.039***
	(0.008)	(0.007)	(0.008)	(0.007)	(0.014)
Household head is literate, 2011/12	-0.064***	-0.048***	-0.064***	-0.046***	0.223***
	(0.016)	(0.014)	(0.016)	(0.014)	(0.024)
Age of household head, 2011/12	0.000	0.000	0.000	0.000	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Constant	0.880	0.321	0.539	-0.253	14.281***
	(0.996)	(0.769)	(0.850)	(0.900)	(0.551)
Observations	10,063	10,063	10,063	10,063	10,063
R2	0.707	0.745	0.706	0.747	0.474

128) suggests that droughts did not occur evenly across Tanzania and that rainfall was particularly severe around Lake Victoria in the north and in the south-west parts of the country during 1973-75. I exploit this exogenous spatial variation in drought as my instrument.

Table 3.4 presents estimates from the first stage of the IV estimation in which

to households that did not move to one of the new settlements (Boesen et al., 1986). Schneider (2014) (page 322) and Bulletin of Tanzania Affairs 1, page 10 also report of this strategy being used by the Tanzanian government.

we see that the Z-score of district rainfall during 1973-75 is a strong predictor of villagization. Results in column (2) suggest that if a district received 0.26 standard deviation less rainfall that the long-run average (the sample the average for 1973-75), the share of a district population living in planned villages would have increased by 18 percentage points. The coefficient on the instrument is significant at the 1% level and the Cragg-Donald F statistic in the first stage regression is comfortably above the rule of thumb of 10 generally used in the literature.

These results are complemented by the fact that the Z-score of rainfall during 1970-72 and 1975-78 are not statistically significant predictors of villagization (Table 3.4 columns 1 and 3, respectively) and act as placebos for my instrument. When all of these variables are included in the model (Table 3.4, column 4), only the Z-score for 1973-75 remains statistically significant, providing more confidence in the instrument. The magnitude of the coefficients for the Z-score of rainfall in 1970-72 and 1976-78 is also much smaller than for 1973-75. All of these results suggest that sporadic drought across Tanzania only had an effect on villagization during the narrow time-frame of 1973-75 and thus is a good instrument for my analysis.

3.6.2 Main results

Table 3.5 presents estimation results of the determinants of the log of household per capita consumption. Column 1 presents the baseline results from OLS estimation. Columns 2-6 address the endogeneity of villagization by instrumenting it with the Z-score of rainfall during 1973-75 but also contain results from analyses on different subsamples. Column 2 is my preferred specification as it contains results for the full HBS sample. Columns 3-6 present results for the following sub-samples of HBS households: residents of the largest city Dar es Salaam, residents of rural areas, residents of urban areas, and households that are engaged in farming. All standard errors are clustered at the district-level to account for within-district correlation in the outcome variable.

The OLS and IV estimates are both negative and significant at the 1% level, sug-

Table 3.5: Determinants of the log of household per capita consumption in HBS (2nd stage IV results)

	(1)	(2)	(3)	(4)	(5)	(6)
Sample	Full	Full	Non-Dar	Rural	Urban	Farming
Estimator	OLS	IV	IV	IV	IV	IV
Intensity of villagization in 1978	-0.380***	-0.556***	-0.534**	-0.613**	0.290	-0.844*
	(0.060)	(0.195)	(0.228)	(0.292)	(1.511)	(0.492)
Share of district population in urban areas, 1967	-0.166	-0.246*	0.116	-0.131	0.722	-0.087
	(0.112)	(0.143)	(0.527)	(0.168)	(3.191)	(0.218)
District government revenues (mn. Sh.), 1967	0.008	0.026	0.024	0.038	-0.152	0.044
	(0.012)	(0.022)	(0.016)	(0.023)	(0.483)	(0.031)
Cattle heads per person in district, 1967	0.036***	0.036***	0.041***	0.042***	0.057	0.023
	(0.013)	(0.012)	(0.013)	(0.014)	(0.271)	(0.020)
Dispensaries per person in district, 1967	1.189	-0.561	3.234	-5.837	6.289	-4.999
	(2.293)	(2.957)	(4.470)	(4.598)	(5.167)	(8.612)
Birth rate per 10,000 pop. of district, 1967	-0.006	0.010	0.018	0.016	-0.145	0.011
	(0.045)	(0.047)	(0.048)	(0.055)	(0.382)	(0.063)
Death rate per 10,000 pop. of district, 1967	-0.157**	-0.161**	-0.160**	-0.171**	-0.080	-0.141**
	(0.072)	(0.069)	(0.070)	(0.072)	(0.237)	(0.072)
Primary school enrolment per person in district, 1967	-0.443	-0.447	-0.409	-0.664*	0.660	-1.086*
	(0.416)	(0.405)	(0.442)	(0.383)	(4.548)	(0.561)
Mean annual rainfall in district ('000 mm), 1940-2000	0.008	0.052	0.047	0.105	-0.746	0.090
	(0.136)	(0.161)	(0.162)	(0.180)	(1.182)	(0.192)
SD of annual rainfall in district ('000 mm), 1940-2000	-1.017	-1.340*	-1.329*	-1.243	0.216	-1.288
	(0.660)	(0.741)	(0.736)	(0.976)	(7.340)	(1.149)
Latitude of district centroid, degrees	0.020	0.011	0.009	-0.003	-0.032	0.020
	(0.026)	(0.030)	(0.030)	(0.032)	(0.180)	(0.030)
Longitude of district centroid, degrees	0.020	0.018	0.015	0.029*	-0.007	0.030
	(0.014)	(0.014)	(0.015)	(0.016)	(0.053)	(0.022)
Household size, 2011/12	-0.070***	-0.070***	-0.067***	-0.064***	-0.084***	-0.058***
	(0.005)	(0.005)	(0.006)	(0.005)	(0.005)	(0.006)
Household dependency ratio, 2011/12	-0.781***	-0.766***	-0.704***	-0.670***	-0.875***	-0.590***
	(0.041)	(0.044)	(0.043)	(0.045)	(0.045)	(0.047)
Household head is female, 2011/12	-0.039***	-0.043***	-0.028	-0.033*	-0.070***	-0.057***
	(0.014)	(0.015)	(0.018)	(0.018)	(0.022)	(0.020)
Household head is literate, 2011/12	0.225***	0.214***	0.213***	0.201***	0.261***	0.185***
	(0.024)	(0.027)	(0.028)	(0.029)	(0.026)	(0.031)
Age of household head, 2011/12	0.002***	0.002***	0.002***	0.002***	0.002*	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	14.234***	14.346***	14.338***	13.718***	15.770***	13.897***
	(0.562)	(0.576)	(0.572)	(0.610)	(2.667)	(0.646)
N	10,063	10,063	7,107	6,324	3,739	5,302
R2	0.474	0.471	0.327	0.325	0.381	0.296
Cragg-Donald F-statistic		1509.988	909.473	625.060	104.050	330.595

Note: Standard errors in parentheses are clustered at the district-level. All specifications include dummies for 7 administrative zones.

gesting a negative impact of the villagization program. The IV coefficient of -0.556 implies that if a district's intensity of villagization in 1978 increased by one percentage point relative to the mean, consumption in 2011/12 would fall by 0.556%, on average. The IV estimate is smaller than the OLS estimate, suggesting that unobservable factors determining the current consumption (such as rural location) are positively correlated with villagization. The OLS estimate of the coefficient of villagization may reflect the additional effect of the unobservable factors. The

IV estimate is smaller than the OLS estimate because the IV method purges the positive correlation between villagization and unobservable factors determining consumption. The fact that the impact of villagization is larger for currently rural residents and farming households but not urban residents suggests that agriculture may be a potential channel through which villagization may have affected current consumption. The next section examines this hypothesis in detail.

All household characteristics have the anticipated signs and are statistically significant at the 1% level. Larger households, households with a higher dependency ratio, and female-headed households have lower consumption while households with a literate and older household head are associated with higher per capita consumption. Cattle-holding is a statistically significant predictor of household consumption at the 1% level in my preferred specification, suggesting that household wealth is positively correlated with consumption. An extra head of cattle owned by a household is associated with 3.6% higher per capita household consumption on average, holding other variables constant. The mean rainfall is not found to be a significant predictor of household consumption, suggesting that households may have already incorporated this variable into their decision-making.

3.6.3 Robustness checks

In this section, I examine if the result in the previous section holds when subjected to various robustness checks. Are the results in Table 3.5 robust to an alternative measure of villagization? An advantage of using NPS data to analyze the effect of the villagization program is that we can exploit an alternative measure of villagization. All 349 communities interviewed in NPS were asked if they were newly formed during the villagization campaign in the 1970s. A majority of these communities (71%) were in fact newly formed during this period, which permits the use of this dummy variable as an alternative measure of villagization. Columns 3 and 4 of Table **??** (page 47) present OLS and IV estimates with this alternative measure of villagization. The IV estimate of villagization is larger than the coefficient using the district-level villagization measure (-1.014 vs. -0.522) and statistically significant at the 1% level. The OLS coefficient is indistinguishable from zero, possibly due to attenuation bias resulting from measurement error in this variable. The IV estimates are reassuring in the sense that if anything, a community-level measure of villagization has the same sign and significance as the district-level measure. The magnitude of the coefficients of the two measures of villagization cannot be compared meaningfully: the continuous measure of the intensity of villagization is at the district level while the dichotomous measure simply says whether a community was newly established during the villagization process or not.

Table 3.6: Dependent variable is log of household consumption (NPS data)

	(1) OLS	(2) IV	(3) OLS	(4) IV
Endogenous variable:				
Intensity of villagization in 1978	-0.289***	-0.522***		
	(0.025)	(0.145)		
Village newly created during villagization			0.020	-1.014***
			(0.013)	(0.354)
Controls	Yes	Yes	Yes	Yes
Observations	10,117	10,117	10,117	10,117
R2	0.521	0.517	0.515	0.236
Cragg-Donald F-statistic		308.361		21.645

I then examine if results reported in Table 3.5 are robust to alternative outcome measures. Table A.1 (page 129) presents the results of regressions in which the effect of villagization is examined on a variety of outcome measures using data from HBS. The outcomes considered are household per capita income, an index of household assets, average years of education in the household, whether the household has access to piped water, and whether the household's primary source of lighting is electricity. The results are consistent with results in Table 3.5 villagization in 1978 had a negative effect on all of these outcomes. The result on education is particularly surprising since universal education, although abandoned in the mid-1980s, was a key feature of the villagization program.

I finally examine if results reported in Table 3.5 are driven by the presence of outliers. I conduct the estimation in Table 3.5 on a trimmed HBS sample without the top and bottom 5% of households ranked by the dependent variable. I find that the coefficient on villagization is negative (as in Table 3.5) and statistically significant at least at the 5% level even in this trimmed sample, although the coefficient on villagization increases from -0.556 to -0.408 (Table A.2 (page 129)). This suggests that my primary results are not driven by the presence of outliers, although they appear to have a small impact on the magnitude of the coefficient.

3.7 Mechanism

This section discusses activity choice as a potential mechanism that explains why villagization may have led to lower levels of outcomes even three decades after the program was abandoned. Given the rush to move as many Tanzanians as possible into government villages, choice of village location was often poorly thought through and often made without adequately considering agriculture. A main requirement of village construction was that it had to be along a major road. Many villages were constructed along roads even when it was not suitable for agricultural production in terms of carrying capacity or water prospects. (Kjekshus, 1977).

Various reasons have b

Table 3.7: Determinants of household labor shares in different activities (NPS data)

	(1)	(2)	(3)	(4)	(5)	(6)
Sample	Full	Full	Non-Dar	Rural	Urban	Farming
Estimator	OLS	IV	IV	IV	IV	IV
Panel A: Dependent variable – Share of annual household labor allocated to farming						
Intensity of villagization in 1978	0.402***	1.099***	1.081***	0.805***	0.298**	1.141***
	(0.043)	(0.099)	(0.107)	(0.132)	(0.145)	(0.175)
R2	0.424	0.297	0.134	0.126	0.359	0.001
Panel B: Dependent variable – Share of annual household labor allocated to wage labor						
Intensity of villagization in 1978	-0.212***	-0.300***	-0.294***	-0.222**	-0.061	-0.202
	(0.030)	(0.083)	(0.091)	(0.107)	(0.188)	(0.129)
R2	0.226	0.223	0.143	0.093	0.148	0.111
Panel C: Dependent variable – Share of annual household labor allocated to self-employment						
Intensity of villagization in 1978	-0.182***	-0.802***	-0.779***	-0.520***	-0.398**	-0.921***
	(0.030)	(0.093)	(0.101)	(0.107)	(0.196)	(0.157)
R2	0.089	-0.057	-0.102	0.023	0.006	-0.224
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
N	10,117	10,117	8,287	6,536	3,581	7,464
Cragg-Donald F-statistic		331.591	275.968	218.413	112.502	114.214

Households may have to increasingly spend more of their labor share on agriculture instead of engaging in wage labor or non-agricultural self-employment because severe restrictions were placed on market activity as a part of the villagization program. To test this hypothesis, I examine the shares of household labor devoted to various activities during 12 months prior to the survey. Table 3.7 presents the OLS and IV estimates of this analysis. We see that villagization is associated with a higher share of household labor allocated to farming but lower shares are allocated to wage labor or self-employment. The IV estimates suggest a larger effect than the OLS estimates. This suggests that exposure to villagization may have led to a reliance on agriculture as the primary source of livelihood, rather than wage-employment or non-agricultural self-employment. Villagization may have had a persistent and negative impact on current outcomes by preventing people from moving out of agriculture.

3.8 Conclusion

This paper attempts to examine if exposure to the villagization program in the 1970s had a persistent impact on outcomes three decades after the program was abandoned. This is an important issue because of the scale of the program at its height, about three quarters of Tanzanians were living in village locations planned by the government. This program is known to have inflicted a heavy toll on the Tanzanian economy in its immediate aftermath (Bevan et al., 1988). This study aimed to contribute to the literature on the legacy of large-scale government programs. It addressed this question by analyzing outcomes at the household and geographic level as a function of the exposure to the villagization program in the 1970s.

This paper addresses the endogeneity of the intensity of the villagization program by instrumenting it with sporadic droughts across Tanzania during 1973-75, when the villagization program was ramped up. I find suggestive evidence that exposure to villagization in 1970s is associated with lower levels of current outcomes. This finding is robust to the choice of the dataset, outliers, and the measure of villagization used. The fact that sporadic droughts may have had a key role in the implementation of the villagization program in Tanzania is an example of the important role that contingencies such as weather events often have in determining government policy (Banerjee and Duflo (2014) review this literature).

Some weaknesses in this analysis could be addressed in future work, given data availability. This paper does not delve into which aspects of agriculture may have been hardest hit by the villagization program. Analyzing agricultural productivity or the use of modern inputs may be potential areas for further work. This study also does not explore other potential mechanisms that may explain why villagization may have had a persistent effect on economic outcomes even three decades after the program was abandoned. My analysis ignores outcomes such as access to infrastructure or the provision of social services (for example, health facilities, schools, or water supply) that may have been positively affected by the villagization program. Understanding the long-run consequences of the villagization program is of huge importance given the significant influence it had and continues to have on the lives of Tanzanians.

Chapter 4

Rainfall shocks and activity choices of Tanzanian households

4.1 Introduction

Although three-quarters of the employed Tanzanian population is engaged in agriculture, only 0.5% of agricultural land is equipped for irrigation (World Bank, 2013). As a consequence, unpredictable rainfall is a major source of income uncertainty for Tanzanian households. Inability to manage this income risk has been found to hurt their welfare and investment decisions (Dercon, 2008; Rosenzweig and Binswanger, 1993; Porter, 2012). Households could deal with income uncertainty using a variety of strategies such as informal risk-sharing (Fafchamps and Lund, 2003), precautionary savings (Dustmann, 1997), or asset depletion (Rosenzweig and Wolpin, 1993). In this paper, I examine if households use labor strategies to manage income risk arising from unreliable rainfall.

Understanding how households manage income uncertainty is important for multiple reasons. An important pathway out of poverty is for individuals to receive higher returns to their labor the asset they are most abundant in. Understanding labor strategies of households may help understand the constraints that prevent people from moving out of poverty. What is worse, African weather is expected to become more variable in the future. Although the consequences of climate change for Africa are uncertain and will likely vary by sub-region, the consensus among climate scientists is that many regions of Africa will experience droughts and floods with higher frequency and intensity in the future (Collier et al., 2008; IPCC, 2007). We need to understand how households are affected by rainfall risk and how they are responding to it. This may inform policy-making in regard to irrigation, credit market, insurance markets, and weather prediction.

My primary research question in this paper is whether Tanzanian households facing income risk arising from unpredictable and harsh weather use labor strategies to manage this risk. Tanzania is a good country for studying this issue since rain-fed agriculture is the predominant source of employment. Moreover, it is a geographically diverse country that consists of mountains, plateaus, lakes, and coastal regions. These result in varied rainfall patterns across the country that could be exploited in an empirical analysis. It is plausible that in areas where rainfall is low and unpredictable, households do not rely solely on agriculture but diversify their income-generating activities away from agriculture and towards nonfarm activities in an effort to smooth income. I tackle this issue by examining household labor supply in farming, wage labor, and self-employment activities using the Tanzanian National Panel Survey conducted in three waves between 2008/9 and 2012/13.

The existing literature on whether households use labor strategies to manage income risk arising from wide distributions of rainfall and rainfall shocks focuses mostly on South Asia, where households appear to participate in non-agricultural work as a means to manage rainfall risk (Skoufias et al., 2015; Bandyopadhyay and Skoufias, 2012; Menon, 2009; Rose, 2001). This study attempts to contribute to the literature on Sub-Saharan Africa on this theme by examining multiple activities that households are engaged in and by using a rainfall dataset with rich spatial and extended temporal coverage. A key challenge in addressing this issue is the fact that households that engage in different activities may be a non-random sample of the population, an issue I deal with by implementing the Heckman two-step estimation technique. I find suggestive evidence that Tanzanian households use labor strategies to deal with income risk arising from unpredictable rainfall. Households appear to be reallocating labor between farming and self-employment in response to rainfall shocks. I do not find evidence that households rely on the market for wage labor to respond to rainfall shocks, suggesting imperfections in the Tanzanian labor market.

The rest of the paper proceeds as follows. Section 2 reviews the empirical literature that examines how households are affected by and manage weather risk. Section 3 describes the two datasets I use in this study: the Tanzania National Panel Survey and satellite-based rainfall data for Tanzania. Section 4 explains the methodology used in this paper. Section 5 presents the main results, while Section 6 presents results of robustness checks on the primary results presented in the previous section. Section 7 summarizes the findings and provides some concluding remarks.

4.2 Relevant literature

Households in developing countries face a variety of risks and shocks that affect their wellbeing (Dercon, 2008). They may face risks, such as unreliable rainfall, that imply an insecure environment. They may also face various shocks, or unexpected negative events, such as drought, illness, or death. Sinha et al. (2002) use the term damaging fluctuations to describe factors that affect welfare such as violence, natural disasters, harvest failure, disease, reduced access to productive work, or worsened terms of trade. The incidence and magnitude of a particular type of risk depends on the location, community, household, and individual. Despite household attempts to deal with these risks, they often have adverse consequences for household welfare (Dercon, 2004).

Some strategies households use to respond to risks are designed to reduce exposure to shocks, to rely on assets to smooth consumption, and to share risks informally with others (Fafchamps, 2003). Households and communities can reduce exposure to the risk of malaria, for example, by spraying insecticides to kill mosquitoes or relocating to an area that is less infested with mosquitoes. Other strategies that reduce exposure to shocks include diversifying income sources, specializing in a particular activity, and maintaining flexible production schedules. Alternatively, households can cope with risk by sharing it with others in the community's social networks so that their consumption does not fluctuate as much as their income does. There is increasing evidence that despite various strategies, they are able to fully insure themselves against the various risks they face. Households are better equipped to protect themselves against idiosyncratic shocks but not covariate shocks such as extremely low levels of rainfall (Dercon, 2004; Porter, 2012). They also diversify to supplement their agricultural income during off-seasons, to manage risk, and as a response to market failures (Barrett et al., 2001).

Recent literature has recognized the important role of rainfall as a source of risk to household income. Menon (2009) and Bandyopadhyay and Skoufias (2012) find that agricultural households in Nepal and Bangladesh, respectively, are more likely to have a member of the household participating in a non-agricultural activity in areas that have historically received more variable rainfall. Ito and Kurosaki (2009) and Kochar (1999) find that Indian households devote a larger share of work hours to non-agricultural work in areas with more variable rainfall. Similarly, Rose (2001) finds that agricultural households in India are more likely to participate in the labor market in response to both weather shocks and historical weather variability. Although the existing evidence is mostly from South Asia, some studies have found that households in Sub-Saharan Africa choose to move out of agriculture if faced with greater rainfall variability (Dercon, 1998; Porter, 2012). Households manage weather risk by diversifying their income sources, although risk management may not be the only reason they diversify incomes. Agricultural households could diversify income in two ways. First, if they decide to remain in agriculture, they could plant weather-resistant crops or varieties (Dercon, 1998). Second, they could decide to engage in activities outside of their farms by either starting a family business or by working for someone else for a wage.

An important pathway out of poverty is for individuals to receive higher returns to their labor, one of their most important assets. Understanding labor strategies of households may help us understand the constraints that prevent people from moving out of poverty (Banerjee and Duflo, 2007; de Weerdt, 2010; Dercon, 2004). There is increasing evidence that despite the use of various strategies, households are not able to fully insure themselves against the various risks they face, particularly, covariate shocks such as extremely low levels of rainfall (Dercon, 2005; Porter, 2012). Estudillo et al. (2012) and Bezu and Barrett (2012) remind us that the quality of nonfarm work matters more than the quantity since the poorest households also participate in activities with the lowest returns. Moreover, Porter (2012) suggests that despite diversification, households may not be able to be fully able to insure themselves against covariate as opposed to idiosyncratic risks.

This paper aims to contribute to the literature in several ways. It adds to the thin literature on whether households use labor strategies to manage income risk arising from rainfall variability in Sub-Saharan countries. This issue is especially important in Tanzanian, where agriculture is predominantly rain-fed and rainfall is variable over space and time. This study also pays careful attention to multiple activities that households may be engaged in by estimating the number of working days that household members allocate to agriculture, wage labor, and non-agricultural self-employment. Finally, most of the existing literature relies on rainfall data collected from weather stations or information provided by households, both of which could potentially exhibit poor quality. This study uses high-resolution rainfall data collected by weather satellites with superior spatial and temporal coverage than station-based data.

4.3 Data and descriptive statistics

Tanzania National Panel Survey (NPS)

I conduct my analysis using the Tanzania National Panel Survey (NPS). Conducted as a part of the World Bank's Living Standards Measurement Survey - Integrated Surveys of Agriculture (LSMS-ISA) project, NPS is a multi-topic household survey with a special focus on agriculture and was conducted on 3,265 households in 2008/9, 3,924 households in 2010/11, and 5,010 households in 2012/13. The first wave of NPS was designed to be a nationally representative sample. The second wave attempted to interview everyone interviewed in the first round, even if they had moved to a different location or joined a new household. The re-interview rate was high: 95% of all individuals and 87% of all households interviewed in the first wave were interviewed in all three waves.

I examine two outcome variables as measures of household labor strategies as they are together more likely to give a better picture of household labor strategies than a single measure. The first is a three-category variable that measures the degree to which a household has moved away from agriculture. I classify households into three groups: those that engage only in self-employed agriculture, those that combine agriculture with a non-agricultural activity, and those that engage only in non-agricultural work. By agricultural work, I mean production of staples, livestock, cash crops, and fruit trees, as well as agricultural labor. Non-agricultural work includes casual labor in non-agricultural work (with contracts shorter than a month), salaried wage, or self-employment (with or without employees). Table 4.1 presents descriptive statistics of NPS. We see that 23% of NPS households are engaged only in agriculture, 41% combine agriculture with a non-agricultural activity, and 30% are engaged only in non-agricultural activities.[1]

The second outcome variable I examine is the number of working days that the household allocated to self-employed agriculture, wage labor, and self-employment in the 12 months prior to the survey. I define the household working days to be the sum of days worked by all members. Annual household days in farming includes time spent in the farm cultivated by the household. Any part time or full time work done for a wage, including in agriculture, is counted as wage employment.

[1] Agricultural wage labor is not a common activity in Tanzania. In NPS3, 5% of the respondents report having worked for a wage in agriculture. The median days worked by these individuals in this activity was 16 days.

Self-employment includes any non-agricultural activity (such as retail trade or small business) in which household members are engaged in but are not paid a wage. I compute the total annual working days of each individual as the sum of days worked in self-employed agriculture, wage labor, and self-employment activities outside of agriculture. For agriculture, I aggregate the number of days that individuals spent on planting, weeding, and harvesting crops during the long and the short rainy season.[2] Unfortunately, the labor data in NPS do not contain information on the household working days devoted to livestock, a major economic activity for about half of all NPS households.[3]

Data on wage labor are collected on the primary and secondary jobs of all household members. I assume that the salaried workers (those with at least monthly contracts) worked for 52 weeks during the last year while casual workers (with contracts shorter than a month) worked only for 26 weeks. I use information on both the primary and secondary self-employment activity of individuals. The conversion factors for working hours that I used are as follows: 1 year equals 52 weeks, 1 month equals 4.35 weeks, 1 week of full-time work equals 40 hours, and 1 week of part time work equals 20 hours. I compute all labor data in days, rather than hours, because most questions in NPS that elicited the amount of time worked in various activities (especially, agriculture) did so in days.

On average, NPS respondents worked for 63 days in the 12 months prior to the survey (Table B.3, page 132). This number is higher for men (73 days) than for women (53 days).[4] The amount of work women and men do is approximately the same in farming and self-employment, but men work for than twice as many days as women in wage labor (34 vs. 14 days). On average, children between 5 and 14

[2]This may underestimate the total agricultural labor since it only includes time allocated to seasonal crops but not permanent or cash crops such as coffee, cashew nuts, or bananas.

[3]Although information is available on time spent in collecting firewood and fetching water (which are also productive activities), I do not use them because this information only relates to the previous day; extrapolating this information to the previous 12 months could result in large errors.

[4]22% of children (between 5 and 14 years of age) work at least one day. Most of this work (78%) was done in farming. The median number days worked by the children that worked at least one day is 21, whereas the mean is 41 days.

years of age work about 6 days per year, whereas adults between 15 and 64 years of age work 90 days, and those older than 64 years worked for 58 days(Table B.4, page 132). What is surprising that is that the elderly spent more days in farming (41 days) than adults between 15 and 64 years of age.

A typical NPS household worked for 273 days during the previous 12 months, of which it allocated 112 days to farming, 102 days to wage labor, and 58 days to self-employment(Table B.5, page 132). This number is fairly consistent across the NPS waves, except for the fact that households allocated more days to wage labor over time (21 days in NPS1 to 26 days in NPS3).

Table B.6 (page 132) presents differences between labor supply of rural and urban households. Urban residents spend much more time in wage labor and self-employment than in farming, while this pattern is the opposite for rural residents. This table also suggests that agriculture is primarily a rural phenomenon, urban households are also engaged in this activity. A typical rural household allocates 158 days to agriculture per year, whereas an urban household allocates 27 days per year. On the other hand, wage labor is much more an urban activity (180 days) than a rural activity (60 days). Self-employment is also much more prevalent in urban areas (83 days) than in rural areas (46 days). Urban households worked for more days than rural households (290 days vs. 264 days), although a part of this difference could be due to the fact that the days worked do not include time spent tending livestock and perennial plants such as fruit trees and cash crops.

Table B.7 (page 133) presents a cross-tabulation of between household labor supply and the diversification status of households. We see that urban households that that only work in agriculture spend fewer days in this activity than similar households in rural areas (108 vs. 182 days). This could possibly be due to the fact that urban households are more likely to engage in profitable cash crops, which may also demand less time, than rural households.

I control for a variety of covariates at the household and community levels. A typical household in the sample has 5.15 members, has a dependency ratio (share of members younger than 15 years or older than 64 years) of 0.42. Nearly two-thirds of the sample resides in rural areas. I also control for assets owned by the household by conducting a principal component analysis, from which I use the first principal component in my model.[5] I similarly create an index of shocks unrelated to the weather that households reported to have experienced in the previous five years. About a fifth of the sample households split off from the main household between survey waves and a quarter of the households are headed by women.

Table 4.1: Summary statistics (NPS waves 1-3, pooled data)

Variable		Mean	S.D.	Min	Max
Household activities	Diversification of activities				
	1. Only agriculture	0.23	0.42	0.00	1.00
	2. Agriculture and non-agriculture	0.47	0.50	0.00	1.00
	3. Only non-agriculture	0.30	0.46	0.00	1.00
	Annual household days in farming	112.27	164.56	0.00	1,994.00
	Annual household days in wage labor	102.19	177.97	0.00	1,959.00
	Annual household days in self-employment	58.49	86.96	0.00	909.94
Rainfall	Mean annual rainfall, mm	719.99	107.74	527.44	1331.00
	Standard deviation of annual rainfall, mm	141.70	26.14	75.98	231.92
	Z-score of rainfall in previous 12 months	-0.03	0.72	-1.63	2.63
Household characteristics	Rural	0.65	0.48	0.00	1.00
	Mean education of household members, years	4.23	2.72	0.00	18.00
	Mean age of household members, years	25.70	12.79	7.50	92.00
	Household size	5.15	3.08	1.00	55.00
	Dependency ratio	0.42	0.25	0.00	1.00
	Index of household assets	0.00	2.76	-3.69	20.46
	Index of self-reported shocks	0.00	1.36	-1.84	6.46
	Household head is female	0.25	0.43	0.00	1.00
	Split-off household	0.22	0.41	0.00	1.00

Note: The analysis sample consists of consists of 12,124 households pooled from 3,214 households that were interviewed in NPS1, 3,924 in NPS3, and 4,997 in NPS3.

Rainfall data

Development economists began examining rainfall as a source of the income risk faced by households (Rosenzweig, 1988; Fafchamps, 1993; Paxson, 1992; Rosenzweig and Binswanger, 1993). The earliest studies on developing countries focused on a variety of measures including effects of its mean level (Rosenzweig (1988) on India, Fafchamps (1993) in Benin), timing and frequency of rainfall (Rosenzweig and Bin-

[5]Since it is unclear which assets owned by households may be important in their choice of activities, I use Principal Component Analysis (PCA) to condense the multiple dimensions of assets into a set of linearly uncorrelated variables (principal components). I use the first principal component to represent the household asset score in my analysis.

swanger, 1993), and variability of rainfall (Paxson, 1992). With better rainfall data, a second generation of studies used rainfall shocks for their analysis (Kochar, 1999; Maccini and Yang, 2009; Miguel, 2005; Porter, 2012). Dercon and Krishnan (2000) and Miguel (2005) use self-reported data on drought conditions faced by households. Although mean and standard deviation are the most commonly used measures, it is noted that they do not adequately capture the riskiness of the natural environment that agricultural households face. Other measures of rainfall variability include inter-annual variation, intra-annual, dry spells, rainy days per year, or timing of the rainy season.

Broadly speaking, the rainfall data fall into these categories: weather station records, satellite images, and global analytical models. Perhaps the most widely-used global weather dataset is the gridded data on temperature and rainfall published by the Climate Research Unit (CRU), which has also been a major input into the analyses of the Intergovernmental Panel on Climate Change (IPCC). Satellite-based data became available from the 1990s after the Global Precipitation Climatology Project (GPCP) began to compile weather data from geostationary satellites operated by various countries (Huffman et al., 1997). GPCP uses data from satellite images of cloud cover calibrated against ground-based rain gauge data. Some studies of the long term economic impact of climate change also utilize "reanalysis data," which is weather data produced by global physical models (Auffhammer et al., 2013).

All three sources of rainfall and temperature data have different strengths and weaknesses. Station-based datasets are the most accurate of these sources as they are direct measures of rainfall at given locations. However, weather stations are irregularly and sparsely located and the point data they collect must be spatially interpolated before converting into area means. Another major weakness of station data is that weather stations often shut down permanently or new ones get added, leading to events that can introduce artificial discontinuities in weather data. The strength of satellite-based data is better spatial coverage of weather outcomes compared with weather stations, especially for those parts of the world such as in Africa where few weather stations operate, although this is an indirect measure of rainfall.

I use satellite data collected by Tropical Applications of Satellite Data (TAMSAT) based at the University of Reading (Tarnavsky et al., 2014). TAMSAT uses thermal infra-red satellite images to identify precipitating cumulonimbus clouds. Essentially, this methodology uses cloud-top temperature as a proxy for rainfall. This dataset is collected at a resolution of 0.0375 degrees (approximately, 4km X 4km cells) and is available, at a 10-day frequency, since 1983. I calculate the mean and coefficient of variation of rainfall for every cell lying between 0° to -12.5° latitudes and at 28.5° to 41° longitudes. This yields approximately 100,000 cells that cover all of Tanzania. I first calculate the annual total rainfall for 1983 to 2007. I then compute the standard deviation (SD) of annual rainfall during this period. A validation study finds that the correlation between TAMSAT and comparable (but station-based) data from the Climate Research Unit and Global Precipitation Climatology Centre is 0.85 and 0.70, respectively (Maidment et al., 2014).

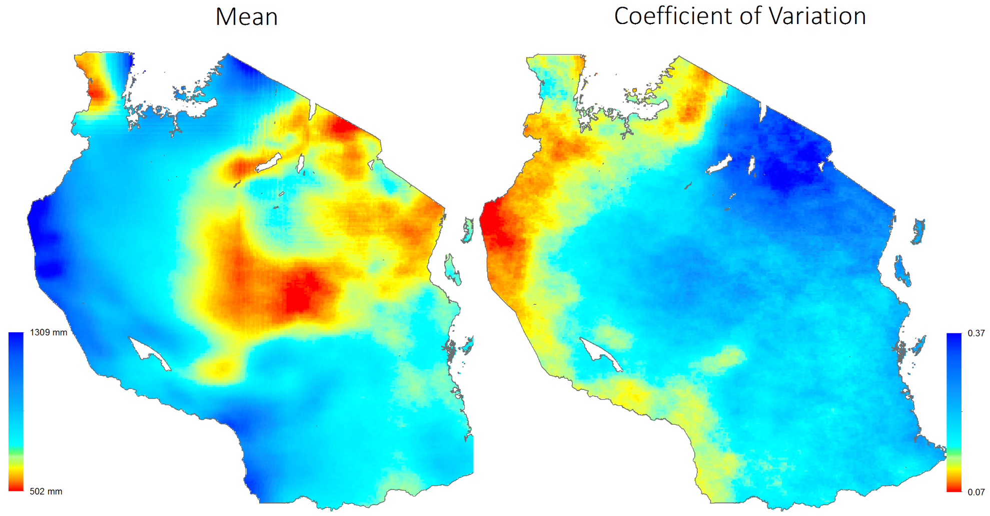
Figure 4.1 presents the mean and coefficient of variation (ratio of SD and mean) rainfall in Tanzania during 1983-2007. The figure shows the considerable amount of variation in the level and variability of historical rainfall in Tanzania. A typical household in the sample faces 720 mm of rainfall per year, with the sample minimum of 527 mm and a maximum of 1331 mm. Similarly, a typical household faces a standard deviation of rainfall of 142 mm. NPS households are spread out fairly evenly across the country and that no large area is unrepresented in the sample.

Asset Index

When analyzing the role of weather in labor supply, controlling for the level of assets owned by the household may be important. Assets may determine household decisions to allocate labor across various sectors. Generating an index of all assets owned by households is difficult since doing so requires collapsing various dimensions of data into one, the process of which invariably necessitates some simplifying assumptions.

The first challenge in determining an asset index is which assets should be in-

Figure 4.1: Mean and coefficient of variation of rainfall in Tanzania (1983-2007)



Source: Author's calculations using data available at www.met.reading.ac.uk/tamsat

cluded to calculate the index. One could argue that the type of assets depends on the outcome we are analyzing. The common types of wealth examined are physical capital, human capital, social capital, financial capital, and natural capital (Ansoms and McKay, 2010; Moser and Felton, 2007). The second challenge is deciding how to aggregate the various asset variables into one. The simplest approach would be to generate dummy variables representing whether a household owns a specific asset before summing up the values for all the assets. This would give equal weight to all of the variables, which is difficult to justify. A more accurate method, although informationally demanding and practically infeasible, may be to estimate the current value of household assets by taking into account the current market resale value for each asset.

Principal Component Analysis (PCA) is an alternative approach to aggregating asset variables into an index (Filmer and Pritchett, 2001; McKenzie, 2005). This method entails calculating the first principal component, which can be used as the proxy measure of wealth. The first principal component is a linear combination of all the asset variables that, intuitively, captures the common information most successfully (Filmer and Pritchett, 2001). The asset index (y) represented by the first principal component, for each household is computed using the following equation (McKenzie, 2005)):

$$y = \alpha_1 \frac{x_1 - \bar{x}_1}{s_1} + \alpha_2 \frac{x_2 - \bar{x}_2}{s_2} + \ldots + \alpha_n \frac{x_n - \bar{x}_n}{s_n} \tag{4.1}$$

where, x represents the asset vector, and s represents the mean values of variable x_n. The weighting vector a=(a_1, a_2, ..., a_n) is obtained by transforming the matrix of correlation between the various assets. The first principal component explains the most variance in the assets, while the additional principal components explain additional amount of variance while being uncorrelated with other principal components. Figure 3 shows that the first principal component explains most of the variance observed in the data; this is also the variable that I use in my analysis.

Table B.1 (page 131) lists the summary statistics of all assets used to compute the asset index. I chose the variables for the asset index to incorporate at least some of the following types of variables: housing quality, furniture, consumer durables, and productive assets. The following assets have the highest weights: television, lighting from electricity, high-quality floor, mobile telephone, iron, fridge, sofas, air-conditioner, cupboards/chests/wardrobes, and high-quality walls.

Table B.2 (page 131) tests the internal consistency of the asset index by plotting the asset index against the log of per capital consumption quintile. We see that these two variables are positively correlated. This makes intuitive sense since wealthy households also have the ability to consume more in the short term than do poor households.

Index of self-reported shocks

The shock index was constructed in a manner similar to the asset index, by using principal component analysis. Although information was collected on 19 types of shocks experienced by the household in the previous five years, severe water shortage droughts/floods were excluded from the index as they are strongly correlated with rainfall. The following variables were also excluded because either they were experienced by very few households or because they may be endogenous with the outcome variable: fire, dwelling damaged or destroyed, jailed, loss of salaried employment, loss of land, break-up of household, and household business failure. I constructed the shock index separately for each NPS wave to allow for the possibility that the magnitude of shocks may have been different during these two waves.

4.4 Methodology

The goal of this paper is to examine the role of rainfall shocks on the labor strategies of households. I examine if households adjust labor allocation between different activities in the face of variable rainfall in an environment with market imperfections. In order to answer this, I provide a simple model of a farm household's maximization problem to motivate the estimation strategy. The estimation strategy consists of two parts. In the first part, I analyze the determinants of the degree to which a household has diversified away from agriculture. In the second part, I begin with estimates of the household labor supply functions in farming, wage labor, and self-employment. Finally, I address the large degree of censoring present in the labor supply variable by implementing the Heckman two-step estimation.

Theoretical framework

The theoretical framework underlying this empirical work builds on the model of household's labor supply decision elaborated in de Janvry et al. (1991) and Jolliffe (2004) in which households allocate labor between farm and off-farm work in the presence of market imperfections. Let us consider a household that engages in three economic activities: agricultural work, wage labor, and non-agricultural wage-employment. The household's optimization problem is to maximize utility which is a function of earnings from its activities, and leisure subject to the time budget constraint:

$$\begin{aligned}
\underset{L_f, L_w, L_n}{\text{maximize}} \quad & U\{(Y_f(L_f, X_f, \theta_f), Y_w(L_w, X_w, \theta_w), Y_n(L_n, X_n, \theta_n)), (L(X_h) - L_f - L_w - L_n)\} \\
\text{subject to:} \quad & L(X_h) \geq L_f + L_w + L_n \\
& L_i \geq 0 \text{ where } i = f, w, n.
\end{aligned} \tag{4.2}$$

In the setup above, Y measures earnings from each activity. The subscript f denotes the farm variable, w denotes the wage variable, and s denotes non-agricultural self-employment variable. L is household labor supply, X measures the stock of semi-fixed inputs such as assets, and represents unforeseen shocks that affect income from each activity. The total stock of potential household labor supply is a function of household characteristics such as gender and age (X_h). Although market prices and the variable input choices in production are important variables, I abstract away from them in my analysis.

de Janvry et al. (1991) show that production and consumption decisions of the household are separable in this scenario if markets are complete. Households engage in each of the three activities such that the values of the marginal product of agricultural labor, wage labor, and non-agricultural self-employment are equated to an exogenously determined market wage. Although complete markets and separability are appealing in that they simplify household decisions, they often do not exist. Benjamin (1992) shows that a testable implication of complete labor markets is that the total supply of labor (household plus hired labor) does not depend on household characteristics such as age and gender composition. I find that the null hypothesis of complete markets is rejected in the NPS data (B.9, page 135).

If labor markets are not complete, de Janvry et al. (1991) show that the solution to the household's optimization problem described earlier is to allocate labor to activities such that the marginal product of each activity is equal to an endogenously determined shadow wage (w_s), which is a function of household characteristics and factors that affect profit.

$$\frac{\partial Y_f}{\partial L_f} = \frac{\partial Y_w}{\partial L_w} = \frac{\partial Y_n}{\partial L_n} = w_s \tag{4.3}$$

In the presence of an incomplete labor market, labor supply of the household in this scenario is a function of household characteristics, prices, and shocks faced by households:

$$L_i^* = L_i(X_h, \theta_i) \text{ where } i = f, w, n \tag{4.4}$$

The key insight here is that the labor allocation to each activity depends on household characteristics when separability does not hold due to incomplete labor markets. My key parameter of interest is $\frac{\partial L_i}{\partial \theta_i}$, and in particular, the marginal effect of rainfall on labor supply. Given the importance of rainfall in agriculture in developing countries with little irrigation, we would expect households to increase their agricultural labor if rainfall in a given year is lower than their expectation, which can be thought of as the long-term mean rainfall. Do we expect households to adjust their labor supply to wage labor and self-employment in response to the specific realization of rainfall in a given year? The answer to this question is not obvious. In the event of poor rainfall, households may decide to reallocate labor away from agriculture to wage labor or self-employment. However, we may not observe this adjustment if labor supply to wage labor or self-employment are restricted due to market failures or unavailability of jobs. Households may simply be forced to consume additional leisure in the event of a poor rainfall season.

Estimation

My econometric methodology examining the role of rainfall variability in the labor strategies of households consists of three components. First, I descriptively examine the degree to which households have diversified out of agriculture using a multinomial logit framework. Second, I analyze the determinants of hours worked by households in different activities. The labor outcome could be estimated as a function of the distribution of rainfall and the realized deviation of rainfall from its long-run level.

My descriptive exercise consists of a multinomial logit model that expresses the probability of a household falling into one of the three activity categories (agriculture only, agriculture and non-agriculture, and non-agriculture only) as a non-linear function of the rainfall shock in the survey year and the mean and standard deviation of rainfall over the period 1983-2007. I also control for a variety of other factors that could affect household diversification away from agriculture. These include the average years of education in the household, household size, dependency ratio, whether the household has an outstanding loan, asset score, rural area, and the split-off status of the household in the second wave.

Next, I verify the findings of the multinomial logit model with an analysis of the determinants of household days supplied to agriculture, wage labor, and self-employment. Censoring is a major challenge in this analysis since the outcome variable contains zero values in some cases. Let y_{it} represent the household supply of labor in agriculture, wage labor, and self-employment. Let x_{1it} represent the Z-score[6] of rainfall during the 12 months prior to the month in which the household was interviewed. Let Z_{it} be a vector of covariates that could also affect household labor supply. The equation I estimate is the following:

$$y_{it} = \beta_0 + \beta_1 x_{it} + \beta_2 Z_{it} + \varepsilon_{it} \tag{4.5}$$

where observation $i = 1, 2, \dots, N$ and t represents the NPS waves. β_1 is our coeffcient of interest and ε_{it} is an error term assumed to be normally and independently distributed with zero mean and constant variance. I estimate model (6) using OLS, First Difference, and Tobit models. I use lagged dependent variables to mitigate potential endogeneity bias.

The large presence of censoring in the labor supply variable is a concern in my dataset as households that engage in an activity may be a non-random sample of

[6]The Z-score is defined as $Z = \frac{x-\mu}{\sigma}$, where x is the raw score (in our case, the realized rainfall in each NPS wave), μ and σ are the mean and standard deviation, respectively, of annual total rainfall over the period 1983-2007.

the population. Although the Tobit model attempts to address this problem, it does not do so adequately as it assumes that the processes that determine participation in an activity and the number of days supplied are independent of each other. I estimate labor supplied to each activity using the Heckman two-step method. A key requirement for this methodology is that we need instruments that affect participation but not the level of outcome. I show in the next section that this requirement is met. I finally conduct a variety of robustness checks to ensure that my results are not sensitive to a variety of assumptions and modeling decisions made in the analysis.

4.5 Results

In this section, I first discuss the results of the multinomial logit model, in which I examine the determinants of household activity diversification. I next examine the determinants of household days allocated to farming, wage labor, and self-employment using the OLS, First Difference, and Tobit models. Finally, I address the possibility that households that engage in different activities may be non-random samples of the population by modeling the household labor supply as a two-step Heckman process.

In the first part of my analysis, I analyze the role of rainfall shocks and variability in the degree to which households have diversified away from agriculture by estimating the multinomial logit model. I categorize households into those that engage only in self-employed agriculture, only non-agricultural self-employment, and those that engage in both. Prior to estimating the multinomial logit model, we need to ensure that Independence of Irrelevant Alternatives (IIA) condition is satisfied. The Small-Hsiao test of IIA assumption yields p-values of 0.174 and 0.363 for alternatives 2 and 3 for the hypothesis that the odds of these outcomes are independent of alternative 1. Thus, we cannot reject the IIA assumption. Table 4.2 presents the estimates of the marginal and impact effects for the determinants of household diversification.

Table 4.2: Multinomial logit model of household activity diversification marginal effects

	Agri. Only		Agri. & Non-Agri.		Non-Agri. Only	
	β	s.e.	β	s.e.	β	s.e.
Z-score of rainfall in previous 12 months	0.019***	(0.007)	-0.002	(0.008)	-0.017***	(0.006)
Mean annual rainfall (1983-2007), mm X 100	0.016**	(0.007)	-0.016*	(0.009)	-0.000	(0.009)
S.D. of annual rainfall (1983-2007), mm X 100	-0.095**	(0.043)	-0.050	(0.057)	0.145***	(0.051)
Asset index	-0.038***	(0.004)	0.023***	(0.004)	0.015***	(0.002)
Shock index	0.016***	(0.003)	0.047***	(0.004)	-0.062***	(0.004)
Rural	0.108***	(0.014)	0.043***	(0.015)	-0.151***	(0.012)
Household size	0.007***	(0.002)	-0.027***	(0.002)	0.020***	(0.002)
Dependency ratio	-0.103***	(0.019)	0.097***	(0.024)	0.006	(0.019)
Mean education of household members, years	-0.008***	(0.002)	0.003	(0.003)	0.004**	(0.002)
Split-off household	-0.027***	(0.010)	-0.049**	(0.012)	0.076***	(0.009)
NPS wave 2	-0.068***	(0.009)	0.030**	(0.012)	0.038***	(0.011)
NPS wave 3	-0.112***	(0.011)	0.047***	(0.013)	0.065***	(0.011)
Observations	12124		12124		12124	

Note: Standard errors in parentheses are clustered at the enumeration area. All specifications include regional dummies.
* $p < .10$, ** $p < .05$, *** $p < .01$

The marginal effects for my primary variables of interest are reported in the first three rows. The coefficient of the mean and standard deviation of historical rainfall represent the ex-ante response of households to rainfall variability. The coefficient of the standard deviation of rainfall is negative and statistically significant at the 1% level for the agriculture-only strategy, suggesting that households facing unreliable rainfall choose not to stay completely within agriculture but to engage in some form of non-agricultural activity. A household facing an additional 0.1 standard deviation of rainfall variability above the mean is 0.95 of a percentage point less likely to engage only in agriculture. The Z-score of rainfall in the 12 months prior to the survey can be thought of as the ex-post response of households to variable rainfall. The coefficient of the Z-score for only non-agriculture is statistically significant at the 1% level, suggesting that if a household faces a negative rainfall shock of 0.1 of a standard deviation, it is 0.17 of a percentage point more likely to engage only in non-agricultural activities. These results suggest that households respond to higher historical rainfall variability by moving out of agriculture and to recent rainfall shocks by engaging only in non-agricultural activities.

The estimated coefficients of the control variables in the model are in line with economic intuition. Rural location, higher mean historical rainfall, and higher dependency ratio are associated with a higher probability of households engaging only in agriculture. Higher average household years of education, household size, and asset index are negatively associated with the agricultural-only strategy. Households that split off from the primary household between the waves appear to be more likely to engage in a non-agriculture only strategy. The estimates suggest that households that reported to have faced more non-weather shocks in the recent past are more likely to stay in agriculture, perhaps because shocks constrained their ability to participate in non-agricultural activities.

Although the Small-Hsiao test suggests that the IIA assumption is fulfilled in the estimation in Table 4.2, a robustness check of these results could be to relax it altogether during estimation. The multinomial probit model relaxes IIA by allowing error terms across different choices to be correlated.[7] However, this model requires alternative-specific variables in order to converge.[8] Since my framework does not have variables that vary across alternatives but only vary across agents, identification of the matrix of variance-covariance parameters requires that the correlation across errors to be independent and standard errors to be homoscedastic. Table B.10 (page 135) presents the results of the model is estimated with these assumptions. The coefficients for the rainfall variables are consistent in direction and similar in magnitude with results reported in Table 4.2.

In the second part of my analysis, I examine the determinants of household labor supply in the 12 months prior to interview using OLS, First Differences, and Tobit models. Since the labor supply data are collected as continuous variables, they have the potential to give a more accurate picture of household labor strategies compared with the trichotomous variable examined in Table 4.2. Table 3 presents estimates of the determinants of household days supplied to farming, wage labor, and self-employment activities in panels A, B, and C, respectively. The first row of each table contains coefficients on the Z-score of rainfall in the 12 months prior to the survey. This coefficient is positive and statistically significant at the 1% level

[7] The associated command in Stata is *asmprobit*.

[8] The multinomial probit model is suited to a case like the choice between transportation alternatives, where the cost and travel time are different for each alternative for each agent. The model allows for variables that vary across agents, such as age, gender, and income.

in all of the three models. Households appear to be adjusting their labor supply to agriculture in response to the level of rainfall in the recent past. When faced with higher than normal rainfall they appear to allocate more household days to farming; when faced with lower than normal rainfall, they allocate fewer days to this activity. The coefficients on other control variables are in line with intuition. Rural and large households supply more days to agriculture as well as households that report to have faced higher degree of shocks. In contrast with this, the asset score and the dependency ratio are negatively correlated with household days supplied to agriculture. A weakness of the Tobit model is that it assumes that the determinants that affect participation in an activity have the exact same effect on participation and the level of labor supplied to each activity. Lin and Schmidt (1984) suggest a methodology to test this restriction.[9] The likelihood-ratio test statistic is distributed chi-squared with 9 degrees of freedom in this case. The null hypothesis that the Tobit specification is valid is soundly rejected at the 1% significance level.[10]

In the third part of my analysis, I attempt to more effectively address the bias caused by non-random sample selection that may be present in the results of Table 4.3 due to the fact that 36%, 57%, and 53% of households do not participate in agriculture, wage labor, and self-employment, respectively. Censoring would not be a cause for concern if it is independent of the outcome of interest. However, this is unlikely to be the case as households that engage in certain activities and those that do not are very likely to have unobservable characteristics that are different from each other. This could also be seen as a case of endogeneity arising due to missing variables, the consequence of which is that the estimates of the model of labor supply of households are potentially biased.

I address the large degree of censored outcomes by implementing the Heckman

[9] They present a Lagrange Multiplier statistic for this test, although Greene (2003) presents a simpler Likelihood Ratio statistic that can be computed as following: $\lambda = -2[\ln L_T - (\ln L_P + \ln L_{TR})]$, where L_T is the likelihood for the Tobit model, L_P is the likelihood for the Probit model, and L_{TR} is the likelihood for the truncated regression.

[10] The Chi-squared test statistic takes on a value of 1038.02, 973.15, and 35.08 for the farm labor, wage labor, and self-employment labor equations, respectively. The 1% critical value for the Chi-squared distribution with 9 degrees of freedom is 21.67.

Table 4.3: Determinants of household labor supply

	OLS		FD		Tobit	
	β	s.e.	β	s.e.	β	s.e.
Panel A: Determinants of household days supplied to agriculture						
Z-score of rainfall in previous 12 months	7.816***	(2.515)	9.297***	(2.597)	9.792***	(3.671)
Rural	59.890***	(4.229)	62.490***	(4.351)	133.112***	(6.386)
Household size	19.961***	(0.598)	18.565***	(0.641)	23.425***	(0.859)
Dependency ratio	72.956***	(9.017)	53.625***	(9.263)	64.507***	(12.665)
Asset index	-14.921***	(0.880)	-14.267***	(0.893)	-29.318***	(1.411)
Shock index	17.846***	(1.145)	14.150***	(1.494)	24.375***	(1.944)
Mean education of household members, years	1.965**	(0.983)	2.119**	(1.017)	1.320	(1.487)
Household head is female	-20.319***	(4.065)	-21.186***	(4.199)	-37.510***	(5.892)
Age of household head	1.383***	(0.116)	1.119***	(0.119)	2.127***	(0.163)
Constant	162.614***	(24.575)	218.855***	(25.439)	188.815***	(34.168)
Panel B: Determinants of household days supplied to wage labor						
Z-score of rainfall in previous 12 months	4.326	(2.829)	3.047	(2.865)	-0.715	(5.296)
Rural	-47.99***	(4.757)	-52.24***	(4.800)	-85.777***	(8.769)
Household size	6.727***	(0.672)	6.373***	(0.707)	13.836***	(1.347)
Dependency ratio	61.243***	(10.143)	40.609***	(10.218)	103.567***	(19.932)
Asset index	19.342***	(0.989)	15.120***	(0.985)	19.481***	(1.775)
Shock index	-1.951	(1.288)	-4.205**	(1.648)	-6.042*	(3.109)
Mean education of household members, years	3.524***	(1.106)	7.606***	(1.121)	13.542***	(2.084)
Household head is female	-9.939**	(4.573)	-2.232	(4.631)	-5.072	(8.759)
Age of household head	-0.349***	(0.130)	-0.449***	(0.132)	-1.966***	(0.258)
Constant	3.223	(27.642)	-3.736	(28.061)	-55.097	(52.914)
Panel C: Determinants of household days supplied to self-employment						
Z-score of rainfall in previous 12 months	5.266***	(1.515)	4.632***	(1.532)	6.169**	(2.710)
Rural	-24.69***	(2.547)	-26.64***	(2.567)	-49.12***	(4.486)
Household size	5.064***	(0.360)	4.155***	(0.378)	7.931***	(0.674)
Dependency ratio	21.152***	(5.430)	14.988***	(5.464)	30.564***	(10.110)
Asset index	6.750***	(0.530)	5.495***	(0.527)	8.774***	(0.919)
Shock index	1.229*	(0.690)	1.191	(0.881)	1.705	(1.565)
Mean education of household members, years	-1.662***	(0.592)	-0.926	(0.600)	-1.291	(1.092)
Household head is female	2.862	(2.448)	2.678	(2.477)	4.153	(4.455)
Age of household head	-0.275***	(0.070)	-0.356***	(0.070)	-1.005***	(0.130)
Constant	92.154***	(14.799)	99.307***	(15.006)	71.176***	(26.727)
Observations	6887		6887		6887	

Note: Standard errors in parentheses. FD refers to the first-difference estimator. The following variables were lagged in the FD and Tobit specifications: Average years of education in household, household size, household dependency ratio, asset index, shock index, age of household head, and gender of household head. * $p < .10$, ** $p < .05$, *** $p < .01$.

two-step estimation procedure. The first step involves estimating a probit model of the likelihood of a household selecting into an activity, while the second step involves OLS estimation of the selection-corrected labor supply equation. The null hypothesis of the Heckman model is that there is no selection bias in the data, i.e. the selection and outcome equations were generated by independent processes.

Table 4.4 presents results of the two-step Heckman estimation of household labor supply in different activities. For identification, the Heckman method requires instruments that affect the probability of the outcome being censored but not the outcome. Specification testing indicates that the variables that I use to instrument participation in various activities are both well correlated with participation in that activity and properly excluded from the outcome equations, thereby identifying the labor supply parameters. An approximate test of the exclusion restriction is that these variables are jointly insignificant in the reduced form model of household days supplied to each activity for the uncensored sub-sample (see Table B.11, page 136). The Heckman model provides selection-corrected estimates of the labor supply equations if good instruments are available.

My instruments for participation into farming are the household distance to the district headquarters. Distance to the district headquarters is likely to subject households to disadvantages regarding market information, social networks, and infrastructure, thus making them more likely to engage in agriculture. The identifying instrument is significant in the selection equation at the 5% level, while it is not so in the reduced form equation of labor supply in agriculture.

My instrument for participation in the labor market is the household's distance to the main road. Proximity to the road is likely to confer advantages to individuals regarding mobility, thus making them more likely to engage in wage labor. The instrument is significant in the selection equation at the 5% level, while it is not so in the reduced form equation of labor supply in wage employment.

My instrument for participation in non-agricultural self-employment is the household's distance to the nearest town with a population of at least 20,000. Bigger populations provide a larger market for products and services, thus making households more likely to initiate and engage in self-employment activities. This instrument is jointly significant in the selection equation at the 1% level, while it is not significant

Table 4.4: Heckman two-step models of labor supply

	Farming (Days)		Wage labor (Days)		Self-employment (Days)	
	β	s.e.	β	s.e.	β	s.e.
Outcome equation						
Z-score of rainfall in previous 12 months	5.288**	(2.506)	0.854	(4.163)	-6.625**	(2.839)
Asset index	-21.994***	(1.218)	21.421***	(2.465)	1.669	(1.646)
Shock index	22.694***	(1.459)	-8.620***	(2.268)	0.637	(0.968)
Rural	87.004***	(6.926)	-42.164***	(10.663)	-0.013	(9.103)
Household size, adult members	45.392***	(1.120)	20.100***	(1.878)	4.832***	(1.586)
Dependency ratio	-64.556***	(8.800)	37.172	(28.578)	-4.080	(7.802)
Mean education of household members, years	-0.018	(1.034)	5.181***	(1.755)	-0.251	(0.893)
Mean age of household members, years	-0.212*	(0.126)	-1.672*	(0.884)	0.573*	(0.338)
Long-run mean rainfall, mm	0.047***	(0.010)	-0.232	(0.154)	0.003	(0.008)
Household head is female	-24.310***	(4.033)	-15.964**	(8.118)	5.492*	(3.027)
Split-off household	-26.833***	(4.957)	6.827	(6.721)	-15.956***	(2.985)
Constant	-97.038***	(13.791)	387.644**	(184.519)	130.211***	(18.296)
Selection equation						
Z-score of rainfall in previous 12 months	0.052**	(0.023)	-0.034**	(0.017)	0.109***	(0.017)
Asset index	-0.145***	(0.007)	0.050***	(0.006)	0.077***	(0.007)
Shock index	0.398***	(0.017)	0.028***	(0.009)	0.011	(0.009)
Rural	1.028***	(0.034)	-0.155***	(0.031)	-0.373***	(0.031)
Household size, adult members	0.170***	(0.010)	0.028***	(0.007)	0.072***	(0.007)
Dependency ratio	-0.815***	(0.083)	0.473***	(0.065)	0.137**	(0.062)
Mean education of household members, years	-0.026***	(0.008)	0.026***	(0.007)	-0.027***	(0.007)
Mean age of household members, years	0.013***	(0.001)	-0.016***	(0.001)	-0.013***	(0.001)
Mean annual rainfall, mm	-0.001***	(0.000)	0.000***	(0.000)	-0.000**	(0.000)
Household head is female	-0.195***	(0.036)	-0.120***	(0.028)	-0.035	(0.028)
Split-off household	-0.357***	(0.041)	0.078**	(0.032)	0.015	(0.029)
Distance to district HQ, km	0.004***	(0.001)				
Distance to major road, km			-0.003***	(0.001)		
Distance to town, km					-0.001**	(0.000)
Constant	1.361***	(0.132)	-0.537***	(0.094)	0.663***	(0.095)
Mills						
Lambda	67.691***	(11.077)	47.260*	(27.102)	-62.121*	(36.755)
Observations	12124		12124		12124	

Standard errors in parentheses. $^{+} < .15$, * $p < .10$, ** $p < .05$, *** $p < .01$

in the reduced form equation of labor supply in self-employment.

The findings from the Heckman estimates in Table 4.4 are consistent with the results reported in Table 4.3. The coefficients on the selection term are significant at least at the 10% level, suggesting that households non-randomly engage in different activities. Households that engage in farming supply are likely to supply 67.7 more days per year to this activity than a randomly selected household. Similarly, households that engage in wage labor are likely to supply 47.3 more days per year to this activity than a randomly selected household. Households that engage in self-employment supply 62.1 fewer days per year to self-employment than a randomly selected household. This may reflect the fact that Tanzanian households that engage in self-employment do so primarily as part-time activities to supplement income from other sources. Among those that participate in self-employment, almost 60% report to have participated in it less than 12 months in the past year. About 40% of all NPS respondents engaging in self-employment activities report to be doing so in retail trade as itinerants or in market stalls. About 85% of self-employment activities also only engage household members, which increases the flexibility to begin or stop the business as the need arises.

Controlling for all other covariates, households appear to be adjusting their labor supply in farming and in self-employment in response to the realization of rainfall in the recent past while they do not appear to be doing so with wage labor. Households shift labor away from self-employment to agriculture during years of good rainfall while they do the opposite during years of poor rainfall. The magnitude of adjustment does not appear to be symmetrical, possibly because households may be adjusting their labor supply in livestock rearing, a major activity households are engaged in. I am not able to test this hypothesis since NPS did not collect information on the quantity of labor supplied by households to rearing livestock.

I next discuss results of the Heckman model of labor supply on the following rural and urban samples. In Table B.12 (page 136), we see that the magnitude and significance of coefficients for the rural subsample, but not the urban subsample, are broadly consistent with the results in Table 4.4 for the full sample. This makes sense since urban households are less likely to engage in agriculture and thus are less affected by rainfall shocks. The results presented in Table 4.4 hold for the subsample of households originally interviewed in NPS 1 (but without the split-off households) and when we exclude either NPS 1 or NPS 3 households. These results suggest that although there are minor differences across sub-samples, the essential results on the rainfall shock are not too sensitive to the change in the estimation sample.

4.6 Conclusion

This paper attempts to examine if households use different labor strategies to cope with variable rainfall in Tanzania. This is an important issue in Tanzania where most households are engaged in rain-fed agriculture but very few have access to irrigation and insurance, and credit markets are poorly developed. This study aimed to contribute to the sparse literature on income-risk, due to unreliable rainfall, faced by Tanzanian households. It addressed this question first by examining the degree to which households diversify away from agriculture and their labor allocation in farming, wage labor, and self-employment in response to rainfall shocks. It also used a unique satellite-based data on rainfall that provides much finer spatial and temporal coverage of rainfall than data from weather stations widely used in the literature.

I find suggestive evidence that households use labor, an important resource they own, to deal with income uncertainty arising from risky rainfall. Analysis of the degree to which households are engaged in agriculture using the multinomial logit model suggests that households facing higher historical rainfall variability are less likely to engage only in agriculture. This evidence was corroborated by the analysis of the determinants of the household labor allocated to farming, wage labor, and self-employment activities. I find that households reallocate labor between farming and self-employment in response to rainfall shocks. When faced with a negative rainfall shock, they devote more hours to self-employment, while they devote more hours to farming during years of better rainfall. I did not find wage labor to be a strategy employed by households to deal with rainfall risk, perhaps suggesting imperfections in the Tanzanian labor market.

There are some weaknesses in this analysis that could be addressed in future work. General equilibrium consequences of rainfall shocks may be important but they are not addressed in this study. With an area that is almost four times the size but only 75% of the population of the UK, Tanzania is a large, sparsely populated, and mostly rural country. Due to the large geographic variation within the country, rainfall realizations may vary significantly even within short distances. All of these reasons suggest that ignoring general equilibrium consequences of rainfall shocks may not be severe. Due to data limitations, analysis in this ignores the role of livestock in the labor allocation strategies of households. A future extension to this study could address the household allocation of labor into farming, wage labor, and self-employment as a joint decision rather than independent decisions as treated in this study. Such an extension would also need to carefully address in the context of a joint system of equations. Finally, this study does not directly examine the impact of various labor strategies on the welfare of households also due to data limitations of precisely estimating income.

Chapter 5

Are there market failures in agriculture in Tanzania?

5.1 Introduction

The efficacy of policies affecting rural households in developing countries depends much on how well markets function. Take the example of a subsidy to encourage adoption of fertilizers. Farmers may not be able to respond to this policy if they cannot adopt the subsidized fertilizer because the transportation cost to acquire it is prohibitively high. Similarly, liberalization of trade in agricultural commodities may have a limited impact in inducing farmers in a fertile area to grow more crops if labor markets are dysfunctional and do not allow farmers to hire the additional workers needed to increase production. For these reasons, market failures may be an impediment to productivity and income growth of rural households. If rural markets are not complete or competitive, agricultural policies implemented by the government may be less effective than intended. Moreover, this may provide a *prima facie* justification for intervention to address the sources of market failures.

Missing or imperfect markets are often used as a rationale for policy recommendations and government interventions. For example, the African Union Assembly of Heads of States and Governments in 2014 issued a statement with recommendations for transforming Africa's agriculture that stated: "government policies must increasingly play a critical role in correcting many of the market failures that still exist" (AFDB, 2014). However, little empirical evidence exists on the magnitude and nature of market failures in developing countries despite how frequently it is invoked in the policy discourse. A typical example is the World Development Report 2008 (World Bank, 2008), which focused on agriculture, has an anecdotal description of how household behavior is affected by market failures but it does not cite any study that tests whether these market failures exist or how serious are these failures. It is plausible that agricultural factor markets function well but that the outcomes of these well-functioning markets are unsatisfactory. Outcomes such as low uptake of fertilizers, inadequate technology adoption, or low wages do not necessarily imply that markets are broken or missing. These outcomes could also mean that the returns to these factors are in fact very low given current market and physical conditions and that future policy interventions should aim to increase these returns.

This paper examines how well agricultural factor markets function in Tanzania. This is a particularly salient issue for Tanzania, where three-quarters of the employed population is engaged in agriculture (World Bank, 2013).[1] Tanzanian agriculture has also been subject to various government interventions in recent history (Cooksey, 2011; Ponte, 2000), while the country may be undergoing an economic transformation as a result of impressive growth in GDP reported in recent years (Arndt et al., 2015). The goal of this paper is twofold: to quantify the extent of market participation in agricultural factor markets of households and to examine whether market failures are present in these markets. In order to do so, I implement tests of market failures commonly cited in the literature using data from the Tanzanian National Panel Survey (NPS) 2012/13 that collected rich data on agricultural production in addition to other aspects of the lives of households.

A recent contribution to this literature is Dillon and Barrett (2014), who examine whether market failures exist in agricultural factor markets in Sub-Saharan Africa.

[1] The precise number is 76.5% for 2006, which is the most recent year for which data is available.

Using a common test in the literature, they find evidence of general and structural market failures that do not vary by location or household characteristics. However, any visitor to Tanzania would notice that markets indeed exist and are vibrant in many parts of the country. de Janvry et al. (1991) remind us that the definition of market failure is not commodity-specific but household-specific: markets for different commodities often exist, but they fail selectively for particular households. Ignoring this advice may lead us to make general statements about whether entire markets fail, instead of making more nuanced statements about the nature and extent of these failures. The literature on this topic relies on the agricultural household model (AHM), which incorporates both of their production and consumption activities. An important prediction of the AHM is the separation theorem: if markets are perfect and competitive, production choices are made independent of consumption preferences. This paper builds on Dillon and Barrett (2014) by implementing several tests of the separation theorem proposed in the literature.

This paper finds that market participation is fairly extensive in Tanzania. More than half of the agricultural households examined in this study participate in at least one factor market, the most common of which is the labor market. This does not imply that these markets function well. Most tests implemented in this paper find that market failures exist in agricultural factor markets in Tanzania. However, I find that markets are more likely to fail in rural locations, locations further away from towns and major roads, areas other than the Eastern Zone (which includes Dar es Salaam, the largest city in the country), and for female-headed households. I find that the labor productivity of family labor is much lower than the market wage, a sign that market imperfections may be causing households to allocate labor inefficiently across activities. However, I find that households are much more likely to hire agricultural labor commensurate with their productivity. These results provide evidence on the nature and extent of market failures in Tanzania.

The rest of this paper is organized as follows. The next section summarizes the theoretical and empirical literature on which this study builds, including the tests of market failure that have been suggested. Section 3 outlines the empirical methodology employed in this paper. Section 4 describes the dataset used in this analysis and presents some descriptive results that give a preview of the more rigorous tests implemented in the next section. Section 5 presents the results of the tests of market failure, whereas Section 6 discusses policy implications, limitations of this study, and possible avenues for further work.

5.2 Relevant literature

This section takes stock of the existing literature on market failures in developing countries. But before doing so, it is important to clarify the meaning of market failure in the context of developing countries like Tanzania, where agriculture is the predominant economic activity. When markets function well, household endowments and resources are efficiently allocated across activities. Households make optimal production and consumption decisions such that no household can be made better off without another one being worse off. A market failure exists when the market equilibrium is Pareto-inefficient. Categories of market failures include externalities, public goods, excess market power, and the absence of markets. Market failures can arise due to high transaction costs, imperfect competition, incomplete enforcement of contracts and property rights, presence of externalities, or under-provision of public goods. When markets fail, prices do not give credible signals for agents to efficiently allocate resources. Or prices do not adjust to clear supply and demand. An example of a market failure in this context is that households sometimes rationally choose not to engage in a market transaction because there is a range of market prices within which it is more sensible for them to be self-sufficient than to buy or sell (de Janvry et al., 1991).

Theoretical framework

The theoretical framework of this paper follows the literature that builds on the AHM elaborated in Singh et al. (1986). The AHM captures a salient feature of households in developing countries: they are both producers and consumers at the same time. An attractive feature of this model is that it incorporates the household's interaction with markets and presents testable hypotheses about these interactions. The hypothesis that is tested in this paper is that households make decisions as if their production and consumption activities are separable (i.e., production decisions are made independent of consumption choices while consumption only depends on production through the budget constraint).

Let an agricultural household derive utility from consumption (C) and leisure (l) of its members, but household utility also depends on a vector of preference shifters (A) such as the number of children or elderly members in the household.[2] The household's consumption expenditures are constrained by the income it receives from its members working on the farm to obtain farm output (Q), whose price is p, and working in the labor market at the market wage (w). The production function for the household farm is defined over the vectors of total labor used by agricultural production, which is a sum of family labor (L) and labor hired in from the market (H), and fixed inputs (F). Household members have a time endowment of T, which they can allocate to farm work (L), market work (m), and leisure (l). Market imperfection is captured by the assumption that household members can work for a maximum of M hours in the market.[3]

The model assumes substitutability between household (L) and hired (H) labor used in production by including the sum of these variables as an input into the production function. Another assumption of the model is that the household faces a market constraint when it tries to supply labor to the market but not when it tries to hire labor from the market. This assumption is plausible in the context of a high degree of unemployment and underemployment common in developing countries like Tanzania. The household's optimization problem can be summarized as follows:

[2] This section follows Bardhan and Udry (1999) and Le (2010).

[3] Although the test of separability that I use is based on the labor market, it is not a test of labor market imperfection. Bardhan and Udry (1999) describe how separability is possible even when one market (for example, the labor market) is missing.

$$
\begin{aligned}
&\underset{L,m,H}{\text{maximize}} && U(C,l;A) && \\
&\text{subject to:} && C = pQ(L+H,F) + wm - wH && \text{[Budget constraint]} \\
& && T = L + m + l && \text{[Labor supply constraint]} \\
& && 0 < m \leq M. && \text{[Market imperfection]}
\end{aligned}
\tag{5.1}
$$

The Lagrangian function for this problem can be expressed as follows:

$$
\mathcal{L} = U(pQ(L+H,F) + wm - wh, T - L - m; A) + \lambda(M - m) + \mu M \tag{5.2}
$$

The following are the first order conditions:

$$
\mathcal{L}_L\colon \frac{\partial U}{\partial C} \cdot p\frac{\partial Q}{\partial l} - \frac{\partial U}{\partial l} = 0 \tag{5.3}
$$

$$
\mathcal{L}_m\colon \frac{\partial U}{\partial C} \cdot w - \frac{\partial U}{\partial l} - \lambda + \mu = 0 \tag{5.4}
$$

$$
\mathcal{L}_H\colon \frac{\partial U}{\partial C} \cdot \frac{\partial C}{\partial H} + \frac{\partial U}{\partial l} \cdot \frac{\partial l}{\partial H} = 0 \tag{5.5}
$$

$$
\mathcal{L}_\lambda\colon M - m \geq 0 \qquad (M - m)\lambda = 0 \tag{5.6}
$$

$$
\mathcal{L}_\mu\colon M \geq 0 \qquad M\mu = 0 \tag{5.7}
$$

Equations 5.3, 5.4, and 5.5 are first order conditions for household labor allocated to agriculture, household labor supplied to the market, and agricultural labor hired in from the market. Equations 5.6 and 5.7 represent complementary slackness conditions (CSCs). Rearranging equation 5.3 gives us the following condition:

$$
w^* = \frac{\frac{\partial U}{\partial l}}{\frac{\partial U}{\partial C}} = p\frac{\partial Q}{\partial L} \tag{5.8}
$$

The equilibrium condition in equation 5.8 states that the shadow wage (w^*), which is the opportunity cost of time and the key variable of interest in our time allocation model, is equal to the value of the marginal product of labor. This is the marginal rate of substitution between leisure and consumption; in other words, the amount of leisure the household is willing give up for a marginal increase in consumption. The market imperfection constraint can result in two scenarios: one in which an interior solution exists and another in which a corner solution exists. In the case of an interior solution, the complementary slackness conditions guarantee that $\lambda = 0$ and $\mu = 0$ and the first order condition form reduces to:

$$w^* = w \tag{5.9}$$

Equation 5.9 says that when labor markets are working perfectly, households allocate labor between their farm and the labor market such that the internal price of labor is equal to the market price. We will have a corner solution in the following scenario:

$$\frac{\frac{\partial U}{\partial l}}{\frac{\partial l}{\partial C}} = w - \frac{\lambda}{\frac{\partial U}{\partial C}} \qquad \Rightarrow \qquad w^* < w \text{ if } m = M \tag{5.10}$$

Equation 5.10 describes the case in which the household is constrained in the labor market because the shadow wage is below the market wage. The household wants to supply additional labor to the market but cannot do so because of constraints in the labor market. This may describe the slack season in agriculture when there is a surplus of labor. An alternate corner solution that is plausible is one in which $m = 0$, in which case the household does not supply labor to the market because the shadow wage is higher than the market wage. I rule out this alternate corner solution to capture the assumption of asymmetry between supplying labor to the market and hiring labor from the market. According to this assumption, households are not constrained in hiring labor from the market, although they may be constrained in supplying labor from the market.

Simplifying the first order condition for hired labor (equation 5.5) gives us:

$$w = p\frac{\partial Q}{\partial H} \tag{5.11}$$

Equation 5.11 suggests that the household should hire in agricultural labor such that the market wage is equal to the value of the marginal product of hired labor in production.

Tests of market failure

All the tests proposed in the literature on market failures in developing countries rely on the AHM and belong to the following three categories: reduced form tests, structural tests, and tests of local separability. All of these tests use the insight that when labor markets are functioning well, the shadow wage is equal to the market wage. The first approach to testing separability is reduced form estimation of the conditional labor demand function in agricultural production. The seminal paper in this strand of the literature is Benjamin (1992). The intuition underlying this approach is that if market failures are absent, production decisions should be invariant to consumption-side variables such as preferences for household size and composition. Benjamin (1992) uses the following econometric specification:

$$\log L_{ij} = \alpha + \beta \log w_j + \gamma \log F_{ij} + \delta A_{ij} + \varepsilon_{ij} \tag{5.12}$$

where L_{ij} is the total labor demand of household i living in community j, w_j is the market wage in community j, F_{ij} is the quantity of fixed inputs used by the household in production, A_{ij} is a vector of household preferences (such as the age and gender composition of the household, assumed to be exogenous to the model), and ε_{ij} is a disturbance term. The null hypothesis of this test is given by the parametric restriction on the vector $\delta = 0$. Benjamin (1992) and Pitt and Rosenzweig (1986) cannot reject the hypothesis of complete markets using data from Indonesia. Bowlus and Sicular (2003) also cannot reject separability among Chinese households using this method. Arcand (2006) rejects separability using a modified version of this method for Tunisia. Dillon and Barrett (2014) also find that this test leads them to reject the separation theorem in five countries in Sub-Saharan Africa. The strength of this approach is its simplicity and intuitive appeal. However, it does not recognize the heterogeneity among households due to its global and reduced-form nature. Households differ in their magnitude of transaction costs, which can result in some households choosing to stay in self-sufficiency. This test yielded mixed results due to this limitation.[4]

The second approach relies on structural estimation of the supply choices of households. The seminal paper in this strand of the literature is Jacoby (1993), who uses a two-stage estimation procedure: estimation of technology parameters of the household production function and a comparison of the estimated household-specific marginal labor productivity (i.e. shadow wage) with the market wage. Jacoby (1994) proposes an alternative test of separability in which he directly tests the hypothesis based on Equation 5.9, that the shadow wage is equal to the market wage if labor markets are perfect and competitive. He implements the following econometric specification:

$$\log w_i^* = \beta_0 + \beta_1 \log w_i + \mu_i \tag{5.13}$$

where w_i^* represents the shadow wage of household h, w_i is the market wage, β_0 and β_1 are coefficients, and μ_i is the random error term. The null hypothesis of the absence of market failures implies that $\beta_0 = 0$ and $\beta_1 = 1$. The shadow wage is estimated as the value of the marginal product of labor using the predicted value of output of households based on estimated coefficients and household characteristics, and the person-days supplied to farming. The shadow wage (the marginal product of labor) used as the dependent variable is estimated from the household agricultural production function. Jacoby (1993) rejects separability in the sample of Peruvian households that he analyzes. Skoufias (1994) and Barrett et al. (2008) also reject separability using datasets from India and Cote d'Ivoire, respectively.

[4] For example, LaFave et al. (2014) uses a slightly modified version of this test to reject the hypothesis of complete markets on Indonesia using more recent data than Benjamin (1992), leading one to make the puzzling conclusion that market performance worsened in Indonesia over time.

In an alternate method to test separability, Le (2010) suggests a reduced-form technique that combines tests proposed by Benjamin (1992) and Jacoby (1993). He begins with equation 5.9, which suggests that the shadow wage is identical to the marginal product of labor at the optimal point in the production function. Using this intuition and assuming a semi-parametric production function, he derives a test of separability that does not require estimation of the entire production function but simply uses the average product of labor as the dependent variable. He begins with the following semi-parametric agricultural production function:

$$\bar{Q} = L^{\lambda_L} f(z, F; \sigma) \tag{5.14}$$

where L stands for household labor, z for hired labor, F for fixed inputs, and for a vector of parameters. This resembles a Cobb-Douglas production function because labor enters in a Cobb-Douglas form (L^{λ_L}). L^{λ_L} is allowed to vary across households in the following manner: $L^{\lambda_L} = L^{\lambda_K + \varepsilon}$ where K is a vector of observed variables that are assumed to be random and account for differences in λ_L across households. The real output is different from the production function $\bar{Q}$ because households are assumed to be exposed to a random weather shock ε in the following manner: $Q = \bar{Q}e^{-\varepsilon}$, where ε is a normalized such that $E(e^{\varepsilon}) = 1$. The value of the marginal product of labor (w^*) in this setup is given by:

$$w^* = p\frac{\partial E(Q)}{\partial L} = p\frac{\partial \bar{Q}}{\partial L} = p\lambda_L L^{\lambda - 1} f = \frac{p\lambda_L \bar{Q}}{L} = \frac{p\lambda_L Q e^{-\varepsilon}}{L} \tag{5.15}$$

Re-arranging the fist and the final expressions, we get:

$$\frac{pQ}{L} = w^* \lambda_L^{-1} e^{\varepsilon} \tag{5.16}$$

According to Equation 5.16, the value of the average product is a function of the shadow wages, household characteristics that are randomly determined, and an error term. Taking logs on both gives the following:

$$\log(\frac{pQ}{L}) = \log(w^*) - \log(\lambda_L) + \varepsilon \tag{5.17}$$

An important assumption that allows Benjamin (1992) to arrive at the empirical specification above is the following approximation:

$$\log w^* = \log w + \alpha A \tag{5.18}$$

Jacoby (1993) proposes an alternative test of separability in which he directly tests the hypothesis based on equation 5.9, that the shadow wage is equal to the market wage if labor markets are perfect and competitive. He implements the following econometric specification:

$$\log w^* = \alpha + \beta \log w \tag{5.19}$$

The shadow wage used as the dependent variable is estimated from the household agricultural production function. The null hypothesis of this test is that $\alpha = 0$ and $\beta = 1$. Equation 5.19 cannot be used to empirically test the separation hypothesis because shadow wage cannot be observed. However, Benjamin (1992) and Jacoby (1993) have proposed approximations, in Equations 5.18 and 5.19, respectively, which Le (2010) combines to form the following general expression:

$$\log w^* = \beta \log w + \alpha A \tag{5.20}$$

Benjamin (1992) and Jacoby (1993) use two separate relationships to test the separation hypothesis: the former uses the relationship between production decisions and preferences, and the latter between shadow wages and market wages. Since both of these are important aspects of the separation theorem, Le (2010) suggests a test of separability that uses both of these relationships. Plugging Equation 5.20 into Equation 5.17, we get the generalized test of separability:

$$\log(\frac{p_j Q_i}{L_i}) = -\log(\lambda_{L_i}) + \beta \log(w_i) + \alpha A_i + \eta_i \quad (5.21)$$

The null hypothesis of separability in this generalized test is given by $\beta = 1$ and $\alpha = 0$. In other words, if household production is separable from consumption, the value of the average product should have a unitary relationship with the market wage and independent of household preferences after controlling for a vector of exogenously determined characteristics of the household, λ_L.

The third approach to testing market failures replaces the global nature of the previous two methods with a local test of separability. de Janvry et al. (1991) articulate the motivation for this approach, noting that the definition of market failure is not commodity-specific but household-specific: markets for different commodities often exist, but they fail selectively for particular households. Transaction costs such as transportation costs, information costs, or enforcement costs are often household-specific. Lambert and Magnac (1998) take up the challenge of testing for separability at the household level rather than at the commodity level. They begin, as in the Jacoby method, by estimating the agricultural production function for a sample of households in Cote d'Ivoire. This allows them to estimate the shadow wage of different types of labor employed by the household, which is equivalent to the value of marginal product of labor. They go further by using the delta method to determine a confidence interval around the predicted shadow wage for male, female, and hired labor for each household. Finally, they examine if the market wage faced by individual households is within the confidence interval of the shadow wage. They find that the market wage is more likely to fall within the confidence interval of the shadow wage for hired labor than for male or female labor. In other words, the relationship between market wage and shadow wage is stronger for hired than family labor. Carter and Yao (2002), Sadoulet et al. (1998), and Vakis et al. (2004) also offer alternative methods to test for local separability.

In summary, there is no consensus within the literature and one is left with an array of competing methods that can be used to test for market failures in developing countries. Despite the presumption of widespread market failures in developing countries, the evidence on their nature and extent is limited. Results naturally differ over space and time, but also according to the methodology and dataset used. Despite the various approaches proposed in the literature, studies most often use only one technique. The consequence of this, as in the context of Indonesia mentioned earlier (Benjamin, 1992; LaFave et al., 2014), is that conclusions are sensitive to the technique used to conduct the analysis. This paper fills the gap in this literature by building on Dillon and Barrett (2014), who only use the reduced form approach to conduct their analysis. This paper implements all three approaches discussed in this section to test the separation theorem in the context of Tanzania. This allows an examination of the findings to determine if they are robust to the choice of methodology. This study also explores patterns in market failures by examining the role of geographic and household characteristics. More importantly, it examines whether markets selectively fail for certain households. Heterogeneity among households is largely ignored in this literature, although it may be crucial in designing policies to mitigate market failures and to optimally allocate resources. The choice of the Tanzania National Panel Survey 2012/13 greatly aids this exercise because this survey collected rich information on agricultural production in addition to the usual information in multi-topic household surveys.

5.3 Empirical methodology

This section outlines the empirical specifications to implement the tests of separability outlined above. These tests allow us to investigate if there are market failures in agricultural factor markets in Tanzania. The first econometric specification was suggested by Benjamin (1992) and is presented in Equation 5.12. In this specification, the null hypothesis implied by the separation hypothesis is $H_0 : \delta = 0$. Rejection of the null hypothesis in favor of the alternative $H_A : \delta \neq 0$ would imply that market failures exist in Tanzanian agricultural factor markets. Although this test of market failures uses information on the labor market, it does not necessarily imply that there is a market failure in labor markets. It is entirely plausible that labor markets are dysfunctional because of market failures in other factor markets (Bardhan and Udry, 1999).

The second test follows from Jacoby (1993), which relies on the prediction that if markets are perfect and competitive, the marginal productivity of labor will be equal to the wage observed on the market. In other words, a comparison of the shadow wage with the market wage should reveal any market imperfections and a violation of separability. The test entails two stages: estimation of the production function and comparison of the implied shadow wage with the market wage. I use the following Cobb-Douglas function to estimate the agricultural production function of household i:

$$\log Y_i = \beta_0 + \beta_1 \log D_i + \beta_2 \log L_i + \beta_3 \log H_i + \sum_{k=1}^{p} \beta_{3k} \log Z_{ik} + \xi_i \tag{5.22}$$

where Y_i the value of crop production of household i, D_i is the land input, L_i is family labor allocated to agriculture, H_i is hired agricultural labor, and Z_i is a vector of variable and fixed inputs. The inputs in this model include land, labor, quantities of other variable inputs (seeds, organic fertilizer, inorganic fertilizer, and other chemicals), and other fixed inputs include the monetary value of all implements owned by the household and a dummy variable for whether the household irrigates any of its plots.[5] In addition to these variables, I include the age, gender, and years of education of the household head as well as the mean years of education of all household members.

$$\log Y_i = \beta_0 + \beta_1 \log D_i + \sum_{j=1}^{4} \beta_{2j} \log L_i + \beta_3 \log H_i + \sum_{k=1}^{p} \beta_{3k} \log Z_{ik} + \xi_i \tag{5.23}$$

The difference between equations 5.22 and 5.23 is that all types of family labor

[5] I ignore livestock production in my analysis, although it is commonly used in this literature, because NPS does not collect credible data on labor allocated by households to livestock production.

(child, adult male, adult female, and elderly) are aggregated in the former whereas they are disaggregated in the latter. The subscript j refers to the days of labor supplied by different categories of family members to agricultural production. Equation 5.22 constrains the returns to labor (β_2) to be the same for all types of family labor, whereas equation 5.23 allows them to be different. I disaggregate total labor used in agricultural production into child, adult male, adult female, elderly, and hired labor. Not all farm households use all inputs in crop production. Since the logarithmic transformation is not defined at zero, I use the $\ln(1+x)$ transformation. The advantage of the Cobb-Douglas specification is ease of interpretation, as the coefficients represent the estimated elasticities of the output with respect to the inputs. However, as de Janvry and Sadoulet (2006) argue, it is recognized that this simple specification does not adequately represent an agricultural production process that unfolds over months, is sequential in nature, and may include complementarities and substitutabilities between inputs. The consequence of not capturing these complexities is that estimates of the marginal productivity of labor may be biased. Despite these challenges, the Cobb-Douglas function is most commonly used in the literature on this topic, which is why it is chosen for this analysis.

The marginal product of labor for aggregated family labor, disaggregated family labor, and hired labor are computed, respectively, using the following formulae:

$$M\hat{R}P_{L_i} = \hat{\beta}_2 \frac{\hat{Y}_i}{L_i} \tag{5.24}$$

$$M\hat{R}P_{L_ij} = \hat{\beta}_2 j \frac{\hat{Y}_i}{L_i j} \tag{5.25}$$

$$M\hat{R}P_{H_i} = \hat{\beta}_3 \frac{\hat{Y}_i}{H_i} \tag{5.26}$$

I estimate the Jacoby test following equation 5.13. This can also be interpreted as a weak test of market efficiency as it does not control for any covariates. A strong test of market efficiency could be implemented by augmenting this specification with covariates that should not directly affect the shadow wage other than through the market wage. These covariates could include long run mean rainfall and temperature, rural location, and distance from roads and markets.

I next implement the method proposed by Le (2010) that combines the tests suggested by Benjamin (1992) and Jacoby (1993). The empirical specification that I use is presented in equation 5.21. I finally examine separability for individual households and for different types of labor employed by each household. For this, I first estimate the agricultural production function. Then I estimate the shadow wage as the value of the marginal product of labor. I compute the confidence interval of the shadow wage using the delta method,

$$\text{Var}(\hat{\Delta}_0) = \left(\frac{\partial\hat{\Delta}_0}{\partial\hat{\beta}_{2i}}\right)^2 \text{Var}(\hat{\beta}_{2i}) + \left(\frac{\partial\hat{\Delta}_0}{\partial\hat{Y}_i}\right)^2 \text{Var}(\hat{Y}_i) + 2\frac{\partial\hat{\Delta}_0}{\partial\hat{\beta}_{2i}}\frac{\partial\hat{\Delta}_0}{\partial\hat{Y}_i}\text{Cov}\left(\hat{\beta}_{2i}\hat{Y}_i\right) \quad (5.27)$$

where $\hat{\Delta}_0 = M\hat{R}P_{Lij}$.

5.4 Data and descriptive statistics

I perform my analysis using the Tanzania National Panel Survey (NPS) conducted by the Tanzanian National Bureau of Statistics. Undertaken as a part of the World Bank's Living Standards Measurement Survey - Integrated Surveys of Agriculture (LSMS-ISA) project, NPS is a multi-topic household survey conducted on 5,010 households in 2012/13, of which 2,661 households cultivated some land and harvested some crop. Although data are available for all three waves of NPS, I use only the latest wave for two reasons. First, the third wave has richer data on labor demand in agriculture than previous waves. Second, deflating market wages (which are important variables in this analysis) between NPS waves and across regions in Tanzania is prone to error. NPS was designed to be a nationally representative sample. It contains an extensive module on various types of agricultural activities in which households may be engaged. The survey provides rich information at the household level on various geographic and agro-climatic variables that could be exploited in the analysis.

My estimation sample contains 2,624 households that cultivated some land in the previous 12 months, report harvesting positive levels of crop output, and do not have any missing data for variables used in this analysis. Table 5.1 summarizes the sample's characteristics. The average household size is 5.70, of which 38% are children, 27% prime age males, 28% prime age females, and 7% elderly. Prime age adults are defined as individuals that aged between 15-64 years (inclusive). Of all the households in the sample, a quarter are headed by women. The typical household head is 48.55 years old and has 4.69 years of schooling, which is higher than the 3.52 years of education for all household members. Although two-thirds of the full NPS3 sample resides in rural areas, 85% of the agricultural households live in rural areas.

Table 5.2 summarizes various aspects of agricultural production of the sample households. The average farming household owns 6.47 acres (2.62 hectares). Of this area, it cultivates 79% of the area, lends 1% of the land for free, rents out 1% of the land, and keeps 8% of the land in fallow.[6] The typical sample household also operates 7.01 acres of land. Of this area, it owns 82%, borrows 12% free of cost, and rents in 6% of land from others. Twelve percent of all households are landless and do not own any of the land that they operate.[7]

Table 5.3 summarizes the market participation of the sample households. Sixty percent of households in the sample participate in at least one of the following factor markets: land, labor, or purchased inputs. Forty-five percent of the sample households hire agricultural labor for either planting, weeding, fertilizing, or harvesting, which suggests that the market for agricultural labor is fairly vibrant in Tanzania. The average household hires 17.02 person days of hired labor. This is the lower bound of market participation if we consider the fact that households are more likely to hire labor over a longer period of time. The amount of hired labor increases with the consumption quintile 32% of the lowest quintile hired agricultural labor,

---

[6]These shares do not add up to 100% because 12% of the households do not own any land but still operate some land. If we only examine households that own some land, they cultivate 90%, rent out 1%, give out 1%, and leave 9% of land to fallow.

[7]The rate is similar to Vietnam, where 12.3% of the population was landless in 2004 (Ravallion and van de Walle, 2008) but below the rate in rural India, where the rate may be as high as 40% (Rawal, 2008).

Table 5.1: Summary statistics

Variables	(1) Mean	(2) SD	(3) Min	(4) Max
Household size	5.70	3.34	1.00	54.00
Share of children in HH	0.38	0.23	0.00	0.86
Share of prime male members in HH	0.27	0.19	0.00	1.00
Share of prime female members in HH	0.28	0.17	0.00	1.00
Share of elderly members in HH	0.07	0.19	0.00	1.00
Mean years of education of HH members	3.52	2.25	0.00	12.00
Mean age of HH members	26.08	13.44	7.50	88.00
HH head is female	0.23	0.42	0.00	1.00
Age of HH head	48.55	16.12	18.00	108.00
Years of education of HH head	4.69	3.64	0.00	18.00
Rural	0.85	0.36	0.00	1.00
Annual mean temperature, Celsius	227.20	24.79	146.00	278.00
Annual precipitation, mm	1,070.55	307.35	462.00	2,377.00
Distance to nearest major road, km	21.35	23.35	0.00	135.40
Distance to nearest town, km	53.16	41.03	0.10	200.00
Distance to agricultural market, km	82.93	54.65	0.70	257.10
Elevation, meters	916.76	539.80	2.00	2,184.00
Latitude, degrees	-6.36	2.90	-11.50	-1.00
Longitude, degrees	35.58	2.95	29.69	40.22

Note: The sample of 2,624 households used for analysis consists of only those households that operate land, harvested some crop, and do not have missing values.

while 63% of the highest quintile did so (Table 5.4).

Market participation in land rental is not as extensive as in labor, but is significant nonetheless. Eight percent of households rent in land, 1% rent out land, and 10% either rented in or rented out land. This incidence is larger if we consider the fact that another 17.42% of households either borrowed or lent land for free. The share of households that purchased organic fertilizer, inorganic fertilizer, and herbicide/pesticide is 3%, 17%, and 16%, respectively. Quantity used and unit prices are available for each household for all of these inputs. Eleven percent of all households bought an input on credit. Market participation in purchased inputs is relatively low considering the widespread use of hired labor.

Descriptive kernel regressions of household labor hiring and labor anticipate some of the multivariate regression results presented in the next section. Figure 5.1 presents a kernel regression of total household labor demand on household size. If labor markets are functioning well, we would expect no relationship between household endowment of labor and the total amount of labor they use in agricultural

Table 5.2: Summary statistics on agricultural production

Variables	(1) Mean	(2) S.D.	(3) Min	(4) Max
Land owned by household, acres	6.47	18.52	0.00	447.50
Share of land cultivated	0.79	0.36	0.00	1.00
Share of land rented out	0.01	0.05	0.00	1.00
Share of land given out	0.00	0.05	0.00	0.92
Share of land in fallow	0.08	0.21	0.00	1.00
Landless farming household	0.12	0.33	0.00	1.00
Land operated by household, acres	7.01	18.46	0.00	447.50
Share of land owned	0.82	0.35	0.00	1.00
Share of land used for free	0.12	0.30	0.00	1.00
Share of land rented in	0.06	0.21	0.00	1.00
Family and hired labor in farming, days	179.56	173.54	4.00	1,920.00
Labor hired for farming, days	17.02	46.16	0.00	952.00
Family labor in farming, days	162.54	162.37	2.00	1,920.00
Family labor in farming, adult females, days	75.35	84.14	0.00	862.00
Family labor in farming, adult males, days	69.33	94.78	0.00	1,280.00
Family labor in farming, children, days	11.13	31.48	0.00	323.00
Family labor in farming, elderly, days	12.29	36.48	0.00	405.00
Crop income, '000 TSH	576.49	1,219.52	0.09	36,960.00
Organic fertilizer, kg	226.78	1,176.15	0.00	32,000.00
Inorganic fertilizer, kg	19.86	100.71	0.00	3,150.00
Other chemicals, kg	4.06	39.35	0.00	1,000.00
Seeds, `000 TSH	14.61	51.58	0.00	1,764.00
Household irrigates land	0.03	0.18	0.00	1.00
Value of farm implements, '000 TSH	326.35	1,997.30	0.00	78,630.00

Note: The sample size is 2,624. See notes to Table 2 for details.

Table 5.3: Market participation in farming

Variables	(1) Mean	(2) S.D.	(3) Min	(4) Max
Household participates in some factor market	0.60	0.49	0.00	1.00
Household hires labor for farming	0.45	0.50	0.00	1.00
Household rents out land	0.01	0.10	0.00	1.00
Household rents in land	0.08	0.28	0.00	1.00
Household rents in or rents out land	0.10	0.29	0.00	1.00
Household buys organic fertilizer	0.03	0.16	0.00	1.00
Household buys inorganic fertilizers	0.17	0.37	0.00	1.00
Household buys other chemicals	0.16	0.36	0.00	1.00
Land rented out, acres	0.07	1.25	0.00	50.00
Land rented in, acres	0.18	0.92	0.00	20.00
Labor hired for farming, days	17.02	46.16	0.00	952.00
Labor hired for planting, days	5.56	16.77	0.00	330.00
Labor hired for weeding, days	6.04	19.20	0.00	364.00
Labor hired for fertilizing, days	0.46	3.42	0.00	60.00
Labor hired for harvesting, days	4.97	19.27	0.00	514.00

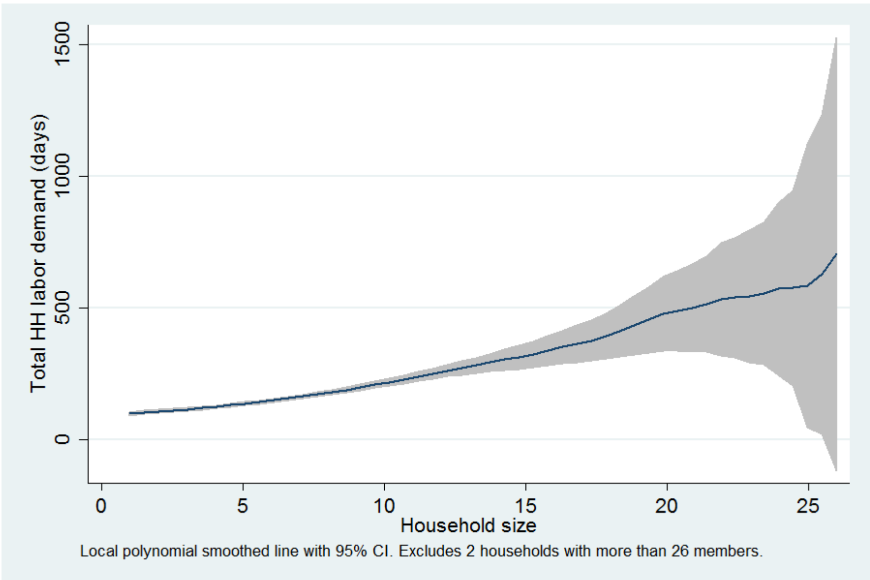
Note: The sample size is 2,624. See notes to Table 2 for details.

Table 5.4: Probability of hiring agricultural wage labor by consumption quintile

Quintile of pc consumption	Planting	Weeding	Fertilizing	Harvesting	Total
1	0.20	0.15	0.03	0.16	0.32
2	0.20	0.19	0.04	0.19	0.37
3	0.28	0.28	0.04	0.26	0.45
4	0.31	0.30	0.05	0.30	0.49
5	0.44	0.45	0.11	0.40	0.63
Total	0.29	0.27	0.05	0.26	0.45

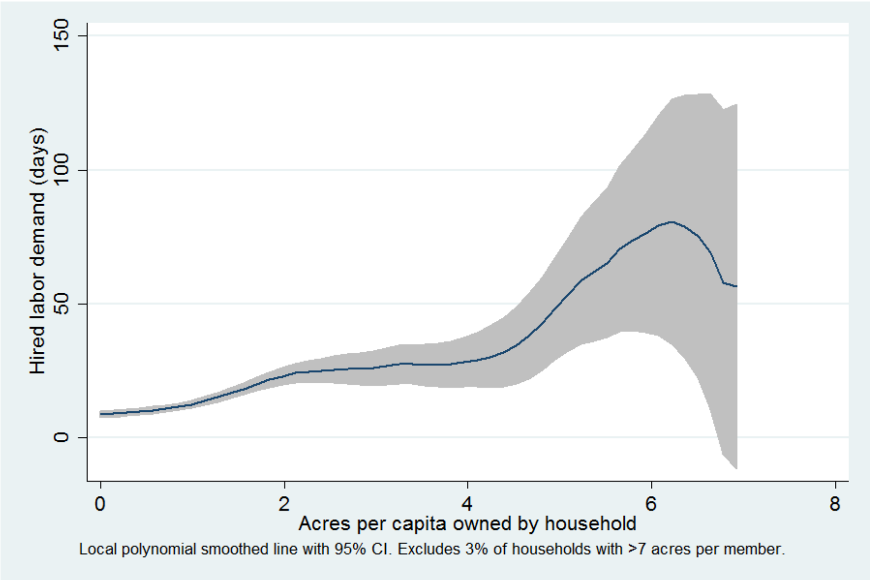
production. Households would simply choose optimal amounts of production contingent on the relevant prices and their own production function. However, we see a strong correlation between total labor demand and household size for our sample of Tanzanian households, suggesting that factor markets do not function properly for these households. This does not necessarily imply imperfections in the labor market because as discussed earlier; market failures in one market can be a consequence of market imperfections in other related markets.

Figure 5.1: Kernel regression of the total labor demand of household on its household size



In Figure 5.2, we see a positive relationship between the amount of labor hired by households and the amount of land they owned. We would not expect any relationship between these two variables if agricultural factor markets were working perfectly. However, we see a positive relationship between these two variables, especially up to about two acres, which includes three-quarters of all households. The fact that households with a higher endowment of land also hire more labor is more likely to be a sign of agricultural factor markets that are not functioning properly. A question these graphs raise is: do these patterns hold after controlling for various covariates?

Figure 5.2: Kernel regression of the labor hired by household on its endowment of land per capita



5.5 Results

This section presents results of the various tests of separability that were discussed in the methodology section. Although the purpose of all of these tests is the same, and all are based on the AHM, they use different information on the lives of households.

Reduced form test of separability

Table 5.5 presents results of the OLS estimates of the reduced form test of market failures proposed by Benjamin (1992), whose econometric specification is given in equation 5.12. In this test, the log of total household labor demand is regressed on household size, market wage rate, and other covariates. If factor markets are functioning properly, household labor demand in agricultural production should only depend on relevant prices and not on consumption-side variables such as preference for household size or structure. The first column is a parsimonious regression with only household size, median agricultural wage in the community, acres cultivated by the household, and a set of variables representing household structure.[8] Household size only includes adult members older than 14 years to avoid treating adult labor and child labor as equal.[9]

The primary coefficient we are interested in is contained in the first row. We note that household size is a statistically significant determinant of household labor demand. This suggests that we can reject the null hypothesis of separability between consumption and production decisions. We interpret the coefficient of household size as reflecting the severity of the market failure, with a coefficient of 0 implying well-functioning markets and coefficient different from zero implying poorly-functioning markets. This coefficient can also be interpreted as the elasticity of labor demand with respect to household size.

Are there any patterns in market failures in Tanzania? This is the question that columns 2-6 attempt to answer by adding the following variables and their interactions of household size to the regression model: dummy variable for households with female household head, distance to the nearest agricultural market, rural location, and administrative zones. We see from these results that household size is a statistically significant determinant of households headed by a woman and in those that live further away from large population centers, in rural areas, and in administrative zones other than the Eastern zone (which includes Dar es Salaam). The inclusion of these variables also lowers the magnitude of the coefficient on household size. These results suggest a portrait of market failures that are more pervasive among female-headed households and in different geographic pockets of the country.

Structural test of separability

We now turn to results from the structural method proposed by Jacoby (1993). This method entails two stages: estimation of the agricultural production function

[8] Median agricultural wage is the sum of cash and in-kind payments reported to have been received by the household. These median wages are computed at each for each of the 131 districts in Tanzania.

[9] In addition to this, children are not as likely to participate in farming as adults are.

Table 5.5: Benjamin Test of separability

	(1)	(2)	(3)	(4)	(5)	(6)
Log of HH size	1.06***	1.01***	1.12***	0.70***	0.67**	0.64**
	(0.06)	(0.07)	(0.10)	(0.12)	(0.26)	(0.24)
Reference category: Share of elderly members in HH						
Share of children in HH	1.37***	1.36***	1.40***	1.44***	1.38***	1.42***
	(0.21)	(0.21)	(0.20)	(0.20)	(0.21)	(0.20)
Share of prime male members in HH	0.68***	0.57***	0.69***	0.64***	0.68***	0.57***
	(0.10)	(0.10)	(0.10)	(0.10)	(0.11)	(0.11)
Share of prime female members in HH	0.63***	0.70***	0.65***	0.64***	0.64***	0.72***
	(0.13)	(0.14)	(0.13)	(0.13)	(0.14)	(0.13)
Log of Median agricultural wage in district	-0.06	-0.06	-0.05	-0.05	-0.02	-0.02
	(0.09)	(0.09)	(0.09)	(0.07)	(0.07)	(0.07)
Log (Acres cultivated)	0.02***	0.02***	0.02***	0.02***	0.02***	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
HH head is female		-0.33***				-0.31**
		(0.12)				(0.11)
HH head is female=1 X Log of HH size		0.15*				0.14**
		(0.07)				(0.06)
Distance to market, km/10			0.00**			0.00***
			(0.00)			(0.00)
Log of HH size X Distance to market, km/10			-0.00			-0.00**
			(0.00)			(0.00)
Rural				-0.19		-0.19
				(0.20)		(0.23)
Rural X Log of HH size				0.44***		0.40**
				(0.14)		(0.18)
Reference category: Eastern Zone X Log of HH size						
Central Zone X Log of HH size					0.71**	0.46
					(0.28)	(0.32)
Northern Zone X Log of HH size					0.27	0.05
					(0.27)	(0.31)
Western Zone X Log of HH size					0.47*	0.26
					(0.26)	(0.32)
Lake Zone X Log of HH size					0.54**	0.26
					(0.26)	(0.32)
Southern Zone X Log of HH size					0.47*	0.26
					(0.26)	(0.31)
Southern Highlands Zone X Log of HH size					0.41	0.18
					(0.27)	(0.30)
Zanzibar Zone X Log of HH size					0.12	-0.09
					(0.26)	(0.32)
Constant	4.21**	4.28**	3.99**	4.71***	5.27***	5.14***
	(1.70)	(1.70)	(1.76)	(1.61)	(1.60)	(1.49)
N	2,624	2,624	2,624	2,624	2,624	2,624
R-squared	0.29	0.29	0.30	0.32	0.31	0.34

Note: Standard errors in parentheses are clustered at the district level. All specifications control for annual precipitation, temperature, elevation, latitude, longitude, and administrative zones (only column 6). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

and comparison of the estimated shadow wages (value of the marginal product of labor) with the market wage faced by households. Table 5.6 reports the OLS estimates of the Cobb-Douglas production function.[10] Column 1 reports the coefficients

[10] I also attempted estimation of the agricultural production function using a translog function, which is a generalized form of the Cobb-Douglas function as it includes squared and interaction

from the specification in which agricultural production labor supply of all family members is aggregated. Family labor is disaggregated into labor supplied by children, adult males, adult females, and elderly members in Column 2. We see that the coefficients on the variable inputs are positive when statistically significant. When labor is disaggregated into different demographic categories, adult male and female labor are seen to have the largest effect on the value of production. However, even these are only about half of the marginal effect of hired labor. Variable inputs such as fertilizers and other chemicals were transformed from continuous to dummy variables since less than 20% of sample households use these inputs.[11] All other inputs to production have the anticipated signs.

The next step in this test is to estimate the shadow wage of labor, or the marginal product of labor. Panel A of Table 5.7 presents summary statistics of the shadow wage for different types of labor along with the market wage they face at the district level. The shadow wages are much lower than the minimum wage of TSH 3,847 for Tanzania in 2013.[12] This may suggest that Tanzanian households put a high premium on time allocated outside of the labor market or that the physical environment they face is inhospitable to seasonal crop production.

The shadow wage is a small fraction of the market wage for most categories of labor, except for hired labor. The fact that the shadow wage for hired labor is closer to the market wage than family labor suggests the decision to hire in labor may be more in line with well-functioning markets than the decision to hire out labor. The shadow wage of adult male labor is higher than all types of family labor. In particular, the shadow wage of the elderly is the lowest and about two-thirds that of adult males. Panel B of Table 5.7 presents the median market wage for different types of labor in the district. We see that the median wage of adult males is the highest, whereas the median wage of children is less than half of the value for adult

terms of the inputs. However, the coefficients on labor variables were imprecisely estimated and led to implausible estimates of the shadow wage (possibly due to the proliferation of the parameters).

[11] Using dummy variables instead of continuous variables barely changes the coefficients but avoids having to add one level of inputs before taking its log.

[12] Gazette of the United Republic of Tanzania, Supplement No. 24, 2013-06-28, Vol. 94, No. 26, 8 pages, ISSN: 0856-034X (Source: ILO)

Table 5.6: Estimate of production function (Dependent variable: Log of total value of crop production)

	(1)	(2)
Log of Family labor in farming, days	0.265***	
	(0.031)	
Log (Child labor, days)		0.021
		(0.014)
Log (Adult male labor, days)		0.092***
		(0.014)
Log (Adult female labor, days)		0.068***
		(0.015)
Log (Elderly labor, days)		0.024
		(0.018)
Log (Hired labor, days)	0.141***	0.141***
	(0.016)	(0.016)
Log (Acres cultivated)	0.479***	0.517***
	(0.043)	(0.041)
Log (Value of seeds, TSH)	0.011**	0.010*
	(0.005)	(0.005)
Log (Value of farm implements, TSH)	0.107***	0.107***
	(0.013)	(0.012)
HH uses organic fertilizer	0.098**	0.097*
	(0.049)	(0.050)
HH uses inorganic fertilizer	0.583***	0.583***
	(0.090)	(0.089)
HH uses other chemicals	0.179**	0.190**
	(0.090)	(0.087)
Household irrigates land	0.371***	0.332***
	(0.128)	(0.123)
HH head is female	-0.104*	-0.029
	(0.053)	(0.055)
Rural	-0.088	-0.056
	(0.083)	(0.085)
Constant	10.994***	11.242***
	(0.818)	(0.804)
N	2,624	2,624
R-squared	0.48	0.47

Note: Standard errors in parentheses clustered at the district level. All specifications control for quarter of interview, distance to town/road, annual precipitation/temperature, latitude, longitude, age of household head, and average education/age of household members. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

males.

Now that we have the shadow wages, we can finally test for the separation hypothesis proposed by Jacoby (1993) in equation (15). Table 5.8 presents the results of OLS estimation in which the dependent variable is the log of the shadow wage of family labor. If markets are perfect and competitive, the coefficient on the wage (first row) would be equal to unity and the value of the constant would be equal to 0. Column 1 presents the weakest version of this test, as it does not have any other

Table 5.7: Summary statistics on shadow and market wages

Variables	Mean	SD	25%	50%	75%
Panel A: Shadow wage based on household production function					
Shadow wage of child labor, TSH	536	994	97	228	503
Shadow wage of adult male labor, TSH	892	1,906	221	424	819
Shadow wage of adult female labor, TSH	657	4,601	130	272	559
Shadow wage of elderly labor, TSH	587	4,384	38	79	183
Marginal product of hired labor, TSH	5,600	9,312	1236	2,621	5,958
Panel B: Market wage in the district					
Median wage of children, TSH	2,649	1,527	1,500	2,000	4,138
Median wage of adult males, TSH	6,234	2,640	4,605	5,199	8,000
Median wage of adult females, TSH	3,823	2,155	2,500	3,250	4,603
Median wage of elderly, TSH	4,530	2,529	2,900	3,218	6,000
Median wage of hired labor, TSH	3,821	7,119	2,364	3,000	4,100

covariates. Columns 2-5 contain results of the strong test of separability, in which covariates are added to the model. We see that the null hypothesis of separability is rejected in all of the specifications at the 5% significance level. Column 5 is the richest specification and includes variables whose effect should already be captured by the market wage and should not independently affect the shadow wage. We see that a female head of household, rural areas, distance to major road, mean temperature, and mean precipitation have statistically significant and negative effects on the shadow wage. Although we can reject the separation hypothesis, these suggest some channels through which this may be happening. Similar to the Benjamin test, we see separability being violated in female-headed household heads and rural households. Female-headed households have approximately a 20% lower shadow wage compared with male-headed households.

Tables C.1 and C.2 (page 139) present two variations of the Jacoby test. Table C.1 presents results of analysis similar to Table 5.8 but conducted at the individual level, which should give us a more precise comparison of the market wage reported by individuals and the shadow wage that is disaggregated for the following types of labor within the household: children, adult males, adult females, and elderly. The results of the test are very similar to those obtained in Table 5.8: separability is

Table 5.8: Jacoby Test of separability (Dependent variable: Log of shadow wage of family labor)

	(1)	(2)	(3)	(4)	(5)
Log (Median wage in district, TSH)	0.255*	0.308**	0.358***	0.227*	0.286***
	(0.133)	(0.118)	(0.117)	(0.118)	(0.088)
Log (Land owned by household, acres)		0.253***	0.308***	0.319***	0.256***
		(0.030)	(0.033)	(0.029)	(0.026)
Log (HH size)			-0.406***	-0.436***	-0.516***
			(0.057)	(0.051)	(0.043)
HH head is female				-0.234***	-0.224***
				(0.043)	(0.037)
Rural				-0.417***	-0.512***
				(0.089)	(0.062)
Distance to major road, km				-0.006***	-0.004***
				(0.002)	(0.001)
Annual mean temperature, Celsius X 10				-0.001	-0.000
				(0.001)	(0.001)
Annual precipitation, mm					0.000
					(0.003)
Elevation, meters					-0.001***
					(0.000)
Constant					0.000*
					(0.000)
N	4.175***	3.364***	3.419***	5.134***	5.329***
R-squared	(1.119)	(0.989)	(0.993)	(1.020)	(1.080)
Test of separability, F statistic	2,624	2,624	2,624	2,624	2,624
Test of separability, p-value	0.01	0.08	0.10	0.17	0.33

Note: Standard errors in parentheses are clustered at the district level. Column 5 also contains dummies for 7 geographic regions. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

again rejected. Table C.2 presents results of analysis conducted only for the subset of households that hired labor. One would expect that if markets are working well, there would be a strong correlation between the wage households pay to hire agricultural labor and the marginal product of hired labor. We reject separability even for this subset of households, suggesting that the markets may not be working well even for hired labor.

Joint test of separability

We next move to the joint test of separability proposed by Le (2010) and presented in equation 5.20 combining features of the Benjamin test and the Jacoby test. Table 5.9 presents results of this test, in which the dependent variable is the value of the average product of labor in agricultural production. The regressors are the median market wage in the district, demographic characteristics of the household, primary crop planted by the household, and agro-ecological regions. Column 1 aggregates all types of household members, whereas column (2) disaggregates this number by different demographic categories. The null hypothesis is that the coefficient on the log wage is equal to 1 whereas the coefficients on household size variables are equal to zero. The test results are presented in the last row and suggest that the null hypothesis of the absence of market failures is rejected at the 1% significance level. The coefficients of some covariates hint at some factors that may explain non-separation. The coefficients on rural location and distance from a major road are both negative and statistically significant at the 5% level, suggesting that these characteristics may be associated with a greater degree of market failure. Similar to the Benjamin, Jacoby, and the joint tests, we see that the coefficient on female-headed households is also negative and statistically significant, suggesting that these households may be more likely to be subject to market failures than male-headed ones.

Test of local separability

We finally implement the local test of separability proposed by Lambert and Magnac (1998). The strength of this test is that it allows for a better characterization of heterogeneity in market failures across households. This is because we compute not only the average value but also the confidence interval of the shadow wage for each household. This allows us to, for each household, compare the shadow wage with the market wage and test the separability hypothesis.

Table 5.10 presents comparisons of the shadow wage with the market wage. We see in the first row that the market wage of aggregated family labor falls below the 95% confidence interval of the shadow wage for about 95% of the households. This implies that we can reject separability for nearly all of these households. The results do not differ much when we disaggregate labor by demographic categories. The market wage for adult males falls below the 95% confidence interval of the shadow wage for nearly 98% of the households.

What is most striking is that the market wage is below the marginal product of hired labor for only about 46% of households. This suggests that many households

Table 5.9: Joint test of separability

	(1)	(2)
Log of Median wage in district, TSH	0.329***	0.322***
	(0.116)	(0.115)
Log of HH size	-0.144*	
	(0.076)	
Number of children in HH		0.012
		(0.014)
Number of adult males in HH		-0.010
		(0.028)
Number of adult female in HH		-0.010
		(0.030)
Number of elderly members in HH		-0.168***
		(0.053)
HH head is female	-0.276***	-0.237***
	(0.061)	(0.060)
Rural	-0.236**	-0.229**
	(0.106)	(0.105)
Distance to major road, km	-0.006**	-0.006**
	(0.003)	(0.003)
Distance to nearest town, km	0.002	0.002
	(0.002)	(0.002)
Primary crop planted by household: (Reference category: Maize)		
Paddy	-0.205	-0.220
	(0.140)	(0.138)
Banana	-0.929***	-0.934***
	(0.172)	(0.171)
Cassava	-0.889***	-0.878***
	(0.128)	(0.129)
Other	-0.047	-0.054
	(0.090)	(0.089)
Constant	5.587***	5.509***
	(1.023)	(1.015)
N	2,624	2,624
R-squared	0.12	0.12
F test (Coeff. on wage=1 and household size=0)	F(2,127)= 19.53, p=0.00	F(5,127)= 10.95, p=0.00

Note: Standard errors in parentheses are clustered at the district level. All specifications include controls for agro-ecological regions. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

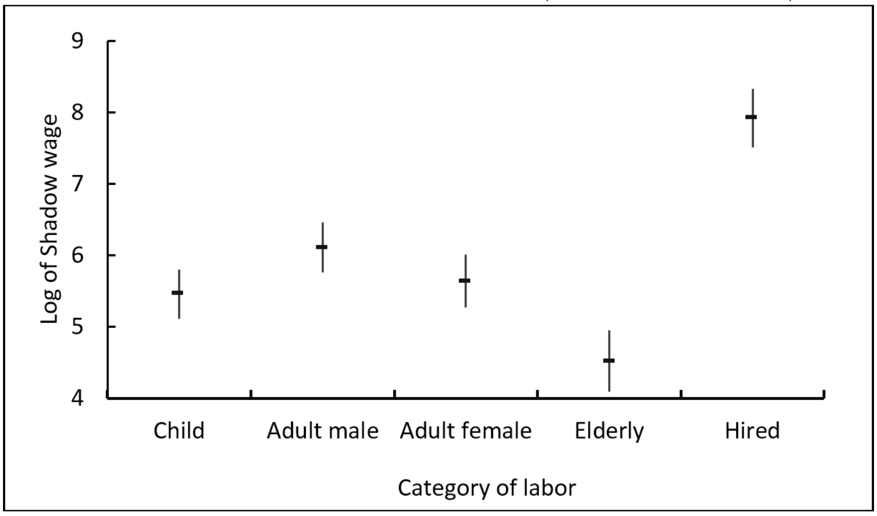
may be hiring agricultural labor by equating the wage with their marginal productivity on the farm, as would be suggested by perfect markets. The last column of Table 5.9 presents correlations between shadow wage and market wage for different categories of labor. We see that this correlation (0.18) is stronger for hired labor than it is for any other category of labor. Figure 5.3 presents the 95% confidence intervals of the shadow wages of different labor categories. We see that although there is significant overlap between the shadow wages of different wage categories, the marginal product of hired labor is visibly higher than that of other labor categories.

Table 5.10: Comparison of market wage with confidence interval (CI) of shadow wage, percent

Category of labor	Below CI	Within CI	Above CI	N	Correlation of shadow and market wage
All family labor	95.05	3.96	0.99	2,627	0.07
Child labor	92.71	2.20	5.08	590	-0.01
Adult male labor	97.71	0.73	1.56	2,049	0.07
Adult female labor	97.64	1.20	1.16	2,247	-0.02
Elderly labor	97.60	0.48	1.92	416	0.03
Hired agricultural labor	46.20	12.99	40.82	1,078	0.18

Note: This table presents the proportion of households who face market wage that is within the 90% confidence interval of the estimated shadow wage in farming.

Figure 5.3: Shadow wage of labor (Mean and 95% CI)



5.6 Conclusion

This paper re-examines the longstanding assumption that underpins a great deal of policy and programmatic interventions in countries such as Tanzania: factor markets are reasonably complete and competitive. The justification for interventions such as subsidy programs for fertilizer, agricultural credit, or insurance rest on the separation assumption that farmers make production decisions independently of their consumption preferences. Policy interventions related to factors of production may be less effective than intended if the assumption of well-functioning markets is not valid. Moreover, if market failures are present, government policy may need to prioritize mitigation of these failures. This study is an attempt to examine how well agricultural factor markets function in Tanzania. The challenge to this effort is that there is no consensus in the literature on the appropriate method to test for the presence of market failures. We take on this challenge by implementing four tests of market failures that have been proposed in the literature on a sample of Tanzanian households.

We find that market participation in factor markets is fairly widespread, with more than half of our sample of households participating in at least one factor market. Two-fifths of the sample households hire labor for crop production at some point during the cropping season. This fact tells us that the relevant question is not whether factor markets exist but how well they work. Three of the existing tests in the literature are global in nature they test hypotheses about how well the entire market is working. We find that these tests do indeed reject the separation hypothesis most of the time. Despite this weakness of the global tests, we are able to tease out factors that are correlated with market failures: households headed by women, those located in rural areas or further away from towns, and located in areas other than the Eastern Zone (which includes Dar es Salaam). The fact that market performance differs by the gender of the household head is also consistent with the finding of Palacios-Lopez and Lopez (2015), who report a 44% lower productivity in plots managed by women (which they argue is primarily due to imperfections in labor and credit markets). The test that examines separability at the household level rejected separability only for about half of the households and suggested that households may be making hiring decisions in farming that are consistent with well-functioning markets. Perhaps the most important finding of this study is that exploring heterogeneity may be crucial in understanding the extent of market failures.

What this study was not able to do was to precisely identify the source of these market failures. Although all of the tests in this literature are based on the labor market, these are not tests of labor market failure per se. Market failures could arise due to high transaction costs, imperfect competition, incomplete enforcement of contracts and poorly-assigned property rights, presence of externalities, or under-provision of public goods. Identifying the role of these factors is difficult because market imperfections could be a result of two or more market failures. A factor market may be dysfunctional because of a failure in another market. Future work could attempt to identify the sources of these market failures.

Chapter 6

Conclusion

This thesis examined several important issues related to the role of agriculture in Tanzania's economic development: household coping mechanisms to deal with unreliable rainfall, consequences of a major policy of rural re-organization, and market failures. Given the predominantly rural nature of poverty in Tanzania and the fact that most Tanzanians depend on agriculture for their livelihoods, this thesis presents a sobering portrait of the hurdles they face in improving their standards of living. The focus on agriculture was helpful in tying the thesis together, although the non-agricultural sector plays a crucial role in each of the research questions addressed here. Here I summarize the key findings of each chapter and suggest potential avenues for further research.

Chapter 3 examined how households cope with a manifestation of a difficult natural environment in the Tanzanian context: unreliable rainfall. In particular, this chapter asked if households diversify outside of agriculture in response to rainfall shocks they face. The primary finding of this chapter was that, to the extent possible, households participate in non-agricultural self-employment activities during years of poor rainfall. One needs to pay careful attention to the complex set of activities that households engage in order to understand how households cope with rainfall shocks. Availability of rich data on labor allocation of respondents and granular rainfall data, as was the case for this study, greatly aids this analysis.

One limitation of this chapter was the quality of the data on the activities and the labor supply of households. Although the Tanzania National Panel Survey used in most of this thesis employs the latest know-how in conducting multi-topic surveys, recall surveys of this nature contain significant noise in capturing the complex set of activities that households are engaged in. This chapter also ignores labor supplied to livestock-keeping, which is significant in many parts of Tanzania. Future research could explore this activity, given sufficient data. A question raised by the findings of this chapter is: what are the welfare consequences of activity diversification in response to rainfall shocks? In other words, how well are households able to manage income shocks arising from unreliable rainfall? Analysis of these issues could be used to extend the research presented in this particular chapter.

Chapter 4 asked if there is a persistent legacy of the villagization program implemented in the 1970s. Although the program is thought to have contributed to the collapse of the Tanzanian economy in the late-1970s, little is known about the persistence of the legacy of this policy. The primary finding of this chapter was that households living in districts where this program was heavily implemented are worse off economically even several decades later. This finding was robust to the outcome investigated, dataset, and the measure of program implementation. A channel through which this policy appears to have led to adverse outcomes is that it prevented households from moving out of agriculture to activities that have higher returns to labor.

A challenge for this chapter was the fact that we do not know the precise locations of the planned villages. In the absence of this information, a district-level measure of the intensity of program implementation had to be used in the analysis. We also do not know the degree of dislocation that communities experienced during villagization, which could have allowed a richer analysis of the impact of the program. Clearly, some communities were moved longer distances and to less favorable locations than others. The degree of dislocation and the conditions of the new environment may have had a major impact on the lives of people. An extension of this chapter could be an exploration of other channels of persistence, including access to infrastructure such as roads or provision of social services such as health, education, or water supply that may have been positively affected by villagization. What is the relevance of villagization for countries other than Tanzania? Although this was a very specific program implemented in a very specific moment in history, it had precursors and emulators. Nyerere was inspired by similar programs in Russia and China. Tanzania also served as an inspiration for similar programs that were implemented in Mozambique, Ethiopia, and Rwanda. Studying the Tanzanian case may help us not only understand similar experiences in other countries but also to be cautious about implementing similar policies in the future.

Chapter 5 examined the presence and nature of market failures in agricultural factor markets in Tanzania by conducting various tests to detect the presence of such failures suggested in the literature. A contribution of this chapter is to examine several tests proposed in the literature to compare the results and insights provided by each of them. It found strong evidence suggesting the presence of market failures, although there exists heterogeneity in terms of location and demographics. The various tests of market failure gave essentially the same result, but painted a different portrait of the nature of market failures in agricultural factor markets in Tanzania.

One limitation of this work is that it does not address the source of the market failure, potential candidates of which include transportation costs, enforcement of contracts, and market power. This chapter does not quantify the welfare losses that are the consequence of poorly functioning markets. For example, are poorly functioning markets preventing gains from trade and specialization? The theoretical foundation of this study is in the agricultural household model, which is appropriate for the Tanzanian context as most households are indeed producers and consumers at the same time. However, an increasing share of the population lives in urban areas and does not engage in agriculture at all. How do we detect the presence of market failures for households that engage in wage labor and are exclusively consumers? Future research could address this issue, although it is beyond the current scope of this thesis.

Although the Tanzanian economy has progressed since independence in 1961, one could argue that limited development in agriculture is holding it back. As this thesis explored, Tanzanians face multiple challenges to earning a livelihood as they live in an environment of uncertain climate, policies, and markets. A decent performance in agriculture helps with poverty reduction since many poor people are engaged in agriculture and not necessarily productively. The themes discussed in this thesis are interlinked in many ways. Tanzanian agriculture is unproductive partly due to its geography and climate, which led its people to spread out across the country to live pastorally. Nyerere saw scattered living as an obstacle to progress and sought a remedy in getting people to live in concentrated settlements. Villagization was also accompanied by price controls touching most sectors of the economy and a general discouragement of private activity. Although most of the price controls were removed in the 1980s and 1990s, weak markets are a legacy of Nyerere's socialist policies.

Bibliography

AFDB (2014). 23rd ordinary session of the african union assembly of heads of states and governments, malabo, equatorial guinea, 26-27 june 2014. 80

Alston, J. M. and Pardey, P. G. (2014). Agriculture in the global economy. *Journal of Economic Perspectives*, 28(1):121–46. 11

Ansoms, A. and McKay, A. (2010). A quantitative analysis of poverty and livelihood profiles: The case of rural rwanda. *Food Policy*, 35(6):584–598. 63

Arndt, C., Demery, L., McKay, A., and Tarp, F. (2015). Growth and poverty reduction in tanzania. *UNU-WIDER Working Paper*, 2015(051). 11, 17, 19, 21, 80

Atkinson, A. B. and Lugo, M. A. (2010). Growth, poverty and distribution in tanzania. 21

Auffhammer, M., Hsiang, S. M., Schlenker, W., and Sobel, A. (2013). Using weather data and climate model output in economic analyses of climate change. *National Bureau of Economic Research Working Paper Series*, No. 19087. 61

Bandyopadhyay, S. and Skoufias, E. (2012). Rainfall variability, occupational choice, and welfare in rural bangladesh. *World Bank Policy Research Working Paper Series*, (6134). 53, 55

Banerjee, A. and Duflo, E. (2014). Under the thumb of history? political institutions and the scope for action. *National Bureau of Economic Research Working Paper Series*, No. 19848. 50

Banerjee, A. V. and Duflo, E. (2007). The economic lives of the poor. *Journal of Economic Perspectives*, 21(1):141–168. 56

Bank of Tanzania (2011). Tanzania mainland's 50 years of independence: A review of the role and functions of the bank of tanzania. Technical report, Bank of Tanzania. 21

Bardhan, P. and Udry, C. (1999). *Development microeconomics*. Oxford University Press. 83, 92

Barrett, C. B., Reardon, T., and Webb, P. (2001). Nonfarm income diversification and household livelihood strategies in rural africa: concepts, dynamics, and policy implications. *Food Policy*, 26(4):315–331. 55

Barrett, C. B., Sherlund, S. M., and Adesina, A. A. (2008). Shadow wages, allocative inefficiency, and labor supply in smallholder agriculture. *Agricultural Economics*, 38(1):21–34. 87

Benjamin, D. (1992). Household composition, labor markets, and labor demand: Testing for separation in agricultural household models. *Econometrica*, 60(2):287–322. 66, 86, 87, 88, 89, 91, 94, 99

Bevan, D., Bigsten, A., Collier, P., and Gunning, J. W. (1988). *Incomes in the United Republic of Tanzania During the "Nyerere Experiment"*. ILO, Geneva. 25, 34, 48, 50

Bezu, S. and Barrett, C. (2012). Employment dynamics in the rural nonfarm sector in ethiopia: Do the poor have time on their side? *Journal of Development Studies*, 48(9):1223–1240. 56

Boesen, J., Havnevik, K. J., Koponen, J., and Odgaard, R. (1986). *Tanzania : Crisis and Struggle for Survival*. Scandinavian institute of African studies, Uppsala. 25, 42, 43

Carter, M. R. and Yao, Y. (2002). Local versus global separability in agricultural household models: The factor price equalization effect of land transfer rights. *American Journal of Agricultural Economics*, 84(3):702–715. 90

Christiaensen, L., Demery, L., and Kuhl, J. (2011). The (evolving) role of agriculture in poverty reductionan empirical perspective. *Journal of development economics*, 96(2):239–254. 11

Clarke, J. I., Khogali, M., and Kosinski, L. A. (1985). *Population and development projects in Africa*. International Geographical Union, Commission on Population Geography. 24, 28

Cliffe, L., Lawrence, P., Luttrel, W. M., Adholla, S., and Saul, J. S. (1975). *Rural Cooperation in Tanzania*. Tanzania House, Dar es Salaam, Tanzania. 31

Collier, P. (1988). Macro-economic policy, employment and living standards in malawi and tanzania, 1973-84. Technical report, International Labour Organization. 25, 34

Collier, P., Conway, G., and Venables, T. (2008). Climate change and africa. *Oxford Review of Economic Policy*, 24(2):337–353. 12, 53

Collier, P., Wangwe, S., and Radwan, S. (1986). *Labour and poverty in rural Tanzania: Ujamaa and rural development in the United Republic of Tanzania*. Clarendon P, Oxford. 12, 25

Cooksey, B. (2011). Marketing reform? the rise and fall of agricultural liberalisation in tanzania. *Development Policy Review*, 29:s57–s81. 80

Coulson, A. (2013). *Tanzania: A Political Economy*. Oxford University Press, Oxford, UK, 2 edition. 15, 24, 30, 31, 32, 33, 34, 39, 42

de Janvry, A., Fafchamps, M., and Sadoulet, E. (1991). Peasant household behaviour with missing markets: Some paradoxes explained. *The Economic Journal*, 101(409):1400–1417. 65, 66, 81, 82, 90 de Weerdt, J. (2010). Moving out of poverty in tanzania: Evidence from kagera. *Journal of Development Studies*, 46(2):331–349. 56

Dell, M. (2012). Path dependence in development: Evidence from the mexican revolution. *Unpublished manuscript, Department of Economics, Harvard University.* 25, 26, 27

Dercon, S. (1998). Wealth, risk and activity choice: cattle in western tanzania. *Journal of Development Economics*, 55(1):1–42. 55

Dercon, S. (2004). *Risk, Insurance, and Poverty: A Review.* Oxford University Press. 54, 55, 56

Dercon, S. (2005). Risk, poverty and vulnerability in africa. *Journal of African Economies*, 14(4):483–488. 56

Dercon, S. (2008). Fate and fear: Risk and its consequences in africa. *Journal of African Economies*, 17(suppl 2):ii97–ii127. 52, 54

Dercon, S. and Gollin, D. (2014). Agriculture in african development: theories and strategies. *Annu. Rev. Resour. Econ.*, 6(1):471–492. 11

Dercon, S. and Krishnan, P. (2000). Vulnerability, seasonality and poverty in ethiopia. *Journal of Development Studies*, 36(6):25–53. 61

Dillon, B. and Barrett, C. B. (2014). *Agricultural Factor Markets in Sub-Saharan Africa: An Updated View with Formal Tests for Market Failure.* Policy Research Working Papers. The World Bank. 80, 81, 86, 91

Dustmann, C. (1997). Return migration, uncertainty and precautionary savings. *Journal of Development Economics*, 52(2):295–316. 52

Earls, J. and Dixon, B. Spatial interpolation of rainfall data using arcgis: A comparative study. In *ESRI User Conference*. 41

Edwards, S. (2012). Is tanzania a success story? a long term analysis. *National Bureau of Economic Research Working Paper Series*, No. 17764. 21

Edwards, S. (2014). *Toxic aid: Economic collapse and recovery in Tanzania*. 26, 34

Ellis, F. and Mdoe, N. (2003). Livelihoods and rural poverty reduction in tanzania. *World Development*, 31(8):1367–1384. 33

Estudillo, J. P., Matsumoto, T., Uddin, H. C. Z., S. Kumanayake, N., and Otsuka, K. (2012). Labor markets, occupational choice, and rural poverty in selected countries in asia and sub-saharan africa. 56

Fafchamps, M. (1993). Sequential labor decisions under uncertainty: An estimable household model of west-african farmers. *Econometrica*, 61(5):1173–1197. 60

Fafchamps, M. (2003). *Rural poverty, risk and development*. Edward Elgar Publishing. 54

Fafchamps, M. and Lund, S. (2003). Risk-sharing networks in rural philippines. *Journal of Development Economics*, 71(2):261–287. 52

Fenske, J. and Kala, N. (2014). Climate and the slave trade. *Unpublished manuscript, Department of Economics, Oxford University*. 26

Filmer, D. and Pritchett, L. H. (2001). Estimating wealth effects without expenditure data - or tears: An application to educational enrollments in states of india. *Demography*, 38(1):115–132. 36, 63

Gollin, D., Parente, S., and Rogerson, R. (2002). The role of agriculture in development. *American Economic Review*, pages 160–164. 11

Greene, W. (2003). Econometric analysis. *New Jersey, United States: Prentice Hall*. 72

Gunning, J. W., Hoddinott, J., Kinsey, B., and Owens, T. (2000). Revisiting forever gained: income dynamics in the resettlement areas of zimbabwe, 198396. *The Journal of Development Studies*, 36(6):131–154. 28

Holland, H. (1988). Soviet agriculture with and without collectivization, 1928-1940. *Slavic Review*, 47(2):203–216. 27

Huffman, G. J., Adler, R. F., Arkin, P., Chang, A., Ferraro, R., Gruber, A., Janowiak, J., McNab, A., Rudolf, B., and Schneider, U. (1997). The global precipitation climatology project (gpcp) combined precipitation dataset. *Bulletin of the American Meteorological Society*, 78(1):5–20. 61

Iliffe, J. (1979). *A Modern History of Tanganyika*. Cambridge U.P. 21, 29

IPCC (2007). *Africa*, pages 433–467. Cambridge University Press, Cambridge UK. 12, 53

Isaksson, A.-S. (2013). Manipulating the rural landscape: Villagisation and income generation in rwanda. *Journal of African Economies*, 22(3):394–436. 25, 27

Ito, T. and Kurosaki, T. (2009). Weather risk, wages in kind, and the off-farm labor supply of agricultural households in a developing country. *American Journal of Agricultural Economics*, 91(3):697–710. 55

Jacoby, H. G. (1993). Shadow wages and peasant family labour supply: An econometric application to the peruvian sierra. *The Review of Economic Studies*, 60(4):903–921. 87, 88, 89, 92, 94, 100, 103

Jensen, S. E. and Mkama, J. (1968). *District data, Tanzania, 1967*. Ministry of Economic Affairs and Development Planning, Dar es Salaam. 36

Jerven, M. (2011). Growth, stagnation or retrogression? on the accuracy of economic observations, tanzania, 19612001. *Journal of African Economies*, 20(3):377–394. 17

Johnston, B. F. and Mellor, J. W. (1961). The role of agriculture in economic development. *The American Economic Review*, pages 566–593. 11

Jolliffe, D. (2004). The impact of education in rural ghana: Examining household labor allocation and returns on and off the farm. *Journal of Development Economics*, 73(1):287–314. 65

Kikula, I. S. (1997). *Policy implications on environment: the case of villagisation in Tanzania*. Nordic Africa Institute. 34, 48

Kjekshus, H. (1977). Tanzanian villagization policy - implementational lessons and ecological dimensions. *Canadian Journal of African Studies-Revue Canadienne Des Etudes Africaines*, 11(2):269–282. 48

Kochar, A. (1999). Smoothing consumption by smoothing income: Hours-of-work responses to idiosyncratic agricultural shocks in rural india. *Review of Economics and Statistics*, 81(1):50–61. 55, 61

Kondylis, F. (2008). Agricultural outputs and conflict displacement: Evidence from a policy intervention in rwanda. *Economic Development and Cultural Change*, 57(1):31–66. 28

Lambert, S. and Magnac, T. (1998). Implicit prices and recursivity of agricultural households. 90, 106

Le, K. T. (2010). Separation hypothesis tests in the agricultural household model. *American Journal of Agricultural Economics*. 83, 88, 89, 94, 105

Leeuwen, M. v. (2001). Rwanda's imidugudu programme and earlier experiences with villagisation and resettlement in east africa. *The Journal of Modern African Studies*, 39(4):623–644. 27

Lewis, W. A. (1954). Unlimited supplies of labour. *Manchester school*. 11

Lin, J. Y. (1990). Collectivization and china's agricultural crisis in 1959-1961. *Journal of Political Economy*, 98(6):1228–1252. 27

Lin, T.-F. and Schmidt, P. (1984). A test of the tobit specification against an alternative suggested by cragg. *The Review of Economics and Statistics*, 66(1):174–177. 72

Lofchie, M. F. (1978). Agrarian crisis and economic liberalisation in tanzania. *The Journal of Modern African Studies*, 16(03):451–475. 39

Lofchie, M. F. (2014). *The political economy of Tanzania : decline and recovery*. PENN/University of Pennsylvania Press, Philadelphia. 26

Lokina, R., Nerman, M., and Sandefur, J. (2011). Poverty and productivity: Small-scale farming in tanzania, 1991-2007. *Preliminary results for International Growth Centre commissioned study*. 21, 22

Lorgen, C. C. (2000). Villagisation in ethiopia, mozambique, and tanzania. *Social Dynamics*, 26(2):171–198. 28, 33

Maccini, S. and Yang, D. (2009). Under the weather: Health, schooling, and economic consequences of early-life rainfall. *American Economic Review*, 99(3):1006–1026. 61

Maidment, R. I., Grimes, D., Allan, R. P., Tarnavsky, E., Stringer, M., Hewison, T., Roebeling, R., and Black, E. (2014). The 30 year tamsat african rainfall climatology and time series (tarcat) data set. *Journal of Geophysical Research: Atmospheres*, 119(18):10,619–10,644. 62

Mascarenhas, A. C. (1977). Resettlement and desertification: The wagogo of dodoma district, tanzania. *Economic Geography*, 53(4):376–380. 40

McCall, M. (1985). *Environmental and agricultural impacts of Tanzania's villagization programme*, pages 123–140. Cambridge University Press, Cambridge, UK. 48

McHenry, D. E. (1979). *Tanzania's Ujamaa Villages: the Implementation of a Rural Development Strategy*. Berkeley. 29, 30, 32, 33, 42

McKenzie, D. J. (2005). Measuring inequality with asset indicators. *Journal of Population Economics*, 18(2):229–260. 63, 64

Menon, N. (2009). Rainfall uncertainty and occupational choice in agricultural households of rural nepal. *Journal of Development Studies*, 45(6):864–888. 53, 55

Miguel, E. (2005). Poverty and witch killing. *Review of Economic Studies*, 72(4):1153–1172. 61

Moser, C. and Felton, A. (2007). The construction of an asset index measuring asset accumulation in ecuador. *Chronic poverty research centre working paper*, (87). 63

National Bureau of Statistics (2014a). Basic demographic and socio-economic profile. Technical report. 18

National Bureau of Statistics (2014b). Press release on highlights of the revised gdp estimates for tanzania mainland. 18

Nunn, N. (2014). Historical development. In *Handbook of Economic Growth*, volume 2, pages 347–402. 25

Osafo-Kwaako, P. (2012). Long run efects of compulsory villagization in tanzania. *PhD Thesis, Kennedy School of Government, Harvard University*. 25, 26, 28, 40

Owens, T., Sandefur, J., and Teal, F. (2011). Poverty outcomes and incomes in ghana and tanzania: 19872007. are macro economists necessary after all? 21, 22

Palacios-Lopez, A. and Lopez, R. (2015). Market imperfections exacerbate the gender gap: the case of malawi. *World Bank Policy Research Working Paper*, (7300). 109

Paxson, C. H. (1992). Using weather variability to estimate the response of savings to transitory income in thailand. *The American Economic Review*, pages 15–33. 60, 61

Ponte, S. (2000). From social negotiation to contract: Shifting strategies of farm labor recruitment in tanzania under market liberalization. *World Development*, 28(6):1017–1030. 80

Porter, C. (2012). Shocks, consumption and income diversification in rural ethiopia. *Journal of Development Studies*, 48(9):1209–1222. 52, 55, 56, 61

Rose, E. (2001). Ex ante and ex post labor supply response to risk in a low-income area. *Journal of Development Economics*, 64(2):371–388. 53, 55

Rosenzweig, M. R. (1988). Risk, private information, and the family. *The American Economic Review*, 78(2):245–250. 60

Rosenzweig, M. R. and Binswanger, H. P. (1993). Wealth, weather risk and the composition and profitability of agricultural investments. *Economic Journal*, 103(416):56–78. 52, 60

Rosenzweig, M. R. and Wolpin, K. I. (1993). Credit market constraints, consumption smoothing, and the accumulation of durable production assets in low-income countries: Investments in bullocks in india. *Journal of Political Economy*, 101(2):223–244. 52

Sadoulet, E., De Janvry, A., and Benjamin, C. (1998). Household behavior with imperfect labor markets. *Industrial Relations: A Journal of Economy and Society*, 37(1):85–108. 90

Sandefur, J. (2013). Africa rising? using micro surveys to correct macro time series. 20

Schneider, L. (2014). *Government of development: Peasants and politicians in postcolonial Tanzania*. Indiana University Press, Bloomington, USA. 26, 43

Shivji, I. G. (2008). *Pan-Africanism or Pragmatism? Lessons of the Tanganyika-Zanzibar Union*. Mkuki na Nyota Publishers, Dar es Salaam, Tanzania Addis Ababa, Ethiopia. 35

Singh, I., Squire, L., and Strauss, J. (1986). *Agricultural household models: extensions, applications, and policy*. Johns Hopkins University Press. 13, 82

Sinha, S., Lipton, M., and Yaqub, S. (2002). Poverty and "damaging fluctuations": how do they relate? *Journal of Asian and African Studies*, 37(2):186–243. 54

Skoufias, E. (1994). Using shadow wages to estimate labor supply of agricultural households. *American Journal of Agricultural Economics*, 76(2):215–227. 87

Skoufias, E., Bandyopadhyay, S., and Olivieri, S. (2015). Occupational diversification as an adaptation to rainfall variability in rural india. 53

Tarnavsky, E., Grimes, D., Maidment, R., Black, E., Allan, R. P., Stringer, M., Chadwick, R., and Kayitakire, F. (2014). Extension of the tamsat satellite-based rainfall monitoring over africa and from 1983 to present. *Journal of Applied Meteorology and Climatology*, 53(12):2805–2822. 62

Timmer, C. P. (2009). A world without agriculture? the historical paradox of agricultural development. *American Enterprise Institute for Public Policy Research*, 1. 11

Vakis, R., Sadoulet, E., de Janvry, A., and Cafiero, C. (2004). Testing for separability in household models with heterogeneous behavior: A mixture model approach. *Department of Agricultural & Resource Economics, UCB*. 90

von Freyhold, M. (1979). *Ujamaa Villages in Tanzania : Analysis of a Social Experiment*. Heinemann. 33, 39, 40

World Bank (2001). *Mexico Land Policy: A Decade After the Ejido Reform*. World Bank. 27

World Bank (2008). World development report 2008: Agriculture for development. 80

World Bank (2013). Africa development indicators: 1960-2012. 52, 80

World Bank (2015). World development indicators 2015. 10, 19, 21, 22, 23, 34

Appendix A

Appendix to Chapter 3

Figure A.1: Locations of villages and urban areas in Tanzania, 1978

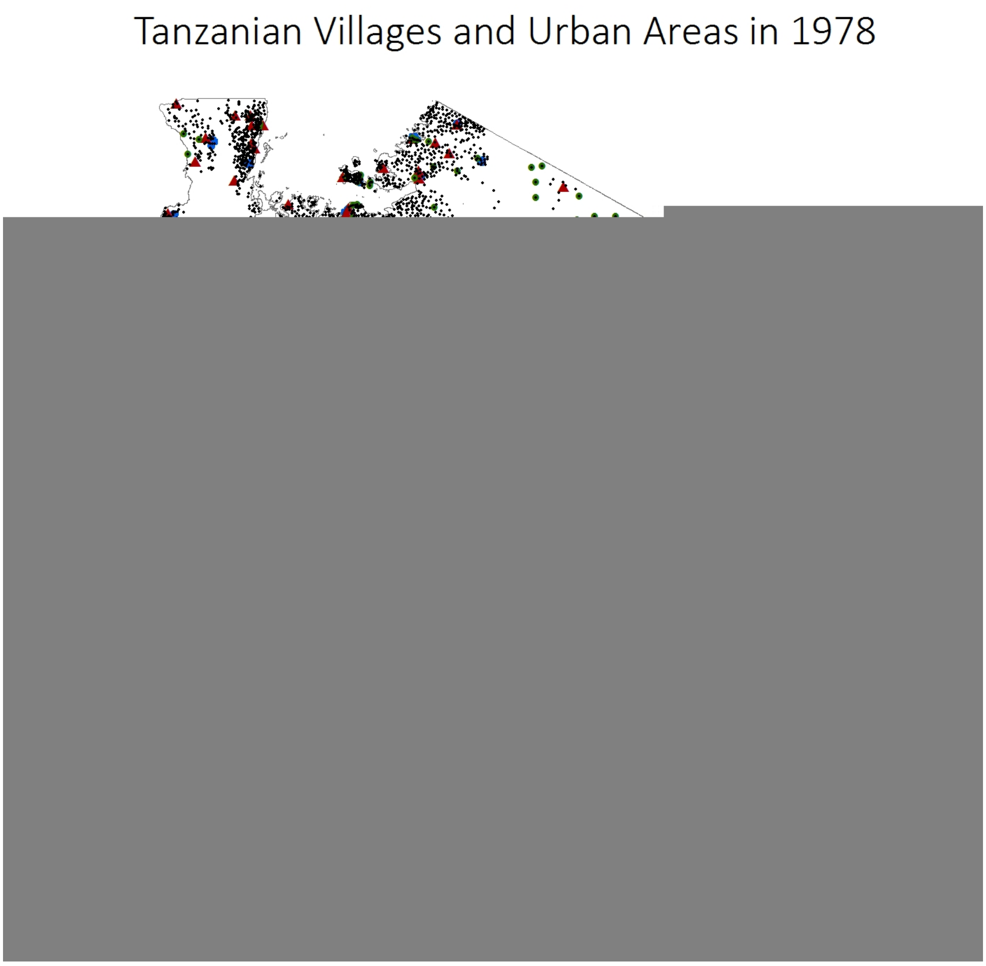


Figure A.2: Rainfall maps of Tanzania

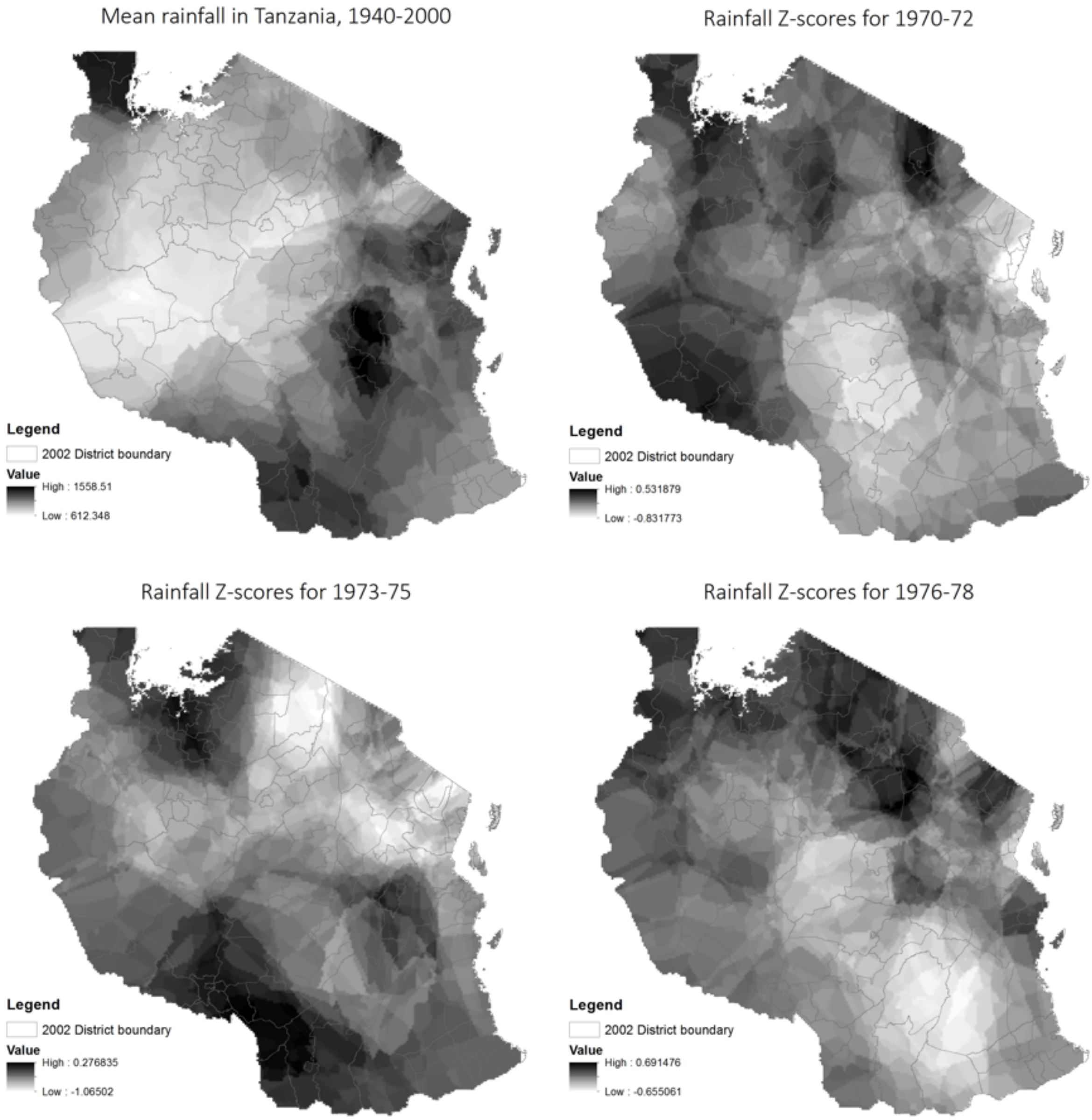


Table A.1: Alternative outcomes (HBS data)

	(1)	(2)	(3)	(4)	(5)	(6)
Sample=>	Full	Full	Non-Dar	Rural	Urban	Farming
Estimator=>	OLS	IV	IV	IV	IV	IV
Panel A: Dependent variable – Log of household per capita income						
Intensity of villagization in 1978	-1.153***	-1.805***	-1.720**	-1.867**	-5.203	-1.686
	(0.213)	(0.594)	(0.694)	(0.918)	(6.358)	(1.100)
R2	0.248	0.242	0.163	0.154	0.000	0.172
Panel B: Dependent variable – Average years of education in the household						
Intensity of villagization in 1978	-1.745***	-2.860***	-2.897***	-3.682***	-1.203	-3.862**
	(0.215)	(0.677)	(0.791)	(1.243)	(2.748)	(1.856)
R2	0.510	0.504	0.476	0.453	0.334	0.454
Panel C: Dependent variable – Household has piped water						
Intensity of villagization in 1978	-0.525***	-1.084***	-1.184***	-1.329***	-2.668	-1.260**
	(0.077)	(0.257)	(0.334)	(0.453)	(2.602)	(0.561)
R2	0.185	0.126	0.114	0.051	-0.106	0.046
Panel D: Dependent variable – Household's primary source of lighting is electricity						
Intensity of villagization in 1978	-0.457***	-0.649***	-0.726***	-0.784***	0.378	-0.634**
	(0.066)	(0.178)	(0.223)	(0.296)	(1.006)	(0.262)
R2	0.332	0.325	0.170	0.129	0.074	0.183
Panel E: Dependent variable – Log of household consumption per adult equivalent						
Intensity of villagization in 1978	-0.377***	-0.530***	-0.506**	-0.573**	0.224	-0.809*
	(0.060)	(0.190)	(0.222)	(0.283)	(1.499)	(0.477)
R2	0.419	0.416	0.268	0.269	0.315	0.238
Panel F: Dependent variable – Asset index						
Intensity of villagization in 1978	-2.196***	-6.964***	-7.305***	-5.346***	-3.096***	-8.604***
	(0.277)	(0.577)	(0.626)	(0.669)	(1.017)	(1.109)
R2	0.550	0.407	0.157	0.057	0.506	0.041
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
N	10,063	10,063	7,107	6,324	3,739	5,302
Cragg-Donald F-statistic		1509.988	909.473	625.060	104.050	330.595

Table A.2: Determinants of log of household consumption (Trimmed HBS sample)

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	Full73	nonDar	Rural	Urban	Farming
Intensity of villagization in 1978	-0.323***	-0.408***	-0.379**	-0.414**	0.902	-0.551
	(0.051)	(0.150)	(0.175)	(0.208)	(1.424)	(0.347)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
N	9,056	9,056	6,465	5,723	3,333	4,764
R2	0.431	0.430	0.284	0.285	0.337	0.251
Cragg-Donald F-statistic		1401.940	846.578	599.924	83.494	294.058

Appendix B

Appendix to Chapter 4

Figure B.1: Household asset index vs. consumption

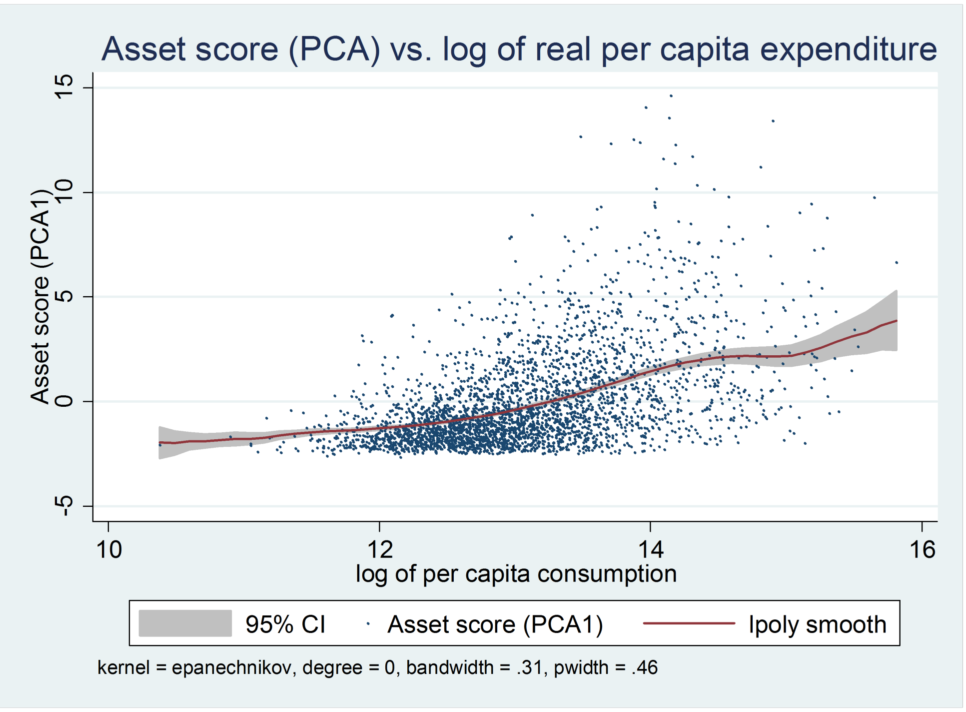


Table B.1: Summary of asset index

		Scoring coefficient	Scoring coefficient squared	Mean value	SD	Mean value for asset terciles: Bottom	Middle	Top
1	Toilet - pit	-0.14	0.02	0.66	0.47	0.80	0.74	0.44
2	Toilet - flush	0.16	0.03	0.08	0.28	0.00	0.02	0.23
3	Toilet - other	0.04	0.00	0.26	0.44	0.20	0.24	0.33
4	Water - piped	0.16	0.03	0.41	0.49	0.10	0.44	0.68
5	Water - surface	-0.18	0.03	0.52	0.50	0.86	0.49	0.21
6	Water - other	0.04	0.00	0.07	0.25	0.04	0.07	0.11
7	Walls of high quality	0.20	0.04	0.48	0.50	0.12	0.47	0.85
8	Floor of high quality	0.26	0.07	0.44	0.50	0.01	0.37	0.94
9	Roof of high quality	0.20	0.04	0.67	0.47	0.23	0.79	0.99
10	Lighting from electricity	0.27	0.07	0.23	0.42	0.00	0.03	0.65
11	Cupboards/chests/wardrobes	0.24	0.06	0.60	1.07	0.05	0.34	1.42
12	Tables	0.14	0.02	1.12	1.15	0.57	1.17	1.62
13	Sofas	0.24	0.06	1.14	2.05	0.02	0.50	2.90
14	Chairs	0.12	0.01	2.94	3.07	1.89	3.06	3.88
15	Cooking pots/kitchen utensils	0.16	0.03	39.51	42.37	24.28	34.44	59.83
16	Electric/gas stove	0.19	0.04	0.08	0.32	0.00	0.02	0.23
17	Iron (Charcoal or electric)	0.25	0.06	0.35	0.55	0.02	0.22	0.82
18	Motor cycle	0.09	0.01	0.04	0.23	0.00	0.02	0.11
19	Motor Vehicles	0.15	0.02	0.05	0.30	0.00	0.00	0.14
20	Computer	0.02	0.00	0.08	1.41	0.01	0.07	0.15
21	Sewing Machine	0.15	0.02	0.13	0.43	0.01	0.06	0.33
22	Refrigerator or freezer	0.25	0.06	0.15	0.41	0.00	0.01	0.44
23	Air-conditioner	0.23	0.05	0.23	0.77	0.00	0.02	0.68
24	Television	0.29	0.08	0.24	0.50	0.00	0.01	0.71
25	Watches	0.20	0.04	0.41	0.73	0.11	0.31	0.83
26	Bicycle	0.03	0.00	0.52	0.78	0.42	0.59	0.54
27	Radio and Radio Cassette	0.13	0.02	0.82	0.74	0.48	0.86	1.12
28	Telephone(mobile)	0.26	0.07	0.98	1.24	0.19	0.72	2.03
29	Donkeys	-0.02	0.00	0.06	0.48	0.09	0.07	0.02
30	Plough etc.	-0.03	0.00	0.06	0.34	0.09	0.08	0.02
31	Fields/Land	-0.11	0.01	1.51	1.74	2.06	1.68	0.79
32	Livestock	-0.02	0.00	3.64	16.12	4.43	4.51	1.98
33	Poultry	0.01	0.00	5.55	13.50	5.93	5.76	4.95
34	House(s)	-0.06	0.00	1.11	0.99	1.33	1.18	0.81

Table B.2: Index of self-reported shocks in NPS1-3 (Pooled data)

		Scoring coefficient	Scoring coefficient squared	Mean value	SD	Mean value for asset terciles: Bottom	Middle	Top
1	Crop disease or pests	0.45	0.20	0.22	0.41	0.00	0.11	0.55
2	Livestock died or were stolen	0.34	0.11	0.21	0.40	0.00	0.21	0.42
3	Large fall in crop sale prices	0.52	0.27	0.23	0.42	0.00	0.04	0.66
4	Large rise in price of food	0.29	0.08	0.67	0.47	0.42	0.75	0.86
5	Large rise in agri input prices	0.53	0.28	0.24	0.43	0.00	0.09	0.65
6	Illness/accident of HH member	0.11	0.01	0.10	0.30	0.03	0.12	0.15
7	Death of HH member	0.08	0.01	0.14	0.35	0.07	0.17	0.19
8	Death of other family member	0.18	0.03	0.40	0.49	0.14	0.56	0.51
9	Robbery, burglary, or assault	0.04	0.00	0.11	0.31	0.08	0.12	0.12

Table B.3: Annual working days by gender

	Farming	Wage labor	Self-employment	Total
Male	25.31	34.20	13.49	73.00
Female	25.97	13.51	13.33	52.82
Total	25.65	23.47	13.41	62.53

Table B.4: Annual working days by age category

	Farming	Wage labor	Self-employment	Total
5-14 years	5.38	0.51	0.44	6.33
15-64 years	34.32	36.16	19.93	90.40
>64 years	41.44	5.49	11.45	58.38
Total	25.65	23.47	13.41	62.53

Table B.5: Annual working days by NPS wave (unit: household)

	Farming	Wage labor	Self-employment	Total
NPS1	110.77	91.65	57.69	260.11
NPS2	114.25	101.13	59.64	275.03
NPS3	111.68	109.80	58.11	279.59
All NPS waves	112.27	102.19	58.49	272.95

Table B.6: Annual working days by rural/urban location (unit: household)

	Farming	Wage labor	Self-employment	Total
Rural	157.5	60.35	45.50	263.81
Urban	27.46	179.87	82.61	289.94
Total	112.7	102.19	58.49	272.95

Figure B.2: Annual rainfall experienced by NPS households

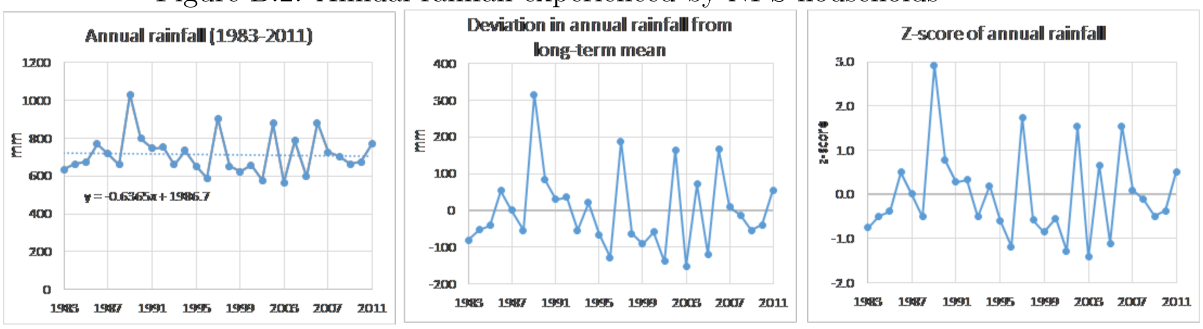


Table B.7: Annual working days by diversification status and rural/urban location (unit: household)

	Farming	Wage labor	Self-employment	Total
Rural				
Agri only	182.24	0.00	0.00	182.24
Agri and non-agri	175.94	77.80	69.68	323.42
Non-agri only	0.00	143.09	52.96	196.06
Total	157.95	60.35	45.50	263.81
Urban				
Agri only	107.93	0.00	0.00	107.93
Agri and non-agri	70.77	161.20	109.59	341.57
Non-agri only	0.00	204.55	77.25	281.80
Total	27.46	179.87	82.61	289.94
All				
Agri only	175.75	0.00	0.00	175.75
Agri and non-agri	152.52	96.37	78.57	327.46
Non-agri only	0.00	189.34	71.24	260.57
Total	112.27	102.19	58.49	272.95

Figure B.3: Kernel density estimate of rainfall Z-score

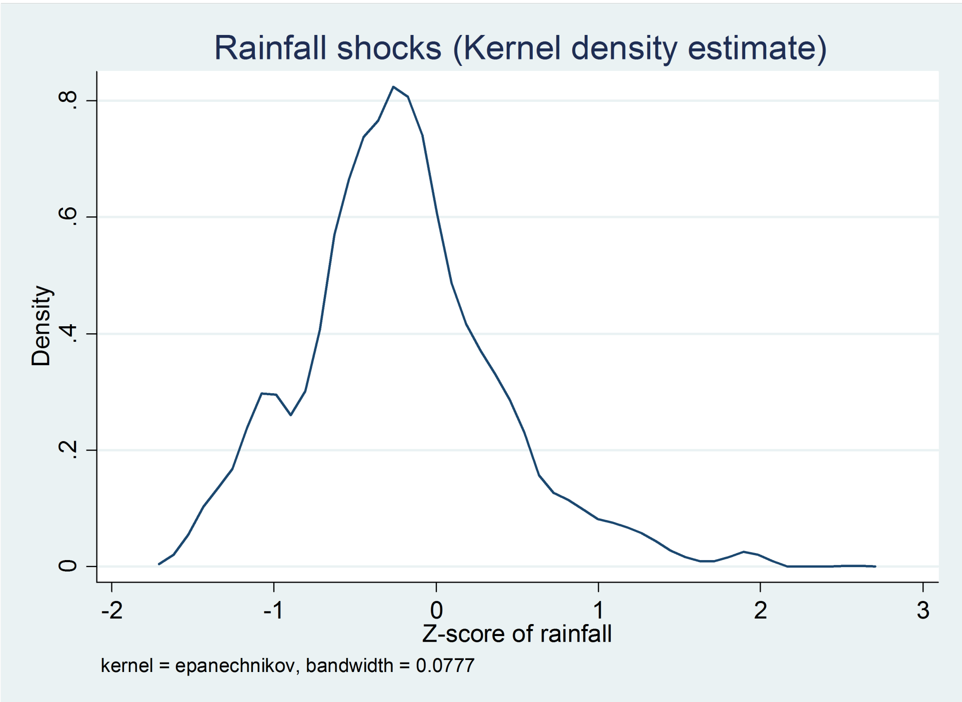


Table B.8: Mean deviation in rainfall from 1981-2007 mean by region and year(Z-scores)

Region	2008	2009	2010	2011	2012	2013
Dodoma	-0.11	-0.33	-0.44	0.30	0.51	-0.67
Arusha	-0.15	-0.26	-0.23	-0.15	0.30	-0.21
Kilimanjaro	0.12	0.05	-0.15	0.12	0.11	0.05
Tanga	-0.63	-0.82	-0.55	-0.24	0.15	-0.62
Morogoro	-0.20	-0.31	-0.46	1.07	0.30	-0.76
Pwani	-0.09	-0.91	0.00	0.77	0.71	-0.78
Dar es salaam	-0.23	-1.37	-0.16	0.64	0.88	-0.96
Lindi	0.16	-0.58	-0.21	0.70	0.74	-0.78
Mtwara	0.31	-0.14	-0.11	0.83	0.68	-0.71
Ruvuma	0.27	-0.37	-0.75	-0.12	0.19	-1.11
Iringa	0.35	-0.26	-1.10	0.58	0.00	-0.74
Mbeya	0.21	0.16	-0.98	0.44	0.07	-0.41
Singida	0.15	0.10	-0.64	0.12	0.26	-0.18
Tabora	-0.30	0.27	-0.60	-0.16	0.54	-0.26
Rukwa	0.24	0.19	-1.05	0.13	0.03	-0.23
Kigoma	-0.11	0.34	-0.19	-0.11	0.32	0.21
Shinyanga	0.18	0.69	-0.20	0.36	1.25	-0.14
Kagera	0.44	0.79	0.95	1.55	1.09	-0.36
Mwanza	0.21	0.97	0.30	1.00	1.17	-0.11
Mara	0.73	1.74	0.46	2.19	1.43	0.15
Manyara	-0.17	-0.28	-0.20	0.01	0.42	-0.39
Kaskazini Unguja	-0.65	-0.67	-0.15	-0.06	0.44	-0.87
Kusini Unguja	-0.49	-1.20	-0.16	0.04	0.58	-1.08
Mjini/Magharibi Unguja	-0.48	-0.62	-0.37	0.19	0.44	-1.07
Kaskazini Pemba	-0.87	-1.15	-0.48	-0.80	-0.16	0.14
Kusini Pemba	-0.96	-1.24	-0.43	-0.56	-0.21	0.21

Table B.9: Test of separability of household production and consumption

	OLS		OLS		FE	
	β	s.e.	β	s.e.	β	s.e.
Household size	17.089***	(0.426)	17.456***	(0.428)	12.513***	(1.117)
Share of children	50.676***	(14.706)	46.130***	(14.544)	-34.547	(26.931)
Share of prime male members	93.241***	(10.853)	74.614***	(10.738)	6.518	(21.360)
Share of prime female members	73.928***	(10.809)	64.441***	(10.671)	-2.007	(21.279)
Log of median agricultural wage in district	-1.707	(2.134)	-0.820	(2.114)	7.521***	(2.359)
Land operated by household, acres	2.751***	(0.116)	2.483***	(0.114)	1.830***	(0.153)
Mean age of members, years	1.481***	(0.186)	1.437***	(0.184)	-0.079	(0.407)
Mean education of members, years	-4.674***	(0.543)	1.889***	(0.619)	0.969	(1.354)
NPS wave 2	-4.083	(2.859)	-7.494**	(3.213)		
NPS wave 3	0.074	(2.841)	0.537	(2.963)		
Asset index			-8.084***	(0.595)	-0.108	(1.333)
Shock index based on all 19 shocks			9.751***	(0.778)	6.472***	(0.923)
Z-score of rainfall in previous 12 months			-3.380*	(1.768)	-5.689***	(1.918)
credit			-6.247*	(3.753)	0.841	(4.748)
Distance to town, km			0.231***	(0.036)	0.676***	(0.218)
Rural			36.397***	(3.112)	-5.290	(6.117)
Latitude			-1.557	(1.966)	3.083	(4.325)
Longitude			-7.661***	(2.122)	2.462	(4.826)
Annual Mean Temperature (°C * 10)			-0.608***	(0.218)	1.380	(1.126)
Annual Precipitation (mm)			-0.004	(0.005)	-0.000	(0.005)
Elevation (m)			-0.044***	(0.013)	0.071	(0.069)
Constant	-41.502*	(23.022)	345.767***	(107.095)	-461.060	(368.475)
Observations	11718		11415		11415	

Standard errors in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$

Table B.10: Multinomial probit model of household diversification strategies (marginal effects)

	Agri only		Agri & Non-agri		Non-agri only	
	β	s.e.	β	s.e.	β	s.e.
Z-score of rainfall in previous 12 months	0.013	0.013	0.023	0.014	-0.036***	0.010
CV of rainfall (1983-2007)	-1.156**	0.353	0.349	0.395	0.808*	0.329
Rural	0.199***	0.015	0.051*	0.020	-0.249***	0.017
Distance to nearest town of 20,000+ (km) X 100	0.067**	0.019	0.013	0.022	-0.08**	0.018
Average years of education in HH	-0.024***	0.003	0.012***	0.004	0.013***	0.002
Household size	-0.008***	0.002	0.026***	0.003	-0.018***	0.002
Household dependency ratio	0.128***	0.030	-0.1***	0.033	-0.028	0.023
Asset index	-0.061***	0.005	0.048***	0.004	0.014***	0.002
Index of self-reported shocks	0.024***	0.004	0.044***	0.005	-0.068***	0.005
Household has an outstanding loan	-0.071***	0.023	0.042	0.025	0.03	0.019
Migrant household	0.015	0.029	-0.068**	0.029	0.053**	0.021
Wave 2	-0.081***	0.013	0.001	0.014	0.08***	0.010
Observations	6,548		6,548		6,548	

All standard errors are clustered at the enumeration area. The correlations between the categories are assumed to be independent. The standard errors are assumed to be homoscedastic. Standard errors in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$.

Table B.11: Heckman model of labor supply (Diagnostics)

	Farming (Days)		Wage labor (Days)		Self-employment (Days)	
	s.e.	β	s.e.	s.e.	β	s.e.
Z-score of rainfall in previous 12 months	6.119	(7.322)	4.713	(4.110)	-3.356	(2.073)
Asset index	-17.622***	(1.031)	22.265***	(2.525)	4.670***	(0.915)
Shock index	16.337***	(3.411)	-10.047***	(1.580)	1.466	(1.120)
Rural	48.707***	(9.141)	-47.991***	(7.095)	-13.083***	(3.872)
Household size, adult members	44.564***	(4.460)	17.544**	(5.046)	6.985***	(1.504)
Dependency ratio	-52.021***	(11.818)	25.574*	(11.783)	1.716	(7.706)
Mean education of household members, years	0.523	(1.624)	4.710**	(1.637)	-0.653	(0.849)
Mean age of household members, years	-0.331*	(0.157)	-1.199***	(0.332)	-0.020	(0.105)
Mean annual rainfall, mm	0.076*	(0.034)	0.009	(0.025)	-0.005	(0.012)
Household head is female	-19.775***	(3.987)	-12.999	(9.534)	3.990	(2.795)
Split-off household	-12.994*	(6.013)	1.139	(8.309)	-16.737***	(2.686)
Distance to district HQ, km	0.075	(0.142)				
Distance to major road, km			-0.208	(0.138)		
Distance to town, km					-0.080	(0.050)
Constant	-68.743	(43.544)	192.872***	(34.041)	110.933***	(15.146)
Observations	7728		5640		6137	

Standard errors in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$. Dummies for administrative zones are included in all specifications.

Table B.12: Heckman model of labor supply (Rural subsample)

	Farming (Days)		Wage labor (Days)		Self-employment (Days)	
	β	s.e.	β	s.e.	β	s.e.
Outcome equation						
Z-score of rainfall in previous 12 months	5.130*	(2.886)	2.637	(4.851)	-8.087**	(3.725)
Covariates	Yes		Yes		Yes	
Constant	-57.445***	(14.398)	332.521*	(175.026)	125.764***	(28.999)
Selection equation						
Instruments						
Distance to district HQ, km	0.004***	(0.001)			0.001**	(0.000)
Distance to major road, km			-0.003***	(0.001)		
Covariates	Yes		Yes		Yes	
Constant	1.778***	(0.193)	-0.631***	(0.111)	0.369***	(0.109)
Mills						
Lambda	17.204	(18.989)	14.839	(92.022)	-66.279	(49.627)
Observations	7880		7880		7880	

Standard errors in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$. The covariates in the outcome and the selection equations are the same as the ones used in Table 4.

Table B.13: Heckman model of labor supply (Urban subsample)

	Farming (Days)		Wage labor (Days)		Self-employment (Days)	
	β	s.e.	β	s.e.	β	s.e.
Outcome equation						
Z-score of rainfall in previous 12 months	-3.532	(14.674)	40.298	(101.823)	2.772	(8.135)
Covariates	Yes		Yes		Yes	
Constant	166.637	(113.162)	-414.446	(820.091)	48.314	(37.017)
Selection equation						
Instruments						
Distance to district HQ, km	-0.000	(0.002)			0.029^{**}	(0.014)
Distance to major road, km			-0.013	(0.027)		
Covariates	Yes		Yes		Yes	
Constant	-0.690	(0.451)	0.404	(0.381)	0.114	(0.373)
Mills						
Lambda	-97.582	(79.182)	1039.882	(1388.231)	-37.391	(59.438)
Observations	314		314		314	

Standard errors in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$. The covariates in the outcome and the selection equations are the same as the ones used in Table 4.

Table B.14: Heckman model of labor supply (Original households only)

	Farming (Days)		Wage labor (Days)		Self-employment (Days)	
	β	s.e.	β	s.e.	β	s.e.
Outcome equation						
Z-score of rainfall in previous 12 months	4.870^{*}	(2.728)	-0.339	(6.315)	-11.261^{***}	(3.671)
Covariates	Yes		Yes		Yes	
Constant	-88.018^{***}	(14.952)	149.512	(205.803)	142.321^{***}	(20.389)
Selection equation						
Instruments						
Distance to district HQ, km	0.004^{***}	(0.001)				
Distance to major road, km			-0.002^{***}	(0.001)		
Distance to town, km					-0.001^{**}	(0.000)
Covariates	Yes		Yes		Yes	
Constant	1.782^{***}	(0.160)	-0.543^{***}	(0.107)	0.736^{***}	(0.107)
Mills						
Lambda	66.021^{***}	(12.085)	274.025^{***}	(103.622)	-95.858^{**}	(43.054)
Observations	9450		9450		9450	

Standard errors in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$. The covariates in the outcome and the selection equations are the same as the ones used in Table 4.

Table B.15: Heckman model of labor supply (log-log model)

	Farming (Days)		Wage labor (Days)		Self-employment (Days)	
	β	s.e.	β	s.e.	β	s.e.
Outcome equation						
Z-score of rainfall in previous 12 months	0.055^{**}	(0.023)	0.030	(0.025)	-0.097^{***}	(0.032)
Covariates	Yes		Yes		Yes	
Constant	2.749^{***}	(0.129)	4.848^{***}	(0.185)	4.534^{***}	(0.204)
Selection equation						
Instruments						
Log of distance to district HQ, km	0.241^{***}	(0.016)	-0.059^{***}	(0.018)		
Log of distance to town, km					-0.049^{***}	(0.013)
Covariates	Yes		Yes		Yes	
Constant	0.859^{***}	(0.139)	0.267	(0.898)	0.773^{***}	(0.101)
Mills						
Lambda	-0.557^{***}	(0.095)	-0.498^{***}	(0.109)	-0.543	(0.386)
Observations	12124		12124		12124	

Standard errors in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$. The covariates in the outcome and the selection equations are the same as the ones used in Table 4.

Table B.16: Heckman model of labor supply (NPS2 and NPS3 only)

	Farming (Days)		Wage labor (Days)		Self-employment (Days)	
	β	s.e.	β	s.e.	β	s.e.
Outcome equation						
Z-score of rainfall in previous 12 months	7.586**	(3.043)	1.575	(4.441)	-5.825*	(3.017)
Covariates	Yes		Yes		Yes	
Constant	-122.631***	(17.771)	526.131**	(209.129)	126.971***	(16.676)
Selection equation						
Distance to district HQ, km	0.003***	(0.001)				
Distance to major road, km			-0.003***	(0.001)		
Distance to town, km					-0.001**	(0.000)
Covariates	Yes		Yes		Yes	
Constant	0.815***	(0.147)	-0.179*	(0.109)	1.126***	(0.203)
Mills						
Lambda	96.526***	(13.626)	-55.174	(90.471)	-80.961**	(36.740)
Observations	8910		8910		8910	

Standard errors in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$. The covariates in the outcome and the selection equations are the same as the ones used in Table 4.

Table B.17: Heckman model of labor supply (NPS1 and NPS2 only)

	Farming (Days)		Wage labor (Days)		Self-employment (Days)	
	β	s.e.	β	s.e.	β	s.e.
Outcome equation						
Z-score of rainfall in previous 12 months	12.642***	(3.449)	-5.398	(7.327)	-12.271*	(6.672)
Covariates	Yes		Yes		Yes	
Constant	-74.437***	(16.437)	372.975	(231.700)	202.269***	(56.223)
Selection equation						
Distance to district HQ, km	0.002***	(0.001)				
Distance to major road, km			-0.002***	(0.001)		
Distance to town, km					-0.001	(0.000)
Covariates	Yes		Yes		Yes	
Constant	2.253***	(0.185)	-0.532***	(0.123)	0.600***	(0.124)
Mills						
Lambda	62.706***	(12.849)	124.781	(100.019)	-217.736*	(114.814)
Observations	7127		7127		7127	

Standard errors in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$. The covariates in the outcome and the selection equations are the same as the ones used in Table 4.

Appendix C

Appendix to Chapter 5

Table C.1: Jacoby test of separability at the individual level

	(1)	(2)	(3)	(4)	(5)
Log of daily wage received by individual, TSH	0.280***	0.264***	0.267***	0.234***	0.227***
	(0.035)	(0.034)	(0.034)	(0.028)	(0.025)
Age	-0.007***	-0.007***	-0.007***	-0.008***	-0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Sex	-0.423***	-0.411***	-0.413***	-0.351***	-0.316***
	(0.065)	(0.061)	(0.061)	(0.057)	(0.059)
Log of Land owned by household, acres		0.260***	0.278***	0.275***	0.282***
		(0.057)	(0.058)	(0.058)	(0.059)
Log of HH size			-0.110	-0.168	-0.287***
			(0.113)	(0.108)	(0.100)
HH head is female				-0.360***	-0.387***
				(0.094)	(0.084)
Rural				-0.421***	-0.523***
				(0.136)	(0.117)
Distance to major road, km				-0.005***	-0.004**
				(0.002)	(0.002)
Annual mean temperature, Celsius X 10					-0.003
					(0.005)
Annual precipitation, mm					-0.001***
					(0.000)
Elevation, meters					0.000
					(0.000)
Constant	3.806***	3.564***	3.685***	4.597***	6.097***
	(0.300)	(0.285)	(0.328)	(0.279)	(1.295)
N	1,778	1,778	1,778	1,778	1,778
R-squared	0.11	0.16	0.16	0.20	0.29
Test of separability, F statistic	479.54	477.93	343.05	384.06	475.74
Test of separability, p-value	0.00	0.00	0.00	0.00	0.00

Standard errors in parentheses are clustered at the district level. Column 5 also contains dummies for 7 geographic regions. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table C.2: Jacoby Test of separability for hired labor

	(1)	(2)	(3)	(4)	(5)
Log (Wage paid for hired labor, TSH)	0.255*	0.308**	0.358***	0.227*	0.286***
	(0.133)	(0.118)	(0.117)	(0.118)	(0.088)
Log of Land owned by household, acres		0.253***	0.308***	0.319***	0.256***
		(0.030)	(0.033)	(0.029)	(0.026)
Log of HH size			-0.406***	-0.436***	-0.516***
			(0.057)	(0.051)	(0.043)
HH head is female				-0.234***	-0.224***
				(0.043)	(0.037)
Rural				-0.417***	-0.512***
				(0.089)	(0.062)
Distance to major road, km				-0.006***	-0.004***
				(0.002)	(0.001)
Annual mean temperature, Celsius X 10					0.000
					(0.003)
Annual precipitation, mm					-0.001***
					(0.000)
Elevation, meters					0.000*
					(0.000)
Constant	4.175***	3.364***	3.419***	5.134***	5.329***
	(1.119)	(0.989)	(0.993)	(1.020)	(1.080)
N	2,624	2,624	2,624	2,624	2,624
R-squared	0.01	0.08	0.10	0.17	0.33
Test of separability, F statistic	840.15	641.09	367.62	88.02	33.45
Test of separability, p-value	0.00	0.00	0.00	0.00	0.00

Standard errors in parentheses are clustered at the district level. Column 5 also contains dummies for 7 geographic regions. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$