Three Essays Examining the Political, Social, and Economic Factors Determining Agricultural Productivity and Resource Allocation

By

Timothy Mtumbuka

Dissertation

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY

IN DEVELOPMENT POLICY

2024

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Professor Merfeld, Joshua D.

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Abstracts

Chapter 1:

Political alignment and re-distributive politics in agricultural input subsidy programs

While existing literature on distributive politics mainly focuses on allocation across constituencies, regions, and ethnic groups, internal distribution within administrative frameworks is susceptible to elite capture, particularly through political alignment between central and local governments. This study examines the impact of such political alignment on the redistribution of input coupons within constituencies in Malawi's agricultural subsidy program. Using nationwide Integrated Household Survey (IHS) data and tripartite election results, we employ a difference-in-differences design. The results support the co-partisan hypothesis, showing that input coupons are disproportionately allocated to ruling party constituencies and wards. Additionally, redistribution within constituencies, particularly between politically aligned and non-aligned wards, also strongly supports the co-partisan hypothesis. Specifically, households in ruling party wards are notably more likely to receive input coupons compared to their counterparts in opposition wards, regardless of the constituency's political affiliation.

Keywords: agriculture, input subsidies, elections, politics
JEL Codes: D72, P43, Q12, Q18

Chapter 2:

Balancing Efficiency and Equity: Analyzing Customary Land Tenure Systems in Farmland Allocation

This paper explores the role of customary tenure systems in redistributing farmland resources within developing countries, which often face challenges such as market imperfections. Focusing on Malawi, where the farmland market is underdeveloped and land acquisition predominantly occurs through customary tenure systems, the study utilizes data from the National Integrated Household Panel Survey. The study uses Stochastic frontier analysis (SFA) and binary choice models to analyze the data. The findings reveal that higher farming ability is significantly and negatively associated with the likelihood of participating in inherited farmland. In contrast, farmland allocated by chiefs is positively associated with farming ability. Thus, while inherited land is inefficient in its allocation, farmland distributed by chiefs appears to be more efficient, as it correlates with positive farming ability. The total household landholding size does not significantly affect participation in customary farmland tenure systems. These results suggest that customary tenure systems promote equitable land distribution despite the inefficiencies observed with inherited farmland.

Keywords: Customary; Land tenure; Stochastic frontier; Farming ability; Efficiency, Equity
JEL Codes: D63, O13, Q15, R14

Chapter 3:

The Impact of Seasonal Irrigation on Agricultural and Labor Productivity

This paper investigates the impact of seasonal plot-level irrigation on agricultural and labor productivity in Rwanda. Using household-plot-year fixed effects regressions and data from Rwanda's Land and Water Husbandry (LWH) project, the study examines the effects of irrigation during rainy seasons A (September to February) and B (March to June) on crop yield and labor productivity. Results indicate that irrigation significantly enhances productivity more during season A than season B. Specifically, during season A, irrigation increases yields for all crops combined by 43.1% and 37.3% for legumes compared to non-irrigated plots, while in season B, irrigation increases the productivity of legumes by 23.4% compared to non-irrigated plots. Additionally, irrigation increases household and total labor productivity by 14.1% and 13.6%, respectively, compared to non-irrigated fields in season A, with no significant effect observed in season B. The findings highlight the differential impacts of irrigation across seasons, emphasizing the importance of optimizing irrigation practices to enhance crop yields and resource efficiency. These results underscore the need for targeted policy interventions for efficient seasonal irrigation to ultimately improving food security and economic stability in drought-prone regions.

Keywords: Seasonal irrigation, Agricultural productivity, Input use intensity

JEL Codes: Q12, Q16, Q18

Dedication

To my family, for their unwavering support and love.

To my mentors and colleagues, for their guidance and inspiration.

Acknowledgements

I would like to express my deepest gratitude to my supervisor, Prof. Merfeld Joshua D., for his unwavering support, guidance, and encouragement throughout my PhD journey. Your insightful feedback and dedication have been invaluable to my academic and personal growth.

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Special thanks go to my classmates and colleagues, whose fellowship, collaboration, and moral support have made this journey more enjoyable and intellectually stimulating. Your shared experiences and mutual encouragement have been an integral part of my success.

Last but not least, thanks to Deliwe, Peter, and Gracious for their social support. I am greatly indebted to you.

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Chapter 1

Political alignment and re-distributive politics in agricultural input subsidy programs

1.1 Introduction

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Agriculture remains a significant component of GDP in many developing countries, contributing over 20% to the total GDP of Sub-Saharan Africa. It also accounts for about 16.8% and 7.4% of GDP in India and China, respectively, despite these countries undergoing substantial structural changes and shifts towards non-agricultural sectors. In contrast, agriculture contributes less than 4% to GDP in North America and

Western Europe, with only Spain exceeding 2% in agriculture's GDP share [1]. Given agriculture's substantial role in these economies, input subsidy programs (ISPs) are a major focus of public agricultural spending, particularly in Sub-Saharan Africa. Although ISP funding decreased in the 1990s, these programs have become a prominent agricultural policy, with over one billion USD allocated annually in Sub-Saharan Africa (Jayne et al., 2018; Jayne and Rashid, 2013; Arndt et al., 2016). Thus, understanding the allocation of ISPs is crucial for evaluating their impact on poverty reduction and agricultural productivity.

Agricultural subsidy programs have been widely adopted by governments in developing countries to reduce poverty, increase agricultural production, and ensure food and nutrition security (Pan and Christiaensen, 2012; Dionne and Horowitz, 2016). However, these programs are often subject to political manipulation, with ruling parties allocating resources in a way that favors their electoral gain (Cole, 2009; Mason et al., 2013; Harris and Posner, 2019). Some research highlights targeted distribution to specific political groups (Mason et al., 2013; Cox and McCubbins, 1986; Cox, 2009) and swing voters (Cole, 2009; Kvartiuk and Herzfeld, 2021; Dixit and Londregan, 1996; Khemani, 2007; Lindbeck and Weibull, 1987), while other studies suggest a more neutral distribution across ethnic groups (Dionne and Horowitz, 2016; Brazys et al., 2015).To better understand distributive politics in agricultural subsidy programs, this study examines how elections impact fertilizer allocation in Malawi's extensive input subsidy program. Historically, Malawi, an early adopter of agricultural input subsidies in Sub-Saharan Africa (Chinsinga and Poulton, 2014), has experienced uneven distribution of subsidies, often influenced by political considerations (Dorward et al., 2010, 2008). Regional disparities in coupon distribution are linked to political influence, with northern regions receiving more coupons during parliamentary visits or stays, highlighting the role of regional elites in lobbying efforts (Chinsinga and Poulton, 2014).

In response to allocation inequality in Malawi's input subsidy program, the country reintroduced local government structures during its first tripartite elections in 2014, where voters simultaneously elected the head of state, assembly members, and local councilors. Local government structures are crucial for promoting equitable distribution of resources by enhancing local responsiveness, accountability, and participation (Gopal et al., 2008; Cities and , UCLG; Kimenyi, 2018). However, their effectiveness in achieving equality depends on factors such as design, implementation, political capture, and the capacity of local institutions (Singhania, 2022; Faguet, 2014; Bardhan and Mookherjee, 2006). Therefore, this study investigates how election outcomes influenced the distribution of input subsidies. By combining national

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[1] https://ourworldindata.org/grapher/agriculture-share-gdp

election results with data from the Integrated Household Survey (IHS), we analyze the impact of political alignment at both constituency and ward levels on subsidy allocation. Members of parliament represent constituencies, while wards are the smallest units within constituencies, represented by local councilors. We compare constituencies and wards won by the ruling party (Treated group) with those won by other parties (Comparison group) before and after the 2014 elections to assess the distributive effects of political alignment, noting that post-election alignment between local and national parties was unknown at the time of the election.

The study's primary findings indicate a consistent pattern of political alignment at both constituency and ward levels. Households in constituencies and wards aligned with the ruling party are 5.7 and 7.3 percentage points more likely, respectively, to have received input coupons in the three years before the survey, compared to those in non-ruling party areas. This suggests a strategy of favoring co-partisans in both central and local government allocations. Although similar trends are observed in the current year's distribution, these results are not statistically significant. Additionally, households in ruling party constituencies and wards are 4.0 and 3.1 percentage points more likely, respectively, to use fertilizer. These patterns reflect Malawi's political dynamics, where regional voting behavior is crucial. A ruling party in the south focuses on consolidating regional support and gaining ground in the north, while a party strong in the central region aims to solidify local support and win in the north for electoral success (Chinsinga and Poulton, 2014).

This study on input voucher allocation in Malawi's agricultural subsidy programs focuses on micro-level dynamics within constituencies rather than broader regional or constituency-level allocations. The study investigates how political alignment between central and local governments affects input coupon distribution by utilizing a difference-in-differences design with Integrated Household Survey (IHS) data and results from the country's first tripartite elections. Analyzing simultaneous election data at the presidential, parliamentary, and local council levels isolates the impact of political alignment on resource allocation, offering a detailed view of political incentives across administrative tiers. The study not only explores the distribution of subsidies but also examines fertilizer usage, providing additional insights into the effectiveness of subsidies. Its findings highlight a consistent co-partisan allocation strategy and enhance understanding of how political influence shapes subsidy distribution, contributing valuable empirical evidence to the literature on distributive politics.

The remaining chapters cover the historical background and conceptual framework, a review of relevant existing literature, data, and identification methodology. The last but one chapter presents and discusses the results and, finally, the conclusion and policy recommendations.

1.2 Background

1.2.1 State politics and system of government

Malawi has remained a presidential republic since independence in 1964 and embraced multiparty democracy in 1994. The president heads the state and national government – i.e. executive power is vested in the president – while legislative power is exercised by both the government and the National Assembly. Based on the revised constitution adopted in 1995, the president and vice president are elected through the ballot every five years and only allowed a maximum of two terms. The president can select the second vice president at his discretion, but he/she should be from a different party. The president also appoints the cabinet, whose membership is not limited to the legislature. The National Assembly constitutes 193 members representing single-seat constituencies of the country, and these members are also elected for a five-year term but have no term limits. After the start of multiparty democracy, Malawi adopted a new constitution grounded on principles of participatory democracy and initiated key steps towards accelerating participatory democracy. One notable action was the development and approval of the national decentralization policy by the cabinet in October 1998 [2], aimed at expediting the allocation of administration and political authority to the district level, among other pillars. Under this decentralization arrangement, district assemblies form a new local government system. Initially, there were 860 wards within the 193 constituencies, but since the 2010 amendment to the local government act, the number decreased to 461 wards represented by elected councilors. [3]

1.2.2 Farm input subsidy program

Malawi's agricultural input subsidy program was originally conceived as a social protection program to increase food security and reduce poverty though increased agricultural productivity. The program started in 1992 as the Drought Recovery Inputs Project (DRIP) and has undergone several adjustments to the current Agriculture Input Program (AIP). Under the program, selected resource-poor farming households receive a subsidy – by means of vouchers – for two bags (50kgs) of fertilizer, 5kgs of legume seed, and

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[2] https://leap.unep.org/countries/mw/national-legislation/local-government-act-1998-no-42-1998

[3] https://npc.mw/wp-content/uploads/2020/07/Decentralization-policy.pdf

10kgs of maize seed. The beneficiary selection process changed in 2008/2009 by introducing open meetings during beneficiary registration and distribution of the coupons. This change was aimed at ensuring that stakeholders are apprised of the program as well as empowering community-based targeting rather than giving power to the traditional authorities and village headmen (Dorward et al., 2010).

The selection criteria are as follows: (i) the household should own at least 0.4ha of land; (ii) the beneficiary should not be labor constrained, i.e., should be between the age of 18 and 64 and able to work in the field; (iii) one beneficiary is eligible per household; and (iv) the household should be resident in the village verified by the village chief (Juergens and Pellerano, 2016). The implementation arrangements of the program in the 2015/16 season underwent significant changes initiated by the central government. These changes included: (i) incorporating the private sector in the retailing of subsidized fertilizer in certain districts; (ii) implementing a randomization process for beneficiary targeting at the village level, but not necessarily in the overall allocation of subsidies across space; and (iii) reducing the subsidy from 96.8% in the 2014/15 season to 82.1% in the 2015/16 season. Prior to the 2015/16 season, beneficiaries were required to contribute MK500 per 50kg bag of fertilizer, while seed packages were provided free of charge. However, the 2015/16 reforms increased the contribution to MK3,500 per bag of 50kg fertilizer, MK1,000 per 5kgs of improved maize variety, and MK500 per 2kg bag of legume seeds (Chirwa et al., 2016). The randomization process involved districts updating the names of farming households per village and submitting them to the relevant ministry headquarters for verification. After the verification process, the list was returned to the districts to ensure its accuracy before the actual randomization took place. Subsequently, the list of selected beneficiaries was sent back to the districts for vetting. Once the district confirmed that the intended beneficiaries had been selected, they would recommend the printing of beneficiary registers for the distribution of coupons (Ministry of Agriculture, 2018). As such, the government remains heavily involved in the overall selection process. Table A1.1 in the appendix provides details on the restructuring of the program since its inception.

1.3 Theoretical Framework and Literature Review

Understanding the dynamics of distributive politics within agricultural subsidy programs necessitates a multifaceted approach that integrates theoretical frameworks with empirical evidence. This section synthesizes relevant theoretical perspectives and empirical findings to elucidate the factors influencing resource allocation decisions in such programs.

In distributive politics, two prominent theoretical frameworks offer insights into the resource allocation strategies employed by political actors. The Core Voter Model posits that political incumbents, particularly those seeking reelection, prioritize allocating resources to their core supporters to secure electoral backing (Dreher et al., 2019). This model emphasizes the significance of clientelism, wherein ruling party candidates strategically direct resources towards their electoral strongholds or regions where they have considerable influence over voters (Casey, 2015; Cox and McCubbins, 1986; Dreher et al., 2019). For instance, ad hoc agricultural disaster payments in the USA targeted constituencies aligned with the ruling party, bolstering electoral turnout and support (Simonovits et al., 2021). In contrast, the Swing Voter Model suggests that incumbents may strategically direct resources toward swing voters, especially when core supporters cannot penalize deviations in resource allocation (Stokes, 2005). Empirical studies supporting this model demonstrate increased resource allocation to swing districts during election years (Lindbeck and Weibull, 1987; Cole, 2009).

Furthermore, by integrating temporal dynamics into these models, the Electoral Business Cycles Theory predicts fluctuations in resource allocation patterns based on election proximity (Dubois, 2016; Franzese Jr, 2002). Despite evidence favoring swing voters across elections, studies also reveal instances of rewarding co-partisans during the initial years of new governments (Kramon and Posner, 2013; Cole, 2009). Empirical evidence from various studies provides further insights into distributive politics within agricultural subsidy programs. Temporal dynamics and the electoral context significantly influence the distribution of resources, with governments often favoring constituencies aligned with ruling elites, irrespective of ethnic or regional affiliations (Ahlerup and Isaksson, 2015). Moreover, institutional factors play a pivotal role, as centralized decision-making exacerbates favoritism, while decentralization minimizes political bias (Arulampalam et al., 2009; Fisman, 2001).

Social dynamics and information dissemination also shape resource allocation, with social networks facilitating subsidy access and information dissemination, reducing political favoritism ()(Gupta et al., 2020; Patel et al., 2021). Additionally, gender dynamics influence subsidy access and benefits, highlighting disparities based on gender roles and household power dynamics (Tufa et al., 2022) Smith et al., 2020). Challenges exist in generalizing distributive implications based on single goods or outcomes, emphasizing the importance of analyzing multiple goods to discern different effects (Kramon and Posner, 2013).

Distinguishing between ethnic and regional favoritism is crucial, as they may have distinct distributive implications on well-being outcomes (Ahlerup and Isaksson, 2015).

In recent years, emerging areas such as the role of social networks, information dissemination, and gender dynamics in shaping distributive politics within agricultural subsidy programs have garnered attention. These studies offer nuanced insights into the complexities of resource allocation dynamics and highlight the importance of considering socio-economic dimensions in policy formulation (Banerjee and Duflo, 2011;

Anderson et al., 2021; Asfaw et al., 2016; Conley and Udry, 2010)

Moreover, additional literature expands our understanding of distributive politics in agricultural subsidy programs. Studies by Snyder Jr and Strömberg (2010) shed light on how electoral incentives drive resource allocation in the presence of political competition. Again, research by Kramon (2016) examines how electoral malpractice affects resource distribution in African democracies, providing insights into the role of institutions in shaping distributive outcomes.

In conclusion, many factors influence distributive politics in agricultural subsidy programs, including electoral incentives, clientelism, swing voter dynamics, temporal factors, ethnic and regional considerations, institutional arrangements, and social dynamics. Understanding these complexities is essential for designing effective policies and interventions to promote equitable resource allocation and mitigate political bias in agricultural subsidy programs. This synthesis of theoretical insights and empirical evidence provides a comprehensive understanding of the factors influencing distributive politics in agricultural subsidy programs, offering valuable insights for policymakers and researchers alike.

1.4 Data and empirical strategy

The study uses data from several official sources, including the National Statistical Office (NSO) of Malawi, the Malawi Electoral Commission (MEC), and records from the National Assembly of Malawi. The rest of this section discusses the data sources, empirical strategy, summary statistics, and pre-trend test results.

1.4.1 Integrated Household Survey (IHS) data

The study uses data from the Integrated Household Surveys (IHSs) on the allocation of agricultural input subsidy coupons and other household characteristics. The surveys are conducted every 3 to 5 years by the National Statistics Office (NSO), with support from the World Bank's LSMS program, to assess changes in household conditions throughout the country. Based on the listing information and cartography for the Malawi Population and Housing Censuses (PHCs), the sampling frame is stratified into rural and urban areas. Excluded populations include those living in institutions like prisons and hospitals. The surveys cover all three regions of the country (north, central, and south) and include household-level data on expenditure, consumption demographic characteristics, health, education, labor force participation, credit and loan, household enterprises, agriculture, housing infrastructure, asset ownership, and food security.[4]

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[4] https://microdata.worldbank.org/index.php/catalog/3818

1.4.2 Parliamentary and local government election results

The parliamentary and local government election data is sourced from the Malawi Electoral Commission (MEC).[5] Unlike presidential elections, which began in 1994, parliamentary elections have a historical context dating back to 1956, albeit with variable parliamentary terms. These elections were harmonized in 1994 and have since been conducted concurrently. Following a 2010 amendment to local government acts, local government elections were also integrated, leading to the tripartite nature of the 2014 general elections.

This dataset encompasses all 193 parliamentary constituencies and 461 local government wards across 28 districts. The results of the 2009 and 2014 general elections are perfectly aligned with the IHS data sets, as surveys occurred during the reigning period of the president, members of parliament, and councilors. The 2009 parliamentary election outcomes correspond to the IHS3 dataset of 2011, while the 2014 tripartite election results are matched with the IHS4 and IHS5 datasets of 2016 and 2019, respectively. Given that the IHS sample frame and constituency shapefiles rely on Population and Housing Census (PHC) listing details and cartography, these two datasets are integrated through the utilization of enumeration areas and household identification codes. This integration process facilitates the identification of households along with their corresponding constituencies and wards. Table 1.1 provides the count of parliamentary seats secured by different parties during the 2004, 2009, and 2014 general elections.

Table 1.1: Distribution of parliamentary and local government seats

	National assembly seats			**Local gov't**
Political party	**2004**	**2009**	**2014**	**councilors**
Democratic Progressive Party	N/A	113	51	165
United Democratic Front	50	17[1]	14	57
Malawi Congress Party	57	27[1]	48	131
People's Party	N/A	N/A	26	65
Independent	39	32	52	35
Alliance for Democracy	6	1	1	1
People's Transformation Party	1	0	0	0
Republican Party	15	0	0	0
Congress for Democracy	N/A	0	0	0
National Democratic Alliance	9	0	0	0
Movement for Genuine Democracy Change	3		0	0
Malawi Forum for Unity and Development	0	1	0	0
People's Progressive Movement	6	1	0	0
Chipani Cha Pfuko	N/A	0	1	2
Maravi People's Party	N/A	1	0	0
Congress for National Unity	1	0	0	0
Vacant seats	6	1		5
Total Seats	**193**	**193**	**193**	**461**

[1] means political parties formed coalition at presidential level but not at national assembly level

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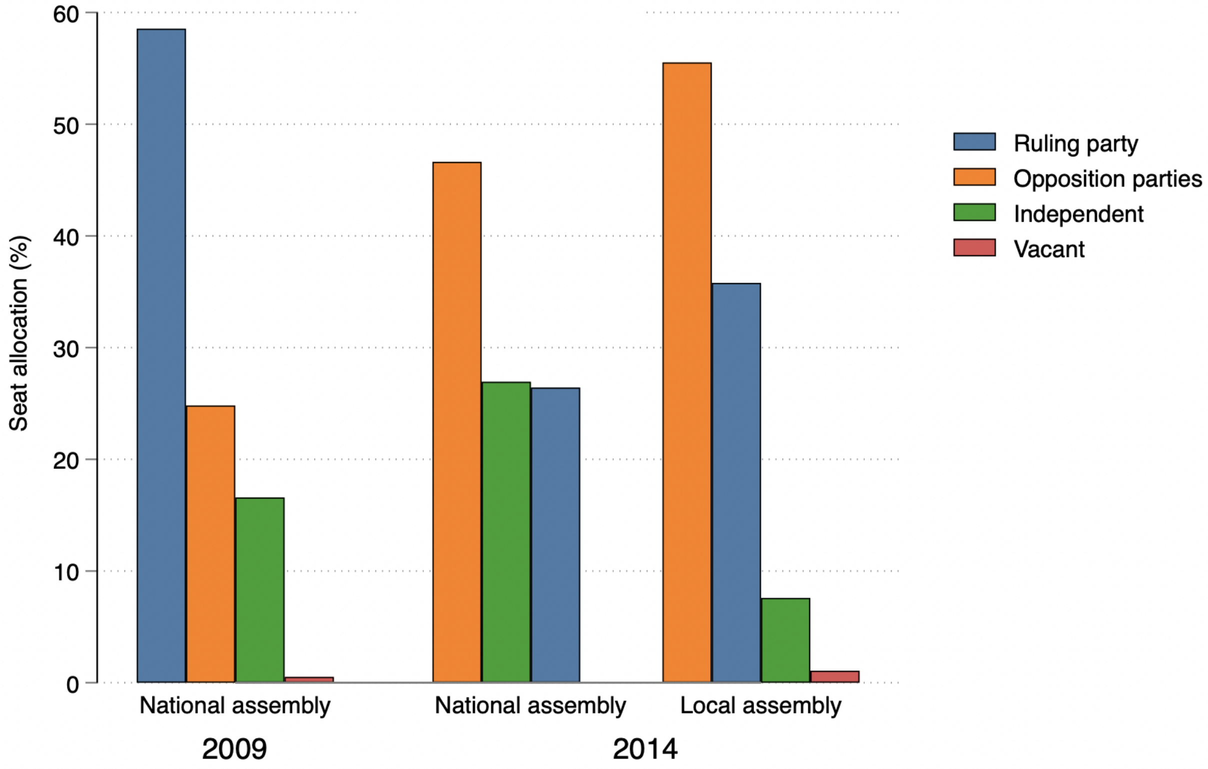
[5] https://mec.org.mw/

The data set from the Malawi electoral commission raises two key considerations. Firstly, despite coalition formations in the general elections, such coalitions were binding solely at the presidential level and did not affect parliamentary and ward arrangements. Consequently, this study treats each party separately in parliamentary and local government elections, even if they were part of a presidential coalition.

Figure 1.1: Share of seats at national and local assemblies



Secondly, in 2012, the sitting president's death led to the vice president assuming the presidency and forming a new faction, the Peoples Party (PP). This shift, including some parliamentarians joining PP, occurred after the survey linking the parliamentary term in 2009 was conducted in 2011. Nonetheless, this event does not impact the identification strategy we discuss below. Additionally, the DPP retained power in 2014, just a year and a half after the PP took over. The IHS 4 and 5 were conducted in 2016 and 2019, during the DPP's tenure. The formation of a faction from the DPP in 2012 resulted in the ruling party accumulating the lowest number of seats compared to the opposition and independents in 2014. Figure 1.1 illustrates the aggregated distribution of parliamentary seats for the ruling party, opposition party, and independents in the 2009 and 2014 general elections.

1.4.3 Identification strategy

We use the differences-in-differences to evaluate the equity implications of distributive politics at lower levels of administration (constituencies and wards), alongside examining factors that could impact the distribution pattern of subsidized input coupons. This approach leverages the context of the 2014 tripartite elections, marking the re-introduction of local government elections after the dissolution of local government councils in 2005. Since voters elected all three levels of representatives simultaneously, the post-election alignment between local and national parties was unknown at the time of the election. This setting enables the identification of constituencies or local government wards won by candidates from the ruling party as our treatment group, while those secured by candidates from non-ruling parties serve as our comparison group.

We first examine how input coupons are distributed at the constituency and ward levels. Next, we analyze the way distribution patterns work within constituencies of the ruling party. This involves comparing core voters who strongly support the party with those on the outskirts (marginal voters), using the victory margins as a guide. Finally, we investigate the factors that may influence the allocation of input vouchers. This includes examining variations among households in terms of their proximity to agricultural markets and their levels of poverty.

The structure of the difference-in-differences model is as follows:

$$Y_{ijt} = \beta_0 + \beta_1 Post_t + \beta_2 T_{ij} + \beta_3 (Post * T_{ij}) + \chi'_{ijt} + \alpha_j + \tau_t + \epsilon_{ijt}, \tag{1.1}$$

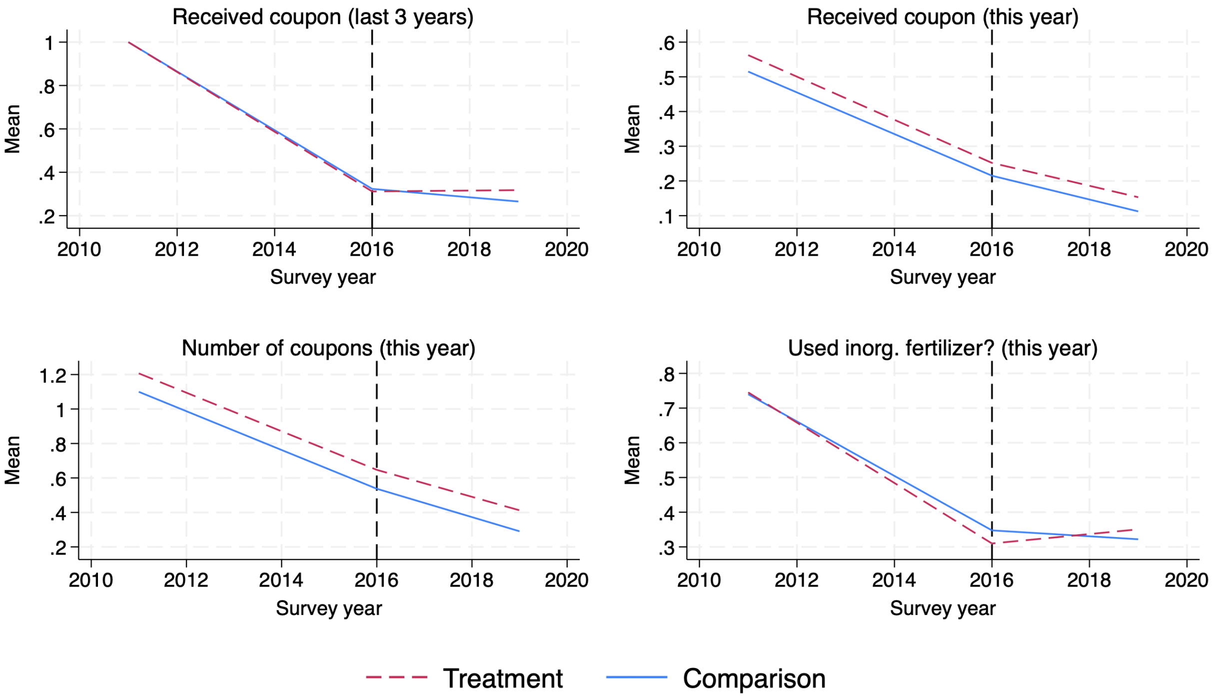
where Y_{ijt} represents outcome variables of interest corresponding to household i from constituency or ward j at time t; T_{ij} is a dummy variable for treatment, i.e., it takes 1 for the constituencies or wards won by the ruling party candidates during the 2014 elections and zero otherwise; χ' represents the vector of other covariates, including distance variables, rainfall, and political variables (effective number of parties); α and τ represent ward-fixed and time-fixed effects, respectively; and ϵ_{ijt} represents the error term.

The $Post$ variable deserves further discussion. While we have data from around 18 months after the date of the tripartite elections, we only consider the 2019 data to belong to the post period. The IHS4 of 2016 is not included in the "Post" period because it occurred immediately after the tripartite elections, and the budget for the first year of the winning party was formulated by the outgoing government. In other words, since elections are slated for May every five years, the winning party used to inherit the budget from the previous regime in their first year of tenure before the much more recent change in the Government Financial Year in December 2020. Previously the financial year spanned from July 1st to June 30th of the subsequent year, meaning that the incoming government after the 2014 elections did not have full control over the budget until late in 2015, just before the 2016 IHS. In addition, our primary variable of interest is whether a household received input coupons in the past three years. For these reasons, we only include 2019 in the post period.

1.4.4 Trends in coupon allocation across survey waves

Since this is a differences-in-differences analysis, the key identifying assumption is whether the treatment and comparison group would have had identical trends in the absence of treatment. While this assumption is inherently untestable, we present a graphical analysis of the common test of pre-trends in Figure 1.2. The trends from 2011 to 2016 are almost identical in treatment and comparison constituencies for all four outcomes. While we see clear changes from 2016 to 2019, the pre-trends are almost identical and are consistent with the parallel trends assumption. Table A1.2 in the appendix presents the empirical results, which are consistent with the figures. We do not see any large differences in pre-trends for our key findings here, specifically for coupon receipt over the last three years and the use of inorganic fertilizer.

Figure 1.2: Testing for pre-trends



1.5 Results

1.5.1 Main results

The first part of the empirical results shows the allocation of subsidized input coupons at constituency and ward levels by comparing ruling and non-ruling constituencies or wards. Panel A of Table 1.2 presents the results at the constituency level, for four separate outcomes: whether the household has received a (fertilizer) coupon in the last three years, whether a household has received a coupon this year, the number of coupons received this year, and whether the household used fertilizer this year. Cumulatively over the past three years, households in constituencies won by the ruling party are 6.2 percentage points more likely to have received coupons – relative to before the tripartite elections – than those in non-ruling-party constituencies. There does not appear to be any substantial differences in receipt of coupons this year, but households are also more likely to have used fertilizer this year. The results using ward political alignment – instead of constituency political alignment – in Panel B show the same patterns.

Table 1.2: Distributive politics at constituency and ward levels

	Last three years	This year		
	(1) Received coupon	(2) Received coupon	(3) Num. of coupons	(4) Used inorg. fert.
Panel A: Constituency level				
Treatment x Post	0.062***	0.012	0.020	0.040**
	(0.018)	(0.017)	(0.040)	(0.020)
Observations	26,517	28,650	28,650	28,626
Panel B: Ward level				
Treatment x Post	0.073***	0.021	0.021	0.031*
	(0.016)	(0.015)	(0.036)	(0.019)
Observations	26,190	28,235	28,235	28,211

Standard errors are in parentheses and clustered at the enumeration area level, in accordance with the sampling design. Survey weights are included in all regressions. All regressions include the following control variables: log(average total annual rainfall), log(distance to the district headquarters), log(distance to the paved road), log(distance to the agricultural market), household size, rural residence, the number of effective political parties, and constituency/ward fixed effects. The rainfall and distance variables are defined at the enumeration area (village).
*** p<0.01, ** p<0.05, * p<0.1

There are a couple of possible explanations for this pattern of results. The overall change in distribution takes some time after the elections to take effect, possibly due to lags in the new government taking full control of the budget process. In other words, if the ruling government took some time to get its affairs in order, we might expect to see effects a year or so after the elections. Since we do not see significant effects in 2019 coupon allocation, the initial changes might have attenuated over time, leading to the pattern of results we see in Table 1.2. Given these results, we focus on the three-year variable in the rest of the results.

How does the government allocate coupons among winning areas? Households in ruling-party constituencies and wards are more likely to have received coupons in the last three years, but do households in certain ruling-party constituencies/wards receive more? In other words, is there evidence that the government tries to allocate coupons to their core voters or to marginal voters? One way to test this is to look at results based on the winning margin, which we do in Table 1.3. We compare based on the 25th percentile of winning margins – across all constituencies or wards – which is around ten points. The first column presents the analysis based on constituency-level results, comparing constituencies where the ruling-party easily won to constituencies where the ruling-party lost handily (top row) versus the difference in close victories (the linear combination with the second row). The second column presents the same general comparison, but with ward-level results instead of constituency-level results.

Table 1.3: Results based on winning margins

	(1) Constituency	(2) Ward
Treatment x Post	0.049*	0.083***
	(0.023)	(0.017)
Treatment x Post x Close win	0.058*	−0.056
	(0.053)	(0.039)
Observations	26,514	26,190

Standard errors are in parentheses and clustered at the enumeration area level, in accordance with the sampling design. Survey weights are included in all regressions. All regressions include the following control variables: log(average total annual rainfall), log(distance to the district headquarters), log(distance to the paved road), log(distance to the agricultural market), household size, rural residence, the number of effective political parties, and constituency/ward fixed effects. The rainfall and distance variables are defined at the enumeration area (village).
*** p<0.01, ** p<0.05, * p<0.1

In both columns, households in areas where the ruling party won easily are more likely to have received coupons in the last three years, although this effect is more than twice as large based on ward-level results. We see large differences, however, when we then compare these results to households in closer elections. Households in constituencies in which the ruling-party won by less than ten points are substantially more likely to have received coupons, indicating that the government might be trying to target marginal voters. We do not see this in wards, however. One possible explanation is that the coupon allocation starts at the central government, where constituency politicians may have more influence, since they are in parliament.

Ward-level results are local, however, and this may reflect less power over central government decision-making.

1.5.2 Effect heterogeneity

The input subsidy program in Malawi was initially targeted towards poor households. In fact, towards the beginning of our sample, beneficiaries were supposed to be selected through open meetings, allowing for community involvement in the selection of beneficiary households. However, the selection process changed dramatically in 2015/16, introducing three key changes: the incorporation of the private sector in the distribution process, implementing randomization in beneficiary selection at the village level (below wards), and the reduction of government subsidies on fertilizer by 14.7% in comparison to the previous year. These changes mean that politician incentives might have changed, as well. For example, insofar as the private sector is important to local political power, there may have been new incentives to target coupon distribution. Evidence has shown that procurement, transportation, and retailing contracts are manipulated as a tool for political favoritism, wherein local businesses receive rewards for their allegiance to the government because they provide financial and material assistance, rather than being evaluated on their technical skills or credentials (Chirwa and Dorward, 2013; Chinsinga, 2011).

Distance to agricultural markets

While we do not have information on the universe of input distributors in the country, we do know how far households are located from agricultural markets. Input distributors tend to be located in more densely populated areas, close to markets. Since households do not always use their coupons, targeting households located closer to distributors might maximize the proportion of households that use their coupons, increasing profits for distributors (and possible funding for the ruling party).

Table 1.4 looks at the results based on whether households are above or below the median distance to an agricultural market. We again see stark differences based on constituency- and ward-level results. Households located far from agricultural markets do not see any increase in coupon receipt based on constituency results. On the other hand, households located far from agricultural markets see large increases based on ward results. Interestingly, we see heterogeneity based on distance when using constituency-level results but not when using ward-level results. In other words, distance to market does not seem to matter for ward-level results but is an important determinant with constituency-level results. Ruling-party-affiliated constituencies apparently focus coupon allocation on households located near markets, while those located

Table 1.4: Heterogeneity by distance to markets

	(1) Constituency	(2) Ward
Treatment x Post	−0.013	0.068***
	(0.026)	(0.022)
Treatment x Post x Close to markets	0.110***	0.000
	(0.036)	(0.031)
Observations	26,514	26,190

Standard errors are in parentheses and clustered at the enumeration area level, in accordance with the sampling design. Survey weights are included in all regressions. All regressions include the following control variables: log(average total annual rainfall), log(distance to the district headquarters), log(distance to the paved road), log(distance to the agricultural market), household size, rural residence, the number of effective political parties, and constituency/ward fixed effects. The rainfall and distance variables are defined at the enumeration area (village).
*** p<0.01, ** p<0.05, * p<0.1

farther from markets see no change in coupon allocation. However, wards do not prioritize this. These findings may be a result of several factors.

Firstly, at the constituency level, politicians have greater control over larger pools of resources, making clientelism a viable strategy to gain political support and ensure voter loyalty, as observed in studies from Malawi and Zambia (Chinsinga and Poulton, 2014; Van de Walle, 2007; Resnick, 2012). The stakes in constituency-level politics are higher, incentivizing politicians to use resources strategically. Additionally, the impact of coupon distribution is more visible to a broader electorate, enhancing political capital (Brierley, 2020).

Conversely, at the ward level, resources are smaller, reducing the potential for significant clientelistic exchanges. Ward-level officials often face closer scrutiny from local communities, making it riskier to engage in clientelism without backlash, as seen in Kenya and Uganda Kramon (2018); Bates and Block (2013). Tighter controls and oversight at the ward level also limit opportunities for clientelistic distribution. The social dynamics at this level may prioritize transparency and fairness over clientelistic practices (Ferree and Horowitz, 2010). Secondly, the broader and more influential social networks at the constituency level further enable politicians to leverage resources clientelistically, contrasting with the community-based networks at the ward level that may create a context less conducive to clientelism Hassan (2020).

Finally, these results align with existing literature on "At-large versus ward elections," emphasizing the significance of geographical size and the source of more votes (Southwick, 1997; Dalenberg and Duffy-Deno, 1991). The smaller ward size enhances fairness in coupon allocation due to proximity. Ward councilors represent geographically concentrated groups with similar needs and are more compelled to prioritize allocation within their wards. In contrast, members of parliament represent diverse groups from different wards and may be less inclined to prioritize specific ward allocations. Additionally, the re-election of ward councilors is often based on neighborhood loyalties, leading them to provide public services with geographically concentrated benefits. In contrast, members of parliament may prioritize densely populated areas near marketplaces to secure more votes.

Poverty status of households

Another key implication of the change in allocation rules is that poor households might have suffered, over and above the fact that they were no longer explicitly targeted by the program. The Malawi IHS collects expenditure information which allows us to analyze whether there were changes in coupon distribution across poor and non-poor households based on election results. We present these results in Table 1.5. The first two columns present constituency-level results while the last two present ward-level results. Interestingly, we do not see differences in allocation based on the poverty status of the household; both poor and non-poor households in ruling areas are more likely to receive coupons than their counterparts in non-ruling areas. None of the differences across columns is statistically significant.

Table 1.5: Heterogeneity by household poverty

Election results at:	Constituency		Ward	
	(1) Poor	(2) Not poor	(3) Poor	(4) Not poor
Treatment x Post	0.062***	0.055***	0.086***	0.061***
	(0.024)	(0.022)	(0.021)	(0.020)
Observations	12,068	14,449	11,863	14,313

Standard errors are in parentheses and clustered at the enumeration area level, in accordance with the sampling design. Survey weights are included in all regressions. All regressions include the following control variables: log(average total annual rainfall), log(distance to the district headquarters), log(distance to the paved road), log(distance to the agricultural market), household size, rural residence, the number of effective political parties, and constituency/ward fixed effects. The rainfall and distance variables are defined at the enumeration area (village).
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

We note that while the change in allocation rules means that poor households are no longer prioritized, this is a different question than focusing on the change based on political affiliation of local assembly and council members. In other words, the government is still able to affect the overall allocation of coupons across areas, even if the randomization works perfectly and they are not able to target households *within* a given area. The results in Table 1.5 also indicate that the results based on heterogeneity by distance to markets are not simply picking up a difference in household welfare across distances. Poor and non-poor households are equally likely to see an increase coupon receipt, at least in absolute terms.

1.6 Conclusion

In conclusion, this research highlights that households in constituencies and wards won by the ruling party are more likely to receive subsidized input coupons. This pattern is observed over a three-year period, suggesting a sustained influence of political affiliations on the distribution of agricultural subsidies. The study also explores variations in coupon allocation based on election margins, revealing an interesting focus on marginal voters.

Additionally, the study sheds light on the dynamic nature of the input subsidy program in Malawi, particularly in terms of the evolving strategies for beneficiary selection. The introduction of private sector involvement, randomization in beneficiary selection, and a reduction in government subsidies raised questions about potential shifts in political incentives. The findings suggest that proximity to agricultural markets plays a crucial role in coupon distribution, with ruling-party-affiliated constituencies appearing to prioritize households near markets. However, this pattern is not observed at the ward level, emphasizing the importance of geographical size and voting sources in constituency-level results. Furthermore, the analysis looks into the impact of beneficiary selection on household poverty, revealing that while poor households are no longer explicitly targeted, the change in allocation rules does not lead to significant differences in coupon distribution based on household poverty status.

Even though the study shows that prioritization of coupon distribution to households near agricultural markets in ruling-party constituencies promotes coupon utilization, policymakers should adopt targeted strategies for both those close and far from agricultural markets. Geographical proximity should be a key consideration to maximize the effectiveness of coupon utilization and ensure a more equitable distribution across regions by introducing more distribution points far from agricultural markets. Again, the disparities revealed between constituency and ward-level results based on distance from agricultural markets emphasize the significance of local decision-making in subsidy allocation. Empowering local councils and assembly members in the allocation process can foster more equitable distribution, particularly in light of the potential influence by constituency politicians.

Furthermore, the findings underscore the importance of establishing robust monitoring and evaluation mechanisms to assess the evolving dynamics of coupon distribution. Continuous scrutiny will enable policymakers to adapt strategies in response to changes in the political landscape and economic conditions, ensuring the sustained effectiveness of subsidy programs. While the study does not identify significant differences in coupon distribution based on household poverty status, policymakers should remain vigilant to potential unintended consequences. Mitigating negative impacts on vulnerable households resulting from changes in allocation rules should be a priority, safeguarding the well-being of those most in need.

In summary, this research provides valuable insights into the intricate interplay between politics and agricultural subsidy programs in Malawi. The proposed policy recommendations, if implemented, have the potential to contribute significantly to more effective, equitable, and transparent coupon distribution practices, ultimately benefiting the smallholder farmers.

Appendix

Table A1.1: Farm input subsidy program

Period	Name of program	Beneficiaries
1992-1993	Drought Recovery Inputs Project	1.3 million
1994-1996	Supplementary Inputs Project	800,000 & 660,000
1998-2000	Starter Pack	2.8 million
2000-2002	Targeted Input Program	1.5 million & 1 million
2002-2004	Extended Targeted Input Program	2.8 million & 1.7 million
2005-2009	Malawi Input Subsidy Program	50% of the farmers
2010-2019	Farm Input Subsidy Program	Between 900,000 & 1.5 million
2020-2025	Agriculture Input Program	Started with 2.7 million

Table A1.2: Testing for pre-trends

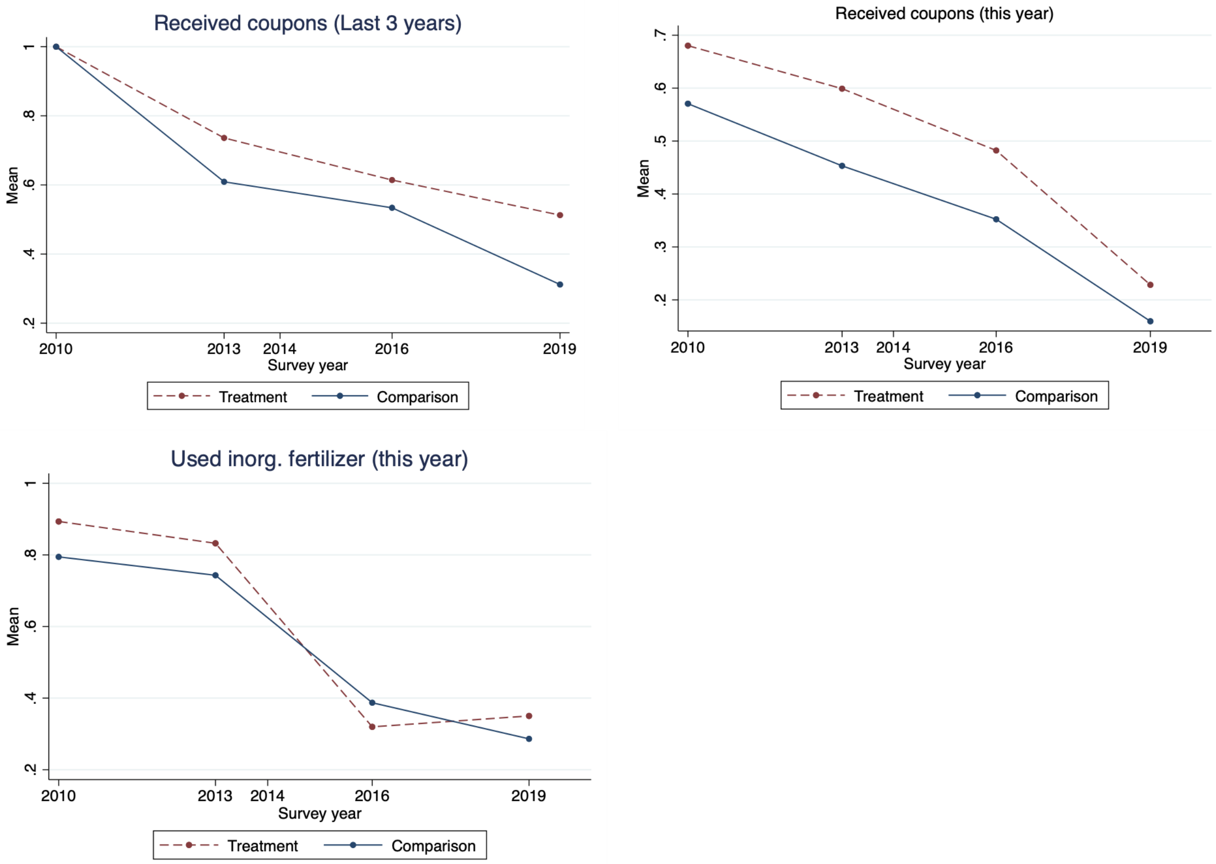
	Last three years	This year		
	(1) Received coupon	(2) Received coupon	(3) Num. of coupons	(4) Used inorg. fert.
Treatment times Post	0.018	−0.014	0.035	−0.024
	(0.019)	(0.021)	(0.047)	(0.023)
Observations	17,826	19,958	19,958	19,934

Standard errors are in parentheses and clustered at the enumeration area level, in accordance with the sampling design.. Survey weights are included in all regressions. All regressions include the following control variables: log(average total annual rainfall), log(distance to the district headquarters), log(distance to the paved road), log(distance to the agricultural market), household size, rural residence, the number of effective political parties, and constituency/ward fixed effects.
*** p<0.01, ** p<0.05, * p<0.1

Table A1.3: Summary statistics

Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Received coupons (past 3 years)	26670	.447	.497	0	1
Received coupons (current year)	28790	.304	.46	0	1
Number of coupons (current year)	28790	.696	1.205	0	20
Number of coupons (Current year)	28790	.28	.449	0	1
Household used fertilizer (current year)	28766	.481	.5	0	1
Fertilizer usage (kgs)	28766	63.288	152.813	0	6800
Average annual precipitation (mm)	33461	1097.307	248.872	755	2142
Annual total rainfall (mm)-last year	33461	917.877	192.558	516	1671
Annual total rainfall (mm)-current year	33461	829.347	202.011	465	1678
Distance to agricultural markets (kms)	33461	27.114	19.607	0	120.67
Distance to the paved road (kms)	33461	9.168	11.137	0	67
Household size	33461	4.497	2.1	1	22
Rural residence	33461	.846	.361	0	1
Ward-level vote margins	30362	-.067	.475	-7.015	.722
Constituency-level vote margins	32924	-.043	.288	-.886	.856
Effective number of parties (constituencies)	33277	3.459	1.073	1.23	7.67
Effective number of parties (Wards)	32872	3.291	1.018	1.2	6.66

Figure A1.1: Alternative pre-trends (using Integrated Household Panel Survey data)



Chapter 2

Balancing Efficiency and Equity: Analyzing Customary Land Tenure Systems in Farmland Allocation

2.1 Introduction

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris. Access to secure land tenure remains a significant challenge in Sub-Saharan Africa (SSA), where Customary Land Tenure Systems (CLTS) govern most land holdings. Byamugisha and Dubosse (2023) emphasize that over 78% of land in SSA is under CLTS, highlighting the region's predominant reliance on customary practices for managing land rights. This dependency is central to governance, agricultural productivity, and socio-economic development, as secure land tenure is essential for investment and community well-being. In Malawi, for instance, Tsutomu (2008) reports that 69% of land holdings are governed by CLTS, further underscoring the widespread prevalence of customary land tenure systems and their role in shaping rural livelihoods. Customary land tenure systems are often considered efficient in farmland allocation due to their reliance on local knowledge and traditions, which account for factors such as soil quality, water access, and historical land use patterns (Roth and McCarthy, 2013; Ostrom, 1990; Deininger and Bresciani, 2001). Recent perspectives also advocate for alternatives to rapid formal land titling through sales or rental markets, which can exacerbate inequality, particularly in regions with underdeveloped credit and land markets (Roth and McCarthy, 2013). Alternatives include policy and legal recognition of customary rights, issuing certificates to secure usufruct and inheritance rights, and implementing community titling (Arko-Adjei, 2011; Roth and McCarthy, 2013; Toulmin, 2009).

However, there is limited empirical evidence on how customary land tenure systems affect efficiency and equitable land distribution. Understanding the nuances of CLTS and their implications for land allocation is crucial for addressing tenure challenges and fostering sustainable development in SSA. This paper aims to empirically assess the efficiency and equity of these systems by focusing on two forms of land allocation: inherited farmland and land allocated by chiefs or employers. Using data from Malawi's Integrated Household Panel Survey (IHPS), this research combines a Cobb-Douglas stochastic frontier model to estimate farming ability and logistic regression analysis to examine factors influencing participation in customary land tenure systems.

This study makes a novel contribution by focusing on the efficiency of customary land tenure in farmland allocation, an area that has been less explored compared to its role in risk management (Deininger et al., 2003; Cotula et al., 2004; Peters, 2004; Ostrom, 1990). It also provides empirical insights into alternative land tenure policies in Sub-Saharan Africa (SSA), particularly how they can enhance Land Tenure Property Rights (LTPR) without exacerbating the inequalities typically associated with market-based systems. Additionally, the study complements existing literature on land tenure systems, which predominantly focuses on sales and rental markets (Chamberlin and Ricker-Gilbert, 2016; Kijima and Tabetando, 2020), often overlooking the importance of customary tenure systems.

The study reveals significant findings on the efficiency and equity of land allocation in customary tenure systems in Malawi. On average, smallholder farmers show significant inefficiencies, with a notable gap between their actual and potential agricultural output. The average farming ability level is 0.286 (on a scale where 1 represents the highest), indicating substantial room for improvement. Households with lower farming ability are more likely to inherit land, emphasizing familial continuity over agricultural productivity. Similarly, land allocated by chiefs is driven by social and political considerations rather than farming ability, reflecting broader socio-political dynamics. Households with higher farming ability prefer to acquire land through purchase or rental, as they are more confident in managing larger agricultural operations. The analysis also reveals that the size of a household's total landholding does not significantly influence participation in customary tenure systems, suggesting that these systems promote equitable land distribution. However, more extensive landholdings increase the likelihood of acquiring additional land through purchase, which can exacerbate inequality by favoring wealthier households. These findings underscore the tension between efficiency and equity in land distribution, highlighting the need for reforms that address both aspects.

The study's policy implications are clear. Integrating and strengthening customary land tenure systems within national policies could enhance equity and efficiency. The finding that customary land tenure is generally more equitable supports the argument for policies that recognize and incorporate these systems into formal land management frameworks. This could reinforce LTPR while reducing the inequalities associated with market-based land distribution. Furthermore, the research provides actionable insights for policymakers to design interventions that address inefficiencies in land allocation and ensure more equitable land access. These efforts can contribute to sustainable agricultural development and improve household welfare across SSA. The following chapters will explore background information, review theoretical and empirical literature, detail data sources, outline the methodologies employed, and conclude the study.

2.2 Background

Land in Malawi is categorized into three forms, namely public, private, and customary (Kishindo, 2004; GoM, 2002; Tsutomu, 2008). The government owns public land and, in some instances, delegates management to the traditional authorities. Government land includes national parks, forest and game reserves, conservation areas, and government farms. The second category of private land covers the land with tenure security under freehold, leasehold title, or obtained through colonial governors with a certificate of claim, such as commercial estate land for tea, sugar, and tobacco. Lastly, customary land is acquired and held under the customary law of each ethnic group and constitutes about 69% of the total land area in Malawi (Tsutomu, 2008). Households from every village are entitled to access and use a piece of land subject to the availability of free land and compliance with traditions and customs. Under the land act, the right to public and customary land is bestowed upon the president, who delegates control and administration to the minister of lands. Upon trust, the minister also delegates control and administration of customary land to chiefs who are empowered to allocate land in compliance with customary laws (Kishindo, 2004). Thus, chiefs ensure customary land is distributed equitably among the villagers and preserved for future generations (Ibid). When a household migrates permanently to other villages, the land is returned to the community for possible allocation to other land seekers. For permanent village residents, the land rights remain in the household and can be passed on along the family generations. Apart from allocation by the village chief, indigenous land tenure can be acquired within the family through inheritance, gifts, or as payment for lobola. Land rights acquired through inheritance depend on the lineage of a specific ethnic group. In patrilineal societies, inherited land rights are primarily transferred from father to son, while in matrilineal societies, land rights are transferred from mother to daughter (Tsutomu, 2008; Kishindo, 2004).

The Malawi National land policy 2002 allows customary land to be registered and protected by law. It encourages all communities, households, and individuals who hold customary land to register it as private estates with tenure rights. Again, the policy aimed to establish private leasehold estates while maintaining ownership of the customary landholder and formalized the roles of chiefs and household heads to allow for orderly and transparent land transactions (Kishindo, 2004; GoM, 2002). In order to operationalize the policy, the Malawi National Assembly passed ten new and amended land-related bills into law in 2016 to ensure tenure security and equitable access to land (NPC, 2021). For more details and chronological order of the land reform process from 1993 to 2016, when the parliament passed the ten amended and new land-related bills into law, see Appendix 1.2. The new land reforms allow individuals or households to formally register their customary land and call for decentralization of the structures for land registration and transfers. Before the enactment of the bills into law, about 4.7 million hectares of land in Malawi were untitled. Insecure land tenure resulted in the low income generated by the government from land rent and an increase in some land-related disputes. The estimates show that about 15 out of every 100 households registered land disputes, and about 20% of the households were afraid that their land might be grabbed or encroached on (NPC, 2021; Msukwa et al., 2021). Therefore, the new land laws are envisaged to improve land tenure security, increase access to credit, reduce investment uncertainty, land transaction costs, and land conflicts, and increase government revenue.

2.3 Literature review

Farmland tenure is a crucial component of agricultural systems, with existing literature predominantly focusing on rental and sales markets. Extensive studies in Sub-Saharan African countries, including Malawi, Zambia, Uganda, and Kenya, have explored how these markets impact efficiency and equity in farmland allocation (Kijima and Tabetando, 2020; Chamberlin and Ricker-Gilbert, 2016; Lunduka et al., 2010; Jin and Jayne, 2013). Research by Kijima and Tabetando (2020) in Uganda and Kenya highlights that land markets can effectively transfer farmland from land-abundant to landless households with higher farming ability, resulting in increased productivity compared to inherited land (Kijima and Tabetando, 2020; Deininger and Mpuga, 2010; Chamberlin and Ricker-Gilbert, 2016). However, the impact on poverty reduction varies, emphasizing the need for context-specific analyses (Kijima and Tabetando, 2020). In Malawi, while rental markets efficiently reallocate land to higher-ability households, the welfare outcomes are mixed (Chamberlin and Ricker-Gilbert, 2016). Similarly, in Zambia and Malawi, land rental markets show positive returns for larger producers, although the returns from renting out land are less favorable or negligible (Chamberlin and Ricker-Gilbert, 2016). A decade-long study in Kenya and Uganda reveals that land markets efficiently transfer land to more capable farmers but also highlight ongoing challenges, suggesting the need for tailored strategies (Kijima and Tabetando, 2020). Additionally, various land tenure arrangements demonstrate differing efficiencies, with systems like sharecropping and fixed rental showing varied performances. Studies argue that land reform measures, especially those redistributing land to owner-cultivators, can enhance agricultural efficiency and contribute to economic development in less developed countries (Ip and Stahl, 1978).

However, a major concern is that market-based land tenure systems may exacerbate inequality, especially in developing countries with underdeveloped land markets and limited access to credit. These systems often result in minimal benefits for the poor and risk transferring land to wealthier households (Nguyen et al., 2021; Bassett, 2005; Roth and McCarthy, 2013). The prevailing perspective on secure land tenure emphasizes the need for more flexible and inclusive approaches, rather than relying solely on rapid private ownership through formal land titling. For instance, the USAID policy advocates a "secure enough" approach, balancing affordability, sustainability, and a continuum of rights. This includes recognizing customary rights, issuing certificates for usufruct, management, or inheritance rights, and implementing community titling to enhance land tenure security without worsening inequality (Bassett, 2005). Empirical evidence supports integrating elements of customary tenure, particularly in systems with overlapping property rights such as free-grazing livestock systems. This flexibility allows for gradual transitions, providing beneficiaries with time to adapt and develop complementary institutions, potentially leading to a more equitable distribution of land tenure and property rights (Niamir-Fuller et al., 1999; Roth and McCarthy, 2013; Toulmin, 2009; Arko-Adjei, 2011). Several countries, including Malawi, have adopted alternative systems maintaining elements of customary tenure. Namibia, for example, is developing an incremental approach based on customary rights, offering a continuum of rights through occupancy licenses and certificates of occupancy. Similarly, Ghana and Botswana involve land boards with traditional leaders or elected officials in land registration processes, while Mexico's 1992 land reform included community voting on communal resource allocation (Roth and McCarthy, 2013). Innovative models such as the Community Land Trust (CLT), where communities own the land and individuals own improvements, and the retention of state ownership over some land to ensure access for marginalized individuals, reflect further adaptive approaches (Arko-Adjei, 2011; Deininger and Bresciani, 2001). Additionally, research in Jiangsu Province, China, indicates that lessor households experience lower total income, while lessee households in lower-income groups benefit most from land rentals. This underscores the importance of carefully considering local market dynamics when designing policy interventions (Zhang et al., 2018).

These recent approaches reflect the broader transformation of African economies and societies due to demographic growth, urbanization, economic monetarization, livelihood diversification, and cultural change. Customary land tenure systems have evolved in response to these shifts, with varying impacts on authority and land rights (Chauveau, 2007). Therefore, alternative formalization strategies in customary areas are emphasized, focusing on flexible tenure and adapting Land Administration Systems (LAS) to local contexts. For example, Arko-Adjei (2011) proposed models for customizing LAS to the institutional framework of customary tenure in peri-urban areas, advocating for community participation and recognition of indigenous knowledge. These perspectives challenge the assumption that private, individual tenure is the most effective means of ensuring property rights security. In sub-Saharan Africa, customary tenure systems, which prioritize community membership and collective control, challenge the universal applicability of private tenure (Mattingly, 2013). Despite ongoing transformation to improve tenure security, the efficiency of customary land tenure has been limitedly researched in the region.

2.4 Conceptual Framework and Identification Strategy

2.4.1 Conceptual Framework

This study builds on the utility maximization framework, as conceptualized by Bliss and Stern (1982) and further developed by Skoufias (1995), to analyze the efficiency and equity of land allocation within customary tenure systems in Malawi. Households aim to maximize their utility by deciding whether to participate in different land tenure systems, such as inheriting land, acquiring land through chief allocation, or engaging in market-based transactions like purchasing or renting. The decision to participate in these systems is influenced by the household's desired or optimal farm size, which is determined by several factors (Chamberlin and Ricker-Gilbert, 2016; Kijima and Tabetando, 2020).

Household endowments play a critical role in these decisions. Farming ability, representing the household's agricultural productivity potential, is expected to influence the preference for acquiring land through both customary systems and market transactions. Other endowments, such as family labor, education, and existing landholdings, also impact farming ability and land tenure decisions (Kijima and Tabetando, 2020). Constraints such as cash availability and transaction costs further shape these decisions. Households with limited financial resources may prefer to rent out land or rely on inheritance rather than purchasing additional land. Risk aversion also affects tenure choices, with more risk-averse households potentially avoiding market-based land transactions and preferring secure land tenure through inheritance or allocation by chiefs (Chamberlin and Ricker-Gilbert, 2016).

External factors, including community-level variables like market access, rainfall, and social or political influences, also affect land allocation decisions. Particularly in the context of land allocated by chiefs, these factors can significantly influence outcomes (Kijima and Tabetando, 2020). The decision-making process can be categorized into three regimes. Households with lower farming ability are more likely to inherit land, as inheritance decisions are driven by traditional norms prioritizing familial continuity over agricultural productivity. Land allocation by chiefs is typically based on social and political considerations rather than farming ability to maintain equity within the community. However, this process can be influenced by patronage, social ties, or political influence. Conversely, households with higher farming ability and better access to financial resources are more likely to participate in market-based land transactions, optimizing their farm size for greater efficiency.

This model highlights the potential trade-offs between efficiency and equity in customary land tenure systems. While these systems may promote equity, they may not optimize land allocation efficiency due to traditional norms, political influence, and transaction costs. On the other hand, market-based land transactions, although potentially more efficient, can exacerbate inequalities as wealthier households expand their holdings, leaving poorer households with fewer resources. This conceptual framework serves as a basis for understanding the dynamics of land tenure systems in Malawi and can inform policy interventions to improve the efficiency and equity of land distribution within customary tenure systems (Chamberlin and Ricker-Gilbert, 2016; Kijima and Tabetando, 2020).

2.4.2 Identification Strategy

To empirically test the conceptual model, this study employs a combination of strategies to estimate farming ability and the factors influencing households' participation in customary land tenure systems. The estimation begins with the assessment of farming ability using a Cobb-Douglas stochastic frontier model. This model has been widely used in farmland rental market studies to estimate entrepreneurial ability as the time-invariant component of the Cobb-Douglas function, applying fixed effects at the household level (Chamberlin and Ricker-Gilbert, 2016; Kijima and Tabetando, 2020; Jin and Deininger, 2009). The fixed-effects stochastic frontier model utilizes the Marginal Maximum Simulated Likelihood Estimation (MMSLE) technique, which effectively accounts for household time-fixed heterogeneity by partialling it out to obtain a non-negative random component for household farming efficiency. This approach is advantageous over traditional true fixed-effect estimation techniques, providing consistent variance estimates even in the presence of incidental parameter problems due to increasing observations while periods remain fixed (Belotti and Ilardi, 2018; Kumbhakar and Wang, 2010; Wang and Ho, 2010). The augmented Cobb-Douglas stochastic frontier function is specified as follows:

$$\ln(Q_{ijt}) = \alpha_0 + \sum_{i=1}^{N} \beta \ln(Z_{ijt}) + \beta_q \chi'_{ijt} + v_{ijt} - \mu_{ijt} \tag{2.1}$$

Where Q_{ijt} is the total value of crop production for household i from plot j during the rainy season of year t, Z_{ijt} represents factor inputs including the total area of plot j cultivated by household i at time t, fertilizer applied, and labor input by household i at time t, captured by adult equivalents (Chamberlin and Ricker-Gilbert, 2016). $\chi'ijt$ represents a vector of household characteristics such as gender, age, and years of education of the household head, total annual rainfall, and temperature. $vijt$ is a normally distributed error term, and μ_{ijt} is a one-sided, strictly non-negative term representing farming ability (Belotti and Ilardi, 2018). The sign of the μ_{ijt} term is positive or negative depending on whether the frontier describes a cost or production function, respectively. Depending on the estimator used, fixed-effect stochastic frontier models allow the underlying mean and variance of farming ability (as well as the variance of the idiosyncratic error) to be expressed as functions of exogenous covariates (Belotti and Ilardi, 2018).

In the second part of the analysis, the estimated level of entrepreneurial ability ($\hat{\mu}_{ijt}$), obtained from Equation (1), is used as an explanatory variable in the logistic regression of farmland tenure systems choice, represented by Equation (2) below:

$$LT_{ijt} = \theta_1 \hat{\mu}_{ijt} + \theta_2 \ln(PA_{ijt}) + \chi'_{ijt} + \epsilon_{ijt} \tag{2.2}$$

Where LT_{ijt} represents dummies for inherited farmland tenure, farmland allocated by chiefs or employers, rented/borrowed farmland, and purchased farmland, taking a value of 1 if the household participated in the land tenure system and 0 otherwise. $\hat{\mu}$ is the estimated level of farming ability from Equation (1), PA_{ijt} is the total farmland area for the household. χ'_{ijt} represents a vector of household and farm plot characteristics such as adult equivalent, household head education, age, sex, household lineage system, access to credit/loans, death of an adult household member and/or experienced agricultural shock, household break-up, geo-location variables (distance to agricultural market and to the paved road), soil quality, and type. ϵ_{ijt} is the error term. The p-values on the coefficients in Equation (2) are obtained using bootstrapping to account for the two-step estimation process, as the estimates from Equation (1) generate $\hat{\mu}_{ijt}$. θ_1 represents the coefficient of interest, indicating whether the level of farming ability determines participation in customary land tenure systems. Although we are primarily interested in the sign of θ_1, studies have shown that it may be biased downwards (Chamberlin and Ricker-Gilbert, 2016; Zhang et al., 2018) because other time-invariant variables, such as soil quality measures and risk aversion, are not fully accounted for in the estimated α. This study mitigates this problem by including soil type and quality for the plot, as well as the level of crop diversification (captured by the number of crops grown by the household in a farming season) to control for other time-invariant variables. For interpretation, when θ_1 is greater than 0, it suggests that the farmland tenure system leads to efficiency in land allocation by transferring or distributing farmland to more efficient farmland seekers; if θ_1 is less than 0, the opposite holds. As with other studies on farmland markets, this study uses averages of household-level time-variant variables (known as the Mundlak-Chamberlain (MC) device) to control for the correlation between unobserved time-fixed household-level covariates and the household-level time-constant averages (Chamberlin and Ricker-Gilbert, 2016; Kijima and Tabetando, 2020; Woodridge, 2010).

2.5 Data source and descriptive statistics

The study uses the Integrated Household Panel Survey (IHPS) data from Malawi's National Statistical Office (NSO). The IHPS is conducted alongside the Integrated Household Survey (IHS) program to capture trends in poverty, social-economic, and agricultural characteristics of individuals and households over time. The first IHPS (baseline) was conducted in 2010 alongside the IHS-3 with a total sample of 3,104 households. The surveys are based on stratified sampling criteria with a total of 6 strata. Firstly, sample selection is representative of the three regions of Malawi and then further divided into rural and urban strata. Later in 2013, the first follow-up survey was conducted, covering a total sample of 4,000 households. The sample increased due to household members' split away and new household formation. The third wave was conducted in 2016 alongside IHS4, but the sample size was scaled down to 1,989 due to budgetary constraints. The last wave of IHPS was conducted in 2019 with a combined sample from the third wave and split-off individuals and their new households. The fourth wave covered a total of 3,104 households. This study only uses the first three IHPS waves because the fourth wave of 2019 did not capture data/information on land tenure through sales and rental markets.

Table 2.1 presents descriptive statistics across various dimensions, including household demographic characteristics, weather indicators, geolocation variables, and soil characteristics of farm plots. The analysis reveals distinct differences in key variables across the four tenure systems: inherited farmland, farmland allocated by chiefs, rented or borrowed farmland, and purchased farmland. For instance, the mean crop production value is much higher on purchased farmland (MWK 203,729.83) than on inherited farmland (MWK 33,117.73). This suggests that plots acquired through market transactions may be more productive due to better land quality or more intensive use of inputs.

Table 2.1: Descriptive statistics

VARIABLES	**Inherited farmland**					**Farmland allocated by chiefs**				
	N	**Mean**	**SD**	**Min**	**Max**	**N**	**Mean**	**SD**	**Min**	**Max**
Crop production value (Malawi Kwacha)	3080	33117.73	81955.29	0	2400000	822	70061.29	266779.82	0	6500000
Plot area (acres)	3309	1.121	0.99	0	12.36	1087	1.23	1.07	.01	9
Total fertilizer used (kgs)	3312	33.07	52.93	0	300	1087	27.40	58.08	0	300
Population density	3312	357.97	648.83	25	5000	1083	344.39	625.26	25	5000
Adult equivalents	3312	3.94	1.59	.76	11.12	1087	3.90	1.61	1.00	10.20
Annual rainfall amount (mm)	3312	780.76	118.14	534	1326	1083	690.05	128.62	531	1266
Average annual temperature (0c *10)	3312	214.45	17.41	181	262	1083	215.26	18.11	181	262
Household head age	3312	40.77	16.03	0	94	1087	44.11	16.02	14	90
Household head education	3312	1.27	0.74	0	7	1087	1.19	0.64	1	7
Male household head (=1)	3312	.75	0.43	0	1	1087	.74	0.44	0	1
Household accessed credit/loan	3312	.18	0.39	0	1	1087	.22	0.42	0	1
Experienced death/agricultural shock	3312	.83	0.38	0	1	1087	.77	0.42	0	1
Household breakup	3312	.04	0.20	0	1	1087	.08	0.27	0	1
Distance to paved road (kms)	3312	9.88	9.70	0	50	1083	10.44	10.21	0	46
Distance to agriculture markets (kms)	3312	18.11	14.68	0	67	1083	23.91	14.30	.71	60
Matrilineal households	3312	.86	0.35	0	1	1087	.896	0.31	0	1

VARIABLES	**Rented/borrowed farmland**					**Purchased farmland**				
	N	**Mean**	**SD**	**Min**	**Max**	**N**	**Mean**	**SD**	**Min**	**Max**
Crop production value (Malawi Kwacha)	423	57600.68	110552.67	0	1370000	214	203729.83	1779366.06	0	26000000
Plot area (acres)	465	1.07	1.03	.01	8.5	238	1.64	1.93	.012	15
Total fertilizer used (kgs)	466	48.94	73.25	0	300	239	54.69	84.73	0	300
Population density	466	564.22	1130.72	25	5000	239	419.46	842.09	25	5000
Adult equivalents	466	4.11	1.60	1.00	11.42	239	4.43	1.61	1.43	9.009
Annual rainfall amount (mm)	466	754.29	122.16	531	1246	239	731.85	111.82	537	1234
Average annual temperature (0c *10)	466	213.09	19.47	181	263	239	217.00	18.00	181	262
Household head age	466	38.53	15.03	15	106	239	41.52	14.25	19	90
Household head education	466	1.46	0.99	0	5	239	1.40	1.01	1	7
Male household head (=1)	466	.84	0.37	0	1	239	.85	0.36	0	1
Household accessed credit/loan	466	.26	0.44	0	1	239	.21	0.41	0	1
Experienced death/agricultural shock	466	.79	0.41	0	1	239	.78	0.41	0	1
Household breakup	466	.06	0.24	0	1	239	.03	0.18	0	1
Distance to paved road (kms)	466	8.13	10.24	0	43.54	239	9.96	9.75	0	46
Distance to agriculture markets (kms)	466	19.38	15.66	.24	59	239	19.78	15.22	.11	56
Matrilineal households	466	.87	0.33	0	1	239	.93	0.26	0	1

Plot area also varies, with purchased plots being the largest on average (1.64 acres), while rented or borrowed plots are the smallest (1.07 acres). Fertilizer use follows a similar trend: the highest average usage on purchased land (54.69 kgs) and the lowest on land allocated by chiefs (27.40 kgs). These differences highlight the varying levels of investment and resource allocation across tenure systems, potentially influenced by factors such as tenure security or the economic status of the households. Climatic conditions, as measured by annual rainfall and temperature, are relatively consistent across tenure types, though slight variations exist. Household demographic characteristics also differ among tenure systems. The age of the household head is highest for those on farmland allocated by chiefs (44.11 years) and lowest for those on rented or borrowed land (38.53 years). Education levels are relatively uniform, though slightly higher for household heads on rented or borrowed land (mean education level of 1.46) than other tenure types. In terms of accessibility, households on rented or borrowed land are generally closer to paved roads (8.13 km) compared to those on purchased land (9.96 km). However, households on purchased land are slightly closer to agricultural markets (19.78 km) than those on inherited land (18.11 km). These descriptive statistics provide a comprehensive overview of the demographic, land tenure, soil, input, and climatic variables that influence Malawi's agricultural production and resource allocation. The considerable variability across these variables highlights the diverse conditions under which households operate, a key factor for the subsequent analyses and interpretations of the data. The summary statistics reveal the presence of outliers in some variables. To mitigate their impact, the econometric analysis uses logarithmic transformations to compress the scale and robust standard errors to account for heteroscedasticity and deviations from standard assumptions.

2.6 Empirical results

2.6.1 Estimation of farming ability/efficiency

This section estimates a Cobb-Douglas stochastic frontier model and derives the post-estimate of farming ability.Table 2.2 presents results from two datasets: an unbalanced panel dataset that excludes observations appearing only once over three years and a balanced panel dataset with observations for all three years. The analysis indicates that plot area, the amount of inorganic fertilizer applied, and adult equivalents are positively and significantly related to crop production value. Specifically, a 1 percent increase in plot size results in a 0.68 percent increase in crop production value, while a 1 percent increase in inorganic fertilizer usage leads to a 0.04 percent increase in crop production value. Additionally, a 1 percent increase in adult equivalents is associated with a 0.25 percent increase in crop production value. These findings are consistent with existing theory and literature on Malawi and other sub-Saharan African countries (Deininger and Mpuga, 2010; Jin and Jayne, 2013; Chamberlin and Ricker-Gilbert, 2016). The results also demonstrate that household education significantly impacts crop production value. An increase in years of schooling by one year results in a reduction in crop production value by 9.4 percent. The balanced dataset reveals a similar trend, with both annual temperature and the household head's sex significantly influencing crop production value. Other factors, such as population density and the household head's age, do not have a significant effect. Given the consistency of results across both datasets, the analysis focuses on the unbalanced panel dataset, with the balanced panel dataset results included in the appendix for robustness.

The predicted farming ability scores represents the ratio of actual crop production output to the maximum attainable crop production output. The post-estimation mean farming ability score is 0.2860 and ranges from a minimum of 0.0008 to a maximum of 0.7769. This indicates that, on average, smallholder farming households in Malawi exhibit significant inefficiency in crop production, with the mean deviation from the maximum feasible output (farming ability = 1) being substantial. The next step involves analyzing factors that determine households' decisions to participate in customary land tenure systems, with the estimated farming ability from the Cobb-Douglas production function included as an explanatory variable.

Table 2.2: Fixed-effects Cobb-Douglas stochastic frontier model

	Unbalanced Panel Dataset	**Balanced Panel Dataset**
VARIABLES	**Log crop production value (Malawi Kwacha)**	**Log crop production value (Malawi Kwacha)**
Log plot area (acres)	0.6757***	0.6505***
	(0.0000)	(0.0000)
Log total inorganic fertilizer (kgs)	0.0360**	0.0688***
	(0.0223)	(0.0002)
Log adult equivalent	0.2490*	0.1906
	(0.0695)	(0.1967)
Log annual rainfall (mm)	0.2349	0.5246*
	(0.3719)	(0.0758)
Log population density	-0.0055	-0.0427
	(0.9440)	(0.6156)
Log annual temperature ($0^c * 10$)	1.2167	3.0623*
	(0.4841)	(0.0951)
Household head age (years)	0.0870	-0.0195
	(0.4813)	(0.8884)
Household head education (years)	-0.0936**	-0.0647
	(0.0376)	(0.2147)
Male household head (=1)	-0.0313	-0.3154*
	(0.8272)	(0.0515)
U-sigma Constant	1.7468***	1.8124***
	(0.0000)	(0.0000)
V-sigma Constant	1.1534***	1.1542***
	(0.0000)	(0.0000)
N	4760	3533

*Note: The model includes year, region, and crop fixed effects, as well as soil quality and type variables, which are not shown in the table. Standard errors in parentheses clustered at household level. * p < 0.10, ** p < 0.05, *** p < 0.01. The number of observations for the balanced panel dataset is not divisible by 3 because some households did not provide production values for certain years, as the crops had not yet been harvested at the time of the survey.*

2.6.2 Determinants of household participation in customary land tenure systems

The analysis of household participation in land tenure systems identifies several key factors influencing decisions across different tenure types. Marginal effects from the logistic regression in Table 2.3 show that higher farming ability significantly reduces the likelihood of participation in inherited land, with a marginal effect significant at the 1% level. This inefficiency arises because inheritance tends to follow traditional norms based on familial rights rather than agricultural productivity. In many customary systems, land is passed down through lineage, prioritizing family continuity over the farming abilities of heirs (Peters, 2004). Farmland allocated by chiefs is associated with positive farming ability, reflecting efficiency in land allocation. Chiefs generally strive for equitable land distribution within the community, ensuring households have access to this vital resource and community stability (Kishindo, 2004; Chimhowu and Woodhouse, 2005). This approach is essential in rural areas, where farmland is a critical livelihood asset. Fair distribution promotes efficiency and helps prevent the overaccumulation of farmland, a significant issue among smallholder farmers in developing countries, often linked to inverse land productivity. Although patronage, informal land markets and cultural norms may influence decisions, favoring those with strong social connections or the ability to offer favors (Kishindo, 2004), the system remains largely effective.

The analysis further reveals that households with greater farming ability prefer to acquire land through alternative means, such as purchase or rental, rather than relying on customary systems. More capable farmers may manage existing holdings more efficiently or have the financial means to expand their operations independently (Deininger et al., 2003). Consequently, farming ability has a positive marginal effect on participation in rented or borrowed land and purchased land, with significance at 5% and 10%, respectively. This suggests that skilled farmers are more likely to rent or borrow land to expand their operations or invest in purchasing additional land, reflecting their confidence in their farming capabilities and their ability to make productive use of additional land (Holden et al., 2010; Deininger and Mpuga, 2010; Jin and Jayne, 2013; Chamberlin and Ricker-Gilbert, 2016).

Table 2.3: Determinants of household participation in customary land tenure (Panel Logit Model: Marginal Effects)

VARIABLES	**(1) Inherited farmland. (=1)**	**(2) Chief/employer farmland. (=1)**	**(3) Rented/borrowed farmland. (=1)**	**(4) Purchased farmland. (=1)**
Farming ability (\alpha)	-0.127***	0.0177	0.0724**	0.0427*
	(0.0486)	(0.0395)	(0.0337)	(0.0227)
Household land holding (acres)	-0.00468	-0.00139	-0.00688	0.0150**
	(0.0116)	(0.00936)	(0.00924)	(0.00606)
Number of crops grown	0.0335***	-0.0167**	-0.0139**	-0.00596
	(0.00855)	(0.00711)	(0.00574)	(0.00387)
Log adult equivalents	-0.00687	0.00225	-0.00740	0.00611
	(0.0360)	(0.0295)	(0.0248)	(0.0156)
Log household head age	0.00708	-0.00216	-0.00836	0.00811
	(0.0294)	(0.0247)	(0.0189)	(0.0143)
Male household head (=1)	-0.0383**	0.00281	0.0237**	0.00921
	(0.0166)	(0.0135)	(0.0121)	(0.00872)
Accessed credit/loan (=1)	-0.0184	-0.00343	0.0182*	0.00182
	(0.0157)	(0.0121)	(0.00993)	(0.00672)
Log population density	0.00435	-0.0148	0.0140	0.00394
	(0.0209)	(0.0163)	(0.0152)	(0.00797)
Member death/agricultural shock (=1)	0.0285*	-0.0172	0.00352	-0.00195
	(0.0149)	(0.0121)	(0.0101)	(0.00786)
Household breakup (=1)	0.0451*	-0.0247	0.0147	-0.0258
	(0.0268)	(0.0201)	(0.0183)	(0.0177)
Log distance to paved road (kms)	0.0300	-0.00394	-0.0222	-0.00850
	(0.0196)	(0.0149)	(0.0141)	(0.00941)
Log distance to agricultural markets (kms)	-0.0159	-0.00181	0.0212***	-0.00959
	(0.0112)	(0.00999)	(0.00767)	(0.00635)
Matrilineal households (=1)	0.0690*	-0.0158	-0.0519**	-0.00609
	(0.0362)	(0.0258)	(0.0231)	(0.0204)
Rural households (=1)	0.127***	0.0349	-0.0483**	-0.0599***
	(0.0357)	(0.0302)	(0.0214)	(0.0168)
Observations	4,760	4,760	4,760	4,760

Note: The models are estimated using logistic regression with the Mundlak-Chamberlain device, which includes time averages of all time-variant covariates (not shown in the table). Other control variables not displayed in the table include year, crop, and region fixed effects, soil quality and type dummies. Cluster robust standard errors, shown in parentheses, are bootstrapped at 500 repetitions: $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

Household total landholding size does not significantly impact participation in customary farmland tenure systems, although the negative coefficients suggest potential equitable land distribution. This implies that both customary tenure systems promote equitable distribution, despite the negative association between inherited farmland and farming ability. This effect may be due to land being viewed as a fundamental right of community membership, supported by cultural norms and social ties. In contrast, farmland tenure through purchase demonstrates significant marginal effects. Larger landholdings increase the likelihood of acquiring additional farmland, as evidenced by a positive and significant marginal effect at the 5% level. This finding is consistent with the literature on land consolidation and agricultural efficiency, which indicates that larger landholdings provide economies of scale and encourage further land acquisition (Boserup, 2014; Lipton, 2009). Households with abundant land are more likely to acquire additional farmland compared to those with less land under the land sales market (Roth and McCarthy, 2013; Holden and Otsuka, 2014). This situation may be compounded by limited access to credit or loans, where financially constrained households might sell their land to address immediate needs, such as medical expenses or loan repayments (Kishindo, 2004).

The number of crops a household grows significantly influences participation in various land tenure systems. The positive and highly significant marginal effect at the 1% level indicates that households practicing diversified farming are more likely to participate in inherited farmland tenure. This may be because diversified farming households seek stability and continuity, which inherited land can provide. However, the adverse and significant marginal effects at the 5% level for land allocated by chiefs, as well as for rented or borrowed land, suggest that diversified farming households prioritize stability and control over their land resources, which is more easily maintained with inherited land (Djurfeldt et al., 2018).

Gender dynamics and lineage systems play a critical role in land tenure decisions. Male-headed households show a significant negative marginal effect on participation in inherited farmland tenure, likely reflecting traditional gender norms that shape land access and decision-making. These households are more inclined to acquire land through purchase or rental rather than inheritance (Yngstrom, 2002). Conversely, male-headed households are more likely to rent or borrow land, as indicated by a significant positive marginal effect, suggesting their proactive approach to acquiring additional land due to their involvement in agricultural expansion and market activities (Deininger and Xia, 2017; Agarwal, 2003). Economic factors further underscore these dynamics. Male-headed households typically enjoy better economic mobility and resource access, enabling them to actively engage in land markets for agricultural expansion or as a capital investment (Perez et al., 2015; Hajjar et al., 2020; Lambrecht, 2016). In contrast, female-headed households, particularly in rural areas, often face limited economic opportunities and thus rely more heavily on customary land systems where social and familial connections mediate land access (Yngstrom, 2002).

Lineage systems reinforce these gendered patterns. In matrilineal households, there is a higher likelihood of participation in inherited farmland tenure, consistent with the matrilineal inheritance system, where land is passed down through the female line (Peters, 2004; Quisumbing et al., 2001; Azong and Kelso, 2021). Conversely, these households are less likely to participate in rented or borrowed land, reflecting cultural norms that prioritize retaining land within the family and reducing reliance on rental markets (Wily, 2017;

Takane, 2008; Namubiru-Mwaura, 2014). In contrast, patrilineal societies favor land inheritance through the male line. Male-headed households in these systems may already have access to inherited land but also seek to expand their holdings through purchases or rentals to consolidate wealth and ensure lineage continuity. This drives their active participation in the land market to secure and increase their landholdings (Fortes, 2017; Lunduka et al., 2010; Peters, 2010). Customary tenure systems are particularly significant for matrilineal and female-headed households, offering social protections and community support that help women overcome barriers in formal land markets (Namubiru-Mwaura, 2014; Doss and Meinzen-Dick, 2020). On the other hand, male-headed and patrilineal households often benefit from broader social networks, which aid their participation in land markets through access to credit, market information, and legal support (Quisumbing and Doss, 2021; Agarwal, 2003). Traditional gender roles also influence these patterns, with women in female-headed households often focusing on subsistence farming under customary tenure. At the same time, men engage in commercial agriculture, driving their involvement in land markets to scale production and capitalize on economic opportunities (Doss et al., 2013; Quisumbing and Maluccio, 2003).

Finally, the analysis highlights significant differences between rural and urban households' participation in various land tenure systems. Rural households show a positive and highly significant marginal effect at the 1% level for participation in inherited farmland tenure, consistent with the prevalence of customary land tenure systems in rural areas, where land is often passed down through generations (Chimhowu and Woodhouse, 2005). However, rural households are less likely to participate in rented or borrowed land and purchased land, with both negative and significant coefficients. This could be due to the limited availability of land rental and sales markets in rural areas or a preference for maintaining traditional land tenure arrangements within the community (Peters, 2004; Cotula et al., 2004; Holden and Otsuka, 2014).

The results from the logistic regression presented in Table 2.3 consistently align with the probit results shown in Table A1.1 of the appendix. Although a 3-year gap between panels is significant, I conducted a robustness check to assess whether lagged farming ability affects the likelihood of participation in farmland tenure systems during the current period. The results in Table A1.2 of the appendix indicate no significant correlation between lagged farming ability and the likelihood of current participation in these systems. Additionally, Table A1.3 in the appendix presents the logistic regression results from a balanced panel dataset, which are also consistent with the unbalanced panel results.

2.7 Conclusion

The study provides valuable insights into the relationship between farming ability and land allocation under Malawi's customary tenure systems, revealing the complex dynamics of land distribution shaped by traditional norms, social considerations, and economic factors. Households with lower farming ability are more likely to inherit land, a process focused on maintaining family and community continuity rather than optimizing agricultural productivity. This inheritance system emphasizes lineage over economic efficiency, potentially leading to inefficiencies in land use as it does not prioritize the heirs' farming capabilities. Conversely, farmland allocated by chiefs demonstrates efficiency in land distribution, as chiefs often aim to allocate land equitably among households within the community. This approach ensures that households have access to this critical resource, promoting social harmony and preventing overaccumulation of land. While social and political ties may sometimes influence allocations, the system generally supports efficient land use by maintaining community stability and ensuring that land remains a productive resource for a broad range of households. By balancing equitable access and the community's long-term needs, chiefs' land allocation supports agricultural productivity and social cohesion.

In contrast, more capable farmers prefer acquiring land through purchase or rental, reflecting their confidence in managing and expanding agricultural operations. These skilled farmers are more likely to participate in land markets, indicating a divergence in land acquisition strategies based on farming ability. The study also finds that the size of a household's landholding does not significantly influence participation in customary tenure systems, suggesting a degree of equity in land distribution. However, larger landholders are more likely to expand through purchases, exacerbating inequalities as wealthier households consolidate land. In contrast, poorer households may be forced to sell land to address immediate financial needs.

These findings highlight challenges of both efficiency and equity in customary land tenure systems. While these systems ensure social stability and access to land, they also harbor inefficiencies that may impede agricultural productivity and perpetuate inequality. The study calls for reforms to align land allocation with farming ability and ensure market-based land transactions do not disproportionately favor wealthier households. In conclusion, addressing the inefficiencies and inequities in customary land tenure systems is crucial for improving agricultural productivity and fostering sustainable development. Policymakers should explore reforms that balance cultural preservation with economic efficiency and fairness, integrating customary practices with modern land tenure principles. Such reforms could help bridge the gap between traditional land management and the needs of contemporary agricultural economies, fostering more inclusive and sustainable land use practices across Sub-Saharan Africa.

Appendix

Table A1.1: Determinants of household participation in customary land tenure (Panel Probit Model: Marginal Effects)

VARIABLES	**(1) Inherited farmland. (=1)**	**(2) Chief/employer farmland. (=1)**	**(3) Rented/borrowed farmland. (=1)**	**(4) Purchased farmland. (=1)**
Farming ability (α)	-0.128***	0.0212	0.0732**	0.0428*
	(0.0486)	(0.0397)	(0.0334)	(0.0229)
Household land holding (acres)	-0.00435	-0.00169	-0.00714	0.0152**
	(0.0115)	(0.00934)	(0.00911)	(0.00605)
Number of crops grown	0.0332***	-0.0166**	-0.0137**	-0.00622
	(0.00850)	(0.00698)	(0.00571)	(0.00387)
Log adult equivalents	-0.00817	0.00170	-0.00620	0.00400
	(0.0356)	(0.0291)	(0.0244)	(0.0159)
Log household head age	0.00864	-0.00589	-0.00931	0.00740
	(0.0297)	(0.0244)	(0.0189)	(0.0144)
Male household head (=1)	-0.0384**	0.00360	0.0224*	0.00804
	(0.0165)	(0.0135)	(0.0119)	(0.00859)
Accessed credit/loan (=1)	-0.0183	-0.00426	0.0173*	0.00205
	(0.0158)	(0.0122)	(0.00994)	(0.00669)
Log population density	0.00395	-0.0139	0.0128	0.00320
	(0.0209)	(0.0166)	(0.0150)	(0.00828)
Member death/agricultural shock (=1)	0.0287*	-0.0172	0.00438	-0.00175
	(0.0150)	(0.0120)	(0.0101)	(0.00779)
Household breakup (=1)	0.0456*	-0.0286	0.0156	-0.0257
	(0.0266)	(0.0206)	(0.0182)	(0.0180)
Log distance to paved road (kms)	0.0307	-0.00630	-0.0209	-0.00815
	(0.0195)	(0.0148)	(0.0138)	(0.00956)
Log distance to agricultural markets (kms)	-0.0153	-0.00340	0.0205***	-0.00946
	(0.0112)	(0.00999)	(0.00759)	(0.00623)
Matrilineal households (=1)	0.0698*	-0.0174	-0.0536**	-0.00664
	(0.0361)	(0.0254)	(0.0231)	(0.0200)
Rural households (=1)	0.127***	0.0286	-0.0483**	-0.0603***
	(0.0357)	(0.0291)	(0.0216)	(0.0169)
Observations	4,760	4,760	4,760	4,760

*Note: The models are estimated using probit regression with the Mundlak-Chamberlain device, which includes time averages of all time-variant covariates (not shown in the table). Other control variables not displayed in the table include year, crop, and region fixed effects, soil quality and type dummies. Cluster robust standard errors, shown in parentheses, are bootstrapped at 500 repetitions: *p < 0.10, **p < 0.05, and ***p < 0.01.*

Table A1.2: Determinants of household participation in customary land tenure (Panel Logit Model: Marginal Effects with lagged farming ability)

VARIABLES	**(1) Inherited farmland. (=1)**	**(2) Chief/employer farmland. (=1)**	**(3) Rented/borrowed farmland. (=1)**	**(4) Purchased farmland. (=1)**
Lagged farming ability (-1)	0.108	-0.0251	-0.0743	-0.00620
	(0.0699)	(0.0580)	(0.0492)	(0.0345)
Household land holding (acres)	-0.00519	0.00135	-0.00935	0.0160**
	(0.0131)	(0.0120)	(0.0102)	(0.00706)
Number of crops grown	0.0375***	-0.0173*	-0.0114*	-0.0100**
	(0.0101)	(0.00976)	(0.00662)	(0.00501)
Log adult equivalents	0.00132	0.0324	-0.0486	0.00760
	(0.0448)	(0.0388)	(0.0305)	(0.0204)
Log household head age	0.00312	0.0136	-0.0161	0.00409
	(0.0414)	(0.0373)	(0.0269)	(0.0197)
Male household head (=1)	-0.0135	-0.0108	0.00946	0.0131
	(0.0186)	(0.0177)	(0.0149)	(0.0110)
Accessed credit/loan (=1)	-0.0271	-0.00551	0.0203*	0.00842
	(0.0184)	(0.0162)	(0.0120)	(0.00814)
Log population density	-0.0178	-0.00594	0.0171	0.0106
	(0.0251)	(0.0212)	(0.0184)	(0.0116)
Member death/agricultural shock (=1)	0.0383*	-0.00188	-0.0163	-0.00447
	(0.0220)	(0.0181)	(0.0151)	(0.0105)
Household breakup (=1)	0.00667	-0.0238	0.0311	-0.00212
	(0.0280)	(0.0244)	(0.0195)	(0.0170)
Log distance to paved road (kms)	0.0303	0.0137	-0.0356*	-0.00732
	(0.0258)	(0.0231)	(0.0182)	(0.0136)
Log distance to agricultural markets (kms)	-0.0533**	-0.0186	0.0581***	-0.00100
	(0.0244)	(0.0236)	(0.0162)	(0.0124)
Matrilineal households (=1)	0.0815*	-0.0193	-0.0549*	0.00141
	(0.0430)	(0.0346)	(0.0286)	(0.0253)
Rural households (=1)	0.134***	0.0491	-0.0660**	-0.0607***
	(0.0496)	(0.0425)	(0.0319)	(0.0220)
Observations	3,065	3,065	3,065	3,065

*Note: The models are estimated using logistic regression with the Mundlak-Chamberlain device, which includes time averages of all time-variant covariates (not shown in the table). Other control variables not displayed in the table include year, crop, and region fixed effects, soil quality and type dummies. Cluster robust standard errors, shown in parentheses, are bootstrapped at 500 repetitions: *p < 0.10, **p < 0.05, and ***p < 0.01.*

Table A1.3: Determinants of household participation in customary land tenure (Balanced Panel logit Model: Marginal Effects)

VARIABLES	**(1) Inherited farmland. (=1)**	**(2) Chief/employer farmland. (=1)**	**(3) Rented/borrowed farmland. (=1)**	**(4) Purchased farmland. (=1)**
Farming ability (α)	-0.112**	0.0354	0.0620*	0.0234
	(0.0551)	(0.0490)	(0.0356)	(0.0262)
Household land holding (acres)	0.00685	-0.00219	-0.0101	0.00717
	(0.0135)	(0.0103)	(0.00967)	(0.00678)
Number of crops grown	0.0523***	-0.0241**	-0.0183**	-0.00835
	(0.0118)	(0.0104)	(0.00895)	(0.00638)
Log adult equivalents	0.00469	-0.0135	0.00672	0.00967
	(0.0375)	(0.0315)	(0.0254)	(0.0186)
Log household head age	0.0418	-0.00270	-0.0265	-0.0183
	(0.0337)	(0.0294)	(0.0219)	(0.0171)
Male household head (=1)	-0.0440**	0.00894	0.0212	0.0131
	(0.0176)	(0.0155)	(0.0137)	(0.0109)
Accessed credit/loan (=1)	-0.0252	-0.000228	0.0129	0.00655
	(0.0165)	(0.0138)	(0.0113)	(0.00841)
Log population density	0.00591	-0.0105	0.00218	0.00396
	(0.0249)	(0.0173)	(0.0150)	(0.0106)
Member death/agricultural shock (=1)	0.0466***	-0.0320**	-0.00661	0.00111
	(0.0166)	(0.0143)	(0.0116)	(0.00870)
Household breakup (=1)	0.0126	-0.00510	0.00546	-0.00261
	(0.0303)	(0.0232)	(0.0225)	(0.0177)
Log distance to paved road (kms)	0.0358	-0.0126	-0.0123	-0.0125
	(0.0223)	(0.0190)	(0.0161)	(0.0103)
Log distance to agricultural markets (kms)	-0.0155	0.000632	0.0197**	-0.0112
	(0.0133)	(0.0127)	(0.00946)	(0.00742)
Matrilineal households (=1)	0.0404	0.0270	-0.0497	-0.00889
	(0.0411)	(0.0318)	(0.0302)	(0.0234)
Rural households (=1)	0.142***	0.0373	-0.0403	-0.0697***
	(0.0400)	(0.0370)	(0.0256)	(0.0191)
Observations	3,533	3,533	3,533	3,533

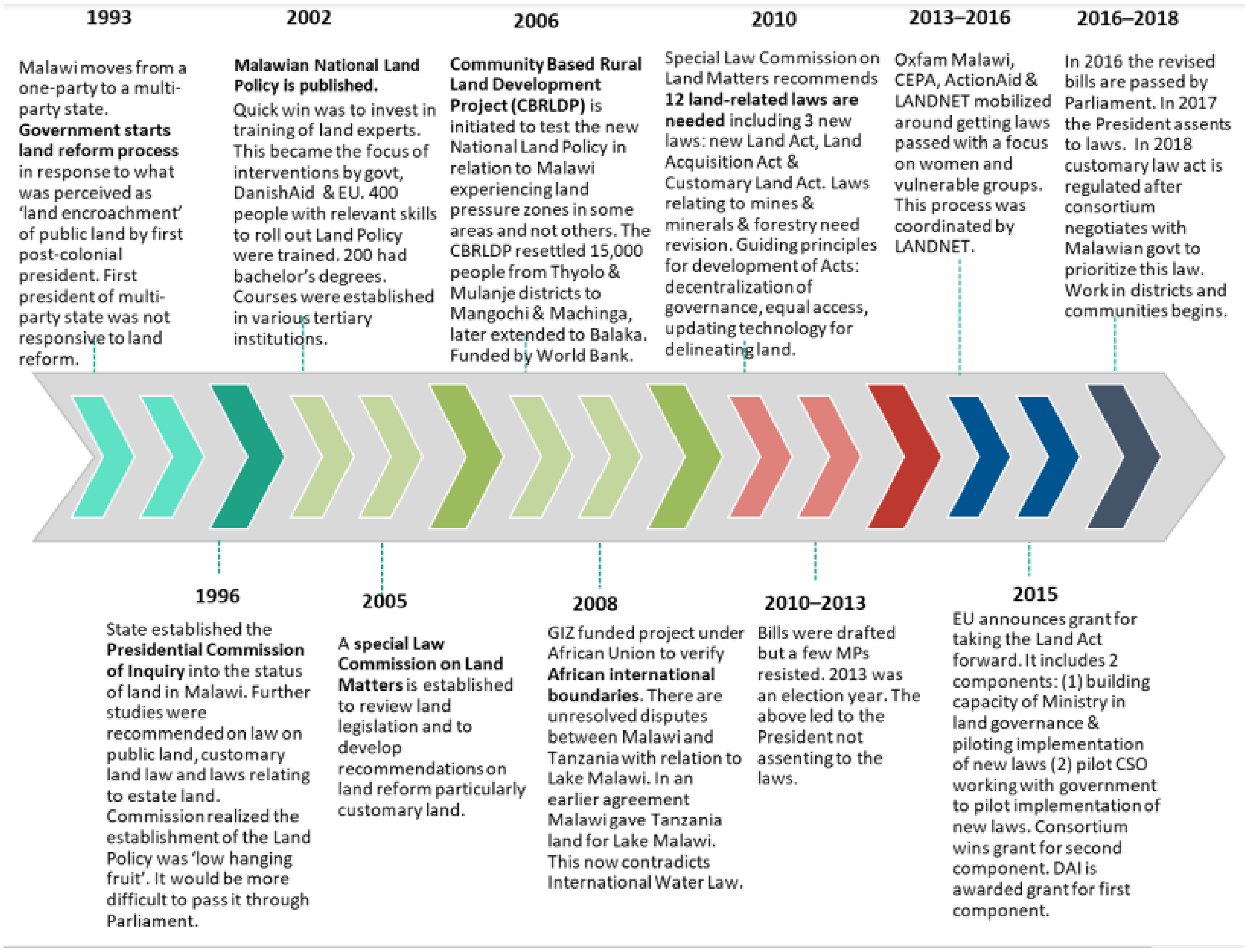
*Note: The models are estimated using logit regression with the Mundlak-Chamberlain device, which includes time averages of all time-variant covariates (not shown in the table). Other control variables not displayed in the table include year, crop, and region fixed effects, soil quality and type dummies. Cluster robust standard errors, shown in parentheses, are bootstrapped at 500 repetitions: *p < 0.10, **p < 0.05, and ***p < 0.01.*

Table A1.4: Descriptive statistics-Balanced panel dataset

VARIABLES	**Inherited farmland**					**Farmland allocated by chiefs**				
	N	**Mean**	**SD**	**Min**	**Max**	**N**	**Mean**	**SD**	**Min**	**Max**
Crop production value (Malawi Kwacha)	2157	34792.24	91703.09	0	2400000	709	62968.64	125123.67	0	1325667
Plot area (acres)	2327	1.11	0.96	0	9.07	965	1.20	1.01	.01	9
Total fertilizer used (kgs)	2331	35.71	55.05	0	300	965	27.19	55.03	0	300
Population density	2331	354.26	669.47	25	5000	961	362.28	680.21	25	5000
Adult equivalents	2331	3.91	1.59	.76	11.12	965	3.88	1.560	1.00	10.20
Annual rainfall amount (mm)	2331	776.96	120.90	534	1377	961	685.59	129.13	531	1266
Average annual temperature (0c*10)	2331	214.50	17.95	181	262	961	215.14	17.82	181	262
Household head age	2331	40.78	16.30	0	94	965	43.67	15.55	14	93
Household head education	2331	1.26	0.71	0	6	965	1.18	0.66	1	7
Male household head (=1)	2331	.74	0.44	0	1	965	.74	0.44	0	1
Household accessed credit/loan	2331	.18	0.39	0	1	965	.23	0.42	0	1
Experienced death/agricultural shock	2331	.83	0.38	0	1	965	.77	0.42	0	1
Household breakup	2331	.04	0.21	0	1	965	.10	0.30	0	1
Distance to paved road (kms)	2331	9.53	9.61	0	50	961	10.34	10.29	0	50
Distance to agriculture markets (kms)	2331	18.60	15.13	0	67	961	24.54	14.01	.71	59
Matrilineal households	2331	.85	0.36	0	1	965	.90	0.30	0	1

VARIABLES	**Rented/borrowed farmland**					**Purchased farmland**				
	N	**Mean**	**SD**	**Min**	**Max**	**N**	**Mean**	**SD**	**Min**	**Max**
Crop production value (Malawi Kwacha)	298	60653.54	115668.65	0	1370000	152	57399.31	113251.27	0	990000.06
Plot area (acres)	338	1.06	0.97	.01	8.5	172	1.39	1.59	.01	15
Total fertilizer used (kgs)	339	50.34	71.80	0	300	173	53.92	77.41	0	300
Population density	339	597.27	1158.38	25	5000	173	489.88	921.47	25	5000
Adult equivalents	339	4.11	1.63	1.00	11.42	173	4.40	1.63	1.43	9.01
Annual rainfall amount (mm)	339	745.35	128.58	531	1246	173	730.62	115.28	537	1234
Average annual temperature (0c*10)	339	213.08	19.79	181	263	173	217.26	17.17	181	262
Household head age	339	38.15	15.28	12	106	173	41.25	14.38	18	90
Household head education	339	1.43	0.98	0	6	173	1.46	1.08	1	7
Male household head (=1)	339	.84	0.37	0	1	173	.84	0.36	0	1
Household accessed credit/loan	339	.27	0.45	0	1	173	.25	0.43	0	1
Experienced death/agricultural shock	339	.77	0.42	0	1	173	.78	0.42	0	1
Household breakup	339	.06	0.24	0	1	173	.05	0.21	0	1
Distance to paved road (kms)	339	8.34	10.32	0	43.54	173	10.09	10.04	0	35
Distance to agriculture markets (kms)	339	19.67	15.63	.24	59	173	19.09	15.38	.11	56
Matrilineal households	339	.86	0.34	0	1	173	.92	0.27	0	1

Figure A1.1: Land reform process since multiparty state in 1993)



1993

Malawi moves from a one-party to a multi-party state. **Government starts land reform process** in response to what was perceived as 'land encroachment' of public land by first post-colonial president. First president of multi-party state was not responsive to land reform.

1996

State established the **Presidential Commission of Inquiry** into the status of land in Malawi. Further studies were recommended on law on public land, customary land law and laws relating to estate land. Commission realized the establishment of the Land Policy was 'low hanging fruit'. It would be more difficult to pass it through Parliament.

2002

Malawian National Land Policy is published. Quick win was to invest in training of land experts. This became the focus of interventions by govt, DanishAid & EU. 400 people with relevant skills to roll out Land Policy were trained. 200 had bachelor's degrees. Courses were established in various tertiary institutions.

2005

A **special Law Commission on Land Matters** is established to review land legislation and to develop recommendations on land reform particularly customary land.

2006

Community Based Rural Land Development Project (CBRLDP) is initiated to test the new National Land Policy in relation to Malawi experiencing land pressure zones in some areas and not others. The CBRLDP resettled 15,000 people from Thyolo & Mulanje districts to Mangochi & Machinga, later extended to Balaka. Funded by World Bank.

2008

GIZ funded project under African Union to verify **African international boundaries**. There are unresolved disputes between Malawi and Tanzania with relation to Lake Malawi. In an earlier agreement Malawi gave Tanzania land for Lake Malawi. This now contradicts International Water Law.

2010

Special Law Commission on Land Matters recommends **12 land-related laws are needed** including 3 new laws: new Land Act, Land Acquisition Act & Customary Land Act. Laws relating to mines & minerals & forestry need revision. Guiding principles for development of Acts: decentralization of governance, equal access, updating technology for delineating land.

2010–2013

Bills were drafted but a few MPs resisted. 2013 was an election year. The above led to the President not assenting to the laws.

2013–2016

Oxfam Malawi, CEPA, ActionAid & LANDNET mobilized around getting laws passed with a focus on women and vulnerable groups. This process was coordinated by LANDNET.

2015

EU announces grant for taking the Land Act forward. It includes 2 components: (1) building capacity of Ministry in land governance & piloting implementation of new laws (2) pilot CSO working with government to pilot implementation of new laws. Consortium wins grant for second component. DAI is awarded grant for first component.

2016–2018

In 2016 the revised bills are passed by Parliament. In 2017 the President assents to laws. In 2018 customary law act is regulated after consortium negotiates with Malawian govt to prioritize this law. Work in districts and communities begins.

Adopted from NPC (2021): "A Cost-Benefit Note: Implementing the National Land Policy in Malawi - Technical Report, Malawi Priorities, National Planning Commission(NPC)," Copenhagen Consensus Center (USA) African Institute for Development Policy (Malawi).

Chapter 3

The Impact of Seasonal Irrigation on Agricultural and Labor Productivity

3.1 Introduction

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Seasonal irrigation is a pivotal element in agricultural systems, particularly in regions like Sub-Saharan Africa (SSA), where rainfall patterns are highly variable and often unreliable. This variability poses a significant challenge to agricultural productivity and labor dynamics, directly impacting food security and economic stability. Understanding how seasonal irrigation influences agricultural productivity and labor allocation is essential for developing effective policies and interventions for the country and other SSA nations.

The motivation for this study is driven by the urgent need to address the persistent inconsistencies in agricultural productivity observed across Sub-Saharan Africa (SSA). Despite considerable investments and interventions to improve agricultural practices, productivity disparities remain widespread. Irrigation has been proposed as a promising strategy to counteract the adverse effects of unpredictable rainfall (Faurès and Santini, 2008; Dubois, 2011). However, a critical gap exists in empirical research concerning the seasonal impacts of irrigation on productivity outcomes. While irrigation is frequently highlighted as a potential solution, existing literature often lacks rigorous, detailed empirical evidence specifically evaluating how seasonal variations influences the effect of irrigation on agricultural and labor productivity. Most studies either focus broadly on irrigation without accounting for seasonal dynamics or do not disaggregate the impacts on agricultural versus labor productivity by seasons of the year.

This chapter addresses the critical literature gap by providing a comprehensive empirical analysis of how seasonal irrigation influences agricultural productivity, measured by crop yield (kgs/ha), and labor productivity, measured by output (kgs) per labor day, across two distinct agricultural seasons in Rwanda. Season A spans from September to February of the following year, while Season B covers March to June. By disaggregating the analysis by season, this study provides a nuanced understanding of the temporal dynamics of irrigation. The research employs a household-plot-year fixed effects estimation technique, leveraging the consistency of household members using the same plot across seasons and years. This approach controls for year-fixed effects and household-plot-crop specific time-constant covariates, isolating the differential impacts of seasonal irrigation on productivity. Utilizing panel data from the Land and Water Husbandry (LWH) project—conducted by the World Bank in collaboration with the Rwandan Government—this study offers a robust basis for analysis. Rwanda's unique topography and climatic conditions, including its hilly terrain and varied rainfall patterns, make it an ideal setting for examining irrigation effectiveness (Nahayo et al., 2017). Additionally, Rwanda's commitment to agricultural transformation through initiatives like the Crop Intensification Program (CIP) highlights the relevance of this research. By providing insights into how seasonal irrigation can be optimized, this study aims to inform more effective agricultural policies and practices, ultimately enhancing productivity and resilience in the face of climate variability.

The analysis indicates that irrigation significantly enhances crop yields, with a 43.1% increase in yield for all crops and a 37.3% increase for legumes. This improvement in yields translates into increased labor productivity, with household labor productivity rising by 14.1% and total labor productivity by 13.6%. These results are consistent with literature that highlights the positive impact of irrigation on productivity, such as studies by Rosegrant et al. (2009) and Molden et al. (2010), which emphasize the role of irrigation in improving agricultural output. However, in Season B, the impact of irrigation on labor productivity is less pronounced and statistically insignificant, reflecting variability in effectiveness based on seasonal conditions. This observation aligns with findings by Agrawal et al. (2019); Puma and Cook (2010); Hasan and Abed (2024), who document that the benefits of irrigation can vary significantly with environmental factors and crop types. Additionally, the interaction between irrigation and drought experience does not significantly alter productivity outcomes, which is consistent with research by Rockström et al. (2003), indicating that while irrigation generally benefits productivity, its effectiveness may not substantially differ based on drought conditions. Irrigation has a profound impact on labor productivity in agriculture by increasing crop yields (Hussain and Hanjra, 2004), extending growing seasons (Namara et al., 2011), reducing the risk of crop failure (Foster and Rosenzweig, 2004), enabling the cultivation of high-value crops, and encouraging the adoption of improved agricultural practices (Rosegrant and Evenson, 1992; Lipton et al., 2003). These factors collectively enhance the efficiency and effectiveness of labor, contributing to greater agricultural productivity and economic benefits for farmers.

These findings have significant implications extending beyond Rwanda, as many countries in Sub-Saharan Africa (SSA) face similar climatic and agricultural conditions. The insights from this research can shape and enhance irrigation policies and practices across the region. By illuminating the differential impacts of irrigation by season, this study contributes actively to the broader discourse on climate adaptation and sustainable agricultural practices in developing regions. Specifically, the focus on plot-level analysis and seasonal variations provides a detailed understanding of irrigation's effects, contrasting with broader studies that may overlook these micro-level productivity fluctuations. This detailed approach offers actionable insights for policymakers aiming to optimize irrigation strategies and boost productivity among smallholder farmers throughout varying farming seasons. Additionally, understanding irrigation performance across seasons facilitates targeted interventions to promote the adoption of efficient irrigation technologies. This, in turn, has the potential to significantly improve food security and economic stability, especially in drought-prone regions.

In sum, this research not only addresses a critical gap in the literature but also provides practical insights for enhancing agricultural productivity and labor efficiency in regions heavily reliant on seasonal agriculture. The study's findings are instrumental in shaping future policies and programs aimed at improving food security and economic resilience in SSA. The remainder of this paper is structured as follows: Section 2 provides a detailed background of the LWH project and outlines the agricultural seasons in Rwanda. Section

3 reviews the literature on irrigation impacts and agricultural productive labor use intensity. Section 4 describes the methodology employed in this study, including data sources, variable definitions, and analytical techniques. Section 5 presents the empirical findings, followed by a discussion of their implications in Section 6. Finally, Section 7 concludes with policy recommendations and avenues for future research.

3.2 Project background and agricultural seasons in Rwanda

The agricultural sector plays a pivotal role in Rwanda's economy, as it actively operationalizes the objectives of Vision 2020 and the Economic Development and Poverty Reduction Strategy. These objectives include reducing poverty, achieving food security, promoting commercialized and professional agriculture, stimulating industrialization, and increasing export earnings (World Bank Development Impact Evaluation Unit). Rwanda's agricultural sector accounts for approximately 39% of the country's GDP and employs around 80% of the population. However, a significant challenge arises because roughly 90% of arable land is on hillsides. Therefore, implementing effective land management practices to prevent erosion and preserve soil quality while fostering agricultural growth is essential.

In response to this challenge, the Rwandan Government introduced the Land and Water Husbandry (LWH) project to execute its strategic plans. The primary focus of this project was to enhance productivity by investing in farmer-participatory land care, water harvesting, and intensified irrigation in hilly areas "Ibid." The project was jointly funded by the Government of Rwanda, the International Development Association (IDA) of the World Bank, the United States Agency for International Development (USAID), the Canadian International Development Agency (CIDA), and the Global Agriculture & Food Security Program (GAFSP).

The LWH project implemented a tailored watershed approach to promote sustainable land husbandry practices in hillside agriculture in selected regions. Additionally, it established hillside irrigation systems in specific sections of each site. The project had three main components: capacity development and institutional strengthening for hillside development, infrastructure for hillside intensification, and integration of the project into the Ministry of Agriculture and Animal Resources (MINAGRI's) SWAP structure (World Bank DIME, 2013, 2015, 2018). The implementation of the LWH project occurred in three phases: Phase 1A commenced in 2010, followed by Phase 1B in 2012, and Phase 1C, which started in late 2013 (World Bank DIME, 2018).

Rwanda stands apart from other sub-Saharan African countries due to its unique climate, which includes two rainy seasons and one dry season (irrigation season). Approximately 15,000 hectares of farmland in

Rwanda are under irrigation. The primary rainy season, "Season A" in this paper, spans from September to February of the following year. It is succeeded by the secondary and shorter rainy season, known as "Season B", occurring from March to June of the same year. The final farming season is the dry season, labeled as "Season C", which lasts from July to September of the same year (World Bank DIME, 2018).

3.3 Theoretical Framework and Literature Review

3.3.1 Theoretical Framework

The study utilizes Production Function Theory, a foundational economic framework that systematically analyzes how inputs combine to produce outputs in various production processes. As famously articulated by economist Samuelson (1947), Production Function Theory examines the relationship between resources such as land, labor, capital, and materials (such as seeds and fertilizer) utilized in crop cultivation. The core premise lies in comprehending how different combinations of these inputs influence agricultural productivity, particularly concerning the impact of irrigation on crop yields.

According to Production Function Theory, the quantity of output (e.g., crop yield) is determined by the quantities and efficiencies of inputs utilized in production. Mathematically, a production function is expressed as $Q = f(L, K, H, M)$, where Q represents output, L stands for labor, K for capital, H for land or natural resources, and M for materials. This framework enables researchers to quantify how modifications in irrigation practices, such as varying water application levels or adopting different irrigation technologies, affect agricultural productivity across diverse seasons or geographical regions.

Central to Production Function Theory is the concept of marginal productivity, famously expounded by Solow (1957), which measures the change in output resulting from incremental changes in inputs while holding other factors constant. In the context of irrigation as a binary variable (where 1 indicates irrigation and 0 indicates no irrigation), marginal productivity assesses how adopting irrigation (changing from 0 to 1) impacts crop yields under specific conditions. This analysis is crucial in optimizing irrigation strategies to enhance output efficiency while conserving resources. Understanding the marginal productivity of irrigation informs decisions on water allocation and the adoption of irrigation technologies, fostering sustainable agricultural practices and achieving improved productivity outcomes.

Applying the Production Function Theory to study irrigation impacts involves estimating production functions for irrigated and non-irrigated agriculture. Their we are able to evaluate how irrigation influences crop yields differently across different seasons of the year, considering rainfall variability and crop-specific requirements.

3.3.2 Literature Review

Seasonal irrigation is critical to agricultural productivity, especially in regions prone to dry spells and variable rainfall. Understanding its impact on crop yields and labor productivity is essential for developing effective agricultural policies and practices. One of the primary benefits of irrigation is the enhancement of crop yields through improved water use efficiency (WUE). Howell (2001) emphasizes the importance of WUE in irrigation practices, noting that improved irrigation techniques, such as precision irrigation, can significantly enhance crop yields by optimizing water usage and reducing waste. Similarly, Fereres and Soriano (2007) examine how deficit irrigation, which involves applying less water than the crop's evapotranspiration requirement, can be strategically used during different seasons. This approach helps optimize water use while maintaining crop yields, proving particularly beneficial during water-scarce periods. Additional studies, such as those by Steduto et al. (2012), have also highlighted the critical role of efficient water management in enhancing agricultural productivity under variable climatic conditions.

Regarding labor productivity, irrigation profoundly impacts labor allocation and economic returns. Takeshima and Yamauchi (2012) explore how irrigation influences labor allocation and productivity, finding that reliable irrigation reduces the labor time spent on water fetching, allowing farmers to allocate more time to other productive activities, thus increasing overall labor productivity. Smith (2004) comprehensively analyzes how irrigation contributes to economic returns, affecting labor productivity. The study finds that irrigated agriculture generally leads to higher labor productivity than rain-fed agriculture due to increased crop reliability and yield. Similarly, research by Hussain and Hanjra (2004) supports these findings, demonstrating that access to irrigation boosts agricultural output and enhances rural livelihoods by increasing labor opportunities and income levels.

Technological innovations in irrigation systems further enhance both water and labor productivity. Studies by Abdullaev et al. (2010) highlight adopting advanced irrigation systems like drip and sprinkler irrigation, which improve water efficiency and labor productivity by delivering water directly to the plant roots, reducing water loss and labor requirements. These technologies help farmers manage irrigation more effectively, reducing the time and effort required for water management and thus boosting labor productivity. Research by Postel (2001) and Cai et al. (2011) also underscores the significance of modern irrigation technologies in improving water management and agricultural efficiency.

Social and economic factors play a crucial role in the adoption and effectiveness of irrigation practices. Feder and Umali (1993) review how social and economic factors influence the adoption of irrigation technologies and practices, suggesting that education and training are crucial for encouraging farmers to adopt efficient irrigation methods, thereby enhancing labor productivity. Njuki and Sanginga (2013) examine gender dynamics in agricultural labor, noting that access to irrigation can differentially impact male and female labor productivity and decision-making in farming activities, highlighting the need for gender-sensitive approaches in irrigation projects. Complementary studies by Meinzen-Dick and Zwarteveen (1998) emphasize the importance of considering gender and social equity in irrigation projects to ensure inclusive benefits.

In conclusion, the literature indicates that seasonal irrigation significantly impacts agricultural and labor productivity. Improved irrigation techniques and technologies enhance water use efficiency and crop yields while reducing labor requirements and increasing productivity. However, the successful implementation of irrigation practices requires considering social, economic, and gender factors to ensure equitable and sustainable outcomes. This comprehensive understanding is essential for developing policies that maximize the benefits of irrigation in agricultural systems.

3.4 Data and Identification strategy

3.4.1 Data

The data comprises 5 years from 2014 to 2018, covering a total of 12 seasons. Each year includes all three seasons (A, B, and C), except for 2014, which has data only for season C, and 2016, which has no data for season A. Data is collected from the same households for the same plots over all 12 seasons across the 5 years. There is variability in the sample size from year to year due to factors such as migration and hospitalization. The surveys were designed based on the project's results framework and other policy-relevant questions. In addition to household characteristics, the research team gathered data on various agriculture-related indicators, including access to agricultural extension services, adoption of agricultural technology, use of irrigation, decision-making regarding crop cultivation, crop production, sales, and input application, off-farm income, food consumption, and utilization of services from financial institutions.

3.4.2 Identification strategy

The study employs a household-plot-year-crop fixed effects regression approach. This methodology has been widely used in the literature to examine the effect of irrigation on crop productivity, income, and poverty alleviation (Huang et al., 2006; Jin et al., 2012). This approach controls for unobserved heterogeneity by eliminating the influence of time-invariant characteristics within each household-plot combination and captures variations across different crops and years. Additionally, using plot-level data allows us to control for time-constant factors that could affect productivity and are correlated with irrigation status simultaneously. The model specification is as follows:

$$\begin{aligned} Y_{ijnkt} = \alpha + \beta \cdot \mathrm{Irrig}_{ijnkt} + \Phi \cdot \mathrm{rainfall}_{kt} + \gamma \cdot \mathrm{fert\_ha}_{ijnkt} + \delta \cdot \mathrm{lds\_ha}_{ijnkt} + \theta \cdot \mathrm{sdq\_ha}_{ijnkt} \\ + \phi \cdot \mathrm{pp}_{ijnkt} + \mathbf{X}'_{ijnkt} + \mu_{ik} + \lambda_n + \epsilon_{ijnkt} \end{aligned} \tag{3.1}$$

where Y_{ijnkt} represents the crop yield from plot i for household j planted to crop n in season k of year t. α is the constant term. Irrig_{ijnkt} is a dummy variable taking the value 1 if the plot was irrigated and 0 if not irrigated. $\mathrm{rainfall}_{kt}$ is the amount of rainfall in millimeters for a particular site in season k. $\mathrm{fert\_ha}_{ijnkt}$ is the fertilizer use per hectare in kilograms. $\mathrm{lds\_ha}_{ijnkt}$ is the total labor days per hectare. $\mathrm{sdq\_ha}_{ijnkt}$ is the seed quantity per hectare in kilograms. pp_{ijnkt} is the proportion of plot i cultivated in season k in hectares. $\mathbf{X}_{ijnkt}$ is a vector of other control variables including the amount of rainfall received in season k in millimeters, sex of the household member managing the plot, number of irrigation days, a dummy for whether the plot is terraced, plot soil quality, household size, whether the plot experienced drought, and other relevant factors. μ_{ik} represents plot-year effects. λ_n represents crop fixed effects. ϵ_{ijnkt} is the error term.

This specification allows us to isolate the differential impacts of irrigation and farming seasons on crop yield while controlling for various confounding factors. By including household-plot-season-crop fixed effects, we mitigate potential biases arising from unobserved factors that could influence both irrigation decisions and crop productivity outcomes.

3.5 Descriptive statistics and empirical results

3.5.1 Descriptive statistics

Appendix A1.1 presents summary statistics for various agricultural and household variables across seasons A and B. In Season A, the mean harvested quantity is slightly higher (50.246 kgs) compared to Season B

(49.672 kgs). However, the standard deviation is notably larger in Season A, indicating more variability in production. Plot areas are nearly identical across both seasons, with mean values of 0.136 ha and 0.133 ha, respectively. Total rainfall is significantly higher in Season A (400.461 mm) than in Season B (273.556 mm), which may partly explain the higher variability in harvested quantity. Labor input also varies, with total labor days being lower in Season A (16.104 days) compared to Season B (21.595 days). However, Season B has an exceptionally high standard deviation, likely skewed by outliers.

Seasons A and B also show differences in input usage and financial outcomes. Season A reports an average of 350.539 kgs of fertilizer usage, while Season B shows a slightly higher average of 360.197 kgs. Yet, the standard deviation for fertilizer in Season B is considerably larger, suggesting inconsistent fertilizer application. Seed usage is similar across both seasons, with averages around 5 kgs. Interestingly, the financial metrics show stark contrasts: total sales in Season A average 5681.355 RWF, significantly higher than in Season B (4224.836 RWF), yet Season B shows an extreme outlier in total costs, reflected in an astronomical mean value due to a few high values. Household and hired labor days show a similar trend, with Season A having lower average values but less variability than Season B. Other variables such as household size, drought experience, and plot irrigation show consistent patterns across both seasons, providing a comprehensive overview of the agricultural and socio-economic landscape during these periods.

3.5.2 Empirical results

Effects of seasonal irrigation on crop yield (kgs/ha)

Table 3.1 provides insights into the impact of irrigation on crop yield, differentiated by crop type and season. The data reveals significant effects of irrigation on yields during Season A for all crops and legumes. Specifically, the coefficient for all crops indicates that irrigation significantly increases yields by approximately 43.1% compared to non-irrigated plots. For legumes, irrigation significantly increases yield by 37.3% compared to non-irrigated plots. This finding underscores the crucial role of irrigation in enhancing agricultural output, consistent with findings from other studies, such as those by Namara et al. (2011), which highlight the positive impact of irrigation on crop yields and agricultural productivity.

While irrigation has clear and significant benefits in Season A, its effectiveness in Season B varies, showing significant benefits for legumes but not for all crops combined. In Season B, irrigation significantly increases the yield of legumes by 23.4% compared to non-irrigated plots. This variability suggests that the benefits of irrigation might be more pronounced for specific crops and under certain seasonal conditions. Similar results were observed by Zilberman et al. (2002), who noted that the effectiveness of irrigation can vary significantly depending on crop type and climatic conditions. Other studies, such as those by de Fraiture et al. (2007) and Faurès and Santini (2008), have also documented the variability in irrigation benefits across different crops and regions.

These findings highlight the importance of targeted irrigation practices tailored to specific crops and seasons to maximize agricultural productivity. They also reinforce the broader understanding that irrigation is a key driver of yield improvements, particularly for water-sensitive crops like legumes. By optimizing irrigation strategies, farmers can achieve significant gains in productivity, contributing to improved food security and economic outcomes in agricultural regions. on the other drought significantly reduces crop yields across most categories in both seasons, with particularly significant adverse effects for cereal crops in Season A. Even though the interaction term between irrigated and drought dummies is not significant, the positive effect of irrigation implies that irrigated plots perform better than non-irrigated plots during drought conditions. Therefore, when there is drought, irrigation helps to improve yields compared with drought and no irrigation.

Seasonal rainfall significantly boosts crop yields across all crops in Season A, indicating its crucial role in maximizing agricultural output during this period. However, in Season B, rainfall does not have a significant impact on crop yields, suggesting that the total rainfall during this season consistently falls below the minimum requirement of 800 millimeters for crop production in Rwanda. This discrepancy underscores the importance of adequate rainfall for crop productivity, particularly highlighting the challenge posed by insufficient rainfall during Season B in the study region. Additionally, labor input significantly influences crop yields across all types and seasons. In both Seasons A and B, an increase in labor days per hectare leads to a notable rise in yields for all crops, legumes, and cereals, with the effect being more pronounced in Season B. This suggests that more labor-intensive farming practices contribute positively to crop productivity, underscoring the importance of labor as a critical input in agricultural production.

Irrigation days have mixed effects on yields, with a slight decrease in legume yields in Season A, possibly indicating diminishing returns from excessive irrigation—however, consistent irrigation boosts cereal crop yields in the same season. Fertilizer use enhances legume productivity in both seasons, highlighting its vital role in crop growth. Seed quantity per hectare also positively affects yields. Conversely, drought and larger plot sizes negatively impact yields, with larger plots showing significant yield reductions likely due to decreased management efficiency. This suggests that optimal plot size and efficient resource management are crucial for maximizing yields in smallholder farming.(Deininger et al., 2008; Deininger and Jin, 2006).

Table 3.1: Fixed effects estimation of seasonal irrigation on log crop yield (kgs/ha)

	Season A			**Season B**		
VARIABLES	**(1) All crops**	**(2) Legumes**	**(3) Cereal crops**	**(4) All crops**	**(5) Legumes**	**(6) Cereal crops**
Irrigated plots	0.431**	0.373***	-0.0304	0.223	0.234*	0.457
	(0.168)	(0.137)	(0.260)	(0.198)	(0.120)	(0.398)
Experienced drought	-0.309**	-0.237**	-0.616***	-0.185	-0.406***	-0.264
	(0.139)	(0.104)	(0.220)	(0.159)	(0.117)	(0.353)
Irrigated X Experienced drought	-0.200	-0.0806	-0.334	-0.134	0.0255	-0.334
	(0.232)	(0.171)	(0.460)	(0.256)	(0.169)	(0.546)
Log rainfall amount (mm)	0.884***	0.837***	2.558***	0.110	0.370	-1.293
	(0.220)	(0.150)	(0.869)	(0.454)	(0.348)	(1.168)
Log total labor (days/ ha)	0.395***	0.472***	0.372**	0.754***	0.553***	0.501*
	(0.0970)	(0.0670)	(0.180)	(0.110)	(0.0937)	(0.262)
Log total days of irrigation	0.0949	-0.138**	0.344***	-0.0295	-0.0495	-0.501
	(0.141)	(0.0620)	(0.125)	(0.114)	(0.0589)	(0.379)
Log fertilizer (kgs/ha)	0.0186	0.0199**	0.00894	0.00731	0.0330***	0.0175
	(0.0137)	(0.0101)	(0.0271)	(0.0162)	(0.0119)	(0.0367)
Log of seed quantity (kgs/ha)	0.195***	0.363***	0.415**	-0.0736	0.439***	0.523*
	(0.0688)	(0.0589)	(0.178)	(0.0647)	(0.0781)	(0.278)
Plot area (ha)						
2nd quartile	-0.308	-0.0727	0.140	0.0654	-0.0162	-0.369
	(0.199)	(0.132)	(0.537)	(0.225)	(0.186)	(0.494)
3rd quartile	-0.489**	-0.194	-0.00250	-0.172	0.174	-0.406
	(0.210)	(0.138)	(0.574)	(0.255)	(0.209)	(0.594)
4th quartile	-0.671***	-0.342**	0.241	-0.146	-0.00923	-0.0249
	(0.243)	(0.166)	(0.659)	(0.295)	(0.255)	(0.691)
Constant	-1.825	-2.465**	-10.41*	2.049	-0.465	9.335
	(1.525)	(1.040)	(5.601)	(2.781)	(2.012)	(7.386)
Observations	1,099	741	208	1,216	653	224

Standard errors in parentheses clustered at household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Other control variables: Soil quality, household head age, female household head and a dummy of whether a plot is terraced or not.

Seasonal irrigation and crop yield by poverty status

Table 3.2 presents the results of an analysis of seasonal irrigation and crop yield using two different poverty measurements: below 50% of the median income and below the median income. In Season A, for households below 50% of the median income, the coefficient for irrigated plots is 0.396, indicating that irrigation increases crop yield by approximately 44.2% for poor households, and this result is statistically significant at the 5% level. In contrast, for non-poor households, irrigation does not have a statistically significant impact on crop yield for non-poor households in Season A. Similarly, under the median income poverty status,irrigation significantly increases crop yield for poor households by approximately 39.2%. For non-poor households, the result is not statistically significant, indicating that irrigation does not significantly impact crop yield for non-poor households in Season A.

Table 3.2: Effects of seasonal irrigation on log of crop yield (kgs/ha) by poverty status

	Below 50% of median income				**Below Median income**			
VARIABLES	**Season A**		**Season B**		**Season A**		**Season B**	
	poor	Non-poor	poor	Non-poor	poor	Non-poor	poor	Non-poor
Irrigated plots	0.574**	0.272	0.514*	0.0349	0.604**	0.200	0.434	0.0406
	(0.280)	(0.177)	(0.266)	(0.253)	(0.241)	(0.195)	(0.279)	(0.255)
Experienced drought	-0.168	-0.371**	-0.0777	-0.218	-0.180	-0.393**	-0.0197	-0.278
	(0.257)	(0.144)	(0.264)	(0.188)	(0.221)	(0.158)	(0.236)	(0.195)
Irrigated X Experienced drought	-0.212	-0.185	-0.527	0.0960	-0.334	-0.100	-0.538	0.157
	(0.394)	(0.241)	(0.388)	(0.300)	(0.345)	(0.265)	(0.372)	(0.306)
Log of rainfall amount (mm)	0.763**	1.193***	-0.721	0.266	0.753**	1.273***	-0.700	0.462
	(0.377)	(0.272)	(0.624)	(0.413)	(0.328)	(0.298)	(0.530)	(0.450)
Log total labor (days/ ha)	0.406***	0.382***	0.727***	0.520***	0.427***	0.361***	0.659***	0.542***
	(0.149)	(0.104)	(0.150)	(0.130)	(0.131)	(0.112)	(0.140)	(0.139)
Log fertilizer (kgs/ha)	-0.0138	0.0236	-0.00342	-0.00283	0.00587	0.0169	-0.00667	0.00340
	(0.0232)	(0.0152)	(0.0265)	(0.0201)	(0.0201)	(0.0168)	(0.0258)	(0.0210)
Log of seed quantity (kgs/ha)	0.0462	0.169**	-0.125	-0.0248	0.0547	0.163**	-0.0189	-0.0829
	(0.103)	(0.0752)	(0.0922)	(0.0707)	(0.0958)	(0.0799)	(0.0833)	(0.0743)
Plot area (ha)								
2nd quartile	-0.435	-0.345	-0.318	-0.315	-0.408*	-0.354	-0.214	-0.424
	(0.282)	(0.215)	(0.332)	(0.256)	(0.246)	(0.235)	(0.308)	(0.272)
3rd quartile	-0.794**	-0.616**	-0.594	-0.468	-0.709***	-0.659**	-0.407	-0.635**
	(0.313)	(0.252)	(0.376)	(0.287)	(0.274)	(0.275)	(0.348)	(0.308)
4th quartile	-1.173***	-0.678**	-0.679	-0.641*	-1.107***	-0.693**	-0.488	-0.823**
	(0.403)	(0.281)	(0.469)	(0.338)	(0.354)	(0.302)	(0.425)	(0.362)
Constant	0.443	-3.120	8.137**	3.581	-0.517	-2.877	8.133**	2.239
	(2.549)	(1.916)	(4.112)	(2.597)	(2.200)	(2.062)	(3.345)	(2.895)
Household size	467	928	495	984	579	816	615	864

*Standard errors in parentheses clustered at household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

Other control variables: Soil quality, household head age, female household head and a dummy of whether a plot is terraced or not.

In Season B, the impact of irrigation on crop yield diminishes for both poverty definitions. This suggests that irrigation does not statistically affect crop yield for either poor or non-poor households in Season B. These findings highlight the importance of considering both households' socioeconomic status and irrigation interventions' timing to maximize agricultural productivity.

Effects of seasonal irrigation on labour productivity

Table 3.3 displays the findings from an analysis examining the impact of seasonal irrigation on labor productivity measured in kilograms per labor day for both households and hired labor during Seasons A and B.

In Season A, the coefficients for irrigated plots indicate a positive and statistically significant effect on labor productivity for household labor and total labor. Precisely, irrigation increases labor productivity by approximately 14.1% for household labor and 13.6% for total labor. For hired labor, the impact is positive but not statistically significant, with a coefficient of 0.0368. An interaction term between irrigated plots and drought experience is included to assess whether the effect of irrigation on labor productivity varies depending on drought experience. While the coefficient for this interaction term is not statistically significant in either Season A or Season B, its inclusion allows for examining how the combined effect of irrigation and drought experience influences labor productivity. This finding indicates that while irrigation generally improves labor productivity, the extent of this improvement does not vary significantly by drought experience under different drought conditions, as captured by the model.

Table 3.3: Effect of seasonal irrigation on log of labor productivity (kgs/labor days)

	Season A			**Season B**		
VARIABLES	**(1) Household labor**	**(2) Hired labor**	**(3) Total labor**	**(4) Household labor**	**(5) Hired labor**	**(6) Total labor**
Irrigated plots	0.141*	-0.0896	0.136*	0.0368	-0.156	0.0631
	(0.0778)	(0.176)	(0.0745)	(0.0822)	(0.195)	(0.0750)
Drought experience	-0.159**	-0.317**	-0.188***	-0.141**	-0.433***	-0.134**
	(0.0619)	(0.141)	(0.0552)	(0.0663)	(0.148)	(0.0592)
Irrigated X Drought experience	-0.0455	0.305	-0.0192	0.0570	0.273	-0.00209
	(0.0994)	(0.222)	(0.0937)	(0.103)	(0.229)	(0.0936)
Log total rainfall (mm)	0.763***	0.276	0.495***	0.274*	-0.0484	0.0617
	(0.121)	(0.211)	(0.0977)	(0.163)	(0.317)	(0.137)
Log fertilizer (kgs/ha)	0.00307	0.00657	0.00225	0.00629	0.00783	0.000257
	(0.00617)	(0.0149)	(0.00567)	(0.00668)	(0.0149)	(0.00603)
Log of seed quantity (kgs/ha)	-0.00825	-0.00101	-0.0136	-0.0553***	-0.0143	-0.0637***
	(0.0222)	(0.0408)	(0.0214)	(0.0214)	(0.0547)	(0.0204)
Log total days of irrigation	-0.0144	-0.0623	0.00624	-0.0514	0.122	-0.0463
	(0.0554)	(0.138)	(0.0586)	(0.0422)	(0.0859)	(0.0389)
Plot area (ha)						
2nd quartile	0.0775	-0.0575	0.00821	-0.0465	-0.0805	-0.0897
	(0.0735)	(0.179)	(0.0682)	(0.0735)	(0.196)	(0.0682)
3rd quartile	0.119	-0.353*	0.0155	-0.0533	-0.0997	-0.129
	(0.0803)	(0.184)	(0.0750)	(0.0847)	(0.201)	(0.0789)
4th quartile	0.130	-0.168	0.0347	-0.0319	-0.104	-0.122
	(0.0925)	(0.215)	(0.0869)	(0.0931)	(0.240)	(0.0898)
Constant	-3.115***	0.838	-1.519**	0.248	2.715	1.412*
	(0.730)	(1.329)	(0.591)	(0.915)	(1.832)	(0.767)
Observations	1,390	463	1,403	1,462	455	1,480

*Standard errors in parentheses clustered at household level. * p < 0.10, ** p < 0.05, *** p < 0.01.*

Other control variables: Soil quality, household head age, female household head and a dummy of whether a plot is terraced or not.

In Season B, while coefficients for irrigated plots are positive across all labor types, none reach statistical significance. The coefficients are 0.0640 for household labor, 0.0463 for hired labor, and 0.0483 for total labor, indicating a modest increase in labor productivity due to irrigation, though not statistically significant.

Overall, the analysis indicates a more pronounced and statistically significant effect of irrigation on labor productivity in Season A compared to Season B, particularly for household and total labor.

3.6 Conclusion

The empirical analysis reveals that seasonal irrigation significantly enhances crop yields and labor productivity, particularly in Season A. Irrigation increases crop yields by 43.1% for all crops and 37.3% for legumes compared to non-irrigated plots during this season. However, the benefits of irrigation are less pronounced in Season B, with significant improvements observed only for legumes (23.4%). Furthermore, the impact of irrigation on crop yields is notably higher for poor households (44.2%) compared to non-poor households in Season A. This suggests that irrigation is particularly beneficial in improving agricultural productivity under favorable seasonal conditions and for vulnerable populations. The study also highlights the detrimental effects of drought on crop yields and underscores the critical role of labor input in boosting agricultural output across both seasons.

To maximize agricultural productivity and support vulnerable farmers, it is recommended that policymakers focus on expanding and optimizing irrigation infrastructure, especially for Season A. Targeted irrigation initiatives should prioritize poor households and water-sensitive crops like legumes to enhance their resilience and productivity. Additionally, investment in training programs for efficient irrigation practices and labor-intensive farming methods can further improve yields. Policymakers should also address the challenges of insufficient rainfall in Season B by promoting water conservation techniques and alternative water sources to ensure sustained agricultural productivity throughout the year.

One of the weaknesses of this paper is that rainfall data is aggregated at a weather station level and not plot-specific. Therefore, future research may consider collecting plot-level rainfall data to improve the robustness of the findings, as well as delving into a comparison of yields from different plots owned by the same household, where fixed effects is more convenient.

Appendix

Table A1.1: Summary statistics by Season

VARIABLES	N	Mean	SD	p25	Median	p75	Min	Max
Season A								
Harvested quantity (kgs)	2118	50.246	186.104	0	10	50	0	5000
Plot area (ha)	2118	.136	0.249	.027	.054	.14	0	4.152
Total rainfall (mm)	2118	400.461	134.824	292	321	536	292	701
Total labor days	2118	16.104	24.358	0	10	23	0	607
Total fertilizer (kgs)	2118	350.539	5790.382	0	0	0	0	262500
Total seed (kgs)	2118	5.21	20.821	0	1.5	4.5	0	600
Total sales (RWF)	2118	5681.355	60720.319	0	0	0	0	2700000
Total costs (RWF)	2118	718.553	18437.594	0	0	0	0	840000
Total household labor days	2118	13.225	16.599	0	9	19	0	212
Total hired labor days	2118	2.954	15.904	0	0	0	0	602
Household size	1834	5.017	2.104	4	5	6	1	13
Experienced drought (=1)	2118	.62	0.485	0	1	1	0	1
Terraced plots (=1)	2118	.661	0.473	0	1	1	0	1
Female headed households	2118	.249	0.433	0	0	0	0	1
Household head age	2105	48.437	14.540	37	47	58	20	99
Plot irrigated (=1)	2118	.337	0.473	0	0	1	0	1
Soil quality	1673	3.332	1.161	2	3	4	1	5
Season B								
Harvested quantity (kgs)	2229	49.672	147.625	0	10	50	0	3000
Plot area (ha)	2229	.133	0.247	.025	.05	.132	0	4.152
Total rainfall (mm)	2229	273.556	61.475	246	256	300	183	546
Total labor days	2229	21.595	246.246	0	10	21	0	10521
Total fertilizer (kgs)	2229	360.197	8415.458	0	0	0	0	395000
Total seed (kgs)	2229	5.756	19.738	0	1	4.5	0	250
Total sales (RWF)	2229	4224.836	15338.968	0	0	0	0	280000
Total costs (RWF)	2229	806786.26	33485541.906	0	0	0	0	1.579e+09
Total household labor days	2229	12.324	15.409	0	9	18	0	168
Total hired labor days	2229	9.283	245.509	0	0	0	0	10503
Household size	1853	5.019	2.099	4	5	6	1	13
Experienced drought (=1)	2229	.62	0.485	0	1	1	0	1
Terraced plots (=1)	2229	.654	0.476	0	1	1	0	1
Female headed households	2229	.241	0.428	0	0	0	0	1
Household head age	2216	48.288	14.464	36	46.5	58	20	99
Plot irrigated (=1)	2229	.359	0.480	0	0	1	0	1
Soil quality	1673	3.332	1.161	2	3	4	1	5

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