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ARTICLE

Does Limited Wealth Hinder Smallholder Farmers' Productivity in Malawi? A Systematic Review and Bayesian Regression Analysis

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ABSTRACT

Malawi's agricultural sector, dominated by poor smallholder household farmers, faces numerous challenges. Farmers usually have limited wealth, and the sector is characterized by low productivity. This study investigates how wealth hinders or supports productivity growth. The study employs a mixed-method approach that combines a systematic literature review and Bayesian moderation and mediation regression analysis. The study reveals a complex relationship, with findings indicating a negative correlation between wealth and productivity growth. This is attributed to the implementation of subsidized fertilizer program benefiting the majority of poor farming households. Further analysis revealed a more complex relationship. Specifically, wealth has a positive indirect effect on productivity through distance from district centers yet has a negative indirect effect on agricultural markets. These findings highlight the need to improve the provision of services in district centers, enhance market functionality, and address spatial disparities to optimize productivity. Initiatives such as promoting digital platforms, modernizing extension services, improving financing, and ensuring demographic management should be employed to address systemic constraints. Together, such initiatives would foster an enabling environment that supports small-

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scale farmers to adopt productive and commercial farming practices that drive wealth and productivity. The study's findings have significant implications not only for agricultural development policies in Malawi but also for similar agricultural development contexts.

Keywords: Wealth; Productivity; Bayesian Model; Mediation; Moderation; Malawi Smallholder Household Farmer; Systematic Review

1. Introduction

Studies have shown that agricultural productivity in Malawi has declined or stagnated over time [1, 2]. Agricultural productivity, in this context, refers to the efficiency with which farmers utilize resources (e.g., labor, land, inputs) to produce agricultural outputs. Low productivity is a pressing concern among smallholder household farmers in the country [3], challenged by many factors, including limited access to credit, inadequate extension services, poor infrastructure, and a lack of mechanization for efficient production. Most of these farmers rely on traditional practices and subsistence maize farming using hoes, for example, a practice that hinders efficiency and productivity. Extension services are not fully functional for adequate support to the farmers [4]. Such challenges limit commercialization efforts, hence trapping farmers in subsistence situations.

Malawi's smallholder farming systems are characterized by low levels of agricultural diversification, which perpetuates engagements in low-income opportunities [5]. Limited business acumen among the farmers contributes to this. Spatial and geographical impediments mostly associated with remote and rural settlements include long distances to district centers (BOMAs) and the prevalence of low-quality weekly markets [6]. Demographic factors, including expansive household sizes, restrict access to agricultural resources such as land.

In Malawi, the National Agricultural Investment Plan (NAIP) provides a framework for agricultural development, which prioritizes the Affordable Inputs Programme (AIP) to play a key role in supporting productivity and commercialization by providing farmers with access to essential inputs [7]. These initiatives align with Malawi's Vision 2063, which prioritizes wealth creation through agricultural productivity and commercialization. Despite these initiatives, challenges persist, such as limited access to finance and inadequate access to digital technologies [8, 9]. To overcome these challenges, a shift in focus towards improving agricultural productivity, such as through diversification, re-designing extension services, and re-channeling funding to support more inclusive and sustainable agricultural development initiatives, is necessary.

Rural household farmers face significant challenges and persistent poverty. Limited access to social services, inadequate economic opportunities, insufficient support infrastructure, and scarce financial resources in remote places hinder them from engaging in activities, other than subsistence agriculture, which would bring them more wealth. In this study, wealth is conceptualized as a multidimensional measure of poverty, encompassing various aspects of socioeconomic well-being [10]. Poverty and low wealth are further exacerbated by the widespread reliance on rain-fed agriculture, which makes households vulnerable to climate-related shocks and crop failures. As a result, these farmers remain stuck in poverty alongside low agricultural productivity.

Access to finance poses a formidable challenge for smallholder household farmers in the country, impeding their ability to transition to commercial agricultural activities. FinScope Survey [8] highlights that small-scale business people in Malawi rely on low-level informal financial mechanisms, and those who may be utilizing formal services remain unbanked. This phenomenon can be attributed to several key factors, such as prohibitively high lending rates (over 35% in 2025) and stringent collateral requirements (up to 200% of the loan amount) [11]. Proximity to banks and institutions that provide financing plays a key role. Limited access to financial services constrains investments in productivity-enhancing technologies, superior inputs for agricultural production, and diversification, as well

as access to essential services for improving productivity. Growing digital technology in the country, however, presents an opportunity to transform into digitally enabled financial access systems and productivity-enhancing services.

Malawi can draw lessons from neighboring countries' initiatives, such as Zambia's e-extension services program[12], Ethiopia's mechanization leasing financing program[13], and Tanzania, Kenya, and Ghana's smart fertilizer subsidy programs[14]. These experiences can inform efforts to revamp extension services, promote mechanization, and improve fertilizer subsidy programs to free up resources for other productivity-enhancing activities. Malawi has several examples of donor-supported initiatives, including the World Bank's Agriculture Commercialization project[15] and the Financial Inclusion and Entrepreneurship project[16]. These projects have demonstrated potential for addressing productivity constraints, improving financing access, and implementing productivity-enhancing technologies. Other donor projects[17] have also shown promise in supporting smallholder farmers, offering valuable insights into potential solutions. These programs, however, are small, disjointed, and short-lived. Notable government initiatives like the National Economic Empowerment Fund, which have the potential to address financial inclusion and access challenges, face limitations in their impact. Promoting productivity and wealth creation among smallholder farmers in Malawi remains pressing.

The relationship between wealth and productivity among smallholder farmers in Malawi, however, remains poorly understood, particularly in terms of how farm, household, and spatial attributes influence this dynamic. This study examines how wealth influences productivity in a typically poor economic environment. It aims to address this in two steps. The first is a systematic literature review to synthesize existing evidence and understand this relationship based on relevant research findings to inform policy, and to identify knowledge gaps that would inform further empirical analysis as our next step. Building on this, the second step is an empirical analysis based on Bayesian mediation and moderation regression techniques to investigate the relationship between wealth and productivity while controlling for potential confounding factors. This study contributes to the existing literature in three key ways: (i) it examines the direct and indirect impact of wealth on productivity among smallholder household farmers in Malawi; (ii) it investigates the mediating role of distance to district centers (BOMA) and local weekly markets in the relationship between wealth and productivity; and (iii) it explores how distance to BOMA and distance to local weekly markets moderate the relationship between wealth and productivity.

2. Literature Review

2.1. Theoretical Perspective

This study is grounded in the Asset-Based Poverty Trap (ABPT) theory, which posits that wealth (or assets) drives productivity. According to the ABPT framework, households with limited assets (e.g., land, livestock, education) are trapped in a cycle of poverty, which constrains their ability to invest in productivity-enhancing activities[18]. This theory is particularly relevant to smallholder farmers in Malawi, who often face significant constraints in accessing productive assets and are trapped in poverty. By exploring the applicability of the ABPT theory in the Malawi context, this study aims to contribute to existing knowledge and literature on productivity and poverty relationships in poor country settings. It examines the specific paths and mechanisms by which wealth affects productivity. A critical review of the existing literature on productivity reveals significant research into productivity and efficiency in the agricultural sector, as well as wealth for household farmers. Despite this substantial research and knowledge, we found that the complexity of the relationship between these, including the specific pathways through which wealth contributes to or constrains productivity, remains understudied.

Building on the ABPT theory, this study draws on conceptual frameworks of moderation and mediation analysis[19, 20] to illuminate the theoretical linkage between wealth and productivity. These frameworks, combined with a systematic review of the literature in this area, offer a unique approach to examining the intricate relationships between variables, and specifi-

cally the moderating and mediating effects that shape the wealth-productivity relationship. In the moderation and mediation analysis, we controlled for confounding factors in this relationship to reduce bias and account accurately for the relationships. Specifically, the analytical approach combines systematic literature review, Bayesian moderation and mediation regression modeling, Bayesian estimation of structural mean (BSEM) modeling, and bootstrapping techniques to test the robustness of our findings. The flexibility and robustness of BSEM models enable us to accurately examine complex relationships, and together with bootstrapping, facilitate verification of our findings [21] using readily available data from the country's Integrated Household surveys [22].

2.2. Empirical Perspective

Studies on efficiency and productivity in Malawi predominantly use stochastic frontier analyses [23, 24]. There have also been studies on income-based poverty measures and multidimensional poverty measures, or wealth. While these studies have advanced the understanding of productivity and poverty or wealth, they have largely overlooked the complex relationships between these parameters. Furthermore, these studies are limited in their methodology, geographical scope, and sample size. This study addresses these gaps by integrating productivity analysis (using Malmquist data envelopment analysis—MDEA) with wealth analysis (based on principal component analysis—PCA) and researching published articles to understand the factors behind these variables. We conducted a systematic literature review (SR) of over 2000 studies and conducted an in-depth analysis of 24 selected studies. This revealed household, farm, and policy attributes influencing wealth and productivity. Notably, we identified a subset of factors such as household size, agricultural land holding, farm size, soil conservation and sustainable agriculture practices, that exert shared influence on wealth and productivity. We also found that, despite a growing body of research, the direct relationship between wealth and productivity, as well as the roles of moderators and mediators, remains poorly understood. This highlighted the need for further investigation. We then employed Bayesian moderation and mediation regression analyses to further examine these complex relationships.

3. Materials and Methods

3.1. Sampling Methodology and Data Collection

The empirical analysis utilized data from Malawi's Integrated Household Survey (IHS), conducted by the National Statistical Office (NSO) in collaboration with the World Bank's Living Standards Measurement Study (LSMS) program [22]. The IHS data was chosen for this study due to the survey data's comprehensive coverage, data quality, and versatility. This allowed multiple analyses, such as Malmquist data envelopment analysis (MDEA), PCA, and regression techniques, using the same database. The survey employed a stratified design to ensure country representation. The survey data collection exhibited low household-level attrition rates (approximately 5.6%) and individual-level attrition (13%).

3.2. Estimation of Key Variables

We used estimates of productivity and wealth based on MDEA [25] and PCA from the IHS as key parameters for the analysis. MDEA and PCA models were estimated using Data Envelopment Analysis Package (DEAP) version 3.1 and Stata version 18, respectively, as described in Chilima et al. [26, 27]. MDEA was chosen for its ability to accommodate panel data and provide a comprehensive picture of productivity growth over time, without requiring price information [25]. The productivity estimation was based on inputs of labour, land, and capital (including machinery, implements, fertilizers, and seeds), and the total output of crops reported by smallholder household farmers, obtained from the IHS. PCA has proven to be a valuable and widely utilized statistical approach to extract meaningful patterns and reduce dimensionality in socioeconomic data [27]. For this we used a set of wealth indicators, including asset ownership (such as television, refrigerator, bicycle, car, clock, and solar panel), dwelling characteristics (such as housing ownership, building material) and access to

utilities (such as drinking water and toilet facilities) [26] obtained from the IHS, using a custom-made DO-file in Stata. We conducted a systematic review of the existing literature to provide context and insights into our analysis. For the systematic review, articles were collected through a comprehensive search of the Google Scholar, ScienceDirect, and Google databases. These articles were searched using a predefined set of keywords and search operators. We followed a structured approach to study selection and quality assessment (See Section 3.3.1). IHS was a source of information for mediation and moderation analysis, complemented by data from the World Bank's World Development Indicators (WDI).

3.3. Review and Analysis

3.3.1. Systematic Review

The systematic review synthesized evidence on the relationship between wealth and productivity among smallholder farmers. The review encompassed a comprehensive search of peer-reviewed articles, published since 2020, to assess relevance and applicability to the Malawian context. This review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines, ensuring a structured and transparent approach to identifying, evaluating, and synthesizing relevant studies [28]. The following six key stages guided our methodology: (i) Defining the research question, objectives, and scope of the review; (ii) Developing a study protocol outlining the systematic review's methodology, search strategy, inclusion/exclusion criteria, and data extraction methods; (iii) Executing a literature search and identifying pertinent studies; (iv) Filtering articles based on predefined inclusion and exclusion criteria; (v) Assessing the quality and relevance of selected studies; and (vi) Synthesizing and interpreting the findings and drawing conclusions.

We registered the review in the International Prospective Register of Systematic Reviews (PROSPERO) database (Registration Number: CRD420251023758) to ensure transparency and accountability. While the PRISMA protocol guided our systematic review, other approaches can also be applied to synthesize evidence about this relationship. Some alternative frameworks include: (i) Campbell Collaboration Guidelines: focusing on systematic reviews of interventions in the social sciences; (ii) Cochrane Review Methodology: emphasizing rigorous methods for systematic reviews, particularly in healthcare; and (iii) Realist Review Approach: suitable for complex interventions, focusing on context-mechanism-outcome relationships. We decided to use PROSPERO because it has comprehensive coverage, is widely recognized and aligns well with the review's interdisciplinary nature and objectives.

We applied the inclusion criteria to focus on studies examining the relationship between wealth and agricultural productivity among smallholder farmers, with a primary emphasis on Malawi. Although our search was tailored to Malawi, we also reviewed relevant studies from other countries to provide a more comprehensive understanding of the wealth-productivity nexus. The eligible articles were peer-reviewed, original research outputs published in English, exploring topics such as the determinants of wealth, poverty, socioeconomic conditions, productivity drivers, and technical efficiency. We also considered studies investigating moderators' and mediators' roles. All research designs, methodologies, and analysis types meeting these criteria were considered for inclusion. Studies were excluded if they: (i) investigated unrelated topics; (ii) were published in languages other than English; (iii) were unpublished, non-peer-reviewed, or non-original research outputs; or (iv) were review articles, editorials, opinion pieces, or focused specifically on food security, maize production, maize productivity, or food security.

To ensure comprehensive coverage, we replicated our search strategy across Google Scholar, ScienceDirect, and Google databases. We developed a search string encompassing keywords and Boolean operators that helped us to identify relevant studies from the online database; as below:

> ("Malawi" AND ("smallholder household farmers" OR "smallholder farming households") AND (("determinants of wealth" OR "determinants of poverty" OR "socioeconomic conditions" OR ("determinants of

productivity" OR "determinants of total factor productivity" OR "determinants of technical change" OR "TFP" OR "productivity drivers")) OR (("wealth" OR "asset" OR "income" OR "poverty") OR ("productivity" OR "TFP" OR "technical efficiency" OR "production efficiency")) OR ("moderation analysis" OR "mediation analysis" OR "moderator" OR "mediator") OR ("distance to district centre" OR "distance to agriculture market")) AND NOT ("food security" OR "maize" OR "food insecurity" OR "maize production" OR "maize productivity")).

To accommodate ScienceDirect's specific search requirements, the search string was adjusted to reduce Boolean operators. This ensures compatibility while maintaining relevance. **Figure 1** below illustrates the comprehensive search and selection process, from initial database searches across the three electronic databases to the final inclusion of eligible studies. The studies were evaluated against predefined eligibility (inclusion) and exclusion criteria.

An initial literature search retrieved 2,033 articles. These comprise 731 articles from Google Scholar, 1300 articles from ScienceDirect, and 2 additional articles from Google Search. While acknowledging that wealth creation is a long-term issue, to ensure the relevance and applicability of our findings, we applied a temporal filter, excluding publications before the year 2020. This decision was driven by the rapidly evolving nature of agricultural practices, policies, and economic conditions in Malawi, which may not be accurately reflected in older studies. By focusing on recent research, we aimed to capture the most current insights and trends relevant to the country's context. This screening process excluded 1194 articles. By focusing on recent studies, we enhanced the contextual relevance of our analysis. This is particularly noteworthy given that our data on wealth and productivity are derived from a survey conducted around 2019. Further eligibility assessment was performed on the filtered pool of 839 articles. This screening of abstracts made it possible for us to exclude 803 articles from the lot, these being deemed to be irrelevant to the wealth-productivity nexus, methodological limitations, or that they did not go through adequate analysis. The remaining 36 articles were subjected to full-text examination and eligibility criteria. To ensure adherence to the systematic screening protocol, two expert reviewers independently reviewed study titles, abstracts, and keywords according to predefined inclusion and exclusion criteria. Based on this, 17 studies were excluded, leaving behind 19 articles, which were deemed closely matched to our research criteria. These formed the final set for our further analysis.

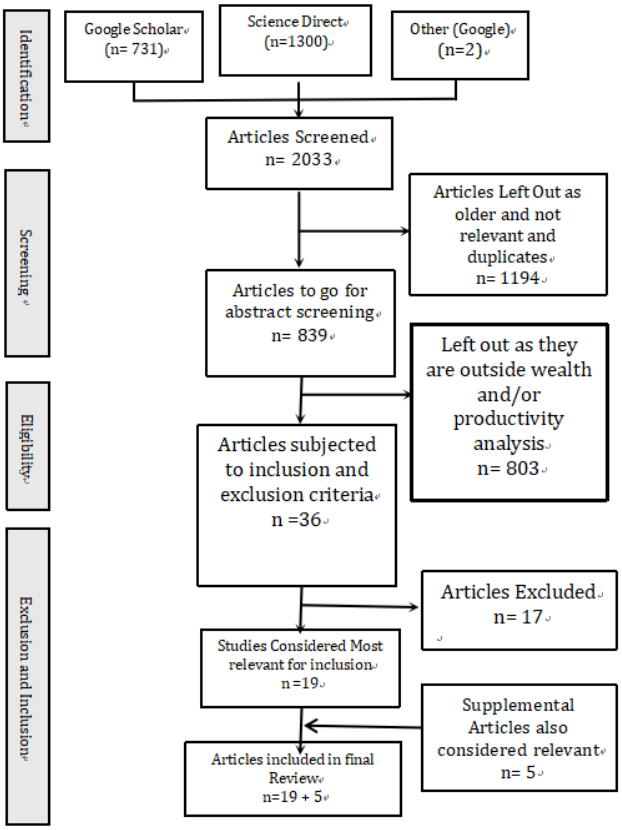

Figure 1. PRISMA Systematic Review Flow Diagram.

To complement our systematic review and identify potential knowledge gaps in productivity analysis specific to Malawi, we undertook a supplementary review of 5 Malawi-focused articles published before 2020. These articles, sourced from Google, provide valuable insights into the wealth-productivity nexus in Malawi. Our review of earlier studies provided valuable insights into the historical development of research in Malawi, revealing areas where further investigation is needed. In aggregate, 24 articles (19 from our systematic review and 5 from the supplementary review) were deemed highly

relevant, as they explicitly examined the relationship between wealth and agricultural productivity within the context.

3.3.2. Moderation and Mediation Analysis

We employed Stata 18 software to analyze the relationships between constructed wealth and productivity indices, moderators, mediators, and confounding factors. The Bayesian regression models accommodated data's complexity and allowed us to relax normality assumptions, accommodate non-linear relationships, and provide more robust estimates of relationships between our variables.

The moderation analysis examined how the relationship between wealth and productivity varied depending on two key moderators: distance to weekly agricultural markets and distance to district centers (BOMA) by smallholder household farmers in Malawi. We chose these because in the Malawi context, they can significantly impact smallholder farmers' access to markets, services, and inputs, ultimately playing a key role in facilitating or hindering economic growth through their influence on productivity and wealth. We controlled potential confounding factors, namely household head age and household size. Initially, we considered access to finance, identified in the SR as a crucial variable in Malawi, as a moderator. However, due to its categorical nature in the IHS database, it was not suitable for inclusion in the Bayesian model. This approach allowed us to examine the sensitivity of the wealth-productivity nexus to contextual factors.

The moderation model [29] is based on a framework proposed by Baron and Kenny [19] as follows:

$$\begin{aligned} ħ = \beta_0 + \beta_1\lambda + \beta_2\psi + \beta_3\varphi + \beta_6(\xi) + \beta_7(\theta) \\ +\beta_4(\lambda \times \psi) + \beta_5(\lambda \times \varphi) + \varepsilon \end{aligned} \quad (1)$$

Where: ħ is productivity; λ is wealth (in log form); ψ is distance to weekly agriculture markets; φ is distance to district centre (BOMA); ξ is age of the household head; θ is household size; β_1 is the main effect of λ on ħ; β_2 is the main effect of ψ on ħ; β_3 is the main effect of φ on ħ; β_6 is the main effect of ξ on ħ; β_7 is the main effect of θ on ħ; β_4 (λ×ψ) is the moderating effect of ψ; and β_5 (λ×φ) is the moderating effect of φ.

The model investigates the direct effects of wealth (λ), moderated by distance to weekly agriculture markets (ψ), and distance from a district centre (φ) on productivity (ħ). This aligns with established moderation analysis frameworks. We also evaluated the statistical significance of the interaction terms, specifically β_4 and β_5.

The mediation [29] regression analysis examined the relationship between wealth (λ) and productivity (ħ), with distance to BOMA (φ) and distance to the weekly agricultural market (ψ) serving as mediators. We controlled for potential confounding factors, age of the household head (ξ) and household size (θ). This approach allowed us to quantify the direct and indirect effects of wealth on productivity, while examining whether the wealth-productivity nexus is sensitive to contextual factors [30, 31].

The mediation regression model, also based on the framework proposed by Baron and Kenny [19], is represented by the following equations:

$$\varphi = \beta_0 + \beta_1(\lambda) + \beta_2(\xi) + \beta_3(\theta) + \varepsilon \quad (2)$$

$$\psi = \beta_0 + \beta_1(\lambda) + \beta_2(\xi) + \beta_3(\theta) + \varepsilon \quad (3)$$

$$ħ = \beta_0 + \beta_1(\lambda) + \beta_2(\varphi) + \beta_3(\xi) + \beta_4(\theta) + \varepsilon \quad (4)$$

$$ħ = \beta_0 + \beta_1(\lambda) + \beta_2(\psi) + \beta_3(\xi) + \beta_4(\theta) + \varepsilon \quad (5)$$

Where: λ is the log of wealth; ħ is productivity; φ is distance to BOMA (first mediator); ψ is distance to weekly agricultural market (second mediator); ξ is Age; and θ = household size. And β_0 is the intercept or constant term; β_1 is the coefficient of λ (wealth); β_2 is the coefficient of φ (distance to BOMA) or ψ (distance to weekly agricultural market); β_3 is the coefficient of ξ (Age); and β_4 is the coefficient of θ (household size).

We also estimated the total effect of λ on ħ using a linear regression model that controls for the age of the household head (ξ) and household size (θ). The total effect represents the overall relationship between wealth and productivity, without considering the mediating roles of distance to BOMA (φ) and distance to the weekly agricultural market (ψ).

The total effect of λ on ħ can be represented by the coefficient β_1 in the following equation:

$$ħ = \beta_0 + \beta_1(\lambda) + \beta_2(\xi) + \beta_3(\theta) + \varepsilon \quad (6)$$

Having established the total effect, we decomposed it into direct and indirect effects to examine the mediating roles of φ and ψ. This decomposition allows us to quantify the extent to which distance to BOMA (φ) and distance to market (ψ) mediate the influence of Wealth (λ) on Productivity (ϱ). By examining the direct and indirect effects, we gain a deeper understanding of the mechanisms underlying the relationship between Wealth and Productivity.

4. Results and Discussions

Analysis of the 24 articles identified through our systematic review and supplementary review revealed three distinct categories of determinants that shape the wealth-productivity relationship among smallholder farmers in Malawi. These categories are illustrated in **Figure 2**:

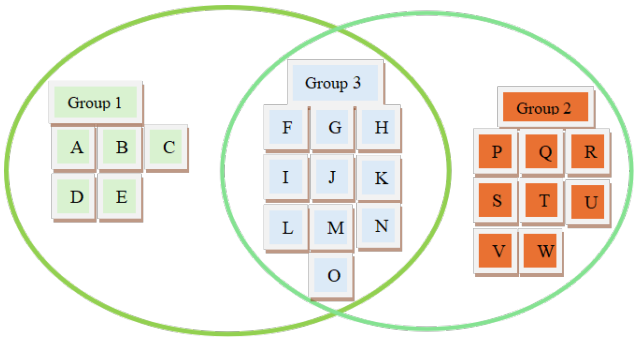

Figure 2. Determinants of Productivity and Wealth: A Venn Diagram Perspective.

This Venn diagram illustrates the intersection of three categorical groups of determinants influencing productivity and wealth:

Group 1

A: Socioeconomic status, including social and economic empowerment
B: Gender of household head
C: Educational level
D: Off-farm income opportunities
E: Development of inclusive food value chains

Group 2

P: Land size holding and utilization
Q: Drought-tolerant maize
R: Contract farming
S: Contract farming
T: Social grants
U: Agricultural inputs and fertilizer use
V: Climate-related shocks and stressors
W: Extension services and technical efficiency

Group 3

F: Household size
G: Agricultural land holding and farm size
H: Soil and conservation agriculture
I: Market Access
J: Asset wealth, including Livestock ownership
K: Access to credit
L: Commercialization and shifting from subsistence farming
M: Crop diversification
N: Mechanization
O: Land tenure security

This categorization provides insights into the complex relationship between wealth and productivity among smallholder farmers in Malawi, highlighting the need for targeted interventions that address both socioeconomic and productivity-enhancing factors.

Figure 3 below shows the frequency of the variables in terms of how many articles mentioned a variable in the selected articles in the SR. This reveals a diverse range of determinants graphically, with some factors having more mentions than others in the reviewed articles. For instance, socio-economic status, including education and gender of household head (Group 1), agricultural inputs and fertilizer use, climate-related shocks and stressors, and extension services and technical efficiency (Group 2), and household size, agricultural land holding and farm size, and soil conservation agriculture and sustainable agriculture practices (Group 3) emerged as prominent factors, receiving more attention across the study articles. See details in the next section. While providing insights into the relationship, the analysis revealed a significant gap in understanding the direct relationship between wealth and productivity, including in terms of moderating and mediating factors.

The identified gaps highlight the need for a deeper understanding of the relationships between wealth, productivity, and other factors influencing these variables in Malawi. To address this gap, we employed a combi-

nation of mediation and moderation analyses to examine more deeply the relationship between these two variables and the roles of moderators and mediators. Mediation analysis allows us to explore the mechanisms by which wealth influences productivity, thereby providing insights into the underlying causal pathways [32, 33]. Additionally, moderation analysis enables us to investigate how certain factors (in our case distance to the market or the district center) modify the relationship between productivity and wealth, shedding light on the contextual factors that shape these relationships, while also accounting for potential confounding variables (in our case age of head of household and household size). Building on this analytical framework, we formulate a research question to guide our investigation—To what extent do distance to the agriculture market and distance to the district center (BOMA) moderate or/and mediate the relationship between productivity and wealth among smallholder farmers in Malawi? We focused on these spatial variables as potential moderators and mediators, as they are particularly relevant to smallholder farmers' challenges, most of whom reside in remote areas. Other factors, such as access to finance, were also identified in our systematic review, but are left to future research.

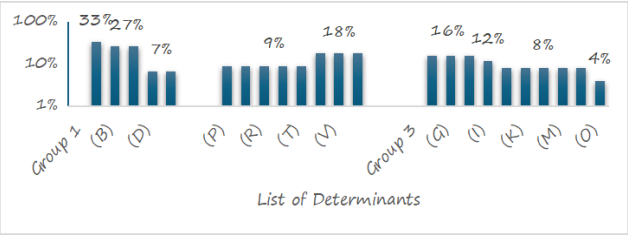

Figure 3. Frequency of variables mentioned in systematic review articles across the three groups.

We began by estimating a simple regression model to examine the relationship between wealth and productivity, following Hayes' theoretical framework recommendations [29]. Our findings revealed a statistically significant inverse association between wealth and productivity, which was contrary to our expectations. This finding was confirmed by substituting output per hectare instead of productivity. A plausible explanation for this counterintuitive finding lies in Malawi's agricultural policies, particularly the subsidized fertilizer program. Research has shown that this program has primarily benefited the poorest smallholder household farmers. This has led to significant productivity improvements in that segment of the smallholder household farmer category. Better-off households in the same category have not shown comparable productivity gains. This suggests that the fertilizer subsidy program may have contributed to a productivity gap between the poor and better-off households within this smallholder farmer category of farmers. Furthermore, the program's dominance in driving productivity growth for only that poorer segment of household farmers highlights the limitations of other support services, such as extension services, access to improved seeds, and others.

The initial regression analysis, however, revealed multi-collinearity issues, suggesting that the relationship between wealth and productivity may be influenced by other factors. Furthermore, the non-linear relationships between wealth and productivity, as indicated by spline and stepwise regression techniques, hinted at the presence of underlying factors that warrant further exploration (**Appendix A**).

Our mediation and moderation analysis models are illustrated in **Figure 4** below. This depicts the relationships between wealth, distance to BOMA, agricultural markets, and productivity. The diagram shows four paths (A, B, C, and D) through which wealth influences productivity, including direct and indirect effects. This framework allows us to visualize and understand the complex relationships between wealth, spatial factors, and productivity.

We examined the role of distance to BOMA and markets in shaping the wealth-productivity relationship using Bayesian mediation analysis. This approach allows us to estimate the indirect effects of wealth on productivity and investigate how these effects vary across spatial contexts. The analysis utilized Bayesian linear regression models in Stata 18, using the ***bayesmh*** command, which implements Markov Chain Monte Carlo (MCMC) methods (details provided in **Appendix B**). We controlled for age of household head and household size to account for the potential influences of these factors on the wealth-productivity relationship and provide a deeper understanding of the pathways through which wealth affects agricultural productivity.

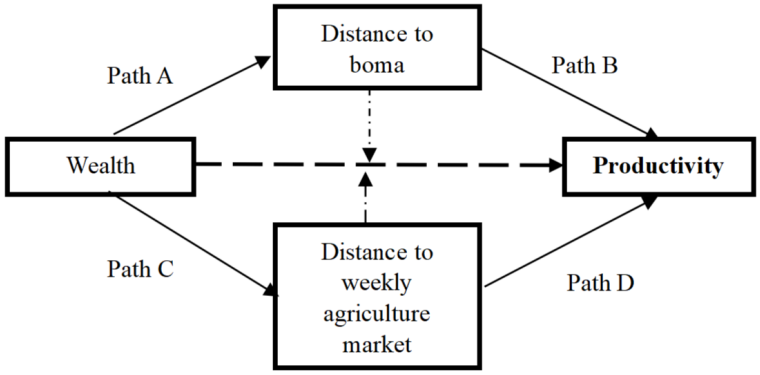

Figure 4. Mediation and moderation concept.

Note:
Moderation (Indirect effects through Paths A, B, C, D)
Direct Effects
Mediation

Table 1 presents the moderation analysis results summary. The table includes coefficients for the log of wealth, distance to district centre (BOMA), distance to weekly agriculture market, and interaction terms between wealth, and both distance to BOMA and distance to market. It also reports mean estimates and equal-tailed 95% credible intervals for the coefficients. This implies that the average impact of each variable had a varying effect on productivity. Worthy to note, the equal-tailed 95% credible intervals provide a range of uncertainty around each mean estimate, indicating the probability that the true effect lies within that range [30].

Secondly, we examined this relationship through a mediation analysis lens, using a Bayesian framework based on the Markov Chain Monte Carlo (MCMC) method [32]. Bayesian mediation regression analysis was conducted in Stata 18, utilizing the ***bayes*** command with a normal prior distribution (normal (0,20)) and five Markov chains. In terms of the age of the head of household and household size, the study opted to use them as control variables in the analysis. We specifically investigated the mediating roles of distance to BOMA and distance to agricultural markets in the relationship between wealth and productivity.

Furthermore, in **Table 2** the study presents coefficients that were unstandardized from the mediation regression analysis (see **Appendix C** for details). From the analysis wealth, distance to BOMA and agricultural markets, and markets, significantly had positive effects on productivity through path A and path B. On the one hand, it was noted that wealth and distance to markets had a significant positive effect (path C). On the other hand, distance to weekly agricultural markets had a negative effect on productivity (path D). Yet, it was found that wealth had a direct significant and positive effect on productivity. This implies that when considering the mediation paths, the study found varying effects of wealth on productivity relative to the effect of wealth on productivity from its direct path counterpart.

Table 1. Moderation Analysis Results.

	Mean	Median	Equal-Tailed (95% Credible Interval)	
Wealth	0.226	−0.100	−8.661	8.156
Distance to the district centre (BOMA)	−0.001	0.006	−0.164	0.188
Distance to the nearest weekly agriculture market	−0.148	−0.026	−0.593	0.093
c.wealth_log#c. dist_boma	−0.258	−0.197	−0.971	0.125
c.wealth_log#c. dist_agmrkt	0.305	0.156	−0.008	0.982

Note: c.wealth_log#c.dist_boma and c.wealth_log#c.dist_agmrkt represent the interaction terms between the log of wealth and distance to the district centre and the weekly agriculture market, respectively. These terms capture the moderating effects of distance to markets on the relationship between wealth and productivity. Distance to district centre (BOMA) and distance to nearest weekly agriculture market are measured in kilometers (km).

Table 2. Mediation Analysis Results.

Step	Coefficient	95% CI
Path A	3.173	(2.276, 4.054)
Path B	0.004	(−0.001, 0.008)
Path C	2.498	(1.729, 3.255)
Path D	−0.007	(−0.012, −0.001)
Direct Effect	0.005	(−0.081, 0.091)
Indirect Effect 1	0.013	N/A
Indirect Effect 2	−0.018	N/A

These findings emphasize the significance of spatial factors and wealth interactions in understanding the relationship between wealth and productivity.

To validate the robustness of our Bayesian mediation analysis, we conducted a complementary analysis based on Bayesian Structural Equation Modelling (BSEM), a statistical framework that enables the examination of complex relationships between multiple variables [33]. BSEM has evolved to become a widely accepted methodology in various social sciences, including economics. By utilizing BSEM, we aim to cross-validate our primary findings and enhance their reliability. BSEM is particularly useful for modelling complex relationships, as it allows for the simultaneous estimation of multiple equations, accounting for interactions and correlations between variables. We employed BSEM to examine the relationships between wealth, distance to BOMA and to agricultural markets, and productivity. We applied the BSEM framework leveraging the Structural Equation Modeling (SEM) builder tool in STATA to remodel this complex relationship, examine direct and indirect effects and account for latent or unobserved constructs or variables. The results of this analysis are in **Table 3**, and details are in **Appendix C**.

Table 3. BSEM Results.

Relationship	Coefficient	*p*-Value
Wealth → Distance to Boma (Path A)	2.67	0.000
Wealth → Distance to Agricultural Markets (Path C)	0.14	0.000
Distance to Boma → Productivity (Path B)	0.00	0.187
Distance to Agricultural Markets → Productivity (Path D)	−0.13	0.052

Note: Distance to district centre (BOMA) and distance to nearest weekly agriculture market are measured in kilometers (km).

The BSEM results in **Table 3** indicate that wealth has a positive and significant association with distance to BOMA and agricultural markets. Additionally, the results suggest that distance to BOMA has a positive but insignificant relationship with productivity. In contrast, distance to agricultural markets has a negative and moderately significant relationship with productivity. The findings are consistent with the results of the Bayesian model. The consistency of these findings across both Bayesian regression and BSEM models supports the findings made earlier about the relationships between wealth, distance to market, and productivity.

To validate the robustness of our moderation model estimates, we employed a bootstrapping approach to examine the stability of the individual paths estimates in our moderation model. Bootstrapping involves repeatedly resampling the data with replacement, generating many simulated datasets, and analyzing each dataset to obtain a distribution of estimates. This approach enables researchers to assess the stability and reliability of their findings while accounting for potential variations in the data. By applying bootstrapping to our moderation analysis, we aimed to confirm the consistency of our estimates and rule out potential biases. Specifically, we conducted a bootstrap analysis with 1000 replications, examining the relationships between productivity, wealth, distance to BOMA, and distance to agricultural markets. We chose 1000 replications for the bootstrap analysis, as research has shown that the bootstrap distribution of estimates converges relatively quickly, often within 1000 replications [20].

Specifically, we estimated four bootstrap regres-

sion models: Path A examined the relationship between wealth and distance to BOMA, Path C analyzed the relationship between wealth and distance to agricultural markets, Path B examined the relationship between distance to BOMA and productivity, and Path D analyzed the relationship between wealth, distance to BOMA, and productivity as shown in **Figure 4**. **Table 4** summarizes the key relationships between wealth, distance to rural services, and productivity. Details are in **Appendix B**.

Comparing the bootstrap results with our Bayesian moderation analysis, we observe consistent patterns. Both analyses suggest that wealth moderates the relationship between distance to markets and productivity. Both revealed that wealth is positively associated with distance to BOMA and agricultural markets. In addition, household size has a significant and negative relationship with productivity. While Bayesian analysis indicates potential convergence issues, bootstrap consistency supports our findings.

Table 4. Bootstrap Summary Results.

Variable	Coefficient	*p*-Value
Relationship between wealth and distance to BOMA (Path A)		
Wealth	3.17	0.00
Age	0.03	0.20
Household size	0.60	0.00
Relationship between wealth and distance to agricultural markets (Path C)		
Wealth	2.50	0.00
Age	−0.04	0.02
Household size	−0.06	0.65
Relationship between distance to BOMA and productivity (Path B)		
Distance to BOMA	0.00	0.19
Wealth	−0.01	0.84
Age	−0.00	0.08
Household size	−0.06	0.00
Relationship between distance to BOMA and productivity (Path D)		
Distance to BOMA	−0.01	0.84
Wealth	0.00	0.19
Age	−0.00	0.08
Household size	−0.06	0.00

Note: Distance to district centre (BOMA) and distance to nearest weekly agriculture market are measured in kilometers (km).

5. Discussion

5.1. Systematic Review

The systematic review of 24 articles reveals that the wealth-productivity relationship among smallholder farmers in Malawi is influenced by a complex array of factors. These factors can be categorized into three groups: variables that exclusively influence wealth, variables that uniquely impact productivity, and factors that influence both wealth and productivity. This categorization provides valuable insights into the intricate relationships between wealth and productivity, highlighting the need for targeted interventions that address both socioeconomic and productivity-enhancing factors.

5.1.1. Determinants that Uniquely Impact Wealth

Socioeconomic status emerges as a dominant factor, with 33% of articles mentioning it as a determinant of wealth. Education level and gender of the household head are equally prominent, each mentioned in 27% of the articles. Off-farm income opportunities also comprise 27% of the mentions, underscoring the potential influence of non-agricultural income sources on wealth. The development of inclusive food value chains plays a lesser but significant role, appearing in 7% of the articles. Notably, socioeconomic status is a pivotal determi-

nant, highlighting the importance of social and economic empowerment in shaping wealth. Within this, the education level of the heads of households serves as a critical enabler, equipping the heads with the knowledge, skills, and confidence necessary to spur households to aim for socioeconomic empowerment. The household head's gender also exerts a significant influence, with cultural and societal norms impacting wealth outcomes. Furthermore, off-farm income opportunities are crucial, emphasizing the potential for non-agricultural income sources to impact wealth. This finding is consistent with human capital theory [34, 35], which posits that investments in education, training, and health can enhance productivity and earnings, as well as Amartya Sen's capability approach [36], which underscores the significance of freedoms and opportunities in determining well-being and development. Our study extends this understanding by quantifying the specific impact of these factors in Malawi's context.

5.1.2. Determinants that Impact Productivity

Elements of total factor productivity (such as efficiency), extension services, and climate-related shocks and possible stressors or factors that pressure or threaten the health, resilience, and stability of crops, livestock, or farming systems are among the prominent factors impacting productivity, each mentioned in 16% of the articles. Land holding size and utilization are critical to influencing productivity through efficient land use and management. Drought-tolerant maize enhances resilience to climate-related shocks. Contract farming provides farmers with access to markets, technology, and other resources. Social grants, including fertilizer subsidies and social protection funds, provide essential support. Improved agricultural inputs and fertilizers enhance soil fertility and improve crop yields. Technical efficiency equips farmers with the knowledge, skills, and technologies necessary for productivity growth. This finding aligns with Robert Solow's work on total factor productivity, which emphasizes the importance of technological progress in driving long term productivity growth. His model highlights the significant of technological advancements in economic growth [37]. Likewise, the emphasis on climate-resilient practices, such as drought-tolerant maize, will underscore the importance of adaptation strategies in the face of climate-related shocks, consistent with the livelihood diversification literature [38]. In the context of Malawi, our analysis suggests that integrating technological advancements with climate-resilient practices can enhance agricultural productivity and support sustainable livelihoods.

5.1.3. Determinants that Impact Productivity and Wealth

Our study found that household size, asset wealth, agricultural land holding, farm size, and soil conservation and sustainable agriculture practices are equally prominent. Household size influences wealth and productivity outcomes. It is worth noting that not only land holdings and farm size influence productivity, but also the wealth status of people. Considering agronomical factors, soil conservation, sustainable agricultural practices, and adoption of farming technology including livestock ownership determine both the wealth creation and productivity of smallholder farmers. The current study reiterates that for farmers who have increased access to loans, their likelihood of having financial resources to support their farming enterprises significantly increases their level of productivity and worth status. Commercialization supports households to shift from subsistence farming and, in that way, supports wealth enhancement and increased productivity. Crop insurance helps farmers manage risks, reduce uncertainty, and protect them from calamities such as drought. In terms of sustainable farming practices attainment, the current study found that a crop insurance scheme, though not intensively adopted, fundamentally reduces the risks and uncertainties affecting farmers' enterprises because of drought. All in all, much as mechanization is being noted to be gradually adopted by the majority of the smallholder farmers in reducing labour costs and improving efficiency, it was found to increase efficiency in production and worth status. Therefore our findings are consistent with the sustainable livelihoods framework, which emphasizes the importance of diverse assets, including natural, physical, and financial capital, in enhancing livelihood outcomes [34]. In the Malawian context, our analysis underscores the importance of integrated approaches that leverage sustainable agriculture practices,

market access, farming technology, extension services, secure land tenure, asset ownership, and risk mitigation strategies (such as crop insurance and diversification) to enhance both wealth and productivity outcomes.

5.2. Insights from SR for Malawi

Based on the SR, which also identified socioeconomic status, agricultural inputs, climate-related shocks, extension services, and technical efficiency as prominent factors influencing agricultural productivity and wealth—four broad themes emerged, namely: household size; access to finance; commercialization, extension services, technical efficiency, and mechanization; and market access, farm technology adoption, and participation. Their significance in the wealth-productivity analysis is further underscored by the fact that these themes were collectively mentioned by approximately 48% of the articles reviewed in the SR. As we examine these themes, we also consider the moderation effect of spatial variables — distance to market and distance to boma — as well as the confounding factors — household farmer age, and household size, which also emerged as strong factors affecting both wealth and productivity in the analysis. The following section explores the four broad themes in greater detail, providing actionable policy recommendations for practitioners.

5.2.1. Household Size

The articles reviewed in our SR highlight the significance of household size in determining agricultural productivity and wealth. Household size can have both positive and negative impacts on wealth and productivity [39–43]. On the one hand, larger households can provide additional labor, leading to increased crop productivity and improved food security. On the other hand, larger households can lead to increased resource utilization, negatively impacting food security [21]. For Malawi, household size emerges as a critical factor in influencing wealth and productivity, where the total fertility rate stands at 3.4 children per woman and the dependency ratio is 75.7% (2022) [40]. To address these challenges, policymakers should promote labor-intensive jobs, expand training and capacity-building programs such as agroprocessing and the promotion of rural industries, and integrate family planning initiatives aimed at enhancing women's reproductive health, educational opportunities, and economic autonomy.

5.2.2. Access to Finance

Limited access to finance significantly hinders wealth creation and productivity in agriculture. Approximately 14% of adults in Malawi rely solely on informal financing mechanisms, while 61% use formal finance services but are not banked (FinScope Survey). Our systematic review also highlights access to finance as a pivotal factor influencing wealth and productivity, with access to credit being a key determinant. Access to finance can improve agricultural productivity and wealth [43]. Furthermore, the disparity in financial inclusion between urban and rural areas exacerbates the challenge, with 93% of urban adults having formal access compared to 67% in rural areas. Our study suggests that policymakers should address this, such as by improving access to credit, reducing barriers to banking and promoting mobile money, and enhancing financial literacy and awareness. Our findings build upon the evidence presented by Montfaucon on the role of mobile technology in increasing access to financial services and agricultural income in Malawi [41]. While this study highlights the positive impact of mobile phone ownership — which provides access to basic services like voice calls, SMS, and mobile money services — on loan acquisition and agricultural incomes, our study further suggests that promoting the use of digital platforms, such as mobile money services, digital financial services, and other online tools, can bridge the gap in access to finance, particularly for rural household farmers. According to the Malawi Vision 2063 document [42], digital finance solutions are mentioned as a potential driver of growth, but more targeted attention is needed to realize their full potential.

5.2.3. Commercialization, Extension Services, Technical Efficiency, and Mechanization

Reviewed studies emphasize the pivotal role of these factors in bolstering productivity and wealth, consistent with the Solow Growth Model's emphasis on technological progress and capital accumulation. These interrelated factors collectively impact wealth and pro-

ductivity, based on our study. The underutilization of mechanization and persistently low technical efficiency continue to hinder productivity gains and efficiency in Malawi's agricultural sector. Commercialization and extension services can facilitate smallholder farmers' transition from subsistence to commercial farming, enhancing their productivity and wealth [38, 39]. This finding is consistent with previous studies identifying key determinants of farm household decisions to seek and access agricultural support services, including extension services in Malawi [43]. Furthermore, our study's emphasis on strengthening extension services and mechanization echoes the government's efforts such as the Malawi Growth and Development Strategies (MGDS III) [44] aiming to improve productivity through enhanced extension, innovation, and mechanization. However, as noted in the mid-term review, limited agriculture extension services and low coverage of improved technologies continue to hinder progress. Therefore, investing in digital infrastructure and e-extension, as well as allocating more government resources to agriculture, could help address these challenges and improve productivity and wealth. This echoes a research study recognizing the potential of digital agriculture services to improve farmer outcomes [45].

5.2.4. Market Access, Agricultural Technology Adoption and Participation

The reviewed studies highlight the crucial role that market access and participation have in enhancing agricultural productivity and wealth. This finding aligns with our hypothesis, which posits that access to agricultural markets in Malawi, facilitated by established weekly markets and proximity to district centers, moderates the wealth-productivity nexus. The MIP-1 recognizes the importance of agricultural development, but our study provides more granular insights into the specific challenges and opportunities facing smallholder farmers in Malawi, particularly with regard to digital platforms and market facilitation initiatives. The study provides actionable recommendations for policymakers to enhance the effectiveness of agricultural development initiatives in Malawi, particularly in the areas of digital platforms and market facilitation such as strengthening market access and facilitating the adoption of technology.

While the MIP-1 recognizes the challenge of limited investment in agricultural research and extension services, our study emphasizes the urgent need for targeted investments in research stations and agricultural research to develop and disseminate innovative technologies and practices tailored to Malawi's specific needs. Furthermore, our study highlights the potential of digital platforms to enhance the dissemination and adoption of these technologies, thereby improving productivity and wealth among smallholder farmers.

5.2.5. Knowledge Gaps

Having noted the valuable insights from the SR in the context of Malawi, we also identified gaps in the analysis of the relationship between wealth and productivity. Specifically, we noted three knowledge gaps in the existing literature. First, while existing studies have explored how various elements of wealth (such as knowledge, proximity, or assets) influence specific aspects of productivity (like crop yields or farming practices), they have largely overlooked the direct relationship between overall wealth and productivity. Secondly, studies have predominantly focused on the unidirectional relationship, examining how productivity affects wealth/poverty, while overlooking the reciprocal relationship where wealth influences productivity. Thirdly, research in this area has been limited by methodological and conceptual flaws, including a narrow geographical focus, limited sample sizes, and outdated datasets. The extent of their validity and the generalizability of the findings remain uncertain.

5.3. Mediation and Moderation Analysis

Building on the insights from the systematic review and the relationships between wealth and productivity outlined in Section 4, we further explored the underlying mechanisms using mediation and moderation analyses, as illustrated in **Figure 4**. These analyses allowed us to examine the direct and indirect effects of wealth on productivity, as well as the moderating roles of distance to BOMA and agricultural markets.

Path A: Relationship between Wealth and Distance to BOMA: The Bayesian linear regression analysis

yielded a positive and statistically significant relationship between wealth and distance from the BOMA at the 5% significance level. This finding may be attributed to the limited availability of basic services and infrastructure in rural district centres, prompting wealthy households within this sector to settle farther out from the BOMA on larger landholdings, in search of better opportunities, privacy, and a quieter lifestyle while not losing much. Additionally, wealthier households' access to resources, such as private transportation, may enable them to reside farther away from the BOMA without being disadvantaged. Instead, these households may opt to live away from BOMA's proximity, suggesting a potential gap in service delivery or infrastructure expected to be available within BOMA's proximity. Upgraded or improved BOMA's services and infrastructure could potentially make it a more attractive location for wealthy households to access opportunities to improve their productivity and wealth. Given the predominantly rural and subsistence-based nature of our study context, these findings underscore the need for targeted investments in both rural and urban infrastructure and services to unlock economic potential for wealth creation. This is consistent with a review highlighting the importance of infrastructure in promoting rural economic growth [46]. Our study further suggests that similar investments and upgrading services in urban areas, such as BOMA, could enhance their attractiveness to wealthier households, providing opportunities for improved productivity and wealth as leverage on urban setting advantages, ultimately driving economic growth and development.

Path B: Relationship between distance to BOMA and productivity: The analysis reveals a positive association between distance to BOMA and productivity, significant at the 10% level. This relationship suggests that households located further away from BOMA tend to have higher productivity. Notably, this association persists even after controlling for potential confounding factors — household size, and age of the household head. Just like in the case of wealth, one possible explanation for this positive relationship is that households residing farther away from BOMA may have more space and resources to devote to productive activities, such as farming or livestock rearing. Alternatively, these households may be more motivated to optimize their practices and increase productivity within their isolated residences from BOMA proximity. The positive association may imply that BOMA's services or infrastructure are inadequate or ineffective at promoting productivity within proximity, and hence, households seek opportunities and resources elsewhere. Consistent with our earlier findings on the relationship between wealth and distance to BOMA, the positive association between distance and productivity highlights the need for targeted investments in BOMA's infrastructure and services. By upgrading these services, policymakers can create a more conducive environment for productivity and wealth creation, ultimately driving economic growth and development.

Path C: Relationship between wealth and distance from the nearest agricultural market: The analysis yielded a positive and statistically significant relationship between wealth and distance to agricultural markets. This finding indicates that households with increased wealth tend to be located farther away from weekly agricultural markets. Just like in the case of wealth, a possible explanation is that wealthier households enjoy broader spatial flexibility, enabling them to engage in productive activities with reduced dependence on proximity to these markets. Consistent with our earlier findings on the importance of infrastructure investments in rural and urban areas, the positive relationship between wealth and distance to agricultural markets highlights the need for more robust market systems that can support farmers' income growth and contribute to broader economic development. However, ensuring well-functioning structured agricultural markets in Malawi (MIP -1) requires addressing issues related to market inefficiencies and policy frameworks, as highlighted in a systematic review of agricultural marketing in Malawi [47]. Notably, this review provides empirical evidence from Malawi, underscoring the importance of context-specific solutions to improve agricultural market systems and support economic growth.

Path D: Relationship between distance to the agricultural market and productivity: The analysis revealed a negative and statistically significant relationship be-

tween distance to agricultural markets and productivity. This finding suggests that households located farther away from weekly agricultural markets have lower productivity. Our study contributes to the existing literature on agricultural markets by providing new insights into the relationship between distance to markets and productivity in Malawi. While agricultural markets are often seen as a key driver of wealth creation [41], our findings suggest that the weekly markets in their current form may not be playing a significant role in supporting household wealth (Path C). Upgraded or improved agricultural markets' infrastructure and services could potentially increase household productivity.

Direct Effects: Overall, we find a non-significant but positive direct relationship between wealth and productivity (coefficient: 0.005; 95% CI: -0.081, 0.091). Specifically, it has a positive indirect effect through distance to BOMA (indirect effect: 0.013), indicating that increased wealth is associated with longer distances to BOMA. Conversely, wealth has a negative indirect effect through distance to agricultural markets (indirect effect: -0.0175). These findings highlight the importance of considering spatial factors (and other mediators) in understanding the relationship between wealth and productivity.

The moderation analysis results reveal that the relationship between wealth and productivity among Malawi's smallholder household farmers is influenced by spatial factors. The coefficient of the log of wealth (0.226) suggests a positive relationship with productivity (95% credible interval: -8.661, 8.156). This means that as wealth increases, productivity also tends to increase. Wealth also plays a moderating role in the relationship between market distance and productivity. Specifically, wealth alleviates the negative impact of distance from BOMA (district centers) on productivity, as indicated by the negative coefficient (-0.258). This means that as wealth increases, the negative effect of being far from BOMA on productivity decreases. Conversely, wealth exacerbates the negative impact of distance from agricultural markets on productivity, as shown by the positive coefficient (0.305). This means that as wealth increases, the negative effect of being far from agricultural markets on productivity increases. However, the effects of distance from markets on productivity are relatively small. In simpler terms, wealth generally increases productivity, helps to reduce the negative impact of being far from BOMA (district centers) on productivity, and increases the negative impact of being far from agricultural markets on productivity. To our knowledge, this is the first study to examine the moderating role of wealth in the relationship between distance to markets and productivity among smallholder farmers in Malawi. Our findings provide new insights into the complex relationships between wealth, market access, and productivity in this context.

6. Conclusion and Recommendations

6.1. Conclusions

This study delves into the relationship between wealth and productivity among Malawi's smallholder farmers. This study's mixed-methods approach brought together a systematic review and Bayesian analysis to inform our findings. The review identified four broad themes: (1) Household size; (2) Access to financial services and markets; (3) Agricultural commercialization, extension services, and mechanization, and (4) Market access and participation as key factors driving wealth and productivity. Further, the review exposed substantial knowledge gaps in understanding wealth and productivity relationships in the Malawian context. To bridge the gap, we employed Bayesian moderation and mediation analyses, leveraging these statistical techniques, to understand the complex relationships between wealth and productivity.

Initial regression analysis revealed a significant negative correlation between wealth and productivity. This unexpected finding suggests that poorer households tend to have higher productivity, while wealthier households within the overall smallholder players tend to have lower productivity. The fertilizer subsidy program, which benefits the poorer segment of smallholder household farmers more, may contribute to this overall negative relationship.

Further, the study revealed that wealth's impact

on productivity is complex, influenced by various factors and moderators/mediators, and shaped by the interactions between these factors. Through moderation and mediation analysis, we found that wealth affects productivity directly and indirectly, depending on the behavior of moderators and mediators. Controlling for the confounding effects of household size and household farmer age, the analysis showed that the overall relationship between wealth and productivity is positive. Specifically, our results show that wealth has a positive indirect effect on productivity through distance to district centers (BOMA), and Malawi's smallholder household farmers may not be benefiting in terms of accessing support or other benefits from proximity to these centers. Notably, this positive effect is reinforced by the finding that wealth alleviates the negative impact of distance to BOMA on productivity. On the other hand, wealth has a negative indirect effect on productivity through distance to agricultural markets. This means that wealthy smallholder household farmers who live further away from weekly markets may be experiencing low productivity, as they also may be facing reduced access to market opportunities. As wealth increases, the negative effect of being far from agricultural markets on productivity increases. Additionally, we found that confounding factors, such as household heads and household sizes also play a significant role in the complex relationship.

6.2. Policy Recommendations

We identified policy-relevant triggers for improving productivity directly or indirectly through wealth, based on the SR findings. We identified that initiatives that promote wealth, such as improved access to finance and markets, could positively impact productivity. We note that some of these triggers may not effectively support wealth or productivity in the context of Malawi unless these services start to be more available and meaningful to household farmers. We note, for example, through moderation and mediation analysis, that wealthier households tend to settle farther away from local government centers (BOMA) and weekly markets, despite the potential benefits of living within proximity. These findings highlight the need for policies addressing limitations in support infrastructure and service provision in these places. To enhance productivity, policies should focus on making markets functional, extension services effective, and BOMA services meaningful. Policymakers should also consider mediators, moderators, and confounding factors within the complex wealth-productivity relationship.

To enhance productivity, policymakers should prioritize initiatives that address spatial constraints. Using digital platforms to connect farmers to markets or initiatives that deliver services directly to rural farmers can mitigate the challenges posed by inadequate infrastructure, which is a key element in this. Consistent with our findings on the importance of technological progress and efficiency in driving productivity growth, investing in research stations and agricultural research can help develop innovative technologies and practices tailored to Malawi's specific needs.

Given the observed tendency of wealthier households to settle farther away from BOMA centers, upgrading the quality of infrastructure and services within the proximity of the BOMA, such as improving access to banking services, utilities, and upgrading road network and other facilities and services, could enable household farmers to take full advantage of the benefits of such centres, thereby enhancing their productivity and wealth growth.

Weekly markets in rural areas aim to serve as hubs for rural farmers to connect with people and markets outside of these places, thus generating wealth. To make them serve their purpose, the government can enhance these markets by improving market infrastructure and market information, hence allowing farmers to make the most of the opportunities that the markets may bring in supporting wealth creation.

It is also essential for extension services to reach beyond district centers to meet the needs of rural farmers. By leveraging digital platforms and e-extension services, farmers can gain better access to markets and essential services, reducing the impact of inadequate rural infrastructure. Zambia's successful implementation of e-extension services offers valuable insights for Malawi's policymakers.

To optimize resource allocation, policymakers should explore the adoption of targeted fertilizer subsidy programs, which can help free up resources to support complementary initiatives. The successful implementation of such programs in Tanzania, Kenya, and Ghana offers valuable insights for Malawi.

Further, policymakers should prioritize demographic management, particularly population growth, to alleviate poverty and income inequality. This could involve supporting initiatives that promote family planning, education, and labor-intensive farming practices that capitalize on larger household sizes, acknowledging that Malawi is rapidly growing.

6.3. Study Limitations and Areas for Further Study

This study has several limitations that may also be opportunities for future research. A key limitation is the limited number of mediators, moderators, and confounding factors (two of each) considered in our analysis. Future studies could expand this list to include other influential factors, such as access to finance, specific crop choice, soil type, and climate conditions. Additionally, we employed Bayesian methods for mediation and moderation analysis, but future research could leverage more sophisticated machine learning tools that could accommodate more moderators and factors to provide deeper insights. Furthermore, due to delays in releasing the Integrated Household Survey (IHS) data, our analysis relied on older data. Future studies should utilize upcoming IHS results to provide more current insights. They should also consider incorporating qualitative data collected through focus group discussions to offer a more comprehensive understanding.

Author Contributions

The conceptual framework, methodological approach, and manuscript refinement for this study were developed by E.C.; K.M. played a crucial role in the design of the study and methodology, as well as reviewing the manuscript; I.P.P. oversaw the study, verified the findings, and reviewed the manuscript; H.P. supported the development of the study's concept, the design of the methodology, and reviewed the manuscript. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement

Not applicable.

Data Availability Statement

Data for the study is available online from World Bank and National Statistics Office portals.

Conflicts of Interest

The authors declare no conflict of interest.

Appendix A. OLS, Spline, and Stepwise Regression Analysis

We conducted a simple regression analysis to examine the relationship between wealth and productivity. The results revealed a statistically significant negative association between wealth and productivity (Coefficient = -0.134, p-value = 0.006). Additionally, we examined the relationship between wealth and yield, defined as the amount of crop output per hectare, using OLS. The results also showed a statistically significant negative association between wealth and yield (Coefficient = $-36{,}429.04$, p-value = 0.001).

Spline Regression Analysis: To further explore the relationship between wealth and productivity, we employed spline regression analysis. The results confirmed the negative relationship between wealth and productivity, showing that it is not linear, but consistently negative across all points.

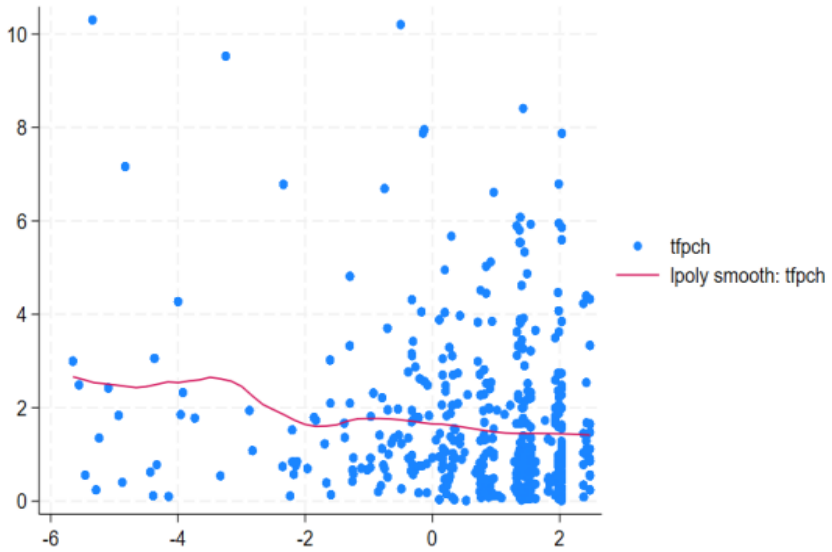

Figure A1. Spline Plot.

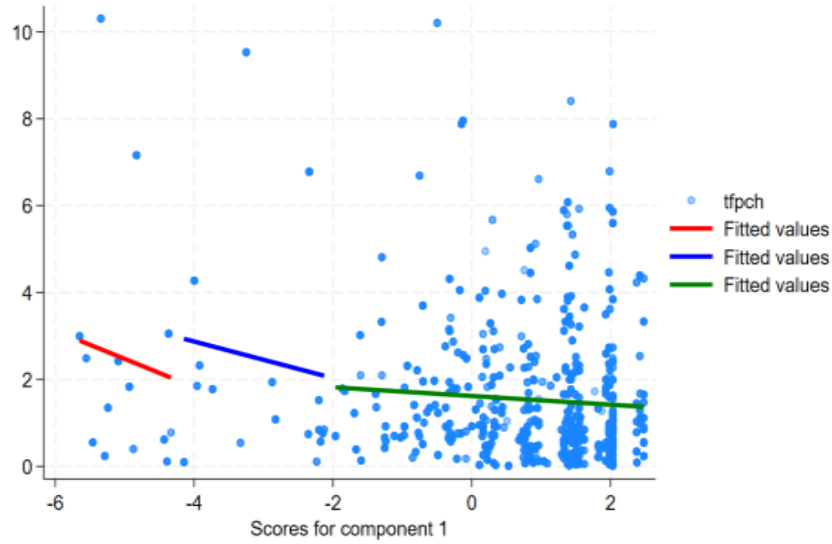

Figure A2. Stepwise Plot.

Stepwise Regression Analysis: We also conducted stepwise regression analysis to examine the relationship between wealth and productivity. The results confirmed the negative relationship between wealth and productivity.

Discussion: The findings from the OLS, spline, and stepwise regression analyses suggest a negative relationship between wealth and productivity, which is counterintuitive given the expected positive correlation between these variables. A plausible explanation for this finding lies in the country's agricultural policies, particularly the extensive subsidized fertilizer program. This program has primarily benefited the poorest households, who have demonstrated significant improvements in productivity. In contrast, slightly better-off households have not demonstrated comparable improvements in productivity.

Appendix B. Moderation Analysis

The analysis uses the bayesmh command in Stata, which implements Bayesian estimation using Markov chain Monte Carlo (MCMC) methods. The Bayesian approach provides several advantages, including the abil-

ity to incorporate prior knowledge, account for model uncertainty, and provide probabilistic statements about the results.

- **Model Summary:** Bayesian normal regression using Markov chain Monte Carlo (MCMC) methods. Econometric model: productivityCH = β0 + β1(wealth_log) + ... Bayesian estimation with 5 chains, 12,500 iterations, and 2500 burn-in. Number of observations: 1796.
- **Regression Equation:** productivityCH = β0 + β1(wealth_log) + β2(dist_boma) + β3(dist_agmrkt) + β4(wealth_log × dist_boma) + β5(wealth_log × dist_agmrkt) + β6(Age) + β7(hhsize) + ε.
- **Stata command:** bayesmh productivityCH = wealth_log dist_boma dist_agmrkt c.wealth_log#c.dist_boma c.wealth_log#c.dist_agmrkt Age hhsize, likelihood(normal({var})) prior({productivityCH:}, normal(0,20)) prior({var}, normal(0,20)) nchains (5)
- Model Summary.

(please refer to variable legend at the end of this Appendix).

Table A1. Moderation Analysis Results.

	Mean	Std. Dev.	MCSE	Median	Equal-Tailed [95% Cred Interval]	
Productivity						
Log of Wealth (wealth_log)	0.226	6.651	0.432	−0.1	−8.661	8.156
Distance to district centre (dist_boma)	−0.001	0.106	0.006	0.006	−0.164	0.188
Distance to weekly agriculture market (dist_agmrkt)	−0.148	0.247	0.014	−0.026	−0.593	0.093
c.wealth_log#c. dist_boma	−0.258	0.413	0.018	−0.197	−0.971	0.125
c.wealth_log#c. dist_agmrkt	0.305	0.387	0.017	0.156	−0.008	0.982
Age	−0.166	0.259	0.014	−0.066	−0.615	0.056
Household size (hhsize)	2.183	3.533	0.141	1.488	−0.424	8.366
_cons	−0.328	8.341	0.438	2.138	−12.659	7.927
var	10.761	6.193	0.333	10.877	2.021	19.018

Bootstrap Analysis for Moderation

The analysis aimed to assess the stability and reliability of our moderation model estimates.

- Bootstrap analysis with 1000 replications to estimate the robustness of the moderation model.
- Examined the relationship between productivity and wealth, moderated by distance to boma and distance to agricultural markets. Controlled for age (Age) and household size in all models.
- Estimated four bootstrap regression models:
  - Step 1: Relationship between wealth and distance to boma.
  - Step 2: Relationship between wealth and distance to agricultural markets.
  - Step 3: Relationship between distance to boma and productivity.
  - Step 4: Relationship between wealth, distance to boma, and productivity.

Table A2. Bootstrap Results.

Variable	Coefficient	Std. Err.	z	*p*-Value	95% Conf. Interval
Relationship between wealth (wealth_log) and distance to the nearest bomas (dist_boma), controlling for Age and household size (hhsize).					
wealth_log	3.1675	0.4455	7.11	0.000	2.2944, 4.0407
Age	0.0300	0.0235	1.28	0.201	−0.0160, 0.0761
hhsize	0.6018	0.1444	4.17	0.000	0.3187, 0.8849
_cons	22.1613	1.3323	16.63	0.000	19.5501, 24.7725
Relationship between wealth (wealth_log) and distance to the nearest agricultural market (dist_agmrkt), controlling for Age and household size (hhsize)					
wealth_log	2.4975	0.4383	5.70	0.000	1.6385, 3.3566
Age	−0.0445	0.0198	−2.25	0.024	−0.0833, −0.0057

Table A2. *Cont.*

Variable	Coefficient	Std. Err.	z	*p*-Value	95% Conf. Interval
Relationship between wealth (wealth_log) and distance to the nearest agricultural market (dist_agmrkt), controlling for Age and household size (hhsize)					
hhsize	−0.0606	0.1313	−0.46	0.645	−0.3178, 0.1967
_cons	29.8627	1.2682	23.55	0.000	27.3770, 32.3484
Relationship between the mediator (dist_boma) and the outcome variable (productivityCH), controlling for the independent variable (wealth_log) and covariates (Age and hhsize).					
dist_boma	0.0037	0.0028	1.32	0.188	−0.0018, 0.0092
wealth_log	−0.0075	0.0382	−0.20	0.843	−0.0824, 0.0673
Age	−0.0041	0.0023	−1.78	0.075	−0.0087, 0.0004
hhsize	−0.0578	0.0186	−3.10	0.002	−0.0943, −0.0213
_cons	1.8743	0.1743	10.75	0.000	1.5327, 2.2159
Relationship between the mediator (dist_boma) and the outcome variable (productivityCH), controlling for the independent variable (wealth_log) and covariates (Age and hhsize)					
wealth_log	−0.0075	0.0382	−0.20	0.843	−0.0824, 0.0673
dist_boma	0.0037	0.0028	1.32	0.188	−0.0018, 0.0092
Age	−0.0041	0.0023	−1.78	0.075	−0.0087, 0.0004
hhsize	−0.0578	0.0186	−3.10	0.002	−0.0943, −0.0213
_cons	1.8743	0.1743	10.75	0.000	1.5327, 2.2159

Note: Variable legend

Variable Name	Description
wealth_log	Logarithm of household wealth
dist_boma	Distance to the nearest boma (local market)
dist_agmrkt	Distance to the nearest agricultural market
productivityCH	Agricultural productivity (crop yield)
Age	Household head's age
hhsize	Household size

Appendix C. Mediation Analysis

The mediation analysis examines the relationships between household wealth, distance to local economic opportunities, and agricultural productivity. We employ a Bayesian mediation analysis framework using Markov chain Monte Carlo (MCMC) methods to estimate the direct and indirect effects of wealth on productivity

Regression Equations

- Path A: (wealth_log → dist_boma): dist_boma = β0 + β1(wealth_log) + β2(Age) + β3(hhsize) + ε
- Path B: (dist_boma → productivityCH): productivityCH = β0 + β1(dist_boma) + β2(wealth_log) + β3(Age) + β4(hhsize) + ε
- Path C: (wealth_log → dist_agmrkt): dist_agmrkt = β0 + β1(wealth_log) + β2(Age) + β3(hhsize) + ε
- Path D: (dist_agmrkt → productivityCH): productivityCH = β0 + β1(dist_agmrkt) + β2(wealth_log) + β3(Age) + β4(hhsize) + ε
- Direct Effect: (wealth_log → productivityCH): productivityCH = β0 + β1(wealth_log) + β2(Age) + β3(hhsize) + ε
- Indirect Effect 1 (via dist_boma): wealth_log → dist_boma → productivityCH = (β1 from Path A) × (β1 from Path B)
- Indirect Effect 2 (via dist_agmrkt): wealth_log → dist_agmrkt → productivityCH = (β1 from Path C) × (β1 from Path D)

(please refer to variable legend at the end of this Appendix 2).

Stata commands:

- bayes, prior({var}, normal (0,20)) nchains(5): regress dist_boma wealth_log Age hhsize
- bayes, prior({var}, normal(0,20)) nchains(5): regress productivityCH wealth_log dist_boma Age hhsize
- bayes, prior({var}, normal(0,20)) nchains(5): regress dist_agmrkt wealth_log Age hhsize
- bayes, prior({var}, normal(0,20)) nchains(5): regress productivityCH wealth_log dist_agmrkt Age hhsize

- bayes, prior({var}, normal(0,20)) nchains(5): regress productivityCH wealth_log Age hhsize

Structural Equation Model (SEM)

As a robustness check, we employed Structural Equation Modeling (SEM) to validate the mediation relationships between household wealth, distance to local economic opportunities, and agricultural productivity. SEM is a comprehensive statistical framework that enables the simultaneous examination of multiple relationships between variables, providing a deeper understanding of the complex interactions between household wealth, local economic opportunities, and agricultural productivity.

Table A3. Mediation Results.

Step	Path	Coefficient	Standard Error	95% CI
Path A	wealth_log → dist_boma	3.173	0.456	[2.276, 4.054]
Path B	dist_boma → productivityCH	0.004	0.002	[−0.001, 0.008]
Path C	wealth_log → dist_agmrkt	2.498	0.386	[1.729, 3.255]
Path D	dist_agmrkt → productivityCH	−0.007	0.003	[−0.012, −0.001]
Direct Effect	wealth_log → productivityCH	0.005	0.044	[−0.081, 0.091]
Indirect Effect 1	wealth_log → dist_boma → productivityCH	0.0127		
Indirect Effect 2	wealth_log → dist_agmrkt → productivityCH	−0.0175		

Table A4. SEM Results.

Relationship	Coefficient	Std. Err.	z-Value	*p*-Value
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Wealth → Distance to Boma	2.6736	0.1930	13.85	0.000
Wealth → Distance to Agricultural Markets	0.1385	0.0071	19.48	0.000
Distance to Boma → Productivity	0.0033	0.0025	1.32	0.187
Distance to Agricultural Markets → Productivity	−0.1273	0.0654	−1.95	0.052

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