University of Kent
School of Economics

Essays on Gender, Culture, and Household Economic Behavior

Mohammed Yaw Swalisu

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Abstract

This thesis includes three essays that explore how cultural norms, gender dynamics, and climate change affect household and individual outcomes in developing countries.

The first chapter sheds light on the influence of deep-rooted cultural norms on women's agency in Ghana and their far-reaching implications for households' spending decisions on water, sanitation and hygiene (WASH). In particular, the paper exploits variation in cultural norms within matrilineal and patrilineal societies across households in rural Ghana to study how the relative intra-household bargaining power of women influences households' expenditure on WASH. It first provides a simple framework based on the unitary and collective household models. Household members may have different preferences for WASH items and investments, which are either private or public to household members. This framework generates a holistic channel through which WASH interventions and policies can be designed for improved WASH in the household, while targeting women. In principle, we find that the marginal effect of women's bargaining power in matrilineal and patrilineal households has differential impacts on households' budget shares allocated toward improved WASH. However, this impact depends on whether the household WASH item is private or public and how costly this item might be.

The second chapter examines the relationship between climate-induced income shocks, cultural norms, and the hazard of entering first marriages among men and women. Using data from Malawi, a country highly vulnerable to the adverse effects of climate change, the paper shows that drought and flood shocks differentially influence the hazard of entering first marriages and husband-wife age gaps, with nuanced variations across bride price and non-bride price societies. Notably, in bride price societies, drought exposure leads men to delay their first marriages due to the required bride price transfer, unlike in non-bride price societies. Additionally, the husband-wife age gap is larger in bride price societies relative to non-bride price societies, and drought exposure further widens this gap. Further analysis shows that, the widening age gap between spouses is manifested in the increased likelihood of young women entering polygynous marriages as junior wives in bride price societies. Flood shocks, however, do not exhibit a similar effect on first marriage hazards and the age gap. This is primarily due to the localized nature of floods, which are not as spatially correlated as drought shocks, and hence more plausible smoothing mechanisms. From a policy standpoint, policies and interventions that generate windfall revenue during adverse economic shocks could have unintended con-

sequences, especially for women, if the type of shock and cultural setting are not taken into account. Cash transfers, for example, during droughts may have larger effects in bride price societies if targeted at households with marriage-age girls.

The third chapter analyzes the effect of early-life rainfall shocks on breastfeeding duration among children born to co-wives in polygynous rural households in Malawi. It specifically explores how deviations from average rainfall during a child's birth and second year influence breastfeeding patterns. The findings reveal that rainfall shocks during a child's second year significantly prolong breastfeeding, with a stronger effect observed among children of senior wives. Disaggregating the effects, we find that negative rainfall shocks lead junior wives to breastfeed longer than senior wives, while rainfall shocks in the dry season extend breastfeeding duration compared to the wet season. These results suggest that the opportunity cost of maternal time, driven by agricultural labor demands, and the decision-making power of co-wives are critical mechanisms linking weather shocks to breastfeeding practices. The study further highlights the importance of considering family structures and maternal labor dynamics in policies promoting optimal breastfeeding amidst a changing climate in Sub-Saharan Africa.

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Introduction

This thesis comprises three essays that contribute to the understanding of intra-household power dynamics and their effects on individual and household economic outcomes from an empirical perspective. Traditional family structures, which vary across ethnic groups in Sub-Saharan Africa, are closely linked to differences in various socio-economic outcomes. These disparities become even more significant in the face of climate change, as many rural economies in the region depend heavily on rain-fed agriculture. The thesis builds on the shift from the traditional unitary household model to the collective household model, as introduced by Chiappori (1988), which provides the theoretical framework for the first essay. Men and women have distinct preferences, with differences in their allocation of resources, as women typically prioritize education, nutrition, and health-related expenditures (Thomas, 1990; Hoddinott et al., 1997). The strategies households employ to allocate scarce resources and manage competing needs can have a profound impact on key life outcomes. The second and third essays offer insights into the gendered consequences of income shocks due to weather fluctuations on marriage behavior and breastfeeding patterns in polygynous households respectively.

In the first essay (Chapter 1), titled "Intra-household bargaining power and household sanitation: Evidence from kin groups in Ghana," we investigate the role of cultural norms in shaping women's intra-household bargaining power and its influence on household expenditure on water, sanitation, and hygiene (WASH) in rural Ghana. By exploiting the distinct norms within matrilineal and patrilineal societies across households to identify the variation in women's bargaining power, the analysis explores how this relative power affects WASH expenditure. The essay further examines how women's preferences for private or public household WASH goods are shaped as they gain more control of resources. While prior literature has explored the impact of women's decision-making power in households, much of it relies on proxies for unobserved *true* power. In this essay, we identify the bargaining power variable as being influenced by a distribution factor that captures the variation in customs within matrilineal and patrilineal societies across households, as reflected in the relative valuation of women-owned assets, including farm and non-farm enterprises. Using data on nuclear rural households from the Ghana Living Standards Survey and employing OLS and control function techniques, we estimate the effect of wives' bargaining power in both matrilineal and patrilineal households on three categories of WASH expenditure: 1) WASH investment – expenditure on toilets, sewerage and waste disposal; 2) Household hygiene – expenditure on handwashing facilities and household hygiene products; and 3) Personal hygiene. After addressing potential endogeneity concerns, we find that the marginal effect of wives' bargaining power on WASH investment expenditure is positive and statistically significant in both household types, although the size of the effect is greater for matrilineal wives. In addition, the study reveals that an increase in the marginal effect of wives' bargaining power increases the household's budget share on personal hygiene in matrilineal households but has the opposite effect in patrilineal households. These findings highlight how matrilineal women exert greater influence over household WASH expenditure compared to their patrilineal counterparts. The chapter provides insights for the design of policies and more targeted WASH interventions that enhance the agency of women in implementing their WASH preferences within the household while considering differences in cultural norms across societies.

The second essay (Chapter 2), titled "Climate change, culture, and marriage timing in Malawi," provides evidence on how drought and flood shocks interact with cultural norms to influence the hazard of entering first marriages for men and women in Malawi, as well as the resulting spousal age gap at first marriage. The impact of these shocks are analyzed in the context of bride price and non-bride price societies in rural Malawi. The bride price – a transfer from the groom's family to the bride's family upon marriage – is often substantial and can exceed a year's household income (Anderson, 2007), making marriage timing sensitive to income fluctuations caused by weather variability. Thus, drought and flood shocks, which are two major sources of income variability in Malawi, a country heavily reliant on rain-fed agriculture and highly vulnerable to the effects of climate change, are expected to impact the budget available to individuals and households for marriage transfers. While recent literature has documented that the marriage of female household members (from the supply side of the marriage market) is often brought forward to secure bride price payments during negative income shocks (e.g. Hoogeveen et al., 2011; Corno et al., 2020; Corno and Voena, 2023), the response of men (from the demand side of the market), who face the financial burden of bride price, has received less attention. Based on survival analysis techniques and using marriage age data from the Demographic and Health Surveys (DHS) for Malawi, rainfall data from Matsuura and Willmott (2009), and cultural data from Murdock (1967) Ethnographic Atlas, we show that drought and flood shocks differentially influence first marriage entry hazards for men and women and the husband-wife age gap, with nuanced variations across societies that engage (or do not) in the bride price tradition. Specifically, we find that, following drought shocks, the hazard of first marriage entry for men in bride price societies decreases, as they delay marriage due to the binding transfer, while no such effect is observed in non-bride price societies, where the hazard increases. This results in a relative widening of the husband-wife age gap in bride-price societies following drought shocks. Investigating potential mechanisms reveals that young women in these bride price societies are more likely to enter first unions as junior wives in polygynous marriages, as they effectively marry older grooms who are more self-insured and resilient to the drought shock, leading to higher spousal age gaps. Flood shocks, however, do not exhibit similar outcomes, as floods are not as spatially correlated as drought shocks. Consequently, flood shocks allow for potential smoothing opportunities to mitigate their impact, such as work-related short-term migration, diminishing the reliance on self-insurance mechanisms for both young and older grooms. This chapter contributes to our understanding of how policies and interventions can be targeted at households with marriage-age girls across different societies to achieve optimal outcomes.

The third essay (Chapter 3), "Polygyny, weather shocks, and breastfeeding: Evidence from Malawi," examines the effect of early-life rainfall shocks on the breastfeeding duration of similarly aged children (0-48 months) born to co-wives in polygynous rural Malawian households. Unlike prior studies that have largely compared child outcomes between polygynous and monogamous households, this essay focuses on differences within polygynous households, which have hierarchical structures that may affect maternal behavior. The chapter sheds light on how rainfall patterns impact the opportunity cost of maternal labor and the decision-making power between co-wives in influencing the time-consuming child care activity of breastfeeding among polygynous children. The effects of rainfall shocks on maternal behaviour and childcare practices may differ in polygynous versus monogamous households due to factors such as competition, relative bargaining power, risk-sharing opportunities and co-wives engaging in self-serving strategic behaviour. This chapter utilizes data from the Malawi DHS and rainfall data from Matsuura and Willmott (2009). We first find that, linear rainfall shocks in a child's first year has no effect on breastfeeding duration, but this effect is positive and statistically significant in the second year after birth: both senior and junior wives breastfeed longer in the second year, although the effect is larger for senior wives. Disaggregating the rainfall shocks, we find that junior wives respond to negative rainfall shocks by extending breastfeeding duration more than senior wives. This suggests that senior wives, with their established household status, are better able to mitigate the trade-offs between agricultural labor and breastfeeding during periods of negative rainfall shocks. Furthermore, we show that seasonal agricultural cycles influence breastfeeding patterns. In particular, mothers breastfeed their children for longer periods during the dry season relative to the wet season due to reduced agricultural workload and limited alternative employment opportunities. However, drought conditions can significantly shorten this period of extended breastfeeding. Furthermore, prolonged breastfeeding during the dry season is more relevant for children aged 0–6 months and 12–18 months, compared to the 6–12 months and 18–24 months age cohorts. This essay provides valuable evidence for policymakers on how breastfeeding interventions should account for household structures and the broader context of maternal labor demands in rural economies affected by climate change.

Collectively, the three essays in this thesis contribute to the broader field of household economics by offering insights into how intra-household power, cultural norms, and external shocks shape household behavior and outcomes. In what follows, each chapter is discussed in more detail, highlighting their contributions to the existing literature.

Chapter 1

Intra-household bargaining power and household sanitation: Evidence from kin groups in Ghana

1.1 Introduction

Access to improved water, sanitation and hygiene (WASH) is vital and has long-lasting implications for human development, particularly for women and girls who are disproportionately affected over their life course (Dickin et al., 2021). Women bear a disproportionate burden of poor WASH which induces increased psychosocial stress, health risks, harassment and sexual aggression, increased care-giving responsibilities and additional labour from water fetching (Ashraf et al., 2022; Routray et al., 2017; Stopnitzky, 2017). The agency of women in households may well be important in understanding how WASH investments or expenditure decisions are made. Economists have long been interested in how preferences within households are systematically related to gender differences (Agarwal, 1997). There is empirical evidence, for example, that women strongly prefer risk minimization (Eckel and Grossman, 2008) and investment in children's education and nutrition (Duflo and Udry, 2004; Attanasio and Lechene, 2014).

However, significant gaps remain in the economic literature to explicitly understand how the differences in bargaining power between men and women within households influences resource allocation and preferences for WASH uptake (see Augsburg et al., 2021, for recent work on India). In particular, the relative intra-household bargaining power of women which is influenced by entrenched cultural norms in low and middle-income countries, and its far-reaching implications on households' WASH spending decisions have not been fully understood.

Cultural norms in traditional African societies are often specific to social and ethnic kin groups. In many African societies, kinship systems constitute an essential social structure for which obligations to group members are determined and how resources are distributed (Radcliffe-Brown and Forde, 2015; Lowes, 2017). Matrilineal and patrilineal kinship systems are the two types of unilineal descent systems practiced by ethnic groups in Ghana. Individuals are born into these ethnic kin groups and are differentially impacted by the different cultural norms enforced by these groups. A salient feature of both matrilineal and patrilineal kinship systems in Ghana is the variation in land inheritance and inter-vivo acquisition of other assets. Lowes (2020) document that this variation in kinship structure has important economic implications for the welfare of women, including access to assets, how their preferences are shaped and domestic violence.

This paper exploits variation in cultural (ethnic) norms within matrilineal and patrilineal groups in rural Ghana across households, to identify the intra-household bargaining power of women in answering the following questions: First, how does the relative bargaining power of women, engendered by cultural norms, influence households' expenditures on WASH in matrilineal and patrilineal rural households. Second, how are women's preferences shaped towards private or public household WASH goods? These questions can be empirically explored in the context of rural Ghana due to the prevalence and strict enforcement of cultural norms, which are notably distinctive for men and women within matrilineal and patrilineal societies. Moreover, from 2016 to 2020, basic household sanitation coverage has consistently been lower in rural areas of Ghana (averaging 2%) as compared to urban areas (averaging 15%) (WHO/UNICEF JMP, 2020).

In this paper, we use a simple structural equation for analysing household WASH spending decisions, based on ideas from the unitary and collective household models. The 'sharing rule' approach of collective household models by Chiappori (1988, 1992) which represents the Pareto weight of household members is applied to intra-household welfare by analysing how the balance of power between spouses is reflected in the household's spending decisions on WASH. The Pareto weight is influenced by prices, total household expenditure, and distribution factors. The model in this paper considers the Pareto weight to be dependent on a distribution factor that involves the variation in customs within matrilineal and patrilineal societies across households in terms of the relative value of assets (farm and non-farm enterprises) owned by women.

First, we focus on the Ordinary Least Squares (OLS) estimation for causal inference, given that bargaining power is arguably exogenous. Individuals have little to no influence on how they are impacted by the cultural norms and traditions practiced in matrilineality or patrilineality. That notwithstanding, bargaining power might still be endogenous due to a number of reasons. Bargaining power is fundamentally unobserved and difficult to precisely quantify (Doss, 2013), thus leading to plausible measurement errors. In addition, the endogeneity bias could also result from a confounder related to both the bargaining power variable and the WASH budget share outcome variables. For example, women's education relative to their husbands, which indicates their relative socio-economic status in the household, is expected to affect their outside options, and thus their bargaining power. At the same time, a woman's educational attainment is an essential determinant of her ability to make better decisions concerning the health of household members including WASH decisions. To resolve the endogeneity issue in the model, we employ the Control Function (CF) method by Wooldridge (2015) which relies on excluded instruments. In the model, bargaining power has a non-linear effect, via an interaction term, on the WASH outcomes. Wooldridge (2015) posits that such non-linear effects of treatment are better handled by the CF approach with more efficient estimates, compared to the Two Stage Least Squares (2SLS) approach.

The model in this paper focuses on the marginal effect of wives' bargaining power on WASH outcomes in the household. Intuitively, this effect can be broadly interpreted as plausible pathways (either directly or indirectly) through which policy makers can influence the implementation of improved WASH in the household with a lead role taken by women. A direct effect could constitute cash transfer programs directly targeted at women in the household. Such transfers exogenously increase the share of resources controlled by women, which allows for a prioritization and direct implementation of their WASH needs in the household, given that men may have different needs and priorities. An indirect effect, on the other hand, operates through policy levers and interventions that can indirectly reinforce women's agency to meet their specific WASH needs vis-a-vis their husbands in the household. In particular, rural sanitation policies and approaches such as the community-led and market-based approaches could be designed in a way that addresses the needs of both gender but most importantly involves women in the planning and budgetary processes. Education and awareness-raising campaigns targeted at women can also help them to understand their rights and the benefits of improved sanitation practices.

The paper uses household level data from the rural subsample of the most recent household survey data for Ghana, the Ghana Living Standards Survey Round 7 (GLSS7), which is restricted to households with a head, spouse, and children (including adopted and foster children), where the couples are either married or in a consensual union. This allows for possibly capturing the bargaining between spouses in a nuclear household setting, without having to account for other adult decision makers that may be present and influential in extended family households. For the WASH outcomes in this paper, we compute budget shares for the following aggregated household expenditure items: a) Water and sanitation (WASH investment) — which includes expenditure on private toilet facilities and public toilets, sewerage collections and disposal, and refuse collection and disposal b) Household equipment for routine maintenance of sanitation — which includes household handwashing facilities, washing powder, washing soaps, bathing/toilet soaps, bleaches, and c) Personal hygiene — which includes sanitary pads, deodorants, body lotion and toothpaste.

The model is first estimated using OLS, where the bargaining power variable is identified based on the variation in cultural norms within matrilineal and patrilineal societies across households. The OLS estimates reveal that the impact of wives' bargaining power on WASH budget shares may be dependent on the type of good. Specifically, a one-standard deviation increase in the marginal effect of wives' bargaining power has a positive and statistically significant impact on personal hygiene expenditure in matrilineal households (1.6% $\rightarrow$ 2%) but no effect in patrilineal households. This evidence indicates that women in matrilineal societies are better able to implement their private WASH preferences, including menstrual hygiene practices, compared to women in patrilineal societies. For WASH goods that could be considered public to the household, the impact of wives' bargaining power may essentially depend on the type and size of expenditure. First, an increase in the marginal effect of wives' bargaining power by one standard deviation increases the household's budget share on the expenditure category, water and sanitation (WASH investment), in matrilineal households (2.7% $\rightarrow$ 4.5%) and patrilineal households (1.2% $\rightarrow$ 1.9%), albeit this effect does not statistically differ from zero in patrilineal households. Second, we find no effect of wives' bargaining power on the budget share for the other WASH public good – equipment for routine maintenance of sanitation – in both household types. These findings suggest that, although matrilineal wives may not have the ability to assert their agency in household spending on both types of WASH public goods, they are still able to effectively influence decisions on more significant investments than patrilineal wives. For example, the construction or improvement of a private household toilet could be more costly than the purchase of a handwashing facility.

In accounting for the potential endogeneity of wives' bargaining power, we then estimate the model using the CF method and compare these estimates to that from the OLS estimations. Regarding WASH private goods, the CF results show that the marginal effect of wives' bargaining power on personal hygiene expenditure is statistically significant for both household types, which was not the case in the OLS estimation where we find no effect in patrilineal households. However, this effect is positive in matrilineal households (increasing from 1.6% to 1.8%) but negative in patrilineal households, where the budget share nearly doubles in its decline (from 1.4% to -2.6%). For the expenditure category on water supply and sanitation (WASH investment), we find a positive and statistically significant effect of wives' bargaining power in the two household types, albeit the magnitude of the effect is greater in matrilineal households. Specifically, a one-standard deviation increase in bargaining power raises the WASH investment budget share by 4.6 percentage points (from 2.7% to 7.3%) and 0.5 percentage points (from 1.2% to 1.7%) in matrilineal and patrilineal households respectively. Lastly, the marginal effect of wives' bargaining power on the budget share category of household equipment is negative by 0.9 percentage points (a reduction from 3.6% to 2.7%) in patrilineal households, while we find no effect in matrilineal households.

The negative effect of wives' bargaining power on personal hygiene expenditure observed for patrilineal wives from the CF estimates reflects the dominant role men often play in decision-making, which is typical of patrilineal rural societies. As a result, a marginal increase in control over household resources by patrilineal wives may primarily affect spending on competing WASH needs, such as a household toilet, potentially at the expense of their personal hygiene. In contrast, matrilineal wives have the autonomy to influence household spending not only on essential public WASH goods but also on their personal hygiene needs. The findings in this paper suggest that cultural and ethnic norms that have distinct implications for men and women across societies affect women's agency in a way that has far-reaching implications on WASH investments and expenditure in the household. Thus, policies and interventions aimed at improving WASH, especially in rural households, must take into account intra-household power dynamics and household structure via the lens of ethnicity.

The rest of the paper proceeds as follows. Section 1.2 provides closely related literature and the contributions made in this paper. In Section 1.3, an overview of kinship systems and rural sanitation in Ghana is presented. The theoretical framework, on the basis of collective household models, is presented in Section 1.4. Section 1.5 presents the data used in the analysis. A discussion of the empirical strategy that guides the analysis is provided in Section 1.6. The empirical results are presented in Section 1.7, and Section 1.8 concludes.

1.2 Related Literature

This paper mainly contributes to three strands of literature. First, this paper contributes to a burgeoning research agenda on gender and sanitation. This literature mainly investigates sanitation-related decision making within the household from a gender perspective. A more recent paper by Augsburg et al. (2021) documents the contrast in how men and women within Indian households perceive the costs and benefits of sanitation, and the resulting differential impacts on sanitation investment decisions. Previous studies have attempted to answer similar questions and found that: less power by women in households and communities is associated with less involvement in decisions pertaining to WASH investments that are favorable for their needs (Routray et al., 2017; Kayser et al., 2019); the returns of a private household toilet in terms of health and social outcomes varies by gender with women obtaining relatively higher returns (Saleem et al., 2019; Caruso et al., 2017); and men typically regard water insecurity as a less serious problem in the household compared to women (Tsai et al., 2016). Unfortunately, most of this research, with the exception of Augsburg et al. (2021), are either qualitative or correlational studies. Instead, this paper draws on causal inference to understand the agency of women, engendered by cultural norms, in making WASH investment decisions in the household.

Second, this paper contributes to the growing literature that identifies the importance of cultural and kinship norms for economic outcomes and households' economic decisions (Ashraf et al., 2020; Anderson and Bidner, 2015; Barker, 2021; Lowes, 2016; La Ferrara, 2007; Fernández and Fogli, 2009; Gneezy et al., 2009). This literature further rationalizes the view that, understanding the effectiveness of policies while taking into consideration the cultural environment and the cultural practices thereof is essential (Bau, 2021; La Ferrara and Milazzo, 2017). I contribute to this literature by focusing on matrilineal and patrilineal norms to show ways in which policies and interventions targeted at improving WASH in rural households can be effectively designed, while targeting women. Specifically, the model in this paper generates a holistic channel that quantifies women's agency to directly make or be involved in WASH decision making in the household.

Finally, this paper adds to the extant empirical literature on household decision making that is inspired by the unitary and collective household models. The collective model by Chiappori (1988, 1992) is characterized by the basic assumption that each household member has their own preferences, and that outcomes resulting from their joint decisions are Pareto efficient (See Strauss et al. (2000) for a review). Earlier household models assume a unitary framework in which the systematic differences in preferences and power dynamics are ignored. This implies that how the balance of power is distributed within the household has no impact on household outcomes (Doss, 2013). In contrast, a number of empirical studies have provided evidence that the relative balance of power within the household affects household outcomes including expenditure on food (Hoddinott and Haddad, 1995; Duflo and Udry, 2004; Doss, 2006), education (Quisumbing and Maluccio, 2003), and health and nutrition (Thomas, 1990; Phipps and Burton, 1998; Lancaster et al., 2006). I expand this literature by using representative data from Ghana that draws on variation in cultural norms within matrilineal and patrilineal societies across households to identify bargaining power within the household and its impact on WASH outcomes. I also provide interesting insights on the distinction between WASH goods that are private or public in the household to fully investigate the implications of the unitary model.

1.3 Contextual Background

Kinship systems differ across countries and regions around the world. A fundamental feature of kinship systems is the variation in how members of a kin group are traced. One such variation practised by ethnic groups in Ghana is the unilineal descent, where membership is traced via a single parent (i.e. a mother or father). In particular, unilineal descent traced through the mother and father are termed as matrilineal and patrilineal respectively. Thus, children in Ghanaian matrilineal societies are effectively considered to be strictly part of their mother's kin group, whereas children in patrilineal societies are also part of their father's kin group. Both kinship structures thus have differential economic implications for inheritance and transfer of assets to children. In patrilineal societies in Ghana, inheritance and inter-vivo transfer of land and other assets are typically acquired by the male child. The reason for this practice among patrilineal Ghanaian groups is because, it is assumed that land and assets acquired by the female child are lost to another lineage once they eventually get married and become part of their husband's lineage (Bukh, 1979; Duncan, 2010). In contrast, a man's immediate children in matrilineal Ghanaian societies are not part of his kin group but their mother's, and hence the man's property, as per custom, is passed on to his sister's sons (i.e. nephews). However, due to the female line of kinship under matriliny, the female child is able to assert their rights from the matrilineage, ensuring that they acquire land and other assets (Amanor, 2001). Barker (2021) document that, due to a shift in the centrality of nuclear families and the variation in kinship structure between matrilineal and patrilineal groups, matrilineal women in Ghana are more likely to obtain land and assets to a degree not true for patrilineal women. Such differences in women's access to land and other assets may have significant implications for household outcomes. One of such implications investigated in this present study is households' WASH investment and expenditure decisions.

In spite of the major reforms implemented in Ghana's water and sanitation sector, the Millennium Development Goals on safe water and basic sanitation were largely underachieved. As of 2019, only 18 percent of Ghanaians have access to basic sanitation, with significant disparities observed across regions (Ghana Statistical Service, 2018), as shown in Figure A1 in the Appendix. In comparison to urban areas, rural areas continue to significantly lag behind in basic sanitation coverage and open defecation. Data from the World Health Organisation (WHO) and United Nations Children's Fund (UNICEF) Joint Monitoring Programme (JMP) reveal that, for half a decade between 2016 and 2020, only a paltry 0.49 percentage point increase in basic sanitation coverage was observed in Ghanaian rural households, compared to a 2.35 increase in urban households, in addition to relatively high open-defecation rates and poor hygiene practices in rural households (WHO/UNICEF JMP, 2020) (see Figures A2 and A3 in the Appendix). Interestingly, it is observed in Figure A1 that, areas that are relatively worse-off in basic sanitation coverage and open-defecation are predominantly made up of ethnic groups that are patrilineal. Despite efforts made by governments and non-governmental organisations in Ghana to improve sanitation, it is imperative to understand the dynamics of decision-making and the unintended impacts of norms in both matrilineal and patrilineal Ghanaian rural households, particularly on sanitation, that may not yet be fully understood.

1.4 Theoretical Framework

In this section, we employ a simple structural equation (shown in equation 1.5), as in Basu and Maitra (2020), based on the so-called 'sharing rule' (Chiappori, 1988, 1992) in intra-household bargaining and decision making literature. This sharing rule is the relative welfare (or Pareto) weights of household members in the household's spending choices. The Pareto weight may be dependent on prices, the household's total expenditure, and distribution factors (Browning et al., 2006). The relative welfare weights can be directly backed out of the household's consumption decisions (Browning and Chiappori, 1998). Intuitively, the greater the relative welfare weight of a woman in the household, the larger her preferences that are represented in the household's consumption decisions.[1] A significant body of empirical work has followed this approach to i) show that welfare is unequally distributed among spouses, by inferring from the household's consumption decisions (e.g. Fafchamps et al., 2009), or ii) identify plausible factors that influence household's consumption decisions via their impact on intra-household bargaining power (e.g. Duflo, 2003; Fafchamps and Quisumbing, 2005).

A salient feature regarding distribution factors in the literature is income pooling. The theoretical framework in this paper incorporates income pooling, but the allocation of WASH expenditures between the spouses is influenced by a distribution factor, which is expected to enhance women's relative bargaining power. The distribution factor considered here is the variation in customs within matrilineal and patrilineal societies across households in terms of the relative value of assets owned by the wife. The sharing rule is influenced by this distribution factor through the Pareto weight. The sharing rule then informs the individual budget shares of both spouse on WASH goods, which is then aggregated at the household level to obtain the structural equation in equation 1.5. Given that the model in this paper depends on distribution factors but not on prices and total expenditure, it is akin to the case of a distribution factor dependent unitary model, as described in Browning et al. (2006).

Consider a household where decisions are made by two members: wife (w) and husband (h). Let the vectors $\mathbf{q}_w$ and $\mathbf{q}_h$ represent the private goods allocated to w and h

[1] The welfare weights are deduced from a bargaining process. However, Chiappori (1988) documents that, the simplifying approach of the sharing rule is that it does not necessitate a specification of the bargaining process.

respectively, while $\mathbf{Q}$ represent the public goods. The price vectors for private and public goods are denoted by **p** and **P** respectively. y represents total household income/expenditure. In this model, **p**, **P**, and y are assumed to be exogenous. The household's problem constitute a maximization of the weighted sum of individual utilities of both spouse represented as

$$\max \ \ \theta(\mathbf{d})\, u_w(\mathbf{q}_w, \mathbf{q}_h, \mathbf{Q}) \ + \ (1 - \theta(\mathbf{d}))\, u_h(\mathbf{q}_w, \mathbf{q}_h, \mathbf{Q}) \tag{1.1}$$

subject to

$$\mathbf{p}(\mathbf{q}_w + \mathbf{q}_h) + \mathbf{PQ} \leq y$$

where $u_i(i = w, h)$ are utility functions that represents the preferences of both wife and husband. The Pareto weight, θ captures the wife's relative bargaining power within the household, and **d** is a vector of distribution factors.[2] A simplifying assumption that suffices here is that, the balance of power within the household increases in favour of the wife, as θ increases, where $\theta \in [0, 1]$.

A useful approach is to reframe equation (1.1) as a two-step decision-making process that incorporates an income-sharing rule.[3] In the first stage, the incomes of both partners are combined and then divided between them according to a predetermined sharing rule. In the subsequent stage, each spouse maximizes their own sub-utility, given the income allocated to them in the first stage. Following Basu and Maitra (2020), an individual's share of income from the first stage, taking into account their relative bargaining power, can be represented as $\theta_i y, \ i = w, h$. The maximization problem faced by each spouse in the second stage is given as

$$\max \ \ u_i(\mathbf{q}_i) \ \ s.t \ \ \mathbf{pq}_i \leq \theta_i y \tag{1.2}$$

A solution to the problem in equation (1.2) yields the demand function for each consump-

[2] In principle, factors that determine θ may consist of prices, total household income and other variables (distribution factors or extra-environmetal parameters). In this paper, the key factor determining θ is a distribution factor motivated by cultural norms. For an extensive explanation of these other plausible variables, see Chiappori (1992) and McElroy (1990)

[3] A good explanation of this interpretation is provided in Strauss et al. (2000)

tion good, written in reduced form as

$$c_i^g \;=\; c_i^g(p,\;\theta_i y), \quad i = w, h \tag{1.3}$$

where $g = 1, ..., n$ represents the consumption good items.

For simplicity, we relax the assumption of the nature of goods (i.e. whether private or public) and preferences (i.e. whether altruistic, egotistic or caring), as in Bourguignon et al. (1994). However, moving forward in the discussion of the estimation results, we try to clearly classify the WASH goods as either private or public. The demand function for each good from equation (1.3) can be rewritten in a way that captures each spouse's budget share for that good. Let $s_i \quad i = w, h$ denote the budget share of a good for each spouse. As in Basu and Maitra (2020) and Lancaster et al. (2006), we assume a linear relationship between individual budget shares for a good and the share of income for each spouse, which is shown as

$$\begin{aligned} s_w &= \alpha_w + \beta_w \theta y \\ s_h &= \alpha_h + \beta_h (1-\theta) y \end{aligned} \tag{1.4}$$

However, the individual budget shares for a good is not observed due to data limitations. Hence, we consider a household-level aggregation of both spouse's individual budget shares which are observed in the data. Such an aggregation is obtained as a weighted sum of the individual budget shares from equation (1.4). A simplification of the aggregate budget share for a good in the household is thus obtained as follows

$$\begin{aligned} S_g &= \;\theta\; s_w + (1-\theta)\; s_h \\ S_g &= \;\theta\;[\alpha_w + \beta_w \theta y] + (1-\theta)\;[\alpha_h + \beta_h(1-\theta)y] \\ S_g &= \;\alpha_h + (\alpha_w - \alpha_h)\;\theta + \beta_w\;\theta^2 y + \beta_h\;(1-\theta)^2 y \\ S_g &= \;\gamma_0 \;+\; \gamma_1\theta \;+\; \gamma_2\theta^2 y \;+\; \gamma_3(1-\theta)^2 y \end{aligned} \tag{1.5}$$

where $\gamma_0 = \alpha_h,\; \gamma_1 = (\alpha_w - \alpha_h),\; \gamma_2 = \beta_w,\; \gamma_3 = \beta_h$ and $\alpha_h, \alpha_w, \beta_w, \beta_h > 0$. The aggregated household budget shares for the WASH goods is denoted by S_g. θ is wives' bargaining power in matrilineal and patrilineal households. y is per capita household expenditure which serves as a proxy for household income. The empirical analysis that follows in this paper is based on equation (1.5) which applies to both household types. Individually examining the coefficients γ_1, γ_2, and γ_3 does not provide a good understanding of the analysis. However, considering them collectively enables us to investigate the full (marginal) effect of wives' bargaining power on WASH expenditures. This effect serve as a plausible channel for targeting the agency of women in a way that leads to a more efficient and equitable allocation of resources towards sanitation within the household.

1.5 Data

Primarily, this paper uses data from the Ghana Living Standards Survey Round 7 (GLSS7). The GLSS7 is the most recent round of a nationally representative household survey, encompassing an initial 15,000 urban and rural households from 1,000 enumeration areas. The survey spans a period of 12 months, with data collected from October 2016 to October 2017. In principle, the survey seeks to generate data aimed at understanding the living conditions of Ghanaians, with focus on key socio-economic characteristics and households welfare. The data includes detailed information on households' demographic characteristics, education, health, employment, migration, agriculture, housing, expenditure, income, governance, financial services and assets. To ensure a national and regional representation of the sample, a two-stage stratified sampling design was employed. In particular, 1,000 enumeration areas were selected in the first stage to form primary sampling units, and 15 households subsequently selected from each primary sampling unit in a systematic fashion in the second stage. The resulting sample size of urban and rural households was 15,000, out of which 14,009 were successfully enumerated.

To consider settings in which cultural norms pertaining to inheritance and gender, in particular, are relatively strong and more enforced, we restrict the sample to rural households. The sample is then restricted to households with a head, spouse, and children (including adopted and foster children), where the couples are either married or in a consensual union. That way, we are able to possibly capture the bargaining between spouses in a nuclear household setting without having to account for other adult decision makers that may be present and influential in extended family households.[4] We consider 9 ethnic groups that are traditionally matrilineal and 10 ethnic groups that are patrilineal. A direct matching of names of ethnic groups in the GLSS7 and the descent system practiced

[4]The children in these nuclear households who are adults are not considered primary decision makers.

by these groups was done using various sources including Kutsoati and Morck (2014), the Joshua Project, and Wikipedia. The matrilineal group constitute 1,253 rural households and the patrilineal group makes up 2,457 rural household, which yields a final sample size of 3,710 rural households.

For the main outcome variables in this study, we use household aggregated expenditure data on WASH-related items to compute the budget shares. Specifically, we consider household expenditure aggregates on the following three items: a) Water and sanitation — which includes expenditure on private toilet facilities and public toilets, sewerage collections and disposal, and refuse collection and disposal b) Household equipment for routine maintenance of sanitation — which includes household handwashing facilities, washing powder, washing soaps, bathing/toilet soaps, bleaches, and c) Personal hygiene — which includes sanitary pads, deodorants, body lotion and toothpaste.

Turning our attention to the bargaining power variable in this study, a number of measures have been suggested in the economic literature including unearned income (Schultz, 1990), inherited assets (Quisumbing, 1994), women's share of income (Hoddinott and Haddad, 1995), assets brought to marriage (Thomas et al., 2002; Quisumbing and Maluccio, 2003), and women's perception of their relative share of assets in the household (Beegle et al., 2001). To measure the wife's bargaining power in this paper, we follow closely the broad measurement of women's asset ownership by Doss (2006) which includes farmland, savings, and business. We focus on the differences in cultural norms between matrilineal and patrilineal societies, characterized by their inheritance practices and transfer of assets which typically varies by gender (Baland and Ziparo, 2018), to construct wives' intra-household bargaining power which includes ownership of farmland and non-farm enterprises. Thus, the variation in cultural norms is reflected in the measures of bargaining power. See figures A4 and A5 in the Appendix for variation in women's ownership of assets and bargaining power in both household types.

Table 1.1 reports the summary statistics for the sample by household type on key variables of interest (Panels A, B, C) and a number of household characteristics (Panel D). In general, wives in matrilineal households tend to have a relatively higher bargaining power compared to wives in patrilineal households. On average, family size is larger in the sampled patrilineal households with 7.9 members compared to the 5.7 members in matrilineal households. Household heads in patrilineal households are much older than their spouse, than in matrilineal households. The household heads, mostly the husbands, in both household types are also more educated than their spouse. The small percentage of household heads who are wives is significantly higher among matrilineal households (18 percent) than among patrilineal households (7 percent).

Access to sanitary toilet facilities is generally low in both household types, with merely 5 percent and 1 percent of matrilineal and patrilineal households respectively in the sample using flush toilets. 35 percent of households in the matrilineal sample spend on public toilet usage compared to 12 percent of patrilineal households. 55 percent of patrilineal households in the sample do not own any type of toilet facility, compared to 12 percent in matrilineal households. It is evident that some household characteristics such as female heads (which is higher in matrilineal households) coincides with a higher adoption of sanitary flush toilets in matrilineal households, as compared to patrilineal households.

Also, the significant mean differences observed across almost all other household characteristics in Table 1.1 suggest that it is imperative to understand intra-household dynamics separately in both household types in relation to women's agency and WASH-related decisions. Thus, the empirical analysis in this paper is done separately for matrilineal and patrilineal households.

Table 1.1: Descriptive Statistics

	Matrilineal Households		Patrilineal Households		Mean Difference
	Mean	SD	Mean	SD	
Panel A: Expenditure					
Total household expenditure (Ghana Cedis)	12,941.47	8,199.92	9,975.57	9,580.62	2,965.90***
Per capita expenditure (y)	2,578.05	2,168.42	1,428.38	1,338.51	1,149.66***
Panel B: Budget Shares					
Water supply and sanitation	0.027	0.049	0.012	0.038	0.016***
Equipment of routine sanitation maintenance	0.023	0.020	0.036	0.032	-0.013***
Personal hygiene	0.016	0.022	0.014	0.030	0.002
Panel C: Bargaining Weights					
Wife bargaining power (θ)	0.43	0.37	0.25	0.35	0.18***
Husband bargaining power (1 - θ)	0.57	0.37	0.75	0.35	-0.18***
Panel D: Household Characteristics					
Household size	5.70	2.42	7.94	4.23	-2.24***
Age of household head	46.11	12.91	47.16	13.67	-1.73***
Age of spouse	40.11	11.45	39.35	11.49	0.76
Education of household head (in years)	8.95	3.32	8.68	2.81	0.15
Education of spouse (in years)	7.11	3.78	7.67	2.31	-0.57**
Female head (1/0)	0.18	0.38	0.07	0.25	0.11***
Access to electricity (1/0)	0.85	0.36	0.55	0.50	0.30***
Type of dwelling: separate house (1/0)	0.46	0.50	0.32	0.47	0.14***
Type of dwelling: compound house (1/0)	0.44	0.50	0.44	0.50	0.01
Toilet facility: public toilet (1/0)	0.35	0.48	0.12	0.32	0.23***
Toilet facility: pit latrine (1/0)	0.33	0.47	0.23	0.42	0.09**
Toilet facility: flush toilet, W.C (1/0)	0.05	0.21	0.01	0.12	0.03***
Toilet facility: no toilet (bush/fields/beach) (1/0)	0.12	0.33	0.55	0.50	-0.44***
Water supply for general use: bore-hole/pump (1/0)	0.44	0.50	0.48	0.50	-0.11**
Water supply for general use: public tap/standpipe (1/0)	0.18	0.38	0.08	0.27	0.09***
Water supply for general use: river/stream (1/0)	0.12	0.32	0.19	0.40	-0.09***
Ecological zone: Savannah (1/0)	0.01	0.08	0.65	0.48	-0.64***
Ecological zone: Forest (1/0)	0.76	0.43	0.25	0.43	0.51***
Ecological zone: Coastal (1/0)	0.23	0.42	0.10	0.30	0.13***
Observations	1,253		2,457		

Note: *** p<0.01, ** p<0.05, * p<0.10. The test for difference in means between the matrilineal and patrilineal households is provided in the last column.

1.6 Empirical Strategy

This section is mainly divided into two parts. The first part discusses the empirical model that guides the analysis, and the methodological issues faced, particularly the issue of endogeneity. We then discuss how the issue of endogeneity is resolved with focus on the instruments used and their validity.

1.6.1 Empirical Model

First, we estimate the causal effect of the relative bargaining power of wives on WASH budget share goods using OLS regression, separately for both matrilineal and patrilineal household types. Following equation (1.5) earlier described in the theoretical framework, the empirical model to be estimated for each household type takes the form

$$S_g = \gamma_0 + \gamma_1\theta + \gamma_2\theta^2 y + \gamma_3(1-\theta)^2 y + \eta^{'} \mathbf{Z}_g + \varepsilon_g \qquad g = 1, ..., n \tag{1.6}$$

where S_g denotes the budget share of good g in a household. The use of budget shares imply a trade-off in expenditure allocation decisions between the sanitation-related goods considered and other competing goods in the household. We can think of this trade-off as capturing how improved sanitation is valued by household members within the household. θ is a measure of the wife's relative bargaining power in both household types and is constrained between 0 and 1. Thus, the husband's relative bargaining power is intuitively represented by $(1-\theta)$. The household's income is proxied by per capita household expenditure denoted as y. $\mathbf{Z}_g$ is a vector of control variables including spousal and household characteristics, and ε_g an error term.

The bargaining power variable, θ mainly affects S_g via a marginal effect which is obtained as

$$\left.\frac{\partial S_g}{\partial \theta}\right|_{\overline{\theta},\ \overline{(1-\theta)},\ \overline{y}} = \gamma_1 + 2\gamma_2\overline{\theta}\overline{y} - 2\gamma_3\overline{(1-\theta)}\overline{y} \tag{1.7}$$

where $\overline{\theta}$ and $\overline{(1-\theta)}$ are sample averages of the wife and husband's bargaining power respectively in both household types. $\overline{y}$ is per capita expenditure for the full sample (i.e. matrilineal and patrilineal). Note that, in comparing matrilineal and patrilineal households, the marginal effect is evaluated at the average level of y for the whole sample. This is because the difference in marginal effects between the two household types might be due to the different levels of consumption.

This marginal effect provides a direct and indirect way to analyze plausible channels through which the agency of women could be influenced by policies and interventions aimed at improved WASH in the household. Cash transfer programs explicitly targeted at women provides a direct channel where the share of resources controlled by women is exogenously increased. Such transfers then allows for women's direct implementation and prioritization of WASH in the household. On the other hand, indirect channels could be realized through policy levers or WASH interventions that are gender-responsive, but sustains women's agency vis-a-vis their husbands. An example is rural sanitation policies such as community-led and market-based approaches which should actively involve women in the planning and budgetary process.

The bargaining power variable, θ, proxied by the wife's share of asset ownership including land and non-farm enterprise could be potentially endogenous in the model due to a number of reasons. First, bargaining power is not easily observed, making it difficult to quantify (Doss, 2013), and also these assets may not necessarily translate into bargaining power. Thus, wives' bargaining power in my model could be measured with error, resulting in an attenuation bias which is a concern. Second, the endogeneity bias could result from confounders related to both the bargaining power variable and the WASH budget share outcomes. An example is women's education relative to their husbands. The education of women indicates their socio-economic status in the household, which impacts their bargaining power. At the same time, women's education enhances their ability to make better health decisions including WASH decisions.

To resolve the endogeneity issue in the model, and to identify the causal effect of wives' bargaining power on WASH outcomes in both household types, we employ the Control Function (CF) method by Wooldridge (2015). The CF method relies on excluded instruments which generates variation in the residuals derived from a reduced form (Wooldridge, 2015). The identification assumptions of the CF method is particularly ideal for the model, where the endogenous bargaining power variable appear non-linearly in an interaction term. Wooldridge (2015) asserts that such non-linear effects are better handled by the CF approach, in comparison to Two-stage Least Squares. Following the Wooldridge (2015) CF method, we can specify the reduced form for the endogenous bargaining power variable from equation (1.6) which constitutes the first stage for instrumental variables as

$$\theta = \lambda_0 \;+\; \lambda_1 \mathbf{Z} \;+\; \varepsilon_\theta \;, \qquad \mathbb{E}(\mathbf{Z}\varepsilon_\theta) = 0 \tag{1.8}$$

where $\mathbf{Z} = (\mathbf{Z}_g, \mathbf{Z}_\theta)$. The CF method assumes that there is no perfect collinearity between the elements of **Z**, where $\mathbf{Z}_g$ and $\mathbf{Z}_\theta$ represents included and excluded instruments respectively in the model. Equation (1.8) can be rewritten as

$$\theta = \lambda_0 \; + \; \lambda_{1g}\mathbf{Z}_g \; + \; \lambda_{1\theta}\mathbf{Z}_\theta \; + \; \varepsilon_\theta \tag{1.9}$$

with the assumption that the rank condition for identification is satisfied provided that $\lambda_{1\theta} \neq 0$. This implies a basic requirement that there exist at least one excluded exogenous variable that has a partial correlation with the endogenous variable. Based on equations (1.6) and (1.8), the CF method then assumes a correlation between the error terms, ε_g and ε_θ, in a linear fashion as

$$\varepsilon_g = \rho\varepsilon_\theta \; + \; \epsilon \; , \qquad \mathbb{E}(\varepsilon_\theta \epsilon) = 0 \tag{1.10}$$

where $\rho = \mathbb{E}(\varepsilon_\theta\varepsilon_g) \; / \; \mathbb{E}(\varepsilon_\theta^2)$. The idea here is that ε_g and ε_θ are not correlated with **Z**, and hence ϵ becomes uncorrelated with **Z**, which effectively ensures that ϵ is also uncorrelated with the bargaining power variable, θ. By substituting equation (1.10) into the structural equation from equation (1.6), we obtain the final estimating equation for the CF method as[5]

$$S_g = \; \gamma_0 \; + \; \gamma_1\theta \; + \; \gamma_2\theta^2 y \; + \; \gamma_3(1-\theta)^2 y \; + \; \eta^{'}\,\mathbf{Z}_g \; + \; \rho\varepsilon_\theta \; + \; \epsilon \tag{1.11}$$

where ε_θ is the error term from the reduced form in equation (1.8) which now serves as an additional explanatory variable. Its inclusion ensures that the new error term, ϵ is uncorrelated with θ, the interaction terms, and all other exogenous variables in $\mathbf{Z}_g$. Thus, the endogeneity of θ and that from its interaction terms are controlled for. Again, I estimate equation (1.11) separately for both matrilineal and patrilineal households.

1.6.2 Instruments and their Validity

To estimate equation (1.11), we now turn our attention to a discussion of the excluded instruments for bargaining power used in the analysis. In particular, we discuss the instruments' relevance and their exclusion restriction. Identifying acceptable proxies for bargaining power should not be driven only by exogenous factors to household decision-

[5]See Wooldridge (2015) for a description of the 2-step CF procedure to estimate the coefficients of such equations.

making but also their cultural significance (Quisumbing and Maluccio, 2003). Here, we focus on the implications of distinct cultural norms in matrilineal and patrilineal societies in Ghana, which are defined by their inheritance practices, occupations and land rights which typically vary by gender (Baland and Ziparo, 2018) to construct separate instruments for the bargaining power variable in both household types.

1.6.2.1 Matrilineal Households

For matrilineal households in the sample, the bargaining power variable is instrumented for using the difference in educational attainment by fathers of both spouse (i.e. whether husband's father is more educated than wife's father, or otherwise).

Due to customary norms among matrilineal groups in Ghana, fathers were constrained in bequeathing property including land and businesses to their children, particularly males (La Ferrara, 2007; La Ferrara and Milazzo, 2017). For that reason, Ghana enacted the Intestate Succession Law (ISL) in 1985, which authorizes men to bequeath property to their children. La Ferrara and Milazzo (2017) exploit this law by showing that, prior to the policy change, boys from matrilineal groups in Ghana such as the Akan group were mostly compensated by their fathers with a provision of formal education. However, studies such as Fenrich and Higgins (2001) and Kutsoati and Morck (2014) have documented that the ISL, since 1985, has rarely been implemented, and traditional norms persist among matrilineal groups in Ghana.

In view of that, we argue that the relative educational attainment of both spouses' fathers, especially in rural areas, would be vital for their ability to take advantage of the ISL to pass down assets to their children. In particular, matrilineal fathers in rural areas who are educated to a sufficient level are able to fully exploit the ISL to pass down land and businesses, either via inheritance or inter-vivo, to their own children, especially the male child, rather than their maternal nephews as per customary norm. Hence, in the matrilineal household sample, we consider that, prior to or during marriage, if the husband's father is more educated and well-informed of the ISL to exploit it relative to the wife's father, then the husband would have possibly accumulated assets (land and businesses) from his father which would positively impact his bargaining power in the household vis-a-vis the wife's. Furthermore, the relative importance of the husband's paternal education is considered here because property is mostly under the control of men (Fenrich and Higgins, 2001) and the rights to inheritance in both matrilineal and patrilineal societies in Ghana are typically male-to-male (Amanor, 2001; La Ferrara and Milazzo, 2017). It is worth noting that my study is not the first to identify the importance of parental education in spouse's accumulated assets. To address similar endogeneity problems, Quisumbing and Maluccio (2003) use the level of education attained by parents and in-laws as one of the instruments for husband and wife's landholdings in a matrilineal region in Indonesia. The authors, in the same paper, use the education of the spouses' parents as instruments for the spouses' assets in rural Ethiopia.

The exclusion restriction assumption is satisfied here because there is no strong reason to believe that the difference in spouses' paternal educational attainment has any direct effect on the spouses' household budget shares on the sanitation-related items considered in this paper, or any effect possibly running through omitted variables. However, one might argue that, due to intergenerational schooling effect[6], parent's schooling has an effect on children's schooling. As a result of that, the spouses' education which also represents their socio-economic status in the household may directly influence household expenditure patterns, and failure to account for that might result in a correlation between the instrument and the error term. Consequently, we control for the educational attainment of both spouse in the budget-share regressions.

1.6.2.2 Patrilineal Households

The instrument used for bargaining power in my patrilineal household sample is whether the husband's father's occupation is in agriculture or non-agriculture, relative to the wife's father. Essentially, we consider whether the fathers of both spouse are farmers or not.

Given that the rural patrilineal communities considered in my sample are agricultural societies with land being the most important asset, we argue that the differential effect of patrilineal norms on men and women imply that, prior to or during marriage, a woman is less likely to inherit or obtain land inter-vivo from her father regardless of whether that woman's father owns land or not. The choice of instrument here is motivated by the exogenous variation, due to norms, in the strong male-to-male inheritance and the almost non-existent male-to-female inheritance that is pronounced in Ghanaian patrilineal soci-

[6] Holmlund et al. (2011) provide an extensive review of the empirical literature on this subject

eties (Bukh, 1979; Amanor, 2001), and gender roles in agriculture, especially rural women in Ghana (Lambrecht et al., 2018). Duncan (2010) documents that women in patrilineal societies in Ghana have very limited access to their father's land because women are expected to obtain land from their husbands when they get married. This stems from the fact that a married woman from a patrilineal society is effectively subsumed into her husband's lineage, making her irrelevant to her own kin group for inheritance (Lowes, 2017). Thus, if the husband's father is a farmer and the wife's father is not, then the husband is more likely to inherit or obtain land inter-vivo which would positively impact his bargaining power in the household relative to the wife's. This is reflected in my patrilineal household sample where, between both spouse, landholders who inherited their lands from fathers constitute of 92.4 percent husbands and 7.6 percent wives.

The exclusion restriction here is that a father's landholdings can only affect the spouse's household expenditure share on sanitation-related items exclusively via its effect on their bargaining power in the household, given that they inherit or obtain the land inter-vivo. A concern that might be raised is that, the exclusion restriction could be violated if poor WASH in the household requires increased investment or expenditure that causes the household to sell or rent the inherited (or obtained) land. This implies that the income generated from the sold or rented land might be correlated with the error term which directly influences the budget shares. However, Quisumbing et al. (2001) and Amanor (2008) both document that, under communal and customary land tenure systems in Ghana, individuals do not have rights to sell land. In the patrilineal household sample, we find that 99.86 percent of household reported not to have sold any agricultural land in the past 12 months. Also, 99.95 percent of households reported not selling any land 2 years prior to the past 12 months. Additionally, 98.88 percent of households reported not to have rented out any agricultural land in the past 12 months. Thus, a violation of the exclusion restriction assumption might not be a concern here.

1.7 Results

In this section, we discuss the main findings of the empirical analysis. First, we show the OLS results for the causal impact of wives' bargaining power on the WASH outcomes. We then present the first-stage regressions for the endogenous bargaining power variable, and the resulting CF estimates.

1.7.1 OLS Results

Table 1.2 reports the OLS estimates for the causal effect of wives' intra-household bargaining power on WASH outcomes in both matrilineal and patrilineal households. Columns (1) and (4) represent households expenditure on water supply and sanitation. Columns (2) and (5) represent expenditure on routine maintenance sanitation equipment. Columns (3) and (6) represent personal hygiene expenditure.

In the bottom panels of Tables 1.2 and 1.5, we report the joint significance of the coefficients, γ_1, γ_2, and γ_3, with the computed marginal effects[7] of wives' bargaining power on the WASH outcomes.

Given the mean budget shares in Table 1.1, for WASH private goods, we find that a one-standard deviation in the marginal effect of wives' bargaining power is statistically significant and increases the budget share for personal hygiene in matrilineal households (1.6% $\rightarrow$ 2.0%), but not statistically different from zero in patrilineal households. These results suggest that matrilineal women are able to implement their private WASH preferences in the household, such as menstrual needs, to an extent not true for patrilineal women.

[7]The computed marginal effect is based on equation 1.7 in Section 6, and mainly driven by the magnitude and signs of the estimated coefficients of θ, evaluated at the sample averages of the wife and husband's bargaining power, and per capita expenditure.

Table 1.2: OLS Estimates of WASH Budget Shares

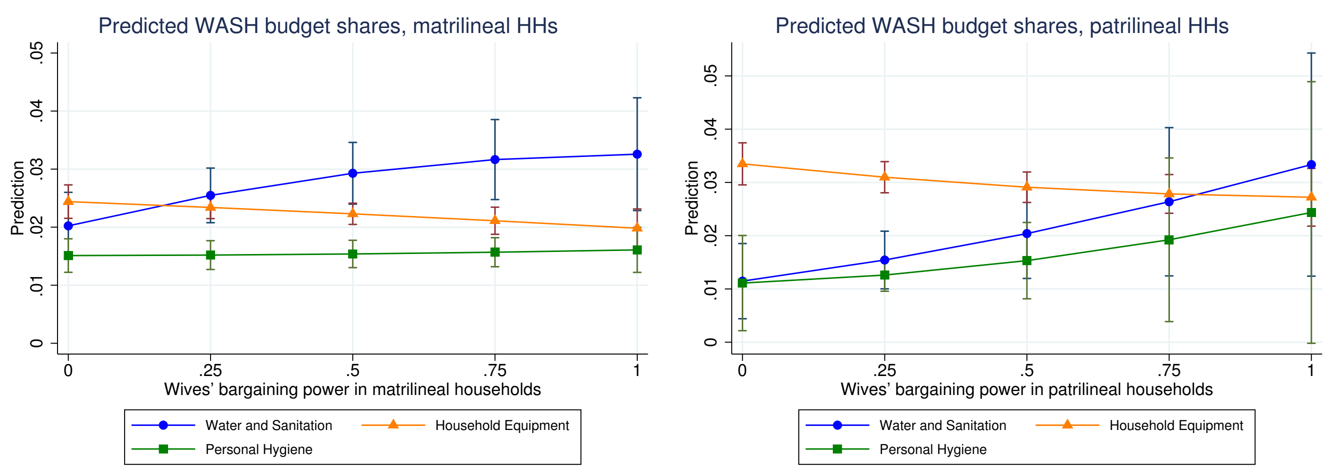
	Matrilineal Households			Patrilineal Households		
	WASH investment (1)	Household equipment (2)	Personal hygiene (3)	WASH investment (4)	Household equipment (5)	Personal hygiene (6)
θ	0.024***	-0.004	0.001	0.014	-0.011**	0.004
	(0.009)	(0.004)	(0.004)	(0.012)	(0.005)	(0.015)
$\theta^2 y$	-0.010	-0.001	0.001	0.007	0.005	0.009*
	(0.006)	(0.002)	(0.004)	(0.007)	(0.004)	(0.005)
$(1-\theta)^2 y$	-0.002	-0.001	-0.002**	0.007	-0.002	0.011
	(0.002)	(0.001)	(0.001)	(0.006)	(0.002)	(0.013)
Marginal effect (θ)	**0.018*** **	**-0.004**	**0.004** **	**0.007**	**-0.005**	**-0.008**
Controls	Yes	Yes	Yes	Yes	Yes	Yes
F-Stat (joint.sig)	4.68	1.18	3.45	1.13	1.53	1.17
R-Squared	0.182	0.177	0.115	0.266	0.236	0.192
Observations	1,253	1,253	1,253	2,457	2,457	2,457

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Robust standard errors are in parenthesis. The joint significance is estimated for (θ, $\theta^2 y$, $(1-\theta)^2 y$). Controls include age-squared of both spouse, education of head and spouse, ethnicity and religious denomination of both spouse, type of housing, household total expenditure and household size.

For the expenditure categories considered as WASH public goods, the influence of wives' bargaining power is somewhat associated with the nature of expenditure or investment. First, we find that the marginal effect of wives' bargaining power increases the budget share of water supply and sanitation (WASH investments) in both household types, albeit a statistically significant impact is observed in matrilineal households (2.7% $\rightarrow$ 4.5%) and an insignificant impact in patrilineal households (1.2% $\rightarrow$ 1.9%). Second, the budget share for the other WASH public good – equipment for routine maintenance of sanitation (Household equipment) – is not statistically significant but negatively impacted by the marginal effect of wives' bargaining power in both household types: 2.3% $\rightarrow$ 1.9% and 3.6% $\rightarrow$ 3.1% in matrilineal and patrilineal households respectively. The overarching conclusion from these findings for WASH public goods is that, the agency of women to influence expenditure on WASH public goods within the household may vary by the type of monetary cost involved. Matrilineal women are relatively able to influence spending decisions on household WASH public goods that are more costly, such as household toilets, compared to patrilineal women who are unable to influence such spending.

Next, we analyze WASH investment decisions at the predictive margin in both household types. Figure 1.1 depicts the predicted budget shares of WASH goods in the household at varying levels of wives' bargaining power. The graph suggest that for WASH public goods, the household budget share for water and sanitation is predicted to increase, as wives' bargaining power increases. This increase is relatively sharper at higher levels of bargaining power in patrilineal households, compared to matrilineal households. However, expenditure on household equipment for sanitation maintenance is reduced. This suggest that some WASH public goods are prioritized than others by women in the household. While personal hygiene expenditure is fairly stable in matrilineal households, patrilineal women increases the budget share on hygiene as they gain more control of resources. Initial levels of expenditure on WASH in the household may also be important in how women's preferences for private and public WASH goods are subsequently shaped at higher levels of bargaining power.

Figure 1.1: Predicted WASH Budget Shares in both household types



1.7.2 CF Results

1.7.2.1 First-Stage Regressions

As earlier discussed in the previous section, the bargaining power variable is potentially endogenous in the budget share equations for both household types. Tables 1.3 and 1.4 reports the first-stage regressions in both household types, which includes the excluded instrument and the other exogenous variables that enter the second stage. The excluded instruments have the expected effects on wives' bargaining power in the first-stage regressions.

For matrilineal households, we find that the excluded instrument (i.e. difference in spouses' paternal educational attainment) is negatively correlated with the wife's bargaining power and statistically significant. This corroborates the notion that if the husband's father is relatively more educated and well-informed of the ISL, this might induce increased assets accumulated by the husband before or during marriage, which in turn increases his bargaining power in the household at the disadvantage of the wife's bargaining power. Following the rule of thumb described in Stock and Yogo (2002) for detecting weak instruments in the first-stage regression, the F-statistic for the excluded instrument is 10.17, which marginally exceeds the threshold of 10, suggesting that a weak instrument problem may not be a major concern in this case.

Table 1.3: First-Stage Regression for Matrilineal Households

Excluded instrument: Difference in spouse's paternal educational attainment

Dep. variable	θ
Excluded instrument	-0.108***
	(0.034)
Included controls	Yes
F-statistic (excluded instrument)	**10.17**
p-value (excluded instrument)	0.002
R-squared	0.200
Observations	1,253

Note: *** p<0.01, ** p<0.05, * p<0.10. Robust standard errors are in parenthesis. The **excluded instrument** used in the first-stage regression is the difference in husband and wife's paternal educational attainment. The **included instruments (controls)** used in the regression are education of household head and spouse, wife's age at first marriage, household size, age-squared of household head, ethnicity of both spouse, religious denomination of both spouse, total household expenditure, and type of dwelling.

For patrilineal households, the excluded instrument (i.e. husband's father's occupation in agriculture or non-agriculture, relative to wife's) has a negative association with the wife's bargaining power as expected and statistically significant. This confirms the idea of the husband's higher chances of obtaining land and other agricultural assets from his father who is a farmer, relative to the wife's, and how that translates into a relatively lower bargaining power for the wife in the household. The F-statistic for the excluded instrument here is 11.98, implying that a weak instrument problem is not necessarily encountered in the patrilineal household analysis.

Table 1.4: First-Stage Regression for Patrilineal Households

Excluded instrument: Relative spouse's paternal occupation (agriculture or non-agriculture)

Dep. variable	θ
Excluded instrument	-0.116***
	(0.034)
Included controls	Yes
F-statistic (excluded instrument)	**11.98**
p-value (excluded instrument)	0.001
R-squared	0.120
Observations	2,457

Note: *** p<0.01, ** p<0.05, * p<0.10. Robust standard errors are in parenthesis. The **excluded instrument** used in the first-stage regression is relative spouse's paternal occupation in agriculture or non-agriculture. That is, whether spouses parents are farmers. The **included instruments (controls)** used in the regression are education of household head and spouse, wife's age at first marriage, household size, age-squared of household head, ethnicity of both spouse, religious denomination of both spouse, total household expenditure, and type of dwelling.

1.7.2.2 CF Estimates

Table 1.5 reports the CF estimates of the causal effect of wives' bargaining power on WASH budget shares in both matrilineal and patrilineal households, which addresses the endogeneity concerns.

For WASH private goods, we find that the marginal effect of wives' bargaining power on the budget share for personal hygiene expenditure in both household types is statistically significant, but this effect is positive in matrilineal households (1.6% $\rightarrow$ 1.8%) and negative in patrilineal households by almost double the initial budget share (1.4% $\rightarrow$ -2.6%). The negative effect observed in patrilineal households could be due to the male dominance in decision making that is typical in patrilineal households. Thus, the WASH preferences of patrilineal wives that are personal in nature are more likely to conflict with those of their husbands. In effect, when women in this household type gain some degree of bargaining power, they may redirect resources towards other competing WASH needs in the household, at the expense of personal hygiene.

For household's budget share on water supply and sanitation (WASH investment), I find that an increase in the marginal effect of wives' bargaining power has a positive effect in both household types and statistically significant at the 1 percent level. In particular, a one-standard deviation increase in wives' bargaining power leads to an increase in the budget share of WASH investment by 4.6 percentage points (i.e. 2.7% $\rightarrow$ 7.3%) in matrilineal households and 0.5 percentage points (i.e. 1.2% $\rightarrow$ 1.7%) in patrilineal households. In the case of the budget share for household equipment for maintenance of sanitation, the marginal effect of wives' bargaining power lead to a decrease of 0.5 and 0.9 percentage points in matrilineal and patrilineal households respectively. However, this effect is only statistically significant in patrilineal households.

Table 1.5: Control Function Estimates of WASH Budget Shares

	Matrilineal Households			Patrilineal Households		
	WASH investment (1)	Household equipment (2)	Personal hygiene (3)	WASH investment (4)	Household equipment (5)	Personal hygiene (6)
θ	0.049	-0.004	-0.001	0.008	-0.022	-0.030*
	(0.051)	(0.006)	(0.004)	(0.023)	(0.018)	(0.015)
$\theta^2 y$	-0.007*	-0.001	0.002	0.007***	-0.005***	0.005***
	(0.004)	(0.001)	(0.002)	(0.003)	(0.001)	(0.001)
$(1-\theta)^2 y$	-0.003***	-0.000*	-0.001***	0.004***	-0.009***	0.007
	(0.001)	(0.000)	(0.000)	(0.002)	(0.001)	(0.004)
Marginal effect (θ)	**0.046*** **	**-0.005**	**0.002*** **	**0.005*** **	**-0.009*** **	**-0.040*** **
Controls	Yes	Yes	Yes	Yes	Yes	Yes
F-Stat (joint.sig)	11.17	2.98	12.59	13.97	80.24	19.49
R-Squared	0.182	0.294	0.144	0.165	0.143	0.122
Observations	1,253	1,253	1,253	2,457	2,457	2,457

Note: *** p<0.01, ** p<0.05, * p<0.10. Bootstrap standard errors in parenthesis (1,000 replications). Controls include age-squared of both spouse, education of head and spouse, ethnicity and religious denomination of both spouse, type of housing, household total expenditure and household size.

Overall, while the CF estimates account for attenuation bias in the OLS estimates, both set of results suggest that, matrilineal wives have a greater autonomy in influencing WASH expenditure decisions in the household compared to patrilineal wives. In addition, WASH investments (on toilets, sewerageand waste disposal) constitute the most prioritized category of expenditure, as wives in both household types gain more control of resources. Sanitation investments are more probable in the case where the household member who enjoys a higher bargaining power positively perceives his net benefit from that investment (Augsburg et al., 2021). However, due to the caregiving role of women in households, they are more likely to shape household spending patterns on WASH, as they gain more influence.

1.8 Conclusion

This paper explores the variation in cultural norms to understand how the relative intra-household bargaining power of women influence WASH investments and expenditure in Ghanaian rural households. We focus on matrilineal and patrilineal societies, where distinct cultural norms between the two groups have differential impact on women's agency in the household, and the potential implications that may have on WASH expenditures in the household. The paper uses a simple framework for analysing decision making within the household, which takes into account that household members may have different preferences for WASH uptake in the household.

We show that women's agency, due to matrilineal and patrilineal cultural norms, potentially influences the household's budget shares on WASH expenditure. This effect of wives' bargaining power provides a plausible channel through which policies and WASH interventions could be designed to facilitate the agency of women to exert their WASH preferences in the household, while taking into account differences in cultural norms across societies.

The analysis provides interesting insights. We find that women's bargaining power influences households' spending decisions on WASH, to an extent that depends on the type of WASH good – private or public to the household. In particular, matrilineal women, in general, are able to exert agency in implementing their WASH preferences to an extent not true for patrilineal women. Matrilineal women are more able to influence spending decisions on more costly WASH public goods such as household toilet facilities, as well as personal hygiene items, relative to patrilineal women who have far less autonomy. These findings highlight the importance of taking into account cultural norms in rural households in the design of WASH interventions and policies.

Chapter 2

Climate change, culture and marriage timing in Malawi

2.1 Introduction

Cultural norms and traditions are significant determinants of economic development and the effectiveness of policy interventions (Collier, 2017; Ashraf et al., 2020; Lowes, 2022). The traditional custom of bride price – a transfer made from the groom's family to the bride's family at marriage – is prevalent in Sub-Saharan Africa, and constitutes an important component of the marriage agreement (Mbaye and Wagner, 2017). In the context of marriage behavior, particularly the age at which individuals marry, the bride price tradition may have differential implications on the economic outcomes of men and women. The empirical evidence on how income shocks, due to climate change, interacts with cultural norms, in influencing marriage behavior in low-income countries is limited.

Malawi is a culturally diverse country, and ranks as the 27th out of the 185 countries globally that are considered the most vulnerable and exposed to the adverse impacts of climate change, as per the Notre Dame Global Adaptation Initiative (ND-GAIN) Index in 2021. In 2022, the World Bank reported that, at the onset of 2010, Malawi experienced two extended periods of severe drought, sixteen significant occurrences of flooding, a landslide triggered by heavy rainfall, and five storms. Droughts, floods, and extreme temperatures are projected to become more frequent and intensified over time (Intergovernmental Panel on Climate Change (IPCC), 2014).

Given the prevalent lack of access to formal credit and insurance in low-income countries, the fluctuations in aggregate income resulting from adverse climate shocks, may have significant implications for marriage behaviour and marriage markets.[1] The economic literature documents that adverse climate shocks pose significant challenges to poor households especially in agrarian economies. In addition, these households encounter difficulties in effectively responding to such shocks (e.g. Rosenzweig, 1988; Platteau, 1997; Kazianga and Udry, 2006; Dinkelman, 2017). While recent evidence have shown that, due to the bride price transfer, female household members from the supply side of the marriage market, can be exploited as a means of insuring against negative climate shocks (e.g. Hoogeveen et al., 2011; Corno et al., 2020; Corno and Voena, 2023), scant attention has been given to how grooms from the demand side of the marriage market may differentially respond to the same shocks. The presence of the bride price custom may impose liquidity constraints for grooms, which are even more pronounced following a contraction in income, and hence could influence marriage timing decisions. In addition, the effect of the custom on grooms' marital decisions may well depend on how they insure against income shocks. Historically and in present times, the size of the bride price in SSA have often been substantial – frequently exceeding a year's household income and sometimes as large as four times that amount (See Anderson (2007) for a review).

In this paper, we provide evidence on how drought and flood shocks interact with cultural norms in influencing the hazard into first marriages for both men and women, and the resulting husband-wife age gap at first marriage. In particular, we explore the differential impact of these shocks across bride price and non-bride price societies in Malawi. First, to estimate the effects of the drought and flood shocks on first marriage hazards for men and women by bride price societies, we conduct a survival analysis using the Cox proportional hazards (PH) model, where the event of interest is the time to first marriage and survival is remaining unmarried. We then examine the outcomes of the marriage hazards (or timing decisions), by estimating the impact of the drought and flood shocks on the husband-wife age gap at first marriage. To carry out these estimations, we exploit the exogenous fluctuations in annual rainfall in Malawi to construct an indicator of drought and flood shocks that are independent of the time-invariant factors that may determine marital decisions, following closely the approach used by Burke et al. (2015) and Corno et al. (2020). Rainfall shocks constitute a primary source of income variability in regions that are dependent on rain-fed agriculture (Corno et al., 2020). We use the Matsuura and

[1] Marriage markets typically assumes a market where supply and demand is simplistically represented by the overall number of men and women in the given country (Tertilt, 2003)

Willmott (2009) rainfall data from the University of Delaware, which is combined with information on age at first marriage from the Malawi Demographic and Health Surveys (DHS), as well as data on culture from the Ethnographic Atlas by Murdock (1967) for the measure of bride price custom prevalence.

During periods of low aggregate income caused by rainfall shocks, the bride price transfer serves as a significant means of consumption smoothing (Anderson, 2007; Corno et al., 2020), resulting in an increased supply of brides. However, households and grooms from the demand side of the marriage market also experience the same income shock, leading to a decrease in the equilibrium bride price (Tapsoba, 2023), as fewer grooms are financially capable of paying the transfer. Despite this price decline, the bride price is still likely to remain a substantial burden for many grooms. The extent to which the marriage market is affected may depend on the insurance mechanisms available to grooms. Young bachelors and older men may have varying capacities in their resilience to the income shocks, due to differences in savings, household wealth, or access to informal insurance networks. Thus, the impact on marriage entry hazards for men and women in societies where the bride price tradition is binding is less clear. In addition, the broader consequences for marital outcomes such as changes in the age gap between spouses, early marriages, and heightened household inequality due to junior and/or senior wives are not fully understood.

First, a key finding in this paper indicate that, the hazard of entering first marriages for both men and women in bride price societies is lower when there is no drought shock. Following exposure to drought shocks, this negative effect is greater, particularly for men. To be specific, men exposed to drought shocks in bride price societies delay the timing of their first marriages by 19.2% relative to men in non-bride price societies. Conversely, in societies without the bride price custom, droughts are associated with a higher hazard of both men and women entering their first marriages. A noticeable outcome of these effects is that, the husband-wife age gap in bride price societies is positive and drought exposure in a given year further increases this gap by 0.051 years.

The widening husband-wife age gap in bride price societies suggest that the presence of the custom plays an influential role in the marriage timing decisions. The practice of the bride price custom imposes liquidity constraints, particularly exacerbated by a decrease in income resulting from the impact of the drought shock. This situation makes it challenging for both young and older grooms to fulfill the transfer payment. However, the financial burden is more pronounced for younger men (Platteau and Gaspart, 2007) than for older men. This is because, older men are relatively more likely to be wealthier and better self-insured to cope with the income shock. We show further evidence in that regard that, due to the liquidity constraints imposed by the bride price custom, young women are more likely to become junior wives in polygynous marriages by marrying older grooms and/or divorced men who are more self-insured and resilient to the drought shock, and hence the higher age gap.

Second, we show that, in the absence of a flood shock, the hazard of entering first marriages for both gender in bride price societies is also lower. However, exposure to flood shocks increases the hazard and makes it positive, but this positive effect is only statistically and significantly different from zero for women. Specifically, the impact of flood exposure on the hazard of entering first marriages for women is higher in bride price societies by 33.6% relative to women in non-bride price societies. In the case of non-bride price societies, flood exposure is associated with a lower hazard of marriage entry for both gender. If we consider the heterogeneous effects for men by age cohorts, we find that the differential effects for both young adult and older men between the two societies are also not statistically significant. This suggests that, unlike droughts, the nature of flood shocks has less impact on marriage timing decisions for both young and older men in bride price societies. In equilibrium, we see no significant differential outcome of flood shocks on the husband-wife age gap. In a supporting evidence, we find that there is no differential impact of the exposure to flood shocks on the probability of younger or older women marrying as junior wives in polygynous marriages in both societies.

A plausible explanation for the results we obtain on the impact of flood shocks on first marriage hazards and the resulting husband-wife age gap, essentially lies in the nature of flood shocks. In contrast to droughts which occur over broader geographical areas, floods are more localized and less concentrated spatially. As a consequence, flood shocks allow for potential smoothing mechanisms to alleviate their impact, such as short-term migration for work. Specifically, after a flood shock, potential grooms may temporarily move away from their villages to nearby areas for employment, rendering them physically absent to initiate marital unions. The potential for income smoothing following flood shocks effectively reduces the significance of relying on self-insurance mechanisms, such as savings, for both young and older men. As a result, there is no discernible differential effect of the bride price tradition when interacted with flood shocks on the likelihood of entering first marriages for men, and on the husband-wife age gap.

Lastly, the findings in this paper uncover that there is a plausible asymmetry in the effects of drought and flood shocks, via their impact on low aggregate income. In the context of marriage behaviour, the results in this paper suggest that, drought and flood shocks potentially have contrasting effects on the hazard of entering first marriages for both men and women in Malawi. In general, a number of reasons for this asymmetry suffices: Droughts are long-lasting, have a broader impact on economies, and can exert a more enduring influence on agricultural productivity compared to floods. In particular, we utilize data from FAOStat for Malawi, combined with our climate data, to provide corroborative evidence regarding the differential impact of drought and flood shocks on crop yields. Our findings indicate that, while droughts and floods lead to a reduction in maize and rice yields – the primary staple crops in Malawi – this impact is not statistically significant in the case of floods. This implies that agricultural productivity and hence income in Malawi is significantly affected by droughts to a degree not observed in the case of floods, and this may have differential consequences for marriage timing decisions.

From a policy standpoint, the findings presented in this paper are important for the formulation and assessment of social safety net programs and other targeted interventions such as cash transfers in Malawi, that may have overlooked the influence of cultural norms and climate fluctuations on household behavior and marital outcomes. Policies and interventions that generate windfall revenue during adverse economic shocks could have unintended consequences especially for women if the type of shock and cultural setting is not taken into account. Cash transfers, for example, during droughts may have larger effects in bride price societies if targeted at households with marriage-age girls. The widening husband-wife age gap and the increased likelihood of young women entering polygynous marriages as junior wives, especially in societies where bride price is customary, could yield adverse long-term consequences. Marital unions with older men is often correlated with diminished bargaining power for women (Browning et al., 1994; Carmichael, 2011) and an elevated risk of early widowhood (Van de Walle, 2013; Lambert et al., 2018). In addition, early marriage for girls have been shown to be associated with adverse health consequences, fertility, and socio-economic outcomes (Field and Ambrus, 2008; Chari et al., 2017; Sunder, 2019).

Our paper mainly contributes to three strands of the literature. First, this paper adds to the body of research on aggregate income shocks and individual or household outcomes (e.g. Hoogeveen et al., 2011; Björkman-Nyqvist, 2013; Burke et al., 2015; Dinkelman, 2017; Corno et al., 2020; Branco and Féres, 2021; Corno and Voena, 2023). In relation to marriage outcomes, Corno et al. (2020) for example, find that the impact of droughts on early marriage varies across regions: In India, droughts are associated with a decrease in early marriages, while in Sub-Saharan Africa where bride price is the customary marriage payment, droughts tend to increase the incidence of early marriages. We contribute to this literature by providing evidence that emphasizes how cultural norms at marriage influence the differential response of societies to aggregate economic conditions due to climate change. We also show that drought and flood shocks are not symmetric in their influence on marriage behavior by individuals and/or households. In addition, we uncover the probable gender-based power dynamics between husbands and wives that could be manifested in the age gap at first marriage in Malawian societies where bride price is customary.

Second, this paper extends the literature on risk management strategies and self-insurance mechanisms in rural economies (e.g. Rosenzweig, 1988; Morduch, 1995; Dercon, 2002; Fafchamps and Lund, 2003; Kazianga and Udry, 2006; Robinson, 2012; Acosta et al., 2021). The contribution to this literature is to show that, in the face of economy-wide covariate shocks, men in bride price societies may strategically delay first marriages to achieve income smoothing. While there is a good understanding of the use of early female marriage as a consumption smoothing strategy by households, less attention in the development economics literature has been paid to the marriage behaviour for men, particularly during periods of adverse income shocks.

Third, this paper fits within the literature on the significance of culture for economic outcomes and decisions (La Ferrara, 2007; Fernández and Fogli, 2009; Anderson and Bidner, 2015; Lowes, 2016; Ashraf et al., 2020; Barker, 2021). We contribute to this literature by showing that the cultural custom of bride price transfer influences the responsiveness of individuals' marriage decisions to income shocks, in a way that has lasting impacts on marital outcomes such as the age gap between spouses. Thus, effective policies and interventions can be achieved by taking into account the cultural nuances of societies, especially in low-income countries.

The rest of the paper is organised as follows. Section 2.2 provides an overview of the marriage patterns in Malawi and the cultural traditions related to marriage, along with insights into climate change vulnerability. In Section 2.3, we present the data and descriptive statistics. Here, we detail the construction of key variables of interest in our analysis. The empirical strategy is provided in Section 2.4, and the empirical results presented in Section 2.5. Section 2.6 provides additional results on the asymmetry between droughts and floods. Section 2.7 present results that illustrate the mechanism underlying the main findings, while section 2.8 discusses robustness checks. Lastly, Section 2.9 concludes.

2.2 Contextual Background

This section discusses the marriage patterns in Malawi and the related cultural traditions at marriage that are prevalent. It also provides an overview of climate variability and its consequential impact on households.

2.2.1 Marriage patterns in Malawi

Marriage in Malawi is almost universal and often geographically localized, as people typically choose partners from within their local villages (Sear, 2008; Cherchye et al., 2018). Malawi is a country that exhibits cultural diversity, where matrilineal and patrilineal systems of kinship coexist, with variations in their traditional marriage customs. Notably, the marriage patterns in Malawi vary significantly across the country's three administrative regions, reflecting the influence of the prevailing kinship systems (Anglewicz and Reniers, 2014). In the southern region of Malawi, matrilineal societies are the most prevalent, and the customary post-marriage living arrangement involves uxorilocal residence, where the husband relocates to reside with or in close proximity to the wife's kinsmen (Berge et al., 2014). In these matrilineal societies, the bride price tradition is less common, and marriage negotiations are generally less extensive and formalised in comparison to patrilineal societies (Reniers, 2003). Additionally, polygamous marriages in matrilineal societies occur infrequently (Angelucci and Bennett, 2017), and marriage decisions are typically made by individual partners with a limited influence by parents or community leaders (Kaler, 2001). In contrast, the northern region of Malawi consists predominantly of patrilineal tribes that adhere to the tradition of bride price and adopt virilocal residence after marriage, wherein the couple resides with or in close proximity to the husband's family (Palamuleni, 2011; Berge et al., 2014). Mwambene (2005) document that the customary validation of marriages in these patrilineal societies in Malawi occurs upon the complete payment of the bride price. The central region exhibits a mixed composition, although it can be mainly classified as matrilineal and uxorilocal (Palamuleni, 2011).

This heterogeneity in marriage customs may have differential implications on the choice of spouse, marriage timing, and the age at first marriage (Makwemba et al., 2019). In particular, the custom of bride price transfers at marriage may impact household behaviour and marriage-related decisions. Households engagement in marriage as a form of insurance strategy can be traced back to the pioneering work of Rosenzweig and Stark (1989), where they provide evidence indicating that households experiencing income fluctuations due to rainfall variations were more inclined to marry off their female members to grooms in more distant locations to improve risk-sharing opportunities. The influence of income variability, due to climate shocks, on the marriage decisions of individuals and households, is likely not to be engendered by incentives from just the supply side of the marriage market but also the demand side. Individual grooms and households with sons – representing the demand side – may adjust their marriage decisions in response to income uncertainty. In times of economic hardship caused by adverse weather shocks, these individuals and households may strategically delay marriages due to insufficient resources to afford the bride price or seek brides from households willing to accept lower bride price transfers.

2.2.2 Climate change vulnerability in Malawi

According to the Notre Dame Global Adaptation Initiative (ND–GAIN) Index in 2021, Malawi is regarded as the 27th out of the 185 countries globally that are most vulnerable and exposed to the adverse impacts of climate change. The World Bank in 2022 documented that, at the onset of 2010 alone, Malawi has encountered two prolonged periods of severe drought, sixteen significant instances of flooding, a landslide due to rainfall, and five storms. Extreme climatic events like droughts, floods, and extreme temperatures are projected to become more frequent and severe over time (Intergovernmental Panel on Climate Change (IPCC), 2014). Malawi's susceptibility to such adverse climate shocks is further worsened by its structural economic conditions and heavy reliance on rainfed agriculture (Asfaw and Maggio, 2018). Adverse climate shocks have the potential to impact agricultural productivity, including crops, livestock, fisheries, and forestry, and can also indirectly impact incomes by reducing labor demand, driving up local prices, and restricting access to markets (Alfani et al., 2019).

Households exposed to severe climate events frequently encounter increased levels of vulnerability due to significant reductions in agricultural income and consumption (Alfani et al., 2019), and given that Malawi is predominantly rural, it is imperative to understand how vulnerable households and individuals make decisions to cope with these climate shocks. In theory, while households can depend on various institutions and coping mechanisms, such as credit, markets, and social safety net programs, these resources are typically only partial, and consumption shortfalls tend to be high (Alderman and Paxson, 1992; Dercon, 2005; Fitzsimons et al., 2018; Malde and Vera-Hernández, 2022). Of particular relevance in this paper is the institution of marriage and the time it occurs. This paper attempts to quantify the ramifications of the interaction of climate change and the traditional custom of bride price, on the hazard of first marriage timing for both men and women in Malawi and its impact on the age gap at marriage.

2.3 Data and Descriptive Statistics

This section mainly outlines the data sources used in the analysis, and the summary statistics for the sample. In what follows, we present a more comprehensive description of the measurement of key variables of interest related to marriage, climate, and culture, and how the dataset is constructed.

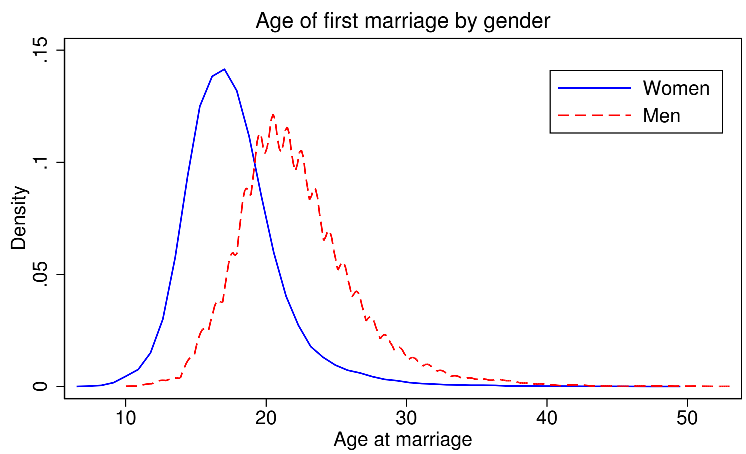
2.3.1 Marriage data and summary statistics

The data on marriage is sourced from repeated cross-sections of the Malawi Demographic and Health Surveys (DHS), for the years, 2000, 2004, 2010 and 2015. The Malawi DHS is a nationally representative and population-based survey that elicits information on basic demographic and health indicators. The survey utilizes a stratified two-stage cluster design approach. The sample is stratified into urban and rural areas, and enumeration areas are independently chosen within each stratum. In the first stage, the enumeration areas are chosen with a probability proportional to the size of the enumeration area, which is determined by the number of households it encompasses. In the second stage, a consistent number of households are each selected from both urban and rural clusters, using an equal probability systematic selection method. Men aged 15 – 54 and women between the ages of 15 – 49, who are either married or not, are selected from sampled households per cluster and individually interviewed.

In the DHS dataset, data on age at first marriage (or cohabitation) for both men and women are gathered retrospectively through interviews. Both men and women are asked to recall and provide information on their current age, and the month and year when they entered into their first marriage. We use information in both men and women samples on the age and year of first marriage, which is merged with our climate data, to construct a pseudo-panel for each individual and at-risk year of marriage.

Figure 2.1 depicts the distribution of age at first marriage for both men and women. The average age at first marriage for women is 17.58 years, whereas men tend to marry at the age of 22.19 years on average. Notably, a considerable proportion of women enter their first marriage in their teenage years, whereas a comparatively smaller number of men do so.

Figure 2.1: Age at first marriage, by gender



Note: The Figure illustrates the kernel density distribution of ages at first marriage for men and women in Malawi. The distributions are presented separately for men and women (as indicated by the legend). Data is from the pooled 2000, 2004, 2010, and 2015 Malawi DHS.

Table A1 in the Appendix shows the summary statistics for the sample, categorized by societal groups (i.e. bride price vs non-bride price societies). Panel A shows the statistics for unique individuals while Panel B describes the survival data. The sample comprises of 68,074 unique individuals, with 12,559 men and 55,515 women. First, the mean age at first marriage for men in bride price societies (i.e. 22.56) is marginally greater than the mean for their counterparts in non-bride price societies (i.e. 22.12), and this mean difference is statistically significant. Similarly, the average age at which women have their first marriage is marginally higher in bride price societies (i.e. 17.76) compared to non-bride price societies (i.e. 17.59) but this difference is statistically significant. If we consider the age at first marriage by age cohort, we see a significant mean difference between the two societies for women who enter their first marriages before turning 18, and those that marry after the age of 40 (but this is a very small sample). For men, we do not observe significant mean difference between the two societies for early marriages before the age of 18, but rather we see a significant difference for marriages that occur between the ages of 18 and 25, and those that marry after turning 40. The age gap at first marriage between husbands and wives, on average, is greater in bride price societies (i.e. 6.73 in bride price societies and 5.72 in non-bride price societies), and this difference is statistically significant. In Panel B, the data is restructured for survival analysis, and the summary statistics obtained are consistent with the original sample of unique individuals.

In Figures A6 and A7 in the Appendix, we plot the Kaplan-Meier survival curves and the Nelson-Aalen cumulative hazards. The survival curve represents the likelihood of an event not having occurred up to a given point in time, while the hazard rate measures the instantaneous risk of an event occurring. The curves compare the survival of remaining unmarried and the cumulative hazard of entering a first marriage in bride price versus non-bride price societies in Malawi, for both men and women samples. The survival curves for men at various ages in bride price and non-bride price societies are reasonably similar, as is the case for the women sample. However, in both samples, it appears that the survival rates are slightly higher in bride price societies. A similar pattern emerges for the cumulative hazards, although the contrast in hazard rates becomes more pronounced in the later years.

2.3.2 Climate data and construction of shocks

To investigate the impact of extreme climate events on the hazard of first marriage for men and women in Malawi, we adopt a commonly used approach in the extant literature to construct climate shocks. This approach utilizes weather fluctuations as a proxy for changes in economic conditions (e.g. Burke et al., 2015; Corno et al., 2020), as adverse rainfall patterns have been shown to significantly reduce agricultural productivity especially in African societies that are predominantly agrarian.

We use the Matsuura and Willmott (2009) data based on the University of Delaware dataset to construct our measure of climate shocks which consist of drought and flood shocks. Historically, droughts and floods have been the most severe of climate hazards in Malawi (World Bank, 2021). The Matsuura and Willmott data provides global coverage of monthly precipitation and air temperature on a 0.5×0.5 degree grid, spanning the period 1900 – 2015. The 0.5 degrees approximately corresponds to a distance of 50km at the equator.

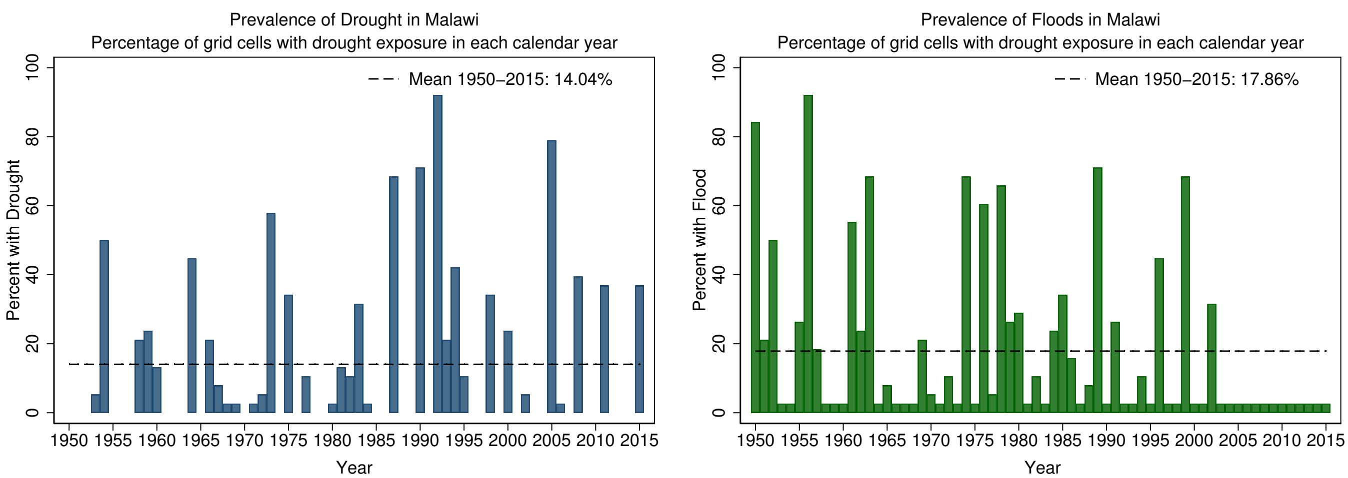
In constructing the climate shock variables, we first utilize the GPS information available in the Malawi DHS data to establish a match between the individual DHS clusters and their corresponding weather grid cells. This procedure yields a total of 38 distinct grid cells from the Matsuura and Willmott data which is matched to the Malawi DHS. Second, we then exploit the relative rainfall patterns at the grid cell level to construct our measure of the climate shocks. To do this for both the drought and flood shocks, we adapt the approach by Burke et al. (2015) and Corno et al. (2020) where weather shocks are characterized by rainfall observations that fall below or above a specific threshold, based on a location's local rainfall distribution. [2] In principle, the approach fits a gamma distribution to the historical annual rainfall data at each grid cell and assigns the respective rainfall observation per year to its associated percentile within the distribution. The choice of the gamma distribution is motivated by its significant adaptability in terms of both shape and scale (Burke et al., 2015). Following Burke et al. (2015) and Corno et al. (2020), we use the historical annual rainfall data from 1950 – 2015 to characterize the climate shocks in the following ways: a drought is an annual rainfall observation that is less than the 15th percentile of a grid cell's historical long-run rainfall distribution, while a flood is defined as rainfall observations that are in excess of the 85th percentile of a grid cell's historical long-run rainfall distribution.

By design, both measures of drought and flood shocks are expected to be independent of other confounding factors that may be related to marriage, such as education and economic prosperity. This is because, the definition of the drought or flood shock in a given grid cell utilizes the same percentile threshold and historical rainfall distributions, ensuring that all grid cells have an equal chance of exposure annually (Burke et al., 2015). However, due to the natural variation in rainfall over time, drought and flood shocks across years may occur randomly, and it is this plausibly random variation that we leverage for our analysis. Figure 2.2 shows the percentage of grid cells in Malawi that are exposed to drought and flood shocks in a specific calendar year. Crucially, the figure depicts that, in each calendar year, these shocks are independent of the long-term trends, as indicated by the long-run averages for the drought and flood shocks. This independence mitigates

[2] Other approaches to measuring shocks in the economic literature include the calculation of a deviation from the local mean rainfall in a specific year. Previous studies such as Fafchamps et al. (1998), Jayachandran (2006) and Dercon (2004) have utilized this method in various forms including absolute levels, percentages or standard deviation units. However, a limitation of these methods is their inability to effectively sum shocks over multiple years, as the high years tend to counterbalance the low years (Burke et al., 2015)

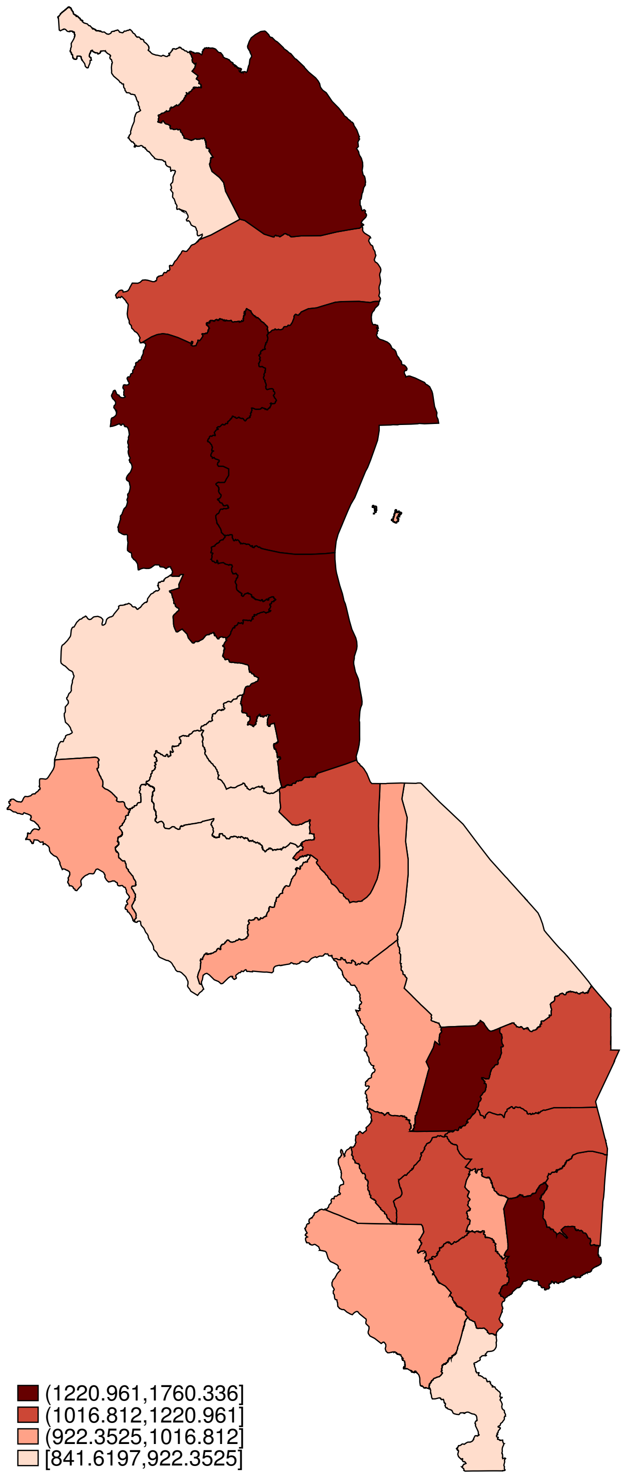
concerns about a spurious relationship influencing our results. Figure 2.3 also shows the long run (1950 – 2015) spatial distribution of rainfall in Malawi.

Figure 2.2: Prevalence of drought and flood shocks in Malawi



The figure illustrates the occurrence of drought and flood shocks in Malawi, depicted as the percentage of grid cells experiencing these events in a given calendar year. The black dashed line represents the long-term average of droughts and floods spanning the period 1950 to 2015.

Figure 2.3: Rainfall distribution, long-run average (1950 – 2015) for Malawi



Author's elaboration using the climate data from Matsuura and Willmott and the district map of Malawi. The long-run averages are calculated at each grid cell.

2.3.3 Culture

For the data on culture, we mainly use information provided in the Ethnographic Atlas by Murdock (1967). The Ethnographic Atlas dataset compiles information at the ethnicity level on traditional cultural practices across a vast majority of ethnic societies globally, encompassing a wide spectrum of social structures, from those characterized by advanced agricultural economies and intricate political systems to smaller hunter-gatherer communities.

Our analysis uses data pertaining to the customary marriage traditions of the distinct ethnic groups in Malawi. In particular, we focus on the traditional custom of bride price and classify ethnic groups in Malawi that engages in this custom or not. Ethnic groups in the Ethnographic Atlas are classified on their engagement in one of the following marriage transfer customs, according to Murdock (1981):
a) Bride price or bride wealth: the transfer of a significant offering, whether in the form of livestock, commodities, or money, from the groom or his family to the bride's kinsmen.
b) Token bride price: a small or symbolic payment only.
c) Bride service: a substantial material exchange where the groom provides labor or various services to the bride's family.
d) Gift exchange: a mutual exchange of valuable gifts between the families of the bride and groom, or an ongoing exchange of goods and services, roughly of equal worth, involving the groom or his relatives and the bride's family.
e) Female relative exchange: an exchange of the groom's sister or another female relative in return for the bride.
f) Dowry: the transfer of a significant quantity of assets from the bride's family to either the bride, the groom, or the groom's kinsfolk.
g) No significant consideration: the absence of any substantial exchange, or bridal gifts only

Our bride price measure comprises an ethnicity-level binary variable, indicating whether an ethnic group (or society) engages in the traditional custom of bride price payment (i.e. category (a) above). There are 10 unique ethnic groups reported in the Malawi DHS. To construct the bride price variable, we first match, by hand, each of these distinct ethnic groups from the DHS to the ethnic groups from the Ethnographic Atlas. This procedure matches 9 of the ethnic groups from both sources, which is also consistent with the previous matching done by Alesina et al. (2013) where 1,265 ethnic groups documented in the Ethnographic Atlas were matched to their respective marriage customs, in addition to other cultural practices. Information on the remaining ethnic group was based on a concordance between the sources, Ibik (1970) and Roberts (1964). From the matching procedure, we find that 30% of ethnic groups in the sample engages in the bride price custom, while the remaining 70% do not.

2.4 Empirical Strategy

This section presents the empirical model to examine the effect of climate shocks on the timing of first marriage for both men and women in Malawi, and explores the variation of this effect across societies where bride price is a customary tradition. Additionally, the section provides an analysis of how the climate shocks influence the age gap between spouses at first marriage across bride price societies. Finally, the section discusses the identification strategy and the potential challenges to the validity of this strategy.

2.4.1 Empirical specification

To assess the impact of climate shocks on the hazard of first marriage timing decisions of both men and women in bride price and non-bride price societies in Malawi, we conduct a survival analysis using the Cox proportional hazard (PH) regression model (Cox, 1972). The event of interest is the time to first marriage for both men and women, and survival is remaining unmarried. The Cox PH model is a semi-parametric model that allows for constant or time-varying covariates.

In the Cox PH model, the hazard rate of an event of interest for an individual i at time t, conditional on covariates $\mathbf{X_i}$, is specified as:

$$h_i(t|\mathbf{X_i}) = h_0(t)\exp(\mathbf{X_i}'\beta) \tag{2.1}$$

where $h_0(t)$ is the unspecified baseline hazard for individuals at $\mathbf{X_i} = 0$. The relative risk of the event associated with the set of covariates $\mathbf{X_i}$ is denoted by $\exp(\mathbf{X_i}'\beta)$, and also known as the hazard ratio. Conceptually, the estimation of the regression coefficients, as demonstrated in Cox (1972) is based on the maximization of a partial likelihood function (assuming that event times do not exhibit ties) as follows:

$$\mathbf{L}(\beta) = \prod_{i=1}^{n} \left[\frac{\exp(\mathbf{X_i}'\beta)}{\sum_{j \in R(t_i)} \exp(\mathbf{X_j}'\beta)} \right]^{d_i} \tag{2.2}$$

where $R(t_i)$ represent the group of individuals susceptible to risk at time t_i. Similarly, the partial log-likelihood function obtains as:

$$\ln(\mathbf{L}(\beta)) = \sum_{i=1}^{n} d_i \left\{ \mathbf{X_i}'\beta - \ln \sum_{j \in R(t_i)} \exp(\mathbf{X_j}'\beta) \right\} \tag{2.3}$$

and inferences about the regression parameters are thus drawn from the maximum log-likelihood function.

In this paper, the set of covariates $\mathbf{X_i}$ is characterized by the climate-related economic conditions at the time of marriage and the cultural custom of bride price transfer. Specifically, we consider the climate-induced income shocks due to droughts and floods, and the bride price custom, to estimate the hazard rate of first marriage for individuals at time t in bride price relative to non-bride price societies as follows:

$$h_i(t|x_1, x_2, x_3) = h_0(t) \exp\{\beta_1 Climateshocks + \beta_2 Brideprice + \beta_3 Climateshocks \times Brideprice + \delta_s\} \tag{2.4}$$

The covariate $Climateshocks$ denotes the drought and flood shocks. We can respecify equation 2.4 for each climate shock variable as:

$$h_i(t|x_1, x_2, x_3) = h_0(t) \exp\{\beta_1 Drought + \beta_2 Brideprice + \beta_3 Drought \times Brideprice + \delta_s\} \tag{2.5}$$

$$h_i(t|x_1, x_2, x_3) = h_0(t) \exp\{\beta_1 Flood + \beta_2 Brideprice + \beta_3 Flood \times Brideprice + \delta_s\} \tag{2.6}$$

Equations 2.5 and 2.6 are estimated separately for the men and women samples. The covariate $Drought$ or $Flood$ is a time-varying measure of droughts or floods respectively in a geographical location (grid cell) during a given year, between 1950 and 2015, when an individual is at age t. To be specific, the $Drought$ variable is a binary indicator coded as 1 in a particular year when a drought occured and 0 otherwise, and similarly the $Flood$ variable is also a binary indicator coded as 1 when a flood occurs in a given year and 0

otherwise. The time-invariant covariate, $Brideprice$, is a dummy indicator for whether an individual belongs to a bride price society. β_3 in both equations 2.5 and 2.6 is the main coefficient of interest defined by the interaction between the climate shock variables and the bride price tradition, which measures the effect of a drought or flood on the timing of first marriage for men and women in bride price societies relative to non-bride price societies. We include survey (DHS) year fixed effects (δ_s) in the estimations and cluster the standard errors at the level of grid cells to accommodate the potential serial correlation of error terms among individuals residing in the same geographic area.

In a further analysis, we examine the equilibrium outcomes of the marriage timing decisions, due to the climate shocks, from both the grooms' side (demand) and brides' side (supply) of the marriage market. To do this, we investigate the impact of the drought and flood shocks on the age gap between husbands and wives at first marriage, and its variation across bride price societies, by estimating the following equation:

$$Agegap_{ig} = \alpha_0 + \alpha_1 Climateshocks_{g,t} + \alpha_2 Brideprice + \alpha_3 Climateshocks_{g,t} \times Brideprice + \delta_s + \gamma_g + \epsilon_g \tag{2.7}$$

where the outcome variable, $Agegap_{ig}$ is the age difference at first marriage between spouses i (husband and wife) in a location g. The climate shocks and bride price tradition covariates are as defined from equations 2.5 and 2.6. Women who have never been married are excluded from the sample. The main coefficient of interest, α_3, measures the impact of the drought or flood shocks on the age gap between husbands and wives at first marriage in bride price societies. This ascertains whether prospective brides get married to relatively older grooms in bride price societies relative to non-bride price societies. We discuss this further in the results section. We include survey year fixed effects (δ_s), as well as grid fixed effects (γ_g) to capture time-invariant grid attributes. The standard errors for the estimates are clustered at the grid cell level.

2.4.2 Identification strategy and potential threats

A major assumption for the identification strategy in our analysis stems from the construction of the climate shocks within each grid cell. The drought and flood covariates are independent of potential confounding factors. This is because, we follow Burke et al. (2015) and Corno et al. (2020) to construct the drought and flood shock variables in a way that each grid cell has an equal likelihood of encountering a shock in any particular year.

As a result, the climate fluctuations across grid cells are distinct through the random occurrences of these shocks. Given the number of unobservables, including the wealth and educational history of parents at the time of an individual's first marriage as well as the quantity of their siblings which may impact the timing of marriage (e.g. Vogl, 2013), the significance of the exogeneity of the climate shocks in our analysis is vital.

Secondly, the DHS dataset only provides information on an individual's current place of residence, as reported during the surveys, but it does not indicate where they lived at the time of their first marriage. Given that the climate shocks considered in our analysis may not have occurred at a location (grid cell) where an individual initially got married, this may potentially pose a challenge to our identification strategy. As a consequence, the measurement of the climate shocks may be erroneous due to the possibility that an individual's current place of residence might vary or be significantly distant from their original location at the time of first marriage. A number of reasons can suffice for this potential threat to identification. As in Corno et al. (2020), first, the traditional customs of patrilocality (residence with or near the husband's kin) and matrilocality (residence with or near the wife's kin) may determine migration at first marriage. Hence, the location (village, town, or city) where an individual currently resides during the survey interviews may vary from their pre-marital residence. A second reason is that an individual and their families could relocate after getting married, but prior to the administration of the surveys.

In the context of our analysis, we find that, migration following marriage, does not seem to pose a significant challenge to the effectiveness of our identification strategy. This is because, we exploit information in the DHS on the number of years ever-married individuals have lived in their current place of residence at the time of the survey interviews and the number of years since they first got married, to determine those who migrated to their current residence within a year of their first marriage. We find that more than 71% and 64% of men and women respectively reported not to have migrated at the time of their first marriage. When marriage-related migration occurs in SSA, it typically involves relatively short distances (Mbaye and Wagner, 2017), with most spouses, on average in Malawi, residing within 5 kilometers of each other prior to marriage (Cherchye et al., 2018).

Finally, another plausible challenge to identification in our analysis is the potential inaccuracies from individual's recollection of their age and year of first marriage, as reported in the DHS dataset. The errors in men and women's ability to accurately recall the age and year of their initial marriage could result in less precise estimates in our analysis. Fortunately, studies such as Pullum (2006) have validated the reliability of age-related information in the DHS, thereby alleviating the potential impact of such measurement errors in our analysis.

2.5 Results

In this section, the main results are presented on the effect of climate shocks (drought and flood) on the hazard into first marriages for men and women, and its variation across societies in Malawi that engages in the custom of bride price and those that do not. The results on the effect of the drought and flood shocks on the age gap at first marriage are also reported. Here, we show the estimates of the Cox PH model from equations 2.5 and 2.6 for both men and women samples. In particular, we report the estimated regression coefficients (Columns 1 and 3) and the corresponding hazard ratios (Columns 2 and 4) for the effect of droughts and floods on the timing of first marriage, and its interaction with the custom of bride price.

2.5.1 Effect of drought shocks on first marriage hazards, and age gap at first marriage

Table 2.1 shows the estimates for the impact of drought shocks on the hazard of first marriages for both men and women in Malawi, as well as the age gap at first marriage. The sign of the coefficients in Columns (1) and (3) indicate a high or low risk of the marriage hazard, while the hazard ratios in Columns (2) and (4) provide the effect sizes of the covariates. The hazard ratios can be interpreted as multiplicative effects on the marriage hazards.

First, we find that, for non-bride price societies, droughts are associated with an increase in the hazard of entering first marriages for both men and women in Malawi, as we obtain hazard ratios greater than 1. In particular, we show that, at age t, drought exposure increases the hazard into first marriages in a given year for men by 28.1% (i.e. (1.281 - 1) $\times$ 100) or a factor of 1.28 ($p < 0.01$). For women in these non-bride price societies, drought exposure in a given year also increases the hazard of getting into their first marriages within that same year by 24.3% (i.e. (1.243 - 1) $\times$ 100) or a factor of 1.24 ($p < 0.01$).

Second, for men and women in bride price societies, the hazard of entering their first marriages in the absence of a drought shock is lower, and these effects are statistically significant. However, when they are exposed to a drought shock, we find that this negative effect (from the interaction term) is even stronger for men. Specifically, we show that men in bride price societies who experience a drought shock in a given year are more likely to delay the timing of their first marriages (thus a lower hazard into marriage) by 19.2% (i.e. (1 - 0.808) $\times$ 100) or a factor of 0.81 ($p < 0.05$) relative to men in non-bride price societies. For women, on the other hand, we find no effect for the interaction term.

Table 2.1: Droughts, First Marriage Hazards, and Age Gap at First Marriage in Malawi

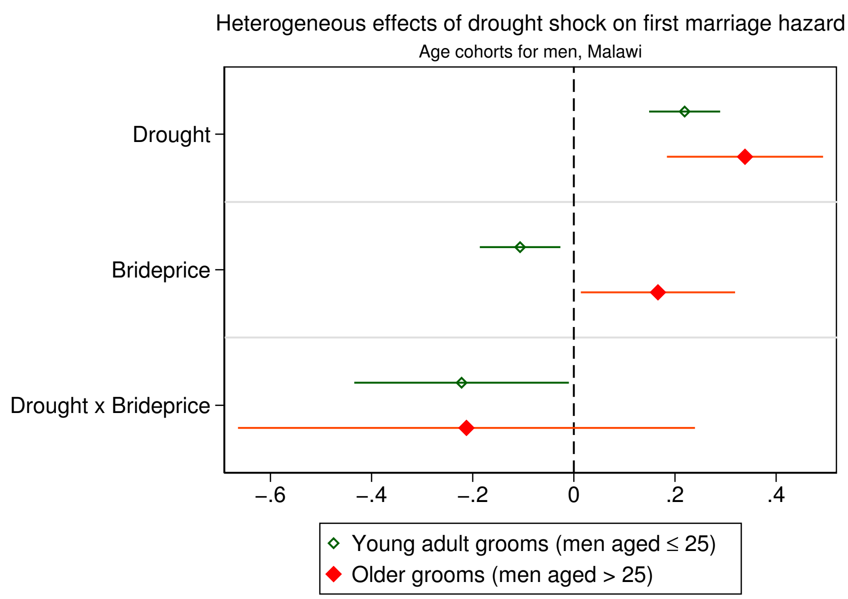
	Men Sample		**Women Sample**		**Husband-wife Age Gap**
	Coefficients[a]	Hazard Ratios	Coefficients[a]	Hazard Ratios	OLS Estimates
	(1)	(2)	(3)	(4)	(5)
Drought	0.248***	1.281***	0.218***	1.243***	-0.013**
	(0.032)	(0.041)	(0.016)	(0.020)	(0.006)
Brideprice	-0.066*	0.936*	-0.031*	0.969*	0.353**
	(0.038)	(0.035)	(0.017)	(0.017)	(0.148)
Drought $\times$ Brideprice	-0.213**	0.808**	0.021	1.021	0.051*
	(0.100)	(0.080)	(0.045)	(0.046)	(0.029)
Survey Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	No	No	No	No	Yes
R-Squared					0.016
Observations	725,387	725,387	3,331,820	3,331,820	2,698,823

[a] Coefficient = ln (hazard ratio)

Note: *** p<0.01, ** p<0.05, * p<0.10. Cox PH estimates for Columns (1) – (4) on the timing of first marriages, and OLS regression for the husband-wife age gap in Column (5). A drought is characterized by a calendar year's rainfall observation that falls below the 15th percentile of a grid cell's historical long-run (1950-2015) rainfall distribution. A flood is characterized by a calendar year's rainfall observation that is in excess of the 85th percentile of a grid cell's historical long-run (1950-2015) rainfall distribution. Standard errors are in parenthesis and clustered at the grid-cell level.

The negative interaction term – i.e the differential effect of drought exposure – realized for men could be primarily driven by the custom. The presence of the bride price custom imposes liquidity constraints which are even more pronounced following a contraction in income caused by the drought shock, making it difficult for grooms (young and old) to make the payment. However, the bride price transfer causes a bigger financial duress for younger men (Platteau and Gaspart, 2007), while older men who are relatively more likely to be landowners and wealthier, may be better placed to cope with the income shock following the drought. The opportunity costs of entering into marital unions following adverse income shocks would be high in these bride price societies, as resources may have to be diverted away from other non-income generating activities to fulfill the bride price obligation. We investigate whether the differential impact of drought exposure on first marriage hazards for men in bride price societies are likely to vary by the age cohort of grooms in Figure 2.4: young adult grooms (men aged ≤ 25) and older grooms (men aged > 25).[3] The estimated coefficients in Figure 2.4 show that, in bride price societies, younger men have a lower hazard of entering their first marriages relative to older men. However, while the marriage hazard is negative for both set of grooms following a drought shock, it is not clear whether the effects are relatively stronger for younger grooms.

Figure 2.4: Drought shock: Heterogeneous effects by age cohort of men



We next explore the equilibrium outcome of the hazard into first marriages for both men and women following drought shocks on the age gap at first marriage. We show this in Column (5) of Table 2.1 which reports the estimation result from a version of the OLS regression in equation 2.7 that considers the effect of drought shock on the husband-

[3]We categorize men aged below 25 as young adult grooms, given that the United Nations (UN) and the World Health Organization (WHO) considers individuals aged 15 to 24 as youth. In addition, the median age at first marriage for men in the sample is approximately 23.

wife age gap at first marriage, and the differential impact by bride price societies. The results are obtained using the women's sample (but excluding women who have never been married), and information on the age of their respective partners at the time of first marriage.

We find that the husband-wife age gap in bride price societies is positive and statistically significant. Drought exposure increases this effect even further – in particular, we find that, on average, the husband-wife age gap at first marriages in a given year of drought exposure is increasing in bride price societies by 0.051 years. Conversely, exposure to droughts in non-bride price societies is associated with a decline in the age gap at first marriages and this effect is also statistically significant. The widening husband-wife age gap observed in societies that engage in the custom of bride price transfer in Malawi suggests that the presence of the custom plays an influential role in marriage timing decisions. As a result, the bride price transfer, which can be a significant constraint, is likely to influence women to marry grooms who are better able to meet this obligation, potentially contributing to an increased prevalence of polygynous marriages and larger husband-wife age gaps in bride price societies. We provide evidence on this later in section 2.7.

2.5.2 Effect of flood shocks on first marriage hazards, and age gap at first marriage

The estimates for the impact of flood shocks on the first marriage hazards for men and women in Malawi is reported in Table 2.2. We find that, in non-bride price societies, exposure to floods is associated with a decrease in the hazard of first marriages for both men and women, and these effects are statistically significant. Specifically, floods decrease the probability of men and women entering their fist marital unions by 27.9% (i.e. (1 - 0.721) $\times$ 100) or a factor of 0.72 and 29.6% (i.e. (1 - 0.704) $\times$ 100) or a factor of 0.70 respectively.

Table 2.2: Floods, First Marriage Hazards, and Age Gap at First Marriage in Malawi

	Men Sample		**Women Sample**		**Husband-wife Age Gap**
	Coefficients[a]	Hazard Ratios	Coefficients[a]	Hazard Ratios	OLS Estimates
	(1)	(2)	(3)	(4)	(5)
Flood	-0.327***	0.721***	-0.350***	0.704***	0.005
	(0.037)	(0.027)	(0.020)	(0.014)	(0.009)
Brideprice	-0.121***	0.886***	-0.067***	0.935***	0.372**
	(0.038)	(0.034)	(0.019)	(0.018)	(0.147)
Flood $\times$ Brideprice	0.133	1.142	0.290***	1.336***	-0.052
	(0.113)	(0.129)	(0.040)	(0.053)	(0.069)
Survey Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	No	No	No	No	Yes
R-Squared					0.016
Observations	725,387	725,387	3,331,820	3,331,820	2,698,823

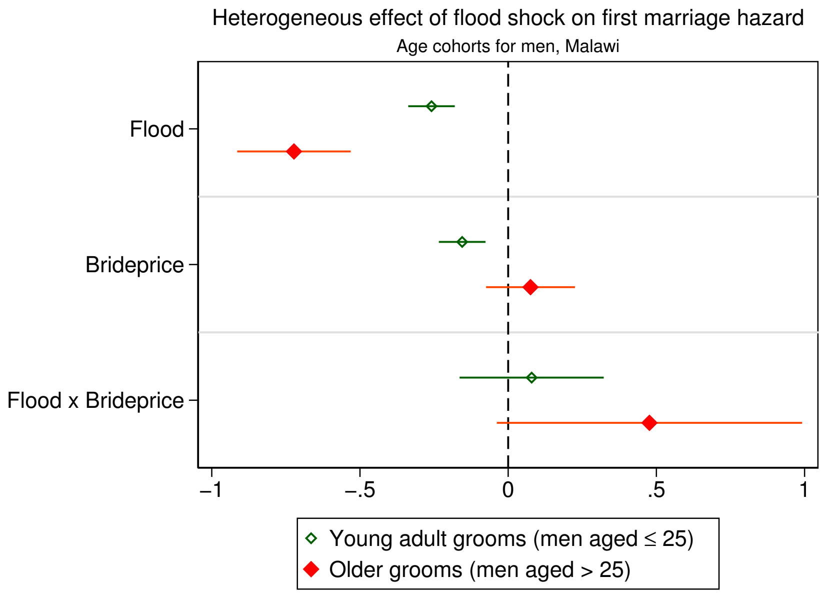
[a] Coefficient = ln (hazard ratio)

Note: *** p<0.01, ** p<0.05, * p<0.10. Cox PH estimates for Columns (1) – (4) on the timing of first marriages, and OLS regression for the husband-wife age gap in Column (5). A drought is characterized by a calendar year's rainfall observation that falls below the 15th percentile of a grid cell's historical long-run (1950-2015) rainfall distribution. A flood is characterized by a calendar year's rainfall observation that is in excess of the 85th percentile of a grid cell's historical long-run (1950-2015) rainfall distribution. Standard errors are in parenthesis and clustered at the grid-cell level.

In the case of bride price societies, the hazard of entering first marriages is negative (and hence lower) for both men and women. However, following a flood shock in these bride price societies, this effect becomes positive for both gender but only statistically significant for women. In particular, we find that the hazard of entering first marriages is higher for women in bride price societies following a flood shock in a given year, as they are more likely to enter their first marital unions by 33.6% relative to women in non-bride price societies.

In Figure 2.5, we show the heterogeneous effects for the sample of men by age cohort. The marriage hazard is negative for young adult grooms in bride price societies but no effect for older grooms. We also find that, while the main coefficient of interest – the interaction term – is positive, it is not statistically different from zero for both young adults and older grooms. This imply that, unlike droughts, the nature of flood shocks make it less influential for marriage timing decisions for both set of grooms in bride price societies.

Figure 2.5: Flood shock: Heterogeneous effects by age cohort of men



Column (5) of Table 2.2 reports the equilibrium outcome of the husband-wife age gap at first marriage, following the marriage hazards for both men and women after exposure to floods. We find that, the age gap between spouses at first marriage is positive and statistically significant in bride price societies relative to non-bride price societies. However, exposure to flood shocks have no impact on the age gap in both societies. This suggest that the constraints faced during drought shocks, particularly by the demand side of the market, are not true in the case of flood shocks. Hence, in contrast to drought shocks, the bride price transfer is less binding in bride price societies following a flood shock. A plausible reason for this could be attributed to the nature of flood shocks.

Flood shocks are more localized and less spatially concentrated, relative to droughts which occur over a wider geographical area. Thus, flood shocks allow for potential smoothing mechanisms to mitigate their impact, such as work-related short-term migration. Specifically, following a flood shock, both young adults and older men may temporarily migrate out of their villages to less distant areas for work, making them physically absent to initiate marital unions. The potential income smoothing opportunities following flood shocks effectively diminishes the significance of relying on self-insurance mechanisms, such as savings, for both young and older men. As a result, we see no differential effect of the bride price custom interacted with the flood shocks on the hazard into first marriages for men, and on the husband-wife age gap. The positive hazard of entering first marriages observed for women may possibly involve migration from these bride price societies. We discuss in detail the asymmetric effect of drought and flood shocks in the next section.

2.6 Asymmetry between Drought and Flood Shocks

Drought and flood shocks have been shown to be a significant source of income variability, particularly in rural economies that are heavily reliant on rain-fed agriculture. The adverse effect of these extreme weather events on household income, particularly in agricultural economies, has been validated and well-documented in existing economic literature. To confirm that in this paper, Table A2 in the Appendix shows the estimated effect of drought and flood shocks on total annual household consumption per capita (a proxy for household income) using data from the World Bank's Integrated Household Survey for Malawi, and combined with our climate data. The estimations involve an OLS regression with grid fixed effects and standard errors clustered at the grid cell level. We also include controls in the estimations. From Table A2, we find a negative impact of droughts and floods on household consumption: specifically, droughts and floods reduce household consumption by 6.2% and 13.2% respectively, and are both statistically significant at the 1% level.

However, there exist a plausible asymmetry in the economic and social impacts of droughts and floods. In the previous section, we show that drought and flood shocks, via their impact on low aggregate income, potentially have contrasting effects in the context of marriage behaviour for men and women in Malawi. Here, we discuss in general, a number of reasons for the asymmetry between drought and flood shocks.

First, droughts are long-lasting and can exert a more persistent impact on agricultural productivity compared to floods. As a result, droughts can lead to sustained negative impacts on crop failures and livestock deaths (e.g. Ding et al., 2011). While floods, on the other hand, are capable of causing damage to crops and livestock, they can also deposit fertile silt on farmlands, contributing to improved crop yields (e.g. Pauw et al., 2010; Shah and Steinberg, 2017). Table A3 in the Appendix present evidence supporting the apparent variation in the impact of drought and flood shocks on crop yields in Malawi. We estimate the effect of the drought and flood shocks on the natural logarithm of maize and rice yields, the two main staple crops in Malawi. Maize is the main staple food in Malawi, which is grown in 80% of all Malawian farms, and also an income-generating crop that accounts for about 25% of agricultural employment (FAO, 2020). To carry out the estimations, we use data from FAOStat for Malawi over the period 1961 – 2017 together with our climate data [4]. The results from Table A3 show that droughts and floods reduce maize and rice yields in Malawi, but this effect is insignificant in the case of floods. Droughts in particular reduce both maize and rice yields by 21.5% (Column 3). These findings suggest that agricultural productivity in Malawi is substantially impacted by droughts to an extent not true for floods.

Second, droughts can have a more widespread impact on an economy than floods. This distinction arises from the localized nature of floods, which are less spatially concentrated and typically occurs on short time scales due to heavy rainfall. In contrast, droughts are extensive and can affect large regions or entire countries (Trenberth, 2005; Intergovernmental Panel on Climate Change (IPCC), 2014). Additionally, unlike floods, drought conditions are relatively slower to develop, until precipitation shortages reach a critical level, implying that it already has a significant impact on households and the economy by the time it is detected (Ding et al., 2011).

2.7 Mechanism: Junior Wives in Polygynous Marriages

In this section, we investigate the mechanism that explains the main findings of this paper. We show in the previous section that: First, men exposed to drought shocks in bride price societies delay the timing of their first marriages whereas women in these same societies do not, leading to higher husband-wife age gaps. This suggests that, women in these societies marry men who are still able to meet the bride price obligation in spite of income shocks. Second, following a flood shock, we find no differential effect for the hazard of entering first marriages for men, due to the potential income smoothing of flood shocks, and the bride price transfer which is less binding in this instance. On the other hand, we see that the differential effect of the hazard into first marriages for women is significant when exposed to flood shocks. In equilibrium, we find no significant differential impact of the flood shock on the husband-wife age gap.

[4] The drought and flood shocks are as defined in the previous sections but the long-run distribution used in the calculations are from 1961 – 2017, to ensure consistency with the period from the FAOStat dataset

In what follows, we examine the potential mechanism for the above findings, by investigating whether women in bride price societies are more likely to enter their first marital unions as junior wives (i.e. second or higher order wives) in polygynous marriages, rather than as a first or sole wife. To do this, we use the women sample to estimate a version of equation 2.7 given as:

$$Juniorwife_{ig} = \alpha_0 + \alpha_1 Climateshocks_{g,t} + \alpha_2 Brideprice + \alpha_3 Climateshocks_{g,t} \times Brideprice + \delta_s + \gamma_g + \epsilon_g \quad (2.8)$$

where the dependent variable is an indicator for whether a woman i in location g marries as a junior wife in her first marriage, as opposed to being the first and/or only wife. The covariates representing climate shocks and the bride price custom are defined in the same manner as in equation 2.7, as well as the survey and grid fixed effects.

We show in Figures 2.6 and 2.7 that, the effects are likely to differ by the age cohorts of women. We find that, potential brides – particularly young adults (aged between 18 and 29) and older brides (aged above 30) – in societies that engage in the bride price custom have a higher likelihood of entering their first marriages as junior wives, compared to their counterparts in non-bride price societies. However, we observe no effects for the same age cohort of brides in these bride price societies following a drought shock. The only effects observed are concentrated among child brides, where the interaction term is statistically significant at the 5 percent level. In particular, girls below the age of 18 who are exposed to a drought in bride price societies have a higher likelihood to be married as junior wives in polygynous unions by 1.1 percentage points, which constitute 16.4% of the mean proportion of junior wives in the sample. This suggest that, following drought shocks in societies where liquidity constraints for initiating marriage are binding due to the bride price custom, older women are less desirable on the market by grooms and particularly as second/higher order wives. As a result, younger women have a higher likelihood to marry older men (relative to younger men) who are perhaps already married, wealthier and more self-insured and resilient to the drought shock. This result confirms the higher husband-wife age gap, following droughts in bride price societies, that we find in section 2.5.1. In a related evidence, Tapsoba (2023) document that, following a negative income shock, the demand for second wives exhibits a higher sensitivity to reductions in income and bride price than the demand for first wives.

Figure 2.6: Drought shocks and junior wives, by age cohorts

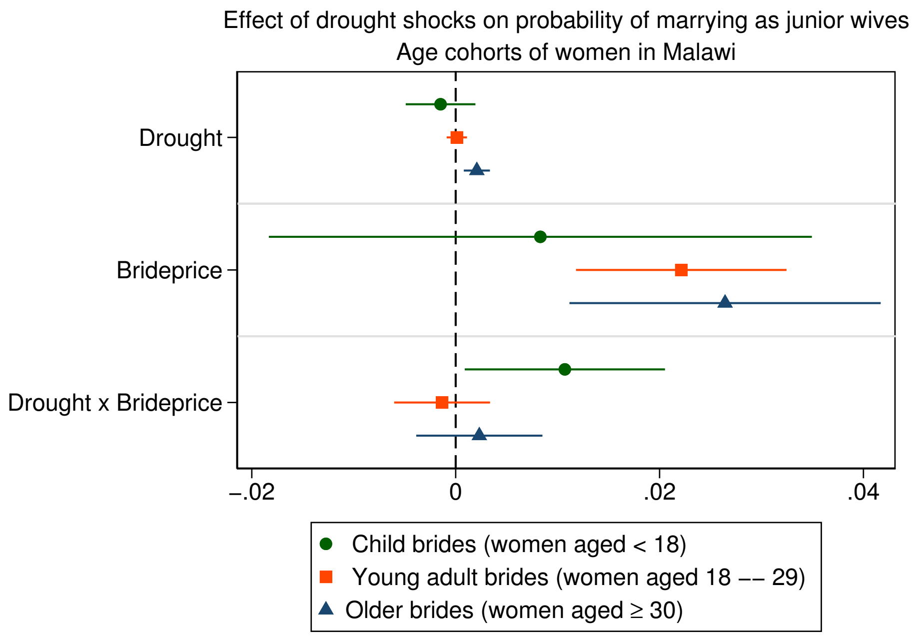
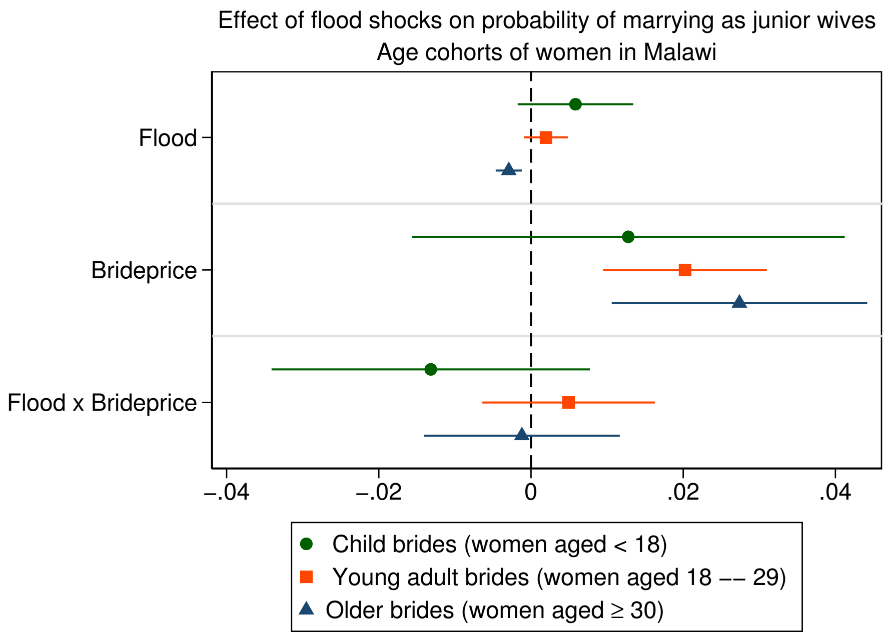


Figure 2.7: Flood shocks and junior wives, by age cohorts



Coefficients of regressions: The indicator for junior wives on climate shocks and interaction with bride price societies. A drought is characterized by a calendar year's rainfall observation that falls below the 15th percentile of a grid cell's historical long-run (1950-2015) rainfall distribution. A flood is characterized by a calendar year's rainfall observation that is in excess of the 85th percentile of a grid cell's historical long-run (1950-2015) rainfall distribution. All the regressions include survey year FE and standard errors are clustered at the grid-cell level.

In the case of floods, we find that the differential effects are not significantly different from zero for the different age cohorts of women. This suggest that there is no differential impact of the exposure to flood shocks on the probability of younger or older women marrying as junior wives in both societies. This finding is consistent with the results we find for the husband-wife age gap following flood shocks, which is not statistically significant. A plausible explanation that suffices here is the previously mentioned nature of flood shocks, which have important implications on the demand for brides. In particular, the potential smoothing opportunities such as short-term migration by both young and older men, as well as the notion that the bride price, in effect, may not bind as much following a flood shock.

2.8 Robustness Checks

In this section, we consider various robustness checks to affirm the validity of our main findings from section 2.5.

First, we re-estimate the impact of the drought and flood shocks on the marriage timing for men and women, by adjusting the threshold levels for our measure of drought and flood. For the drought measure, we vary the cut-off for rainfall realization that falls below the 20th and 45th percentile of a grid cell's historical long-run rainfall distribution. For floods, we consider rainfall observations that are in excess of the 75th and 90th percentiles. Tables A4 and A5 in the Appendix show the outcomes of the Cox PH and OLS estimations using the revised measures for drought and flood, for both men and women samples respectively. In principle, we find that the hazard ratios for our main variable of interest – the interaction between droughts or floods and the indicator for bride price societies – remain relatively consistent in comparison to the default cut-offs used in the main analysis. We also show the results for the age gap at first marriage using the revised cut-offs for the drought and flood measure. The results are very similar to the default cut-off from the main analysis, albeit we find no significant point estimate for the interaction term for drought.

Second, we show in Appendix Tables A6 and A7 that the effect of drought and flood shocks on the hazard into first marriages and husband-wife age gaps are robust to the inclusion of year fixed effects to account for differential trends over time.

Finally, we assess the robustness of the main findings by excluding communities near the lake, which are the most vulnerable to flooding. The Lower Shire Valley, located in the flood-prone southern region of Malawi, is drained by the Shire River – the only outlet of Lake Malawi. This valley spans two administrative districts, Chikwawa and Nsanje, both of which have poverty rates (defined as living on less than $0.40 per person per day) exceeding 80%, the highest in the country (Mwale et al., 2015). After excluding communities from these districts, we show in Appendix Tables A8 and A9 that the key results on the impact of drought and flood hazards on first marriage entry and age gaps remain consistent, albeit the interaction term for the age gap analysis in the case of drought shocks is not statistically significant.

2.9 Conclusion

This paper provide empirical evidence on the interplay between climate shocks, cultural norms, and marriage behaviour in Malawi. It sheds light on how drought and flood shocks differentially impact the hazard into first marriages and husband-wife age gaps, with distinct implications for men and women across bride price and non-bride price societies. Droughts result in delayed first marriages for men in bride price societies due to the financial burden of the binding bride price custom, while there is no differential effects realized for women, leading to a higher husband-wife age gap in these societies. Flood shocks, on the other hand, do not exhibit a similar differential effect on marriage hazards for men, due to its localized nature and potential smoothing mechanisms. However, women in bride price societies experience a higher likelihood of marrying early after exposure to flood shocks, indicating a unique gendered response to different climate shocks. The widening husband-wife age gap in bride price societies in Malawi, following a drought, is manifested in the increased likelihood of young women entering polygynous marriages as junior wives. This merits attention, as it may have adverse long-term consequences for women's empowerment, socio-economic outcomes, and health.

The findings in this paper provide insight for policy makers, researchers, and practitioners working towards sustainable and inclusive development in the face of climate change and evolving cultural landscapes. It underscores the need for nuanced policy interventions and effective safety net programs which takes into account cultural norms and climate fluctuations to address socio-economic disparities and promote sustainable development.

Chapter 3

Polygyny, weather shocks and breastfeeding: Evidence from Malawi

3.1 Introduction

Polygyny – the practice of marriage between a man and multiple wives – is prevalent in Sub-Saharan Africa (SSA), particularly in rural areas, where over 50 percent of children in some SSA countries live in polygynous households (Wagner and Rieger, 2015) and 1 in 4 women are in polygynous marriages (Dalton and Leung, 2014; Arthi and Fenske, 2018). In many of these SSA countries where rural poverty is widespread and local economies depend heavily on rain-fed agriculture, early-life weather shocks play a crucial role in determining children's health outcomes (e.g. Hoddinott and Kinsey, 2001; Dercon and Hoddinott, 2004). These shocks may have particularly significant effects in polygynous rural households, where the dynamics of co-wives' relationships, pertaining to resource and time allocations could lead to different welfare outcomes for women and their children.

Existing research on the impact of family structure on children's health outcomes primarily focuses on the effects of polygamy relative to monogamy (e.g. Smith-Greenaway and Trinitapoli, 2014; Wagner and Rieger, 2015). Moreover, while the effect of rainfall shocks on children's health outcomes in developing countries are well documented, the mechanisms driving these effects within polygynous rural households remain largely unclear. Much of the literature on developing countries have concentrated on mechanisms including income shocks and the disease environment, but insufficient attention has been given to how the opportunity cost of parental time may influence these outcomes.[1] In

[1] It is well-established in the literature that rainfall significantly influences income fluctuations. See Paxson (1992), Dercon (2004), Duflo and Udry (2004), and Levine and Yang (2006)

particular, rainfall shocks can alter women's labor demand, which could in turn affect maternal behavior and childcare practices. These effects may be different in polygynous relative to monogamous households due to factors such as competition, relative bargaining power, risk-sharing opportunities, and co-wives engaging in self-serving strategic behavior.

In this paper, we study the effect of early-life rainfall shocks on the breastfeeding duration of similarly aged children (0 – 48 months) born to co-wives in polygynous rural households in Malawi. The paper utilizes data from Malawi's Demographic and Health Surveys (DHS), which is combined with historical rainfall data from the Matsuura and Willmott (2009) dataset. Rainfall shocks are measured as deviations from the long-term average in a child's location (grid cell) during their birth year and the second year of life. Given that crop production in Malawi relies on rain-fed agriculture, fluctuations in rainfall can significantly affect household income, and consequently children's nutrition and health. However, rainfall variability impacts more than just income; it also influences the opportunity cost of agricultural labor time, particularly for women.

This study hypothesizes that rainfall shocks will differentially affect breastfeeding practices among co-wives in polygynous households due to the interplay between resource allocation dynamics, particularly in terms of decision-making power, and the opportunity cost of labor time. On one hand, first wives, often holding a more established role in the household, may face a relatively lower opportunity cost of labor during rainfall shocks. Consequently, they might maintain breastfeeding practices even when agricultural labor demand increases. This is because they may have more direct access to household resources or greater decision-making power. On the other hand, junior wives, who might have less secure access to household resources and weaker bargaining power, are likely to be more affected by the increased opportunity cost of time brought about by rainfall shocks. This could result in a reduction in breastfeeding duration due to a stronger necessity to participate in agricultural or income-generating activities. The differential responses of first and junior wives are expected to reflect their varying access to household resources and their strategic behavior in ensuring the survival and well-being of their children.

This paper explores the opportunity cost of time and household decision-making power between co-wives as potential mechanisms linking rainfall shocks to breastfeeding patterns within polygynous households in rural Malawi. According to the World Health Organisation (WHO) and the United Nations Children's Fund (UNICEF), optimal breastfeeding, where children are exclusively breastfed for the first 6 months, followed by the introduction of nutritionally adequate foods alongside continued breastfeeding up to 2 years or beyond, could save the lives of over 820,000 children under the age of 5 each year. While breastfeeding is crucial for children's health and development, it is also a time-intensive childcare activity that can be influenced by rainfall patterns, via changes in maternal labor demand. We provide evidence in this paper that suggests the opportunity cost of time channel through which rainfall affects the duration of breastfeeding among children of polygynous co-wives.

First, we estimate the effect of linear rainfall shocks in the first and second years of a child's life, on the length of time they are breastfed. We find that, while rainfall shocks during a child's birth year has no effect on breastfeeding duration, rainfall in the second year after birth does have a statistically significant positive effect on breastfeeding duration. Rainfall shocks in the second year leads both senior and junior wives to breastfeed longer, although the effect is relatively larger for children of senior wives. This suggest that exposure to rainfall shocks in the second year are most crucial for prolonged breastfeeding. Additionally, the larger effect observed among senior wives highlights the complementary role of resource access and bargaining power, which allows them to better mitigate the trade-offs between labor and caregiving. In the first year, mothers tend to breastfeed intensively – about 85 percent of children in the sample are breastfed beyond 6 months, albeit this rate drops sharply after 12 months. In some African countries, women are given ample time to recover and care for their infants post-childbirth (Kim, 2010). This finding relatedly aligns with previous research (e.g. Glewwe and King, 2001; Hoddinott and Kinsey, 2001; Dercon and Porter, 2014) that identifies the second year after birth as the most critical for children's nutrition and health. Rainfall shocks often lead to income shocks and nutritional shortages with a delay (Weldesenbet, 2022), as reduced crop yields from low rainfall, for instance, only become apparent during the harvest season. Additionally, rural households often rely on food stores, which temporarily cushions them from nutritional shortages. The effects of lack of income or food on extended breastfeeding days is thus likely to be realized in the second year. Breastfeeding provides a critical, low-cost source of nutrition that can help mitigate the effects of low income and food scarcity. In situations where income is limited and food supplies are uncertain due to rainfall variability, particularly during lean periods between harvests, mothers may rely on breastfeeding as a way to ensure that their children receive adequate nourishment. As a consequence, infant's nutritional shocks and the time cost of continued breastfeeding for mothers, due to rainfall shocks, are more likely to be felt in the second year after childbirth.

Secondly, in contrast to treating rainfall shocks linearly, we disaggregate the rainfall shocks into negative versus positive shocks to estimate their differential impacts on breastfeeding duration. We find that negative rainfall shocks in the first year do not impact breastfeeding duration, with no differences between co-wives. This suggests that breastfeeding in the first year may be less affected by the opportunity cost of agricultural labor, as labor market pressures are low and consistent across co-wives. However, for negative rainfall shocks in a child's second year, junior wives in polygynous households tend to breastfeed longer (by approximately 32 days) than senior wives. This suggests that, when households are hit by adverse rainfall shocks in a child's second year, the opportunity cost of time mechanism is more dominant for junior wives. In effect, a decline in agricultural labor enables junior wives to breastfeed for longer periods. In contrast, senior wives, with more resources and bargaining power, may prioritize breastfeeding, but economic pressure from negative rainfall shocks may lead them to wean earlier and reduce breastfeeding duration. In these polygynous rural households, how resources and time are allocated in response to rainfall shocks can have different outcomes, especially if they either favor senior or junior wives. The trade-off between work and childcare time implies that positive rainfall shocks may prompt women to wean their children sooner, as taking time away from farming could result in significant income losses. Conversely, during negative rainfall shocks, reduced farm labor demand and limited alternative employment opportunities in rural areas result in more time for childcare. Senior wives, however, may wean their children earlier because their established household status imply that they might have more control over household resources and can afford alternative nutrition, such as supplementary foods or formula. In addition, because senior wives may be pressured to remain productive to maintain their status within the household, they might wean their children earlier to quickly return to alternative off-farm economic activities such as trading. In SSA polygynous rural households, the relationship between co-wives is often characterised by competition rather than co-operation (e.g. Rossi, 2019), which implies that co-wives compete for agricultural resources, food, and wealth (Kazianga and Klonner, 2009; Mammen, 2019). While some previous studies have shown that women in SSA can rely on extended family networks for childcare support (e.g. Serpell, 2010; Madhavan and Gross, 2013; Clark et al., 2018), recent evidence by Donald et al. (2024) across 32 SSA countries indicate that direct childcare hours including breastfeeding and weaning largely remains the mother's responsibility. Extended family support to mothers typically includes cooking, cleaning and farming, particularly around childbirth and postpartum periods (Donald et al., 2024).

Finally, we estimate the heterogeneous effect of negative rainfall shocks by the season of a child's birth. That is, whether or not they were born in the wet or dry seasons of the agricultural cycle. We first find that, in principle, children born in the dry season are breastfed for longer periods, relative to those born in the wet season. However, this impact varies depending on whether children are exposed to rainfall shocks and the intensity of the shock, as negative shocks can have different effects depending on whether they take place during the dry or wet seasons. To that end, we find that negative rainfall shocks realized in the dry season – which effectively imply drought conditions – reduces the breastfeeding duration that is seen in the absence of the shock. Moreover, breastfeeding is vital during the dry season for infants (0-6 months) and toddlers (12-18 months). Infants are typically exclusively breastfed, while toddlers rely on breast milk alongside solid foods. The lighter maternal workload in the dry season supports more frequent breastfeeding. However, for children aged 6-12 months and 18-24 months, the wet season has less effect on breastfeeding due to increased food supplementation and ongoing weaning. Women in SSA often bear heavy time burdens due to their roles in agricultural labor and other household responsibilities (Blackden and Wodon, 2006; Raney et al., 2011), which leads to a trade-off between farming, wage work, and nutrition-related activities like food preparation and childcare (Johnston et al., 2018). In Malawi, during the peak agricultural season when labor shortages are most severe, women face the greatest time burdens (Wodon and Beegle, 2006), making it harder to balance farm work with breastfeeding or weaning. In contrast, during the dry season when farming activities slow down coupled with limited availability of irrigation in the case of Malawi (Chafuwa, 2017; de Janvry et al., 2022), these time constraints are expected to ease, allowing mothers more time for infant care. However, droughts during the dry season, due to negative rainfall shocks, can negatively affect maternal nutrition and food consumption, potentially reducing a mother's capacity to produce sufficient breast milk for extended nursing periods.

To effectively promote optimal breastfeeding in the face of a changing climate in SSA, policies must take into account family structures and the realities of maternal labor in rural agrarian communities. In spite of the WHO and UNICEF's efforts to promote exclusive and continued breastfeeding until the age of 2, breastfeeding interventions must be context-specific and more targeted. In response to shocks such as rainfall variability, women in polygynous rural households are likely to make strategic decisions influenced by their rank, which can have varying impacts on the nutritional welfare of polygynous infants.

This paper mainly contributes to the following strands of literature. First, this paper relates to the body of research on adverse early-life weather shocks and health outcomes including children's nutrition in developing countries (e.g. Hoddinott and Kinsey, 2001; Dercon, 2004; Maccini and Yang, 2009; Ampaabeng and Tan, 2013; Rabassa et al., 2014; Rosales-Rueda, 2018; Le and Nguyen, 2021; Nübler et al., 2021; Blom et al., 2022). Second, this paper fits within the literature that looks at the effect of polygyny on children's health outcomes in Sub-Saharan Africa (e.g. Jacoby, 1995; Omariba and Boyle, 2007; Kazianga and Klonner, 2009; Diallo et al., 2012; Lawson et al., 2015; Wagner and Rieger, 2015; Arthi and Fenske, 2018). Most of the studies in the first set of literature either focuses on long-term health outcomes in adulthood or short-term outcomes typically beyond the age of 2 such as height-for-age. In nearly all of the studies in the second set of literature, the outcomes of children in polygynous households are compared to their counterparts in monogamous households. In addition, these studies do not specifically investigate how polygyny affects children's health investments within the context of a changing climate, which affects the time and resources available to polygynous women, particularly in rural households that rely heavily on rain-fed agriculture. We contribute to an intersection of both sets of literature in the following way. We consider the initial effect via breastfeeding until the age of 2 as an important investment for subsequent health outcomes, and then unmask the potentially different breastfeeding outcomes for children born to different mothers in polygynous rural households due to weather shocks.

The rest of the paper is structured as follows. Section 3.2 presents the data and descriptive statistics. The empirical strategy is provided in Section 3.3, and the empirical results are presented in Section 3.4. A discussion on suggestive mechanisms drving the results is provided in Section 3.5. Robustness checks are presented in Section 3.6 and Section 3.7 concludes.

3.2 Data and Descriptive Statistics

3.2.1 Breastfeeding data

This paper uses a nationally representative data from Malawi's Demographic and Health Surveys (DHS) for the 2004, 2010, and 2015 waves.[2] This repeated cross-sectional dataset provides detailed information on various demographic characteristics and health indicators, including nutrition of women and children. The DHS retrospectively provides information on the birth history of women for children born in the five years preceding the survey. Detailed questions about a child's health were asked, including the duration of breastfeeding (in months).

The following sample restrictions are made. First, for the purpose of our analysis, we exclude monogamous households and only consider similarly aged children (0 - 48 months) of co-wives in polygynous rural households. Second, as in Jayachandran and Kuziemko (2011), we consider children who are alive and exclude those who have died, as otherwise their breastfeeding duration would be censored in a way that is not indicative of a mother's decision; this restriction leads to a reduction of fewer than 3 percent of the remaining observations. The final sample involves 3,061 observations.

Descriptive statistics on breastfeeding duration, children and mothers' characteristics are provided in Table 3.1. The sample in Table 3.1 is split to compare summary statistics for children of senior wives versus junior wives in the polygynous households. Note that the sample in the table includes children who are still being breastfed and those already weaned. The average breastfeeding duration for children of senior wives is 16.93 months compared to the 15.60 months observed for junior wives' children, and the mean difference between the two subsamples is statistically significant. The average proportion of children in the sample who have been breastfed for at least a year is 68 percent and 60 percent for senior and junior wives respectively with a significant mean difference. Unsurprisingly, children of senior wives, on average, are older than that of junior wives, given the differential entry into marriage and motherhood. The mean of birth order in the senior wives' subsample is 4.66 and 4.32 in the junior wives' subsample. Both senior and

[2]We exclude the 2000 wave, as it does not include information on a wife's rank in polygynous households.

junior wives in the sample, on average, enter into polygynous marriages at an early age – 17.05 versus 17.50 years respectively. The average years of schooling for junior wives (3.70 years) is slightly higher than that of senior wives (3.42 years), with a statistically significant difference.

3.2.2 Rainfall data

This paper utilizes historical monthly rainfall data spanning the period 1950 – 2016 from the Matsuura and Willmott (2009) dataset, which provides weather conditions globally that are estimated at the 0.5×0.5 degree latitude and longitude grid. To construct early-life rainfall shocks in children's birth location, we first utilise the GPS information from the Malawi DHS to establish a match with corresponding weather grid cells in the Matsuura and Willmott (2009) dataset. Following closely the approach by Maccini and Yang (2009), we then consider rainfall during the wet and dry seasons (instead of calendar years), as these are more closely linked to the agricultural cycle. In Malawi, the wet season is between November and April, while the dry season is between May and October (World Bank, 2023).

We use information in the DHS to identify the birth season for each child, based on their birth month and location (grid cell). Similar to Maccini and Yang (2009), for children born in the last month of a particular season, the subsequent season is considered as their birth season. The allocation of children in the DHS to seasons that define their birth season is illustrated in Figure 3.1.

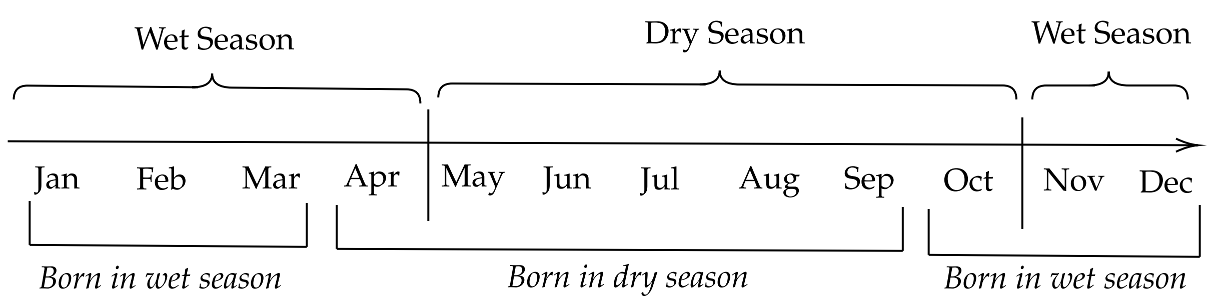


Figure 3.1: Definition of rainfall in a child's birth year in Malawi

As in Maccini and Yang (2009), *rainfall in a child's first year* is the sum of rainfall in their birth season and the subsequent season, which implies total rainfall over 12 consecutive months covering a child's first wet and dry seasons. We then define rainfall shock in a child's first year as the deviation of rainfall in the child's first year after birth from the long-run average in that child's grid cell. That is, the difference in the natural logarithm of birth year rainfall and mean annual rainfall in that grid. The long-run average for each grid cell is calculated over the 1950 – 2016 period. In a similar fashion, we construct rainfall shocks for a child's second year after birth.

The rainfall shock variable is interpreted as the percentage deviation from the average rainfall in a given grid cell. For example, a value of -0.2 implies that rainfall is roughly 20 percent lower than normal. Rainfall shocks exhibit both positive and negative percentage deviations from the norm. From Table 3.1, the average rainfall shock realized in a child's first year is positive, but negative in the second year. The mean difference in exposure to these rainfall shocks between children of senior and junior wives is statistically significant.

Table 3.1: Summary Statistics

	Overall		Children of Senior Wives		Children of Junior Wives		Mean Difference
	Mean	SD	Mean	SD	Mean	SD	
Breastfeeding duration (in months)	17.42	8.95	16.93	8.48	15.60	8.93	1.33***
Breastfeeding over 12 months (=1, 0 otherwise)	0.68	0.47	0.68	0.47	0.60	0.49	0.08***
Breastfeeding over 18 months (=1, 0 otherwise)	0.48	0.50	0.44	0.50	0.40	0.49	0.04**
Rainfall shock, first year (pct. deviation from norm)	0.003	0.117	0.009	0.115	-0.002	0.118	0.010*
Rainfall shock, second year (pct. deviation from norm)	-0.090	0.355	-0.094	0.329	-0.148	0.415	0.054***
Height-for-age (HAZ)	-1.88	1.76	-1.92	1.79	-1.85	1.74	-0.07
Weight-for-age (WAZ)	-0.94	1.21	-0.97	1.21	-0.91	1.21	-0.06
Child age (in months)	26.82	17.35	22.40	13.60	20.96	13.97	1.44**
Child is male (=1, 0 otherwise)	0.49	0.50	0.52	0.50	0.47	0.50	0.04**
Child is female (=1, 0 otherwise)	0.51	0.50	0.48	0.50	0.53	0.50	-0.04**
Birth order	4.43	2.25	4.66	2.26	4.32	2.16	0.34***
Preceding birth interval (in months)	43.34	22.84	42.30	20.19	46.00	25.24	-3.69***
Total children born	4.70	2.23	4.84	2.25	4.49	2.17	0.35***
Mother's age (in years)	30.84	6.64	31.18	6.84	30.60	6.54	0.58*
Mother's age at first marriage (in years)	17.28	3.34	17.05	3.10	17.50	3.52	-0.45***
Mother's education (in years)	3.56	3.21	3.42	3.11	3.70	3.30	-0.28*
Mother works in agriculture (=1, 0 otherwise)	0.51	0.50	0.51	0.50	0.50	0.50	0.01
Mother is household head (=1, 0 otherwise)	0.22	0.41	0.19	0.39	0.25	0.43	-0.06***
Observations	3,061		1,488		1,573		

Note: *** p<0.01, ** p<0.05, * p<0.10. Survey sampling weights are applied in the computation of the summary statistics.

3.3 Empirical Strategy

To study the effect of early-life rainfall shocks on breastfeeding duration, we estimate the following reduced-form equation for similarly aged children (0 - 48 months) of co-wives in polygynous rural households in Malawi, and born between 1999 - 2015.

$$Y_{ifgt} = \beta_0 + \beta_1 \sum Shock_{g,t} + \beta_2 SeniorWife_i + \beta_3 \sum Shock_{g,t} \times SeniorWife_i + \eta Z_i + a_i + \gamma_g + \nu_s + \varepsilon_{ifgt}$$

where Y_{ifgt} is breastfeeding duration for child i in polygynous family (household) f in location g at time t, defined as the number of months a mother reported to have breastfed her child (Jayachandran and Kuziemko, 2011).

$\sum Shock_{g,t}$ is a vector of time-varying measures of rainfall shocks experienced by a child in the first and second years after birth. Given that average breastfeeding duration in the sample is less than 24 months, we consider exposure to rainfall shocks in a child's first and second years of life, which is also potentially the most critical period for breastfeeding according to the World Health Organization. $SeniorWife_i$ represents the rank of a child's mother who is a co-wife in a polygynous household. The variable is a dummy indicator coded as 1 for senior wives and 0 otherwise (i.e. junior wives). The covariates Z_i is a vector of child-specific and maternal-specific characteristics including age, gender and birth order of children, as well as maternal age and education. a_i is age-in-month fixed effect. Following Jayachandran and Kuziemko (2011), we include age-in-month fixed effect to account for the censoring of breastfeeding duration. For example, a six-month-old child being breastfed at the time of the survey would have a breastfeeding duration censored at six months. γ_g is grid fixed effect which controls for time-invariant unobservable grid (location) attributes, such as social and geographic factors that may affect breastfeeding patterns and outcomes. ν_s is survey year fixed effect and ε_{ifgt} is the error term. Standard errors are clustered at the grid cell level.

On one hand, rainfall could affect whether a woman breastfeeds due to its impact on the opportunity cost of time spent on agricultural labor. On the other hand, rainfall may affect nutrition and the timing of weaning via its effect on agricultural output. We identify the effect of early-life shocks in polygynous households by comparing similarly aged children of co-wives, who may be differentially exposed to rainfall shocks due to differences in their birth season. This provides insight into how the hierarchical structure of polygynous households interact with environmental factors in potentially influencing resource and time allocation towards breastfeeding among co-wives, and thus children's health investment.

3.4 Results

3.4.1 Early-life rainfall shocks and breastfeeding duration

We first examine the effect of linear rainfall shocks in the first and second years of a child's life on the length of time they are breastfed. These results are presented in Table 3.2; Column 1 reports the main effect of birth year and second year rainfall shocks on breastfeeding duration, while Column 2 reports the full estimated model from section 3.3 which includes the differential effect of these shocks by children of co-wives in polygynous households. The regressions in Table 3.2 include fixed effects for age-in-month, grid cell and survey year, as well as additional controls. Standard errors, clustered at the grid cell level, are shown in parenthesis.

Rainfall shocks in the birth year positively affect breastfeeding duration, but this effect is not statistically significant (Panel A, Column 1). In contrast, rainfall shocks in a child's second year have a statistically significant positive impact on breastfeeding duration (Panel B, Column 1). Additionally, there is no differential effect of birth year rainfall shocks on breastfeeding duration between children of co-wives; however, the differential effects in the second year are statistically significant. Specifically, while rainfall shocks in the second year lead both senior and junior wives to breastfeed longer, the effect is relatively larger for children of senior wives (Panel B, Column 2).

Table 3.2: Effect of early-life rainfall shocks on breastfeeding duration and differential effect by wife rank in polygynous households

	(1)	(2)
Panel A: Effects of rainfall shock in birth year		
Rainfall shock in birth year	1.444	2.113
	(1.441)	(1.389)
SeniorWife		0.373**
		(0.185)
Rainfall shock in birth year × SeniorWife		-1.397
		(1.728)
Panel B: Effects of rainfall shock in second year		
Rainfall shock in second year	0.844***	0.567*
	(0.271)	(0.295)
SeniorWife		0.441**
		(0.210)
Rainfall shock in second year × SeniorWife		0.713**
		(0.298)
Covariates	Yes	Yes
Age-in-month Fixed Effects	Yes	Yes
Grid Fixed Effects	Yes	Yes
Survey-Year Fixed Effects	Yes	Yes
Observations	3,061	3,061
R-Squared	0.760	0.761

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.10$. The table shows OLS regressions with breastfeeding duration as the dependent variable. Standard errors are in parenthesis and clustered at the grid cell level. The covariates included in columns (1) and (2) include mother's years of education, a linear and quadratic control for mother's age, birth order of children, age and sex of child.

We next discuss the magnitude of these effects. A 10% increase in rainfall during the second year increases breastfeeding duration for children of junior wives by 0.7 days (0.567

$\times$ log(1.1) $\times$ 30), and this effect is statistically significant. Similarly, the same increase in rainfall leads to a statistically significant increase in breastfeeding duration for children of senior wives by 1.4 days (1.154 $\times$ log(1.1) $\times$ 30). This finding suggests that rainfall shocks in the second year are crucial for extending children's breastfeeding duration, and the more positive the rainfall shock, the longer children of senior wives are breastfed compared to those of junior wives. The mechanisms of co-wives' access to resources, shaped by decision-making power and the opportunity cost of labor time, are both at play but with varying intensities and may depend on the timing. During the child's second year, labor demand and its associated opportunity cost seem to drive longer breastfeeding durations. However, the stronger effect among senior wives underscores the complementary influence of resource access and bargaining power, enabling them to balance labor and caregiving more effectively.

Although the magnitude of the differential effects in terms of breastfeeding days may seem small at first, they are crucial for children's health outcomes, particularly in the second year. Previous literature have emphasised that the second year of a child's life is potentially the most critical for health outcomes (e.g. Glewwe and King, 2001; Hoddinott and Kinsey, 2001; Dercon and Porter, 2014). During this period, children are more vulnerable to malnutrition and nutritional shocks, as mothers are more likely to stop breastfeeding; thus continued breastfeeding is essential. In Table A10 in the Appendix, we estimate the effect of early-life rainfall shocks on children's nutritional health outcomes using height-for-age (HAZ) and weight-for-age (WAZ) z-scores. The results show that rainfall shocks in the second year have a statistically significant relationship with HAZ and WAZ z-scores, and this effect significantly varies between children of senior and junior wives in magnitude. The coefficients for the effect of birth year rainfall shocks are not statistically significant.

3.4.2 Disaggregated rainfall shocks (negative vs. positive) and breastfeeding duration

The analysis so far has considered rainfall shocks in a linear fashion. However, the nature of these shocks – whether negative or positive – may have distinct implications. In this section, we disaggregate the rainfall shocks into negative versus positive shocks to estimate their differential impact on breastfeeding duration.

This approach aims to uncover the potential mechanisms associated with each type of shock. In what follows, a 'negative shock' is defined as a dummy variable that is equal to one if the percentage deviation from the norm is negative and zero otherwise (i.e. a positive shock). The regression results are presented in Table 3.3, where we estimate the effect of early-life negative rainfall shocks on breastfeeding duration in the birth and second years of a child's life. Columns (1) and (2) report estimates for the birth and second years respectively.

Table 3.3: Effect of early-life negative rainfall shocks on breastfeeding duration and differential effect by wife rank in polygynous households

	Birth Year	Second Year
	(1)	(2)
Negative shock	-0.301	1.098**
	(0.366)	(0.466)
SeniorWife	0.358	1.432***
	(0.406)	(0.505)
Negative shock × SeniorWife	0.023	-1.388**
	(0.449)	(0.569)
Covariates	Yes	Yes
Age-in-month Fixed Effects	Yes	Yes
Grid Fixed Effects	Yes	Yes
Survey-Year Fixed Effects	Yes	Yes
Observations	3,061	3,061
R-Squared	0.760	0.762

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.10$. The table shows OLS regressions with breastfeeding duration as the dependent variable. Standard errors are in parenthesis and clustered at the grid cell level. The covariates included in columns (1) and (2) include mother's years of education, a linear and quadratic control for mother's age, birth order of children, age and sex of child.

In Column 1 Table 3.3, we show that negative, relative to positive rainfall shocks, realized in a child's first year has no impact on breastfeeding duration, and this effect does not differ between co-wives in polygynous rural households. This suggests that during the child's first year, breastfeeding may be less sensitive to the opportunity cost of agricultural labor, as labor market pressures are relatively low and consistent across co-wives.

However, in Column 2, the coefficients are statistically significantly different from zero and a different pattern emerges. We find that, for junior wives, a negative rainfall shock in a child's second year is associated with an increase in breastfeeding duration by 1.098 months (approximately 33 days) compared to a positive shock, and this effect is statistically significant. For senior wives, we show that, in the absence of a negative rainfall shock, they breastfeed for about 1.432 months (approximately 43 days) longer than junior wives in the second year. However, the presence of a negative rainfall shock reduces this duration by about 1.388 months (approximately 42 days), effectively neutralizing the duration gains observed in the absence of such shocks. Put together, the result in Column (2) indicate that, for negative rainfall shocks in a child's second year, junior wives breastfeed for a longer duration compared to senior wives. These findings suggest the following. The mechanism on the opportunity cost of labor time appears to dominate for junior wives during negative shocks in the child's second year. As agricultural productivity declines, labor demands are reduced, freeing junior wives to spend more time on caregiving and extending breastfeeding duration. For senior wives, the resource access and bargaining power associated with their household position generally allow them to prioritize breastfeeding over other labor demands. However, in the face of negative rainfall shocks, these resources may be insufficient to offset the increased economic pressure, leading to a sharp decline in breastfeeding duration. Alternatively, senior wives are more likely to initiate weaning earlier than junior wives.

3.4.3 Heterogeneous effect by agricultural season of birth

In this section, we explore heterogeneous effects by season of birth – whether the birth of a child occurred in the dry or wet season. This may well be important because varying labor needs at different times of the agricultural year can impact children's breastfeeding at critical points of their development.

We estimate a model that includes the main effect of negative rainfall shocks in the first and second years, as well as interaction terms with whether or not a child was born in the dry season. The results are presented in Table 3.4, where the variable 'born in dry season' is a dummy variable equal to one for a child who was born in the dry season of the agricultural cycle and zero otherwise (i.e. born in the wet season). The negative shock variables in birth and second years are as previously defined as dummy variables that are negative percentage deviations from the rainfall norm.

Table 3.4: Effect of early-life negative rainfall shocks on breastfeeding duration and differential effect by agricultural season of birth

	(1)
Negative shock in birth year	-0.808**
	(0.336)
Born in dry season	1.007**
	(0.476)
Negative shock in birth year × Born in dry season	-1.836***
	(0.529)
Negative shock in second year	-0.049
	(0.404)
Negative shock in second year × Born in dry season	-2.054***
	(0.562)
Covariates	Yes
Age-in-month Fixed Effects	Yes
Grid Fixed Effects	Yes
Survey-Year Fixed Effects	Yes
Observations	3,061
R-Squared	0.617

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.10$. The table shows OLS regressions with breastfeeding duration as the dependent variable. Standard errors are in parenthesis and clustered at the grid cell level. The covariates include mother's years of education, a linear and quadratic control for mother's age, birth order of children, age and sex of child.

In Table 3.4, we find that children born in the dry season, on average, are breastfed longer than those born in the wet season. We also find that the interaction terms for negative rainfall shocks in the first and second years of a child's life with the initial season of birth are statistically significant.

In particular, we show that children born during the dry season, relative to the wet season, are breastfed longer for about 1.007 additional months (approximately 30 days). This extended breastfeeding period is likely because mothers have more time to nurse when they are less occupied with farming activities during the dry season. However, when negative rainfall shocks occur during the dry season – implying drought conditions – in the child's birth year, the breastfeeding duration decreases by approximately 1.836 months (around 55 days) for these children. This reduction more than offsets the initial increase, leading to a net decrease of about 0.829 months (approximately 25 days) in breastfeeding duration. These findings suggest that while mothers, in principle, may breastfeed longer during the dry season due to reduced agricultural workload, drought conditions can significantly shorten this period. Droughts adversely affect maternal nutrition and food intake, which may limit a mother's ability to produce milk and sustain breastfeeding. If these negative rainfall conditions persist into the child's second year, the negative impact on breastfeeding duration is likely to be even greater.

The argument for prolonged breastfeeding during the dry season is particularly relevant for children in the critical age ranges of 0–6 months and 12–18 months, compared to those aged 6–12 months and 18–24 months. This is because exclusive breastfeeding is most common during the early months of a child's life (0–6 months), and as children transition through their second year, particularly between 12 and 18 months, they continue to rely on nursing for essential nutrition while gradually incorporating solid foods into their diet. Increased maternal availability during these periods enables more frequent and extended breastfeeding sessions. Consequently, if a child's birth coincides with a season of reduced maternal workload, such as the dry season, breastfeeding during these critical periods may naturally be prolonged. In contrast, the 6–12 month and 18–24 month age ranges, which essentially overlap with the wet season in the agricultural cycle, may be less influenced by maternal time availability due to factors like increased food supplementation and the ongoing weaning process.

3.5 Discussion

Understanding the effect of different type of shocks on parental behavior and investments in children, particularly in low-income countries is crucial. Rainfall shocks in rural areas are of particular interest due to households' reliance on rain-fed agriculture. Two channels on the link between rainfall variability and children's health outcomes in the economic literature has been well documented: income shocks and disease environment. In principle, positive rainfall shocks enhances agricultural productivity, boosts income, and hence children's health investments. The epidemiological environment is also affected by rainfall, resulting in the prevalence of vector– or water–borne diseases, which could affect children's health. An additional channel that is underexplored in developing countries' context is the opportunity cost of agricultural labor time especially for women, which may adversely impact investments in children's health.

This paper sheds light on how the opportunity cost of time mechanism interacts with the decision-making power of co-wives in affecting children's health by investigating the link between early-life rainfall shocks and breastfeeding duration. Breastfeeding constitute a crucial determinant of children's health, but it is also a time-consuming activity. We show how exposure to early-life rainfall shocks differentially affect the length of breastfeeding time of children by co-wives in polygynous rural households, where the dynamics of decision making in terms of resource and time allocation is even more profound. The key findings in this paper are the following: a) Rainfall in a child's second year after birth is positively associated with breastfeeding duration, and this effect is greater for senior wives than for junior wives b) Negative rainfall shocks in a child's second year leads junior wives to breastfeed for a longer duration compared to senior wives, and c) Children born in the dry season are breastfed longer than those born in the wet season, but drought conditions during the birth year significantly reduces this breastfeeding duration.

First, we demonstrate that while rainfall in a child's birth year does not influence breastfeeding duration, rainfall in the child's second year has a significantly positive effect, with stronger effects for senior wives compared to junior wives. This indicates that rainfall shocks occurring in the second year of a child's life are most critical for extending breastfeeding duration and impacting subsequent health outcomes. Furthermore, the stronger effect observed among senior wives underscores the importance of resource access and bargaining power, enabling them to better navigate the trade-offs between labor and caregiving. In certain African cultures, women are socially isolated after childbirth to provide them with sufficient time for recovery and infant care (Kim, 2010). Previous literature (e.g. Hoddinott and Kinsey, 2001; Dercon and Porter, 2014) have shown that the second year after birth is the most critical period for children's nutrition and development. Intensive breastfeeding during the first year of life provides children with essential protection against nutritional deficiencies. However, as children transition out of the intensive period of breastfeeding stage, the protective benefits of breastfeeding diminishes and they become less resilient to external shocks, particularly in the second year. It is also worth noting that rainfall shocks lead to income shocks and nutritional deficiencies with a delay (Weldesenbet, 2022), and this delay arises because reduced crop yields due to lower rainfall manifests during the harvest season. In Malawi, the harvest for major staple crops is typically between April and June, following the wet season. Moreover, rural households often have food stores to sustain their nutritional needs for a certain period, further delaying the impact of low rainfall-induced nutritional deprivation. As a consequence, maternal nutritional shocks and the time cost of breastfeeding due to rainfall shocks are more likely to be experienced in the second year after childbirth.

Second, we find that in polygynous households, when negative rainfall shocks occur during a child's second year, junior wives tend to breastfeed their children for longer periods than senior wives. This pattern suggest that during economic hardships – characterized by tight household budgets and intensified competition for limited food and resources – senior wives are more inclined to limit breastfeeding and resort to weaning their children earlier than junior wives. For junior wives, the lower opportunity costs of labor time during agricultural downturns may encourage longer breastfeeding compared to senior wives. In rural polygynous households, the way resources and time are reallocated in response to rainfall shocks can affect wives differently, depending on whether senior or junior wives are prioritized. The necessity to balance time between agricultural labor and childcare means that during periods of favorable rainfall, women might choose to wean their children sooner, as spending less time on farm work could result in significant income losses. In contrast, during times of negative rainfall shocks, reduced demand for farm labor and the scarcity of alternative employment in rural areas create more time for childcare. Despite this, senior wives however, may choose to wean their children sooner than junior wives, as their higher status within the household and increased responsibilities give them greater influence over decisions related to resource distribution and childcare practices. Previous studies (e.g. Serpell, 2010; Madhavan and Gross, 2013; Clark et al., 2018) have shown that women in Sub-Saharan Africa are often reliant on their extended family members for childcare support. However, breastfeeding and weaning largely remain the sole responsibility of the mother. Donald et al. (2024) document recent findings from 32 Sub-Saharan African countries, showing that extended family support for mothers is generally focused on responsibilities such as cooking, cleaning, and farming, especially around the time of childbirth and the postpartum period, rather than directly assisting with childcare. In Sub-Saharan Africa, co-wives in polygynous households tend to engage in competition rather than cooperation (e.g. Rossi, 2019). This competitive relationship means that co-wives typically vie for access to agricultural resources, food, and wealth (Kazianga and Klonner, 2009; Mammen, 2019). Kazianga and Klonner (2009) examine the intra-household efficiency assumption on children's survival and investments in rural Mali, where the efficient resource allocation hypothesis was rejected for children of junior wives but not that of senior wives. Their findings support the evidence which emphasises the reduced bargaining power and disadvantaged economic status of junior wives in polygynous households.

Finally, the effect of negative rainfall shocks on extended breastfeeding duration is likely to be greater for children born in the dry season than for those born in the wet season. However, extreme conditions such as droughts in the dry season may curtail this prolonged period of breastfeeding. In principle, during the dry season, agricultural activity slows significantly, reducing the demand for women's labor on farms. With fewer time pressures related to farming, mothers have more flexibility to focus on childcare and breastfeeding. In contrast, during the wet season, which coincides with the peak agricultural period, women are heavily involved in farm work, leading to greater time constraints. Breastfeeding is most crucial during the dry season for infants aged 0-6 months and toddlers aged 12-18 months. In the early months, exclusive breastfeeding is common, while at 12-18 months, children continue to depend on breast milk as they introduce solid foods. The reduced maternal workload during the dry season facilitates more frequent breastfeeding. In contrast, for children aged 6-12 months and 18-24 months, the wet season has less impact on breastfeeding due to increased food supplementation and ongoing weaning. Women often play a pivotal role in agricultural labor, which imposes substantial time demands on them, alongside their other household responsibilities (Blackden and Wodon, 2006; Raney et al., 2011). The seasonal nature of agricultural work thus have important implications for the allocation of time, and how that occurs across gender lines (Vemireddy and Pingali, 2021). Wodon and Beegle (2006) document that, in Malawi, women experience the heaviest overall time burdens during the peak agricultural season when labor shortages are most acute. This intense demand on women's time during the wet season exacerbates the challenges they face in balancing farm work with other essential activities including breastfeeding, while the opposite may hold true during the dry season when farming activities are minimal and availability of irrigation is limited. In effect, the time constraints on breastfeeding are likely to be less severe, as mothers have relatively more time to care for infants born in the dry season. The benefits of this extended breastfeeding period, however, can be undermined by drought conditions, which may negatively impact maternal nutrition and food consumption. This may in turn impair a mother's ability to produce adequate breast milk to sustain breastfeeding.

3.6 Robustness Checks

This section provides some robustness checks to validate the main findings in this paper. First, we address the potential concern that rainfall shocks could be correlated over time, as rainfall effects in one year could be dependent on adjacent years. If so, then the results obtained in Table 3.2 which identifies rainfall shocks in the second year as the most crucial for prolonged breastfeeding duration could be confounded by rainfall shocks realized in the first year. To address this, we re-estimate the model that includes both the rainfall shocks in the first and second years as well as their differential effects. The estimates are reported in Appendix Table A11, and the results are similar to the initial results obtained in Table 3.2, as we find a statistically significant differential effect of rainfall shocks only in the second year. Second, given that Malawi is predominantly rural, the analysis included the 5 percent of children in the sample from polygynous rural households. To test how sensitive the main results are to the inclusion of these urban children, we exclude them from the sample and re-estimate the model. The results are reported in Table A12 in the Appendix, which show that the initial results are not sensitive to the inclusion of urban children.

3.7 Conclusion

In several Sub-Saharan African countries, weather shocks around the time of birth have been linked to both short-term and long-term health outcomes. These effects may be mediated by factors such as income shocks, the disease environment, and/or the opportunity costs of parental time. This paper uses data from Malawi to empirically examine the effect of early-life rainfall shocks on breastfeeding duration among children of co-wives in polygynous rural households. We find that rainfall shocks have a statistically significant and differential impact on breastfeeding duration between children of senior and junior wives, with these effects also varying by the agricultural season of a child's birth. Notably, the most pronounced effects occur during the second year of a child's life, which is crucial for extended breastfeeding. Policies aimed at improving early-life health through breastfeeding should consider family structures and the effects of maternal labor demands.

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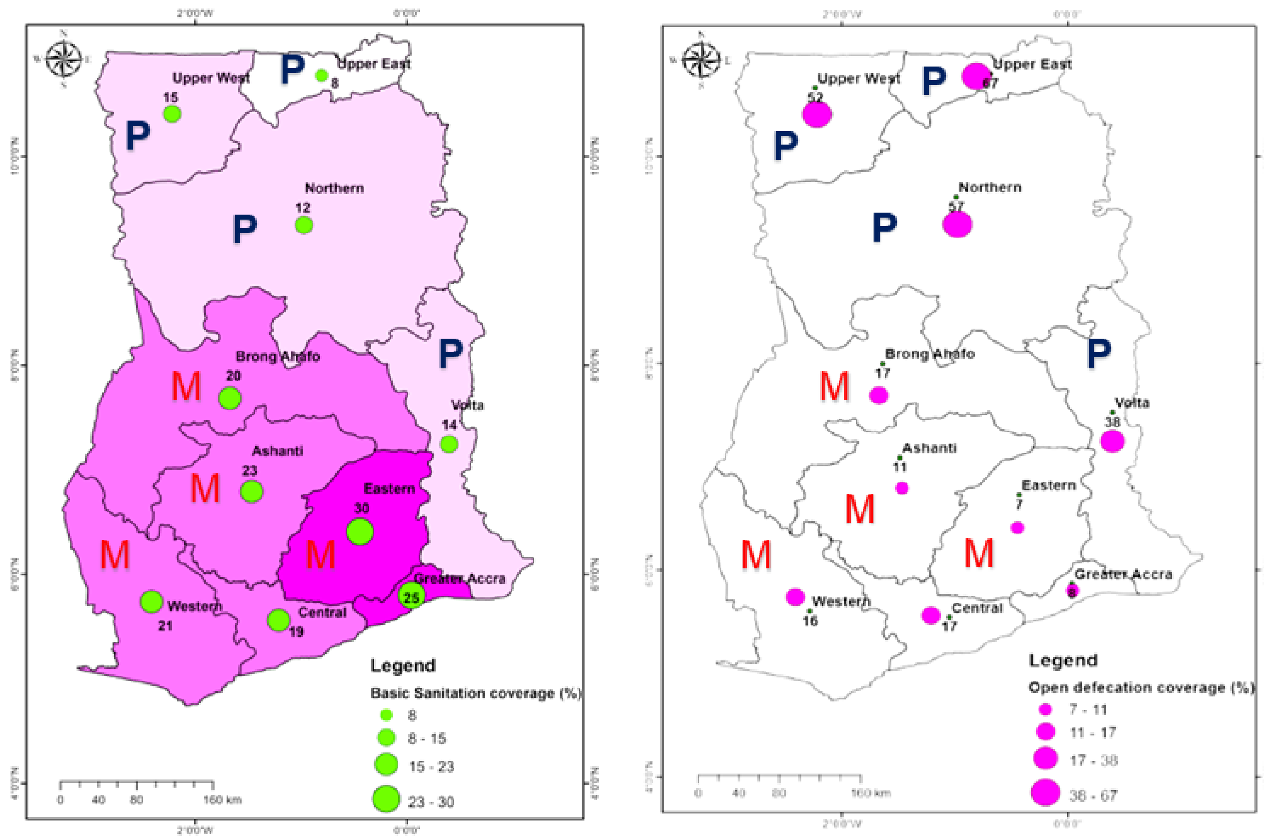
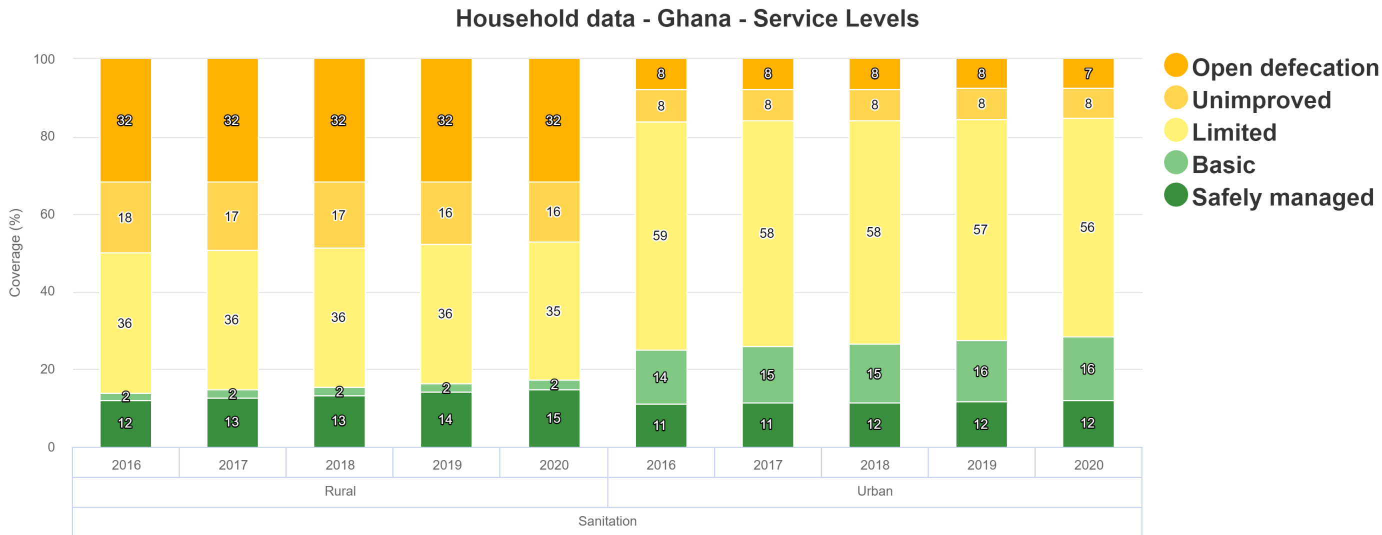
Appendix to Chapter 1

Figure A1: Distribution of basic sanitation coverage and open defecation in Ghana, GSS (2018)



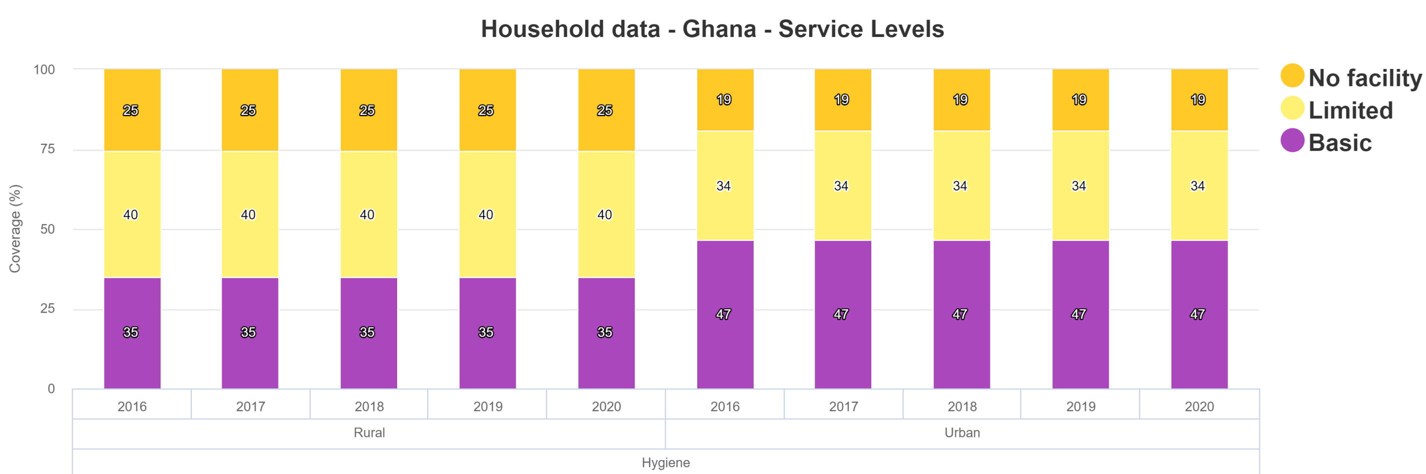
Source: Adapted from the Ghana Statistical Service (2018). Note that the regions labelled **M** and **P** represent societies that are predominantly matrilineal and patrilineal respectively. It is evident from the graphs that patrilineal societies perform poorly in basic sanitation and open defecation, relative to matrilineal households.

Figure A2: Sanitation in Ghanaian households



Source: WHO/UNICEF Joint Monitoring Programme.
Open defecation – Disposal of human faeces in fields, forests, bushes, open bodies of water, beaches and other open spaces or with solid waste; Unimproved – Use of pit latrines without a slab or platform, hanging latrines or bucket latrines; Limited – Use of improved facilities shared between two or more households; Basic – Use of improved facilities which are not shared with other households; Safely managed – Use of improved facilities that are not shared with other households and where excreta are safely disposed of in situ or removed and treated offsite

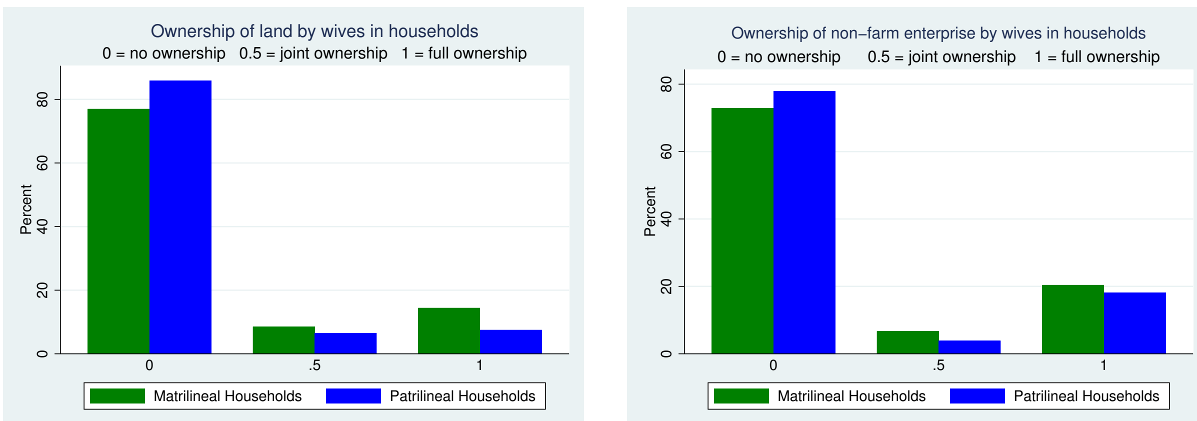
Figure A3: Hygiene in Ghanaian households



Source: WHO/UNICEF Joint Monitoring Programme.
No facility – No handwashing facility on premises; Limited – Availability of a handwashing facility lacking soap and/or water at home; Basic – Availability of a handwashing facility with soap and water at home

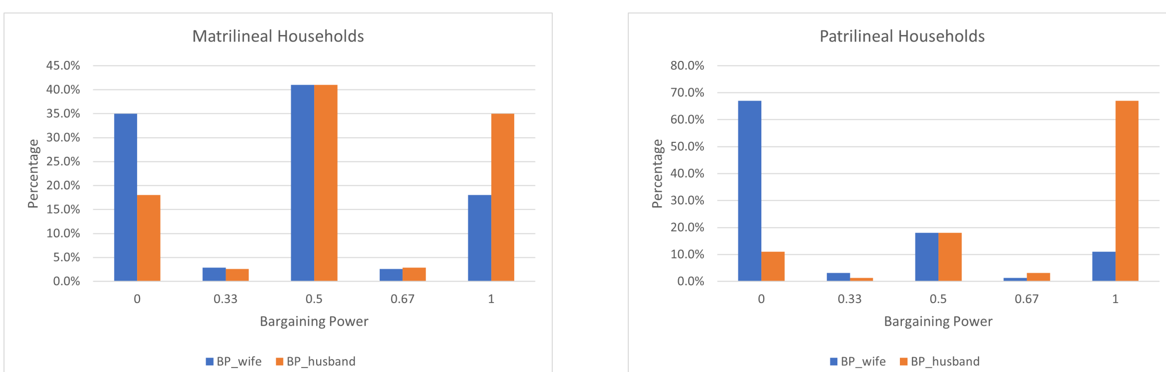
Figure A4 shows the variation in wive's ownership of farmland and non-farm enterprises in both household types (where, on the x-axis, 0 indicates no ownership, 0.5 is joint ownership, and 1 is individual ownership). It is observed that wives in matrilineal households individually and jointly own more land and non-farm enterprises compared to their patrilineal counterparts. The wives' bargaining power in relation to their husbands within both household types is depicted in Figure A5.

Figure A4: Variation in women's ownership of land and non-farm enterprise by household type



(a) Land ownership (b) Non-farm enterprise ownership

Figure A5: Bargaining power of wife vs husband (within and across groups)



(a) Matrilineal Households (b) Patrilineal Households

Appendix to Chapter 2

Table A1: Summary Statistics

	Bride Price Societies		Non-Bride Price Societies		Mean Difference	Observations
	Mean	SD	Mean	SD		
Panel A: Unique Individuals						
Men Sample						
Age at first marriage	22.56	4.76	22.12	4.21	0.45***	12,559
First marriage, by age cohort:						
< 18	16.10	1.20	15.99	1.16	0.11	1,255
18 – 25	21.47	2.41	21.26	2.01	0.20***	9,039
26 – 30	27.53	1.59	27.48	1.32	0.05	1,713
31 – 35	32.36	1.63	32.38	1.27	-0.02	389
36 – 40	37.27	1.56	37.43	1.35	-0.17	125
> 40	42.55	1.25	45.02	3.48	-2.47***	38
Women Sample						
Age at first marriage	17.76	3.77	17.59	3.30	0.17***	55,515
First marriage, by age cohort:						
< 18	15.57	1.61	15.32	1.58	0.25***	30,395
18 – 25	19.73	2.14	19.71	1.78	0.02	23,673
26 – 30	27.33	1.46	27.43	1.28	-0.01	1,099
31 – 35	32.79	1.68	32.34	1.22	0.45	241
36 – 40	36.81	1.25	37.24	1.42	-0.43	79
> 40	41.53	1.19	43.62	2.52	-2.10*	28
Panel B: Survival Data						
Age at first marriage (men)	22.59	4.80	22.11	4.24	0.48***	725,387
Age at first marriage (women)	17.76	3.78	17.59	3.30	0.17***	3,331,820
Drought exposure, ever-married men (=1, 0 otherwise)	0.15	0.41	0.14	0.34	0.01***	725,387
Drought exposure, ever-married women (=1, 0 otherwise)	0.12	0.37	0.14	0.34	-0.02***	3,331,820
Flood exposure, ever-married men (=1, 0 otherwise)	0.15	0.41	0.17	0.37	-0.02***	725,387
Flood exposure, ever-married women (=1, 0 otherwise)	0.30	0.52	0.18	0.37	0.12***	3,331,820

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Survey sampling weights for both men and women samples are applied in the computation of the summary statistics.

Figure A6: Survival and Hazard into First Marriage, Men sample

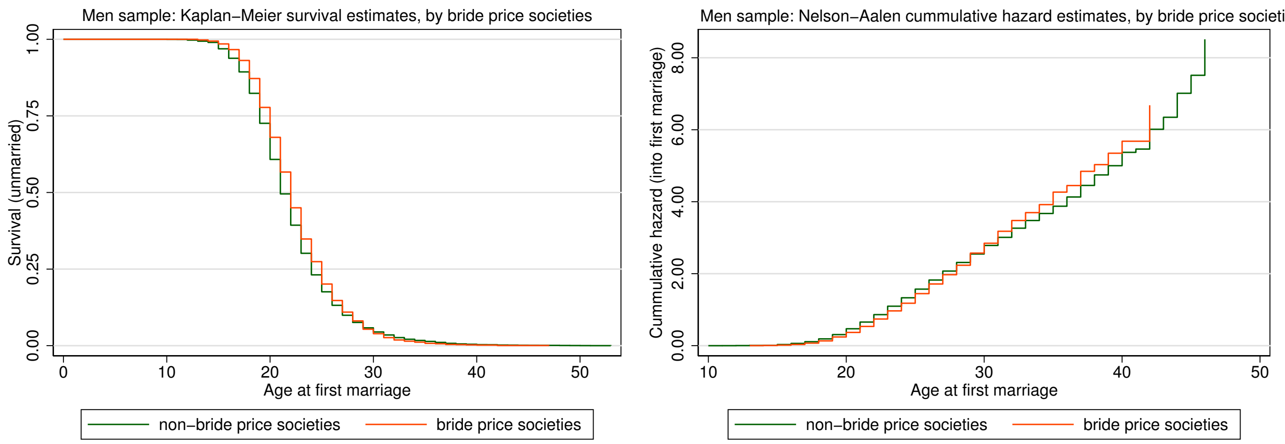
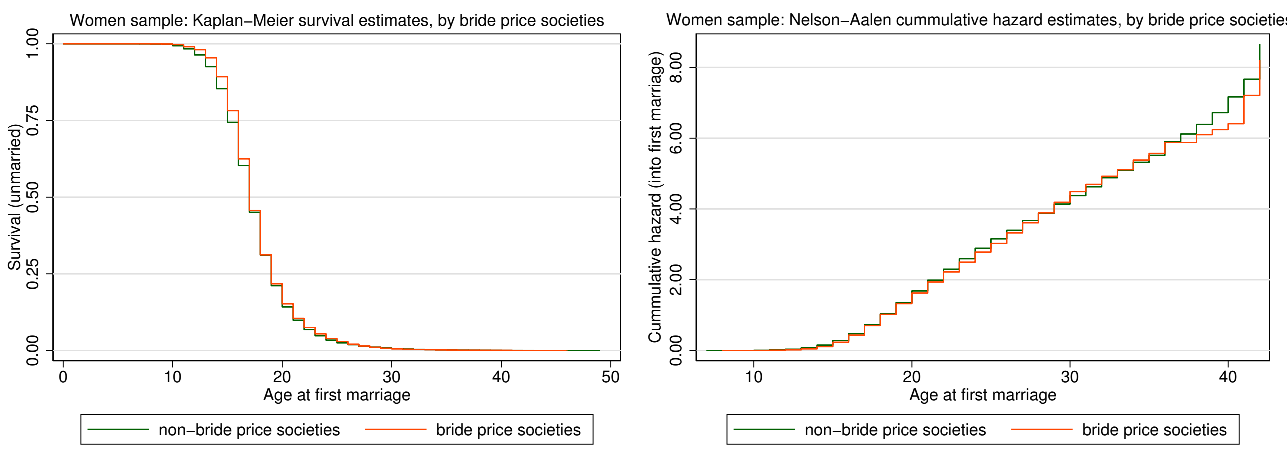


Figure A7: Survival and Hazard into First Marriage, Women sample



Note: The Kaplan-Meier curves depict the proportion of individuals who are still unmarried at a given age, while the Nelson-Aalen cumulative hazards represent the risk of entering first marriages. Data is from the pooled 2000, 2004, 2010, and 2015 Malawi DHS.

Table A2: Climate Shocks and Household Consumption in Malawi

	HH consumption (1)
Drought	-0.062***
	(0.011)
Controls	Yes
Grid Fixed Effects	Yes
R-squared	0.365
Observations	12,171

	HH consumption (2)
Flood	-0.132***
	(0.019)
Controls	Yes
Grid Fixed Effects	Yes
R-squared	0.644
Observations	12,171

Note: *** p<0.01, ** p<0.05, * p<0.10. Controls include household size, number of male and female household children, age and education of household head, region of residence, an interaction term between the climate shocks and region, as well as a dummy for poor households below the national poverty line. A drought is defined as a calendar year's rainfall observation that falls below the 15th percentile of a grid cell's historical long-run (1950-2017) rainfall distribution. A flood is defined as a calendar year's rainfall observation that is in excess of the 85th percentile of a grid cell's historical long-run (1950-2017) rainfall distribution. Robust standard errors are in parenthesis and clustered at the grid cell level.

Table A3: Climate Shocks and Crop Yields in Malawi

	Maize (1)	Rice (2)	Both crops (3)
Drought	-0.329**	-0.101	-0.215**
	(0.127)	(0.106)	(0.093)
R-squared	0.124	0.011	0.050
Observations	57	57	114

	Maize (4)	Rice (5)	Both crops (6)
Flood	-0.072	-0.026	-0.049
	(0.081)	(0.140)	(0.083)
R-squared	0.007	0.001	0.003
Observations	57	57	114

Note: *** p<0.01, ** p<0.05, * p<0.10. A drought is defined as the average annual rainfall observation that falls below the 15th percentile of Malawi's historical long-run (1961-2017) average rainfall distribution. A flood is defined as the average annual rainfall observation that is in excess of the 85th percentile of Malawi's historical long-run (1961-2017) average rainfall distribution. Robust standard errors are in parenthesis.

Table A4: Robustness in revised cut-offs: Droughts, First Marriage Hazards, and Age Gap at First Marriage

	Men Sample		Women Sample		Husband-wife Age Gap	
	20th perc. Hazard Ratios (1)	45th perc. Hazard Ratios (2)	20th perc. Hazard Ratios (3)	45th perc. Hazard Ratios (4)	20th perc. Age gap (5)	45th perc. Age gap (6)
Drought	1.227**	1.126***	1.221**	1.160***	-0.009*	-0.015***
	(0.037)	(0.027)	(0.017)	(0.014)	(0.005)	(0.005)
Brideprice	0.942	0.973	0.978	1.001	0.352**	0.338**
	(0.037)	(0.043)	(0.018)	(0.022)	(0.142)	(0.146)
Drought × Brideprice	0.823**	0.860**	0.978	0.957	0.042	0.052
	(0.079)	(0.065)	(0.041)	(0.035)	(0.032)	(0.043)
Survey Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	No	No	No	No	Yes	Yes
Observations	725,387	725,387	3,331,820	3,331,820	2,698,823	2,698,823

Note: *** p<0.01, ** p<0.05, * p<0.10. A drought is characterized by a calendar year's rainfall observation that falls below the 20th or 45th percentile of a grid cell's historical long-run (1950-2015) rainfall distribution. Standard errors are in parenthesis and clustered at the grid-cell level. Data is from the pooled 2000, 2004, 2010, 2015 Malawi DHS.

Table A5: Robustness in revised cut-offs: Floods, First Marriage Hazards, and Age Gap at First Marriage

	Men Sample		Women Sample		Husband-wife Age Gap	
	75th perc. Hazard Ratios (1)	90th perc. Hazard Ratios (2)	75th perc. Hazard Ratios (3)	90th perc. Hazard Ratios (4)	75th perc. Age gap (5)	90th perc. Age gap (6)
Flood	0.720***	0.797***	0.691***	0.762***	0.007	0.008
	(0.024)	(0.033)	(0.012)	(0.016)	(0.008)	(0.013)
Brideprice	0.892***	0.889***	0.936***	0.942***	0.373***	0.373***
	(0.034)	(0.033)	(0.019)	(0.017)	(0.135)	(0.135)
Flood × Brideprice	1.076	1.177	1.277***	1.301***	-0.044	-0.064
	(0.107)	(0.143)	(0.050)	(0.054)	(0.074)	(0.107)
Survey Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	No	No	No	No	Yes	Yes
Observations	725,387	725,387	3,331,820	3,331,820	2,698,823	2,698,823

Note: *** p<0.01, ** p<0.05, * p<0.10. A flood is characterized by a calendar year's rainfall observation that is in excess of the 75th or 90th percentile of a grid cell's historical long-run (1950-2015) rainfall distribution. Standard errors are in parenthesis and clustered at the grid-cell level. Data is from the pooled 2000, 2004, 2010, 2015 Malawi DHS.

Table A6: Robustness to inclusion of year fixed effects: Droughts, First Marriage Hazards, and Age Gap at First Marriage

	Men Sample		**Women Sample**		**Husband-wife Age Gap**
	Coefficients[a]	Hazard Ratios	Coefficients[a]	Hazard Ratios	OLS Estimates
	(1)	(2)	(3)	(4)	(5)
Drought	0.088**	1.092**	0.011	1.012	-0.020*
	(0.049)	(0.053)	(0.023)	(0.023)	(0.011)
Brideprice	-0.053	0.948	-0.023	0.977	0.352**
	(0.039)	(0.037)	(0.017)	(0.017)	(0.142)
Drought × Brideprice	-0.278***	0.757***	-0.055	0.947	0.054*
	(0.102)	(0.077)	(0.044)	(0.042)	(0.034)
Survey Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	No	No	No	No	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
R-Squared					0.016
Observations	725,387	725,387	3,331,820	3,331,820	2,698,823

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.10$. A drought is characterized by a calendar year's rainfall observation that falls below the 20th or 45th percentile of a grid cell's historical long-run (1950-2015) rainfall distribution. Standard errors are in parenthesis and clustered at the grid-cell level. Data is from the pooled 2000, 2004, 2010, 2015 Malawi DHS.

Table A7: Robustness to inclusion of year fixed effects: Floods, First Marriage Hazards, and Age Gap at First Marriage

	Men Sample		**Women Sample**		**Husband-wife Age Gap**
	Coefficients[a]	Hazard Ratios	Coefficients[a]	Hazard Ratios	OLS Estimates
	(1)	(2)	(3)	(4)	(5)
Flood	0.067	1.069	-0.057**	0.945**	0.007
	(0.053)	(0.056)	(0.025)	(0.024)	(0.016)
Brideprice	-0.099***	0.906***	-0.048***	0.954***	0.373***
	(0.037)	(0.034)	(0.019)	(0.018)	(0.135)
Flood × Brideprice	0.004	1.004	0.086**	1.090**	-0.054
	(0.114)	(0.114)	(0.039)	(0.042)	(0.092)
Survey Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	No	No	No	No	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
R-Squared					0.016
Observations	725,387	725,387	3,331,820	3,331,820	2,698,823

Note: *** p<0.01, ** p<0.05, * p<0.10. A flood is characterized by a calendar year's rainfall observation that is in excess of the 75th or 90th percentile of a grid cell's historical long-run (1950-2015) rainfall distribution. Standard errors are in parenthesis and clustered at the grid-cell level. Data is from the pooled 2000, 2004, 2010, 2015 Malawi DHS.

Table A8: Robustness to exclusion of communities near the lake: Droughts, First Marriage Hazards, and Age Gap at First Marriage

	Men Sample		**Women Sample**		**Husband-wife Age Gap**
	Coefficients[a]	Hazard Ratios	Coefficients[a]	Hazard Ratios	OLS Estimates
	(1)	(2)	(3)	(4)	(5)
Drought	0.245***	1.277***	0.214***	1.239***	-0.014**
	(0.033)	(0.042)	(0.016)	(0.020)	(0.006)
Brideprice	-0.067*	0.935*	-0.031*	0.970*	0.353**
	(0.038)	(0.035)	(0.017)	(0.017)	(0.142)
Drought × Brideprice	-0.208**	0.812**	0.025	1.025	0.052
	(0.010)	(0.081)	(0.045)	(0.046)	(0.033)
Survey Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	No	No	No	No	Yes
R-Squared					0.016
Observations	708,063	708,063	3,260,328	3,260,328	2,638,494

Note: *** p<0.01, ** p<0.05, * p<0.10. A drought is characterized by a calendar year's rainfall observation that falls below the 20th or 45th percentile of a grid cell's historical long-run (1950-2015) rainfall distribution. Standard errors are in parenthesis and clustered at the grid-cell level. Data is from the pooled 2000, 2004, 2010, 2015 Malawi DHS.

Table A9: Robustness to exclusion of communities near the lake: Floods, First Marriage Hazards, and Age Gap at First Marriage

	Men Sample		**Women Sample**		**Husband-wife Age Gap**
	Coefficients[a]	Hazard Ratios	Coefficients[a]	Hazard Ratios	OLS Estimates
	(1)	(2)	(3)	(4)	(5)
Flood	-0.321***	0.725***	-0.344***	0.709***	0.006
	(0.038)	(0.027)	(0.020)	(0.014)	(0.010)
Brideprice	-0.121***	0.886***	-0.067 6***	0.936***	0.373***
	(0.038)	(0.034)	(0.019)	(0.018)	(0.135)
Flood × Brideprice	0.129	1.138	0.285***	1.329***	-0.054
	(0.113)	(0.129)	(0.040)	(0.053)	(0.091)
Survey Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	No	No	No	No	Yes
R-Squared					0.016
Observations	708,063	708,063	3,260,328	3,260,328	2,638,494

Note: *** p<0.01, ** p<0.05, * p<0.10. A flood is characterized by a calendar year's rainfall observation that is in excess of the 75th or 90th percentile of a grid cell's historical long-run (1950-2015) rainfall distribution. Standard errors are in parenthesis and clustered at the grid-cell level. Data is from the pooled 2000, 2004, 2010, 2015 Malawi DHS.

Appendix to Chapter 3

Table A10: Effect of rainfall shocks on children's height-for-age and weight-for-age

	Overall		Children of Senior Wives		Children of Junior Wives	
	HAZ	WAZ	HAZ	WAZ	HAZ	WAZ
Rainfall shock, first year	-0.231	0.281	0.189	1.525***	-1.336	-1.116
	(0.554)	(0.474)	(0.747)	(0.530)	(0.866)	(0.711)
Rainfall shock, second year	-1.463***	-1.359***	-2.022**	-1.000**	-1.473*	-1.652***
	(0.565)	(0.428)	(0.925)	(0.600)	(0.783)	(0.614)
Year-of-birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Grid FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,206	1,218	611	619	595	599
R-Squared	0.104	0.087	0.178	0.133	0.163	0.163

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.10$. The table shows OLS regressions with HAZ and WAZ as the dependent variables. Standard errors are in parenthesis and clustered at the grid cell level. The covariates include mother's years of education, a linear and quadratic control for mother's age, birth order of children, age and sex of child.

Table A11: Robustness: Effect of rainfall shocks on breastfeeding duration and differential effect by wife rank in polygynous households

	(1)
Rainfall shock in birth year	2.843*
	(1.455)
SeniorWife	0.453**
	(0.206)
Rainfall shock in birth year × SeniorWife	-1.638
	(1.739)
Rainfall shock in second year	0.668**
	(0.324)
Rainfall shock in second year × SeniorWife	0.829***
	(0.301)
Covariates	Yes
Age-in-month Fixed Effects	Yes
Grid Fixed Effects	Yes
Survey-Year Fixed Effects	Yes
Observations	3,061
R-Squared	0.762

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.10$. The table shows OLS regressions with breastfeeding duration as the dependent variable. Standard errors are in parenthesis and clustered at the grid cell level. The covariates include mother's years of education, a linear and quadratic control for mother's age, birth order of children, age and sex of child.

Table A12: Robustness (Excluding Urban Sample): Effect of rainfall shocks on breastfeeding duration and differential effect by wife rank in polygynous households

	(1)
Panel A: Effects of rainfall shock in birth year	
Rainfall shock in birth year	1.834
	(1.426)
SeniorWife	0.400**
	(0.185)
Rainfall shock in birth year × SeniorWife	-1.520
	(1.758)
Panel B: Effects of rainfall shock in second year	
Rainfall shock in second year	0.569*
	(0.309)
SeniorWife	0.474**
	(0.215)
Rainfall shock in second year × SeniorWife	0.771**
	(0.305)
Covariates	Yes
Age-in-month Fixed Effects	Yes
Grid Fixed Effects	Yes
Survey-Year Fixed Effects	Yes
Observations	2,907
R-Squared (*Panel A*)	0.758
R-Squared (*Panel B*)	0.758

Note: *** p<0.01, ** p<0.05, * p<0.10. The table shows OLS regressions with breastfeeding duration as the dependent variable. Standard errors are in parenthesis and clustered at the grid cell level. The covariates include mother's years of education, a linear and quadratic control for mother's age, birth order of children, age and sex of child.