ISBN: 978-82-575-1390-0
ISSN: 1894-6402

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Philosophiae Doctor (PhD), Thesis 2016:73

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Four empirical essays on agriculture and human capital in Sub-Saharan Africa

Fire empiriske essays om landbruk og human kapital i Afrika sør for Sahara

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Acknowledgements

Writing this PhD thesis has been a long journey with both ups and downs. It has been extremely frustrating at times, but most of all I have had the privilege of immersing myself in knowledge and the companionship of inspiring people. For this I am grateful to a number of individuals.

I would like to thank my main supervisor Stein T. Holden for encouraging me to take a PhD in the first place, for interesting discussions and in general for his open-door policy. I am also very grateful to Knut Einar Rosendahl for letting me have him as his co-supervisor. His perspective and comments have been very valuable.

I have had the opportunity to participate in several research communities, both in Norway and abroad. A special thanks goes to Peter Berck for making possible my one-year long visit to the Department of Agricultural and Resource Economics at the University of California, Berkeley. I would also like to thank Kalle Moene for facilitating my stay at the Centre for the Study of Equality, Social Organization (ESOP) at the University of Oslo, where I am particularly grateful to Jo Thori Lind for keeping his door open. I am also very grateful for all the help I have received at the NMBU School of Economics and Business throughout these years. Your help has made this journey far less bumpy than it could have been.

Writing a PhD thesis can be lonely, but I have had the pleasure of being surrounded by inspiring fellow PhD students and researchers at the Norwegian University of Life Sciences, the University of Oslo and UC Berkeley. A special thanks goes to Caroline, Maren, Sofie, Svenn and Øyvind for words of encouragement and advice, and cheerful commuting. In particular to Sofie, with whom I have had the enjoyable experience of co-authoring a paper.

I would also like to express my sincere gratitude to my family for cheering and caring for me from all corners of the world, in particular to my parents for showing it to me in the first place and to my twin brother for sharing my passion for development issues. To my friends for supporting me, dining and dancing with me when I needed it the most and in general for making me laugh. Finally, I am extremely grateful to my son, Helmer, for showing me the world again, and to Jon. For his love, for believing in me and encouraging me to embark on this journey, and for giving me the time and affection to complete this thesis.

Nina Bruvik Westberg

Ås, August 2016

Contents

List of papers

This thesis is based on the following four papers:

Paper 1

Exploring technology use under climate risk and shocks through an experimental lens

(Stein T. Holden and Nina Bruvik Westberg)

Paper 2

Learning the hard way? Adapting to climate risk in Tanzania

(Sofie Waage Skjeflo and Nina Bruvik Westberg)

Paper 3

Exchanging fertilizer for votes?

(Nina Bruvik Westberg)

Paper 4

In school on time to marry?

(Nina Bruvik Westberg)

Summary

The objective of this thesis is to shed light on households' agricultural investments and adaptation to climate risk and shocks, and how politicians and local customs may impact households' behavior in Sub-Saharan Africa. The future development of this region is closely tied to households' ability to tackle climate variability, increased efficiency in the use of government resources and raised levels of human capital in the young and growing population. This thesis is an empirical contribution to the debate on how these issues may be tackled. The thesis consists of an introductory chapter and four independent research papers.

In paper 1, my co-author and I assess the use and demand for inorganic fertilizer among smallholders in northern Ethiopia. Paper 1 has both a methodological and an empirical contribution. We exemplify how behavioral experiments can be combined with observational data in order to cast light on technology uptake. In addition, we add to the literature on the determinants of uptake of inorganic fertilizer. Inorganic fertilizer is an example of a modern technology that may enhance yields, but that also involves greater risks. We find that risk aversion is positively correlated with fertilizer use for farm households that are predominantly net buyers, but that higher rainfall variability reduces fertilizer use among more risk averse farmers. Fertilizer use and demand is negatively associated with less than average rainfall in the previous season. These findings indicate that the relationship between risk aversion and input use depends on contextual factors. Further, low levels of fertilizer use seems to be both a function of liquidity constraints, but also existing rainfall conditions.

In paper 2, my co-author and I broaden the view to agricultural yields. We assess the impacts of rainfall shocks in Tanzania and the extent to which previous shocks affect the impact of a current shock. Specifically, we couple detailed plot- and household-level panel data with weather data and create relative measures of grid-specific shocks. We find that the impact of a drought on agricultural yields increases in the severity of the shock. The negative impact is mitigated by previous shock exposure, yet this only holds for milder shocks. We also investigate whether households are able to protect children's health from these same shocks. Severe droughts seem to have a negative impact on short-term nutritional indicators, while we find suggestive evidence that more previous shock experience mitigates impacts of less severe shocks. Exploring possible explanations for these results, we find that households invest in soil- and water conservation facilities in response to more frequent rainfall shocks, whereas they are less likely to apply fertilizer. Further, households seem to use off-farm income sources as a coping strategy when facing shocks, but less so if they have more previous shock exposure.

Paper 3 returns to fertilizer and its role in politics in Malawi. I investigate to what extent the allocations of fertilizer vouchers from the Malawian Farm Input Subsidy Program (FISP) were altered leading up to the presidential election in Malawi in 2009. Core and swing voters are identified based on past election outcomes and voters' likely ethnicity. I use a district-specific fixed effects approach, comparing the official district-level

allocations of fertilizer vouchers in the last season prior to the election to other seasons, and how this relates to the distribution of core and swing voters. I do not find evidence of targeting at the incumbent's core voters, whereas districts with more swing voters receive on average more fertilizer vouchers in the 2008/09 season relative to other seasons. This increase comes at the expense of districts with more of the main opponents' core voters, who receive on average fewer vouchers. Differing between voters by ethnicity only reveals that the incumbent's co-ethnics and the swing voter ethnicities were favored relative to the co-ethnics of one of the main opponents.

Paper 4 revisits the children. I focus on the bride price custom and its role in explaining the female-favored gap in on-time school enrollment in four southern African countries. The bride price custom involves a payment from the groom and his family to the bride's family. Previous qualitative and in part quantitative work has suggested that the bride price is increasing in the bride's education, whereas it may be reduced by non-virginity and previous childbearing, and thus potentially also age. Comparing individuals within the same survey and district, I find that 7-9 year old girls that belong to ethnicities that have historically practiced the bride price custom are more likely to enroll on time relative to boys from bride price ethnicities. This holds in two out of four countries, Malawi and Namibia, and is robust to ethnicity- and household-level controls. In the two other countries, Mozambique and Zambia, girls are less likely to enroll on time than boys, but only among the non-bride price ethnicities. I find less evidence of girls from bride price ethnicities enrolling earlier than other girls. However, bride price teenage girls acquire on average more years of education compared to non-bride price girls in all four countries. I assess a range of alternative explanations, other than returns in the marriage market, that may explain the pattern of results, including the role of child labor, nutritional status, sibling competition and returns in the labor market.

Sammendrag

Formålet med denne avhandlingen er å belyse husholdningers investeringer i landbruk og tilpasninger til klimarisiko og værsjokk, samt hvordan politikere og lokale skikker kan påvirke husholdningers adferd i Afrika sør for Sahara. Den framtidige utviklingen til denne regionen er nært knyttet opp mot husholdningers evne til å takle variasjoner i klima, mer effektiv bruk av offentlige ressurser og økt human kapital i den unge og voksende befolkningen. Denne avhandlingen er et empirisk bidrag som belyser disse temaene, og hvordan relaterte problemer kan løses. Avhandlingen består av et introduksjonskapittel og fire uavhengige artikler.

I artikkel 1 undersøker min medforfatter og jeg bruken og etterspørselen etter kunstgjødsel blant småbønder nord i Etiopia. Artikkelen har både en metodisk og et empirisk bidrag. Vi eksemplifiserer hvordan adferdseksperimenter kan kombineres med observasjonsdata for å analysere teknologiopptak. I tillegg bidrar vi til litteraturen om forklaringsfaktorer bak bruken av kunstgjødsel. Kunstgjødsel er et eksempel på en moderne teknologi som kan øke avlinger, men som også involvere en større grad av risiko. Vi finner at risikoaversjon er positivt korrelert med gjødselbruk for småbønder som er hovedsakelig nettokjøpere, men at høyere nedbørsvariasjon reduserer gjødselbruk blant mer risikoaverse bønder. Gjødselbruk og etterspørsel er negativt assosiert med mindre enn gjennomsnittlig nedbør i forrige sesong. Disse funnene indikerer at forholdet mellom risikoaversjon og bruken av innsatsfaktorer avhenger av kontekst. Videre så ser lave nivåer på gjødselbruk ut til å være en funksjon av både likviditetsskranker og nedbørsforhold.

I artikkel 2 utvider min medforfatter og jeg fokuset til avlinger. Vi ser på effekten av nedbørssjokk i Tanzania, og i hvilken grad tidligere sjokk påvirker effekten av et inneværende sjokk. Vi kobler detaljerte paneldata på plot- og husholdsnivå med værdata og lager relative mål på grid-spesifikke sjokk. Vi finner at effekten av en tørke på avlinger øker med intensiteten til sjokket. Den negative effekten er dempet ved tidligere sjokkerfaringer, men dette holder kun for mildere sjokk. Vi utforsker også hvorvidt husholdninger evner å beskytte barns helse fra de samme sjokkene. Kraftige sjokk ser ut til å ha en negativ effekt på indikatorer som fanger opp kortsiktige endringer i barns helse, mens vi finner tegn på at mer tidligere sjokkerfaring demper effekten av mindre alvorlige sjokk. Vi utforsker mulige forklaringer bak disse funnene. Vi finner at husholdninger investerer i jord- og vannkonservering som en respons til mer hyppige nedbørssjokk, mens de er mindre tilbøyelige til å bruke gjødsel. Videre ser husholdninger ut til å ta i bruk inntektskilder fra utenfor gården som en mestringsstrategi i møte med sjokk, men i mindre grad dersom de har mer tidligere sjokkerfaring.

Artikkel 3 returnerer til gjødsel og dens rolle i Malawis politikk. Jeg undersøker i hvilken grad tildelinger av gjødselskuponger fra Malawis Farm Input Subsidy Program (FISP) ble endret i sesongen før presidentvalget i Malawi i 2009. Kjerne- og svingvelgere er identifisert basert på tidligere valgresultater og velgernes sannsynlige etnisitet. Jeg bruker distrikts-spesifikke faste effekter, og sammenligner de offisielle distriktstildelingene av

gjødselskuponger den siste sesongen før valget med andre sesonger, og hvordan dette er relatert til fordelingen av kjerne- og svingvelgere. Jeg finner ingen bevis på at den regjerende kandidatens kjernevelgere mottar mer, mens distrikter med flere svingvelgere mottar i gjennomsnitt flere gjødselskuponger i 2008/09 sesongen sammenlignet med andre sesonger. Dette kommer på bekostning av distrikter med flere av hovedopponentenes kjernevelgere, som i snitt mottar færre kuponger. Når jeg kun skiller mellom velgere basert på etnisitet finner jeg at den sittende kandidatens kjernevelgere og svingvelgerne ble favorisert sammenlignet med den etniske gruppen til en av hovedopponentene.

Artikkel 4 vender tilbake til barna. Jeg fokuserer på brudepristradisjonen og dens rolle i å forklare at jenter har større sannsynlighet for å begynne på skolen i tide, i fire land i sørlige Afrika. Brudepristradisjonen involverer en betaling fra brudgommen og hans familie til brudens familie. Tidligere kvalitative og til dels kvantitative studier har indikert at brudeprisen er stigende i brudens utdanning, mens den kan bli redusert dersom bruden ikke er jomfru eller tidligere har båret frem barn, og dermed også alder. Jeg sammenligner individer fra samme tidsperiode og distrikt. Jeg finner at 7-9 år gamle jenter fra etnisiteter som historisk sett har praktisert brudepristradisjonen har større sannsynlighet for å begynne på skolen i tide sammenlignet med gutter fra etniske grupper som praktiserer brudepristradisjonen. Dette holder i to ut av fire land, Malawi og Namibia, og holder selv når det kontrolleres for variabler på etnisitets- og husholdsnivå. I de to andre landene, Mosambik og Zambia, viser jenter en lavere sannsynlighet for å begynne på skolen i tide sammenlignet med gutter, men kun blant etniske grupper som ikke praktiserer brudepristradisjonen. Jeg finner begrenset støtte for hypotesen om at jenter fra etniske grupper med brudepris begynner tidligere enn andre jenter. Derimot så finner jeg at tenåringsjenter fra etniske grupper med brudepristradisjonen tilegner seg i gjennomsnitt flere år med utdanning sammenlignet med andre jenter i alle fire landene. Jeg undersøker en rekke alternative forklaringer, andre enn forskjellige avkastning i ekteskapsmarkedet, som kan forklare de observerte funnene. Dette inkludere betydningen av barnearbeid, barns helse, konkurranse mellom søsken og avkastning i arbeidsmarkedet.

INTRODUCTION

1 Introduction

The share of people in absolute poverty has decreased dramatically over that past decades, yet countries in Sub-Saharan Africa are lagging behind. Chen and Ravallion (2010) estimated that by 2015 one-third of the world's poor will live in this region.[1] Poverty alleviation depends on the actions of individuals and broader entities, such as the government. Further, the ability to escape poverty may be conditioned by multiple factors, such as market access, institutions, climate variability, and cultural norms. Against this backdrop, this thesis seeks to inform our understanding of choices and policies that are made with the implicit or explicit aim of reducing poverty.

The thesis consists of an introductory chapter and four independent research papers. In each paper I take the view of a different decision-maker. My co-authors and I explore farm households' perspective on the adoption of inorganic fertilizer (paper 1) and the extent to which they can adapt to the impact of climate risk on agricultural yield and child health (paper 2). Further, I take the view of an incumbent in allocating government funds (i.e. fertilizer vouchers) in order to maximize votes (paper 3) and the parents' perspective on investing in children's education with the expectation of a future bride price (paper 4).[2] The four papers can all be placed within the broad realm of development economics, and scratch at the role of climate variability, ethnic customs and government policies in shaping the future.

In the following I present a brief overview of the literature on the impact of climate risk and shocks on agriculture, gender differences in children's education, the political capture of input subsidy programs, and ethnic inequality in Sub-Saharan Africa. As the wide, yet overlapping, range of topics suggest, this overview is by far exhaustive. The intention is instead to place the four papers in a broader context. Next, I summarize the four papers that constitute this thesis, followed by a discussion of the data and methods used. In the final section I provide some conclusive remarks, policy recommendations, and identify paths for future research.

2 A broader context

2.1 Investment and adaptation in agriculture under climate variability

Agriculture is still the dominant source of income and occupations in Sub-Saharan Africa.[3] Agricultural yields are low compared to other regions and rising population pressure, in combination with limits on the land available, suggests that an increase in yields has to come through technology adoption (Burch et al., 2007). Inorganic fertilizer is an example of a modern technology that may enhance yields, but that also involves

[1] The share of the population living on less than \$1.25 a day.
[2] The bride price is a payment from the groom and his family to the bride's family upon marriage.
[3] In the countries that this thesis deals with around two-thirds or more of the economically active population have their main occupation in agriculture (McMillan and Headey, 2014).

greater risks. The returns to applying fertilizer are more uncertain under variable weather conditions (Dercon and Christiaensen, 2011). Further, the ability and rationale for undertaking this risky investment may depend on access to credit and insurance.[4]

Sandmo (1971)'s seminal model predicts that risk-averse producers facing variability in output prices will produce less than risk-neutral producers when insurance and credit markets are missing. Credit and insurance markets are typically missing or imperfect in developing countries, particularly in rural areas (Conning and Udry, 2007). The development of these markets is constrained by agriculture's inherent dependence on immobile land resources that results in spatially dispersed, seasonal production (especially in rain-fed agriculture) and high transaction costs (Binswanger and Rosenzweig, 1986). Moreover, households within the same geographical area are vulnerable to the same weather variability, inducing yield risk, market price risk and uncertainty in the timing of input allocations (Binswanger and Rosenzweig, 1986). This limits the extent to which they can rely on informal risk sharing. In addition, heterogeneity in inputs and the synchronic timing of events limits the development of other factor markets (Binswanger and Rosenzweig, 1986), including those that households engage in both as a consumer and producer, such as food and labor. Singh et al. (1986)'s seminal farm household model establishes that a consequence of imperfect markets is that production and consumption decisions are no longer separable from each other. Incomplete markets for consumption smoothing thereby affects production decisions and may induce income smoothing, which again may exacerbate the impact of risk and risk aversion on production (Morduch, 1995). For instance, households may avoid risk exposure by limiting the use of fertilizer in order to smooth income (Lamb, 2003) and consumption (Dercon and Christiaensen, 2011). Poorer households are likely to be more risk averse and may thus engage in more risk mitigation (Rosenzweig and Binswanger, 1993). Ultimately, they may be locked into poverty due their reliance on less risky activities with low returns (Dercon, 2002).

Nonetheless, households' production responses to risk depend not only on their risk aversion, but also their position in the market. Net buyers of food may respond to increased output price risk by increasing food production, and thus also input use (Finkelshtain and Chalfant, 1991). In line with this, Fafchamps (1992) finds that farm households that face thin food markets and volatile prices opt for subsistence orientation. Whether this also holds for fertilizer use under exposure to climate risk is less clear. Paper 1 is as such an empirical contribution. We address the role of climate variability and risk aversion, and the interaction between the two, in explaining fertilizer use and demand among predominantly net buyers of food in northern Ethiopia. We also assess the role of shortfall in rainfall in the previous season. Paper 1 adds to the existing literature on fertilizer adoption in Ethiopia in view of rainfall variability and risk aversion (Alem et al., 2010; Hagos and Holden, 2011; McIntosh et al., 2013).

[4] See Jayne and Rashid (2013) for a detailed discussion on other pitfalls in trying to increase agricultural yields by use of inorganic fertilizer in Sub-Saharan Africa.

McIntosh et al. (2013) argue that whether farmers' low fertilizer use is due to risk and credit constraints or low returns remains a policy question. The type and rationale for government interventions depends on the answer to this question. Over the past decade targeted input subsidy programs have regained momentum in Sub-Saharan Africa. Governments have sought to stimulate fertilizer use through the reintroduction of these programs, with the motivation that farm households are underinvesting in modern inputs due to market imperfections (Morris et al., 2007).[5] Paper 3 takes a political economy perspective on such a program, specifically the Malawian Farm Input Subsidy Program.

Recent years have seen a burgeoning literature on the impact of climate variables on both agricultural and non-agricultural outcomes, see Dell et al. (2014) for a review. This is in part in response to the increased emphasis on establishing causal relationships.[6] The exogenous nature of well-defined realizations of weather shocks allows for a robust empirical investigation. The expanding literature on climate variables is, however, also a response to a changing climate. The most recent IPCC report states that the climate system is both warming and increasing in variability (Niang et al., 2014). The predominance of rain-fed agriculture makes farm households in developing countries particularly vulnerable to these changes. Dell et al. (2014) identify avenues for how the impacts of current shocks can inform the understanding of future impacts from climate change. Assessing how the impact of current shocks depend on past shock experience is one identified approach, which my co-author and I follow in paper 2. Specifically, we assess how the interaction between past and current droughts affect agricultural yields using recent panel data from Tanzania. This paper adds to the growing literature that uses household-level data (Di Falco et al., 2011; Salazar-Espinoza et al., 2015) to investigate farm households' adaptive capacities[7] in Sub-Saharan Africa.

Paper 2 also examines the extent to which the impacts on agricultural yield are transferred through to children's health, which is a more final welfare outcome. We are only able to assess the short-term impacts on nutritional status, yet there may be substantial long-term impacts if consequences are irreversible or the impact of shocks persist. For instance, Maccini and Yang (2009) find that girls who experience more than average rainfall during infancy are taller and have lower asset poverty as adults. They attribute this to children's health as being particularly sensitive in early childhood and that negative impacts on health may persist up until adulthood, along the lines of Barker's (1998) fetal origin hypothesis. Moreover, this may impact subsequent accumulation of human capital during childhood and adolescence.

[5] See Morris et al. (2007) for a general discussion on the rationales for input subsidy programs.

[6] A number of papers look at the reduced form impact of weather shocks on a final outcome under the assumption that the shocks affect farm households' agricultural income (see Dell et al. (2014) for a review).

[7] The IPCC define adaptive capacity as "[t]he ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2014).

2.2 Children and their human capital

The population of Sub-Saharan Africa is young and growing,[8] and many are living in poverty. Improving children's human capital is one potential pathway out of poverty. Becker (1975) refers to human capital as "the resources in people" where education is a major component. There are a multitude of studies that link higher educational attainment to other outcomes. These include higher wages (Duflo, 2001), reduced child mortality (Breierova and Duflo, 2004), reduced asset poverty (Maccini and Yang, 2009), improved living standards, larger social networks, and higher political participation (Wantchekon et al., 2015). Educating women has the additional positive externality of reducing fertility (Breierova and Duflo, 2004; Osili and Long, 2008).

The enrollment rates in primary school in Sub-Saharan Africa have improved dramatically over the past decades. This is in part due to the abolishment of primary school fees. However, changes in final educational attainment are less remarkable (Lee and Lee, 2016).[9] Drop-out rates remain high and continuation into secondary school is still limited by supply constraints (Lewin, 2009). Females are in particular disadvantaged. Men have acquired on average one extra year of education than women in Sub-Saharan Africa (Lee and Lee, 2016). This gender gap can be traced back to the parents and their differential treatment of children, which again usually arises from economic conditions (Becker, 1981; Becker and Tomes, 1986). Resource constrained parents with limited access to inter-temporal markets, other than investing in their children's education, may choose to favor their sons. This may be due to an expectation of more old-age support and/or that they expect higher returns to boys' education in the labor market. Further, when facing adverse shocks parents may be more inclined to withdraw girls from schools if they are perceived as having a comparative advantage in replacing the mother in home production (Björkman-Nyqvist, 2013). However, the above comparison in educational attainment masks substantial heterogeneity between and within countries in Sub-Saharan Africa. Paper 4 documents for instance that females may be acquiring on average more education than males in Namibia. Further, focusing on the initial outset, i.e. when children enroll in school, reveals less of a male-favored pattern. Girls may even be more likely to enroll on time relative to boys (Bommier and Lambert, 2000; Hoogeveen and Rossi, 2013). Paper 4 adds to the literature on gender differences in the school cycle and provides cross-country evidence on a female-favored gap in on-time enrollment in Namibia, Malawi and Zambia.

Several explanations have been proposed for why children enroll later than what Becker and Tomes's (1986) human capital investment model predicts. These include credit constraints, lower nutritional status (Glewwe and Jacoby, 1995) and lower cognitive abilities (Akresh et al., 2016). Alderman et al. (2009) expand

[8] In the countries that this thesis deals with (Ethiopia, Tanzania, Malawi, Mozambique, Namibia and Zambia) 36-45 percent of the population are between 0 and 14 years old. In comparison, the world average is 26 percent (United Nations, 2015).

[9] Individuals aged 15-64 had acquired on average 5.5 years of schooling in Sub-Saharan Africa in 2010 (Lee and Lee, 2016).

upon this and find that children with low stature, due to adverse conditions during childhood, both delay school enrollment and attain less education. Only a few papers have identified and sought explanations for why girls may enroll earlier than boys. Bommier and Lambert (2000) propose two explanations for the Tanzanian setting: (i) that boys face higher returns to undertaking other work prior to school enrollment and (ii) that parents discount the value of a future bride price and therefore send girls to school earlier so that they can marry earlier. Hoogeveen and Rossi (2013) hypothesize instead that girls enroll earlier because they are more physically and mentally mature, or that that girls face lower opportunity cost of time relative to that of boys. Neither paper undertakes an empirical investigation of these hypotheses.

The bride price is a payment from the groom and his family to the bride's family upon marriage.[10] Despite its widespread practice in Sub-Saharan Africa, the custom has received limited attention in terms of its implications for human capital investments other than early marriage (Hoogeveen et al., 2011). Ashraf et al. (2016) is an important exception. They examine the girls' school enrollment in response to school constructions in Zambia (and Indonesia) and find that girls belonging to ethnicities that have historically practiced the bride price custom are more likely to enroll in school relative to other girls. Parents' incentive to invest in education in order to obtain a higher bride price is argued to be the main driving force. Qualitative, and in part quantitative work,[11] supports the argument that the bride price payment is increasing in education. Yet, it also indicates that the bride price may be reduced by the bride's non-virginity and previous childbearing, and thus also age. Paper 4 combines these two elements and investigates whether the bride price custom induces earlier enrollment of girls belonging to bride price ethnicities, relative to girls from non-bride price ethnicities and boys. I also assess the subsequent consequences for educational attainment. The paper thus adds to the literature on the impact of marriage payments on economic outcomes in Sub-Saharan Africa (Tertilt, 2005, 2006; Platteau and Gaspart, 2007; Gaspart and Platteau, 2010; Hoogeveen et al., 2011; Ashraf et al., 2016).

2.3 Policies for increasing agricultural productivity and reducing poverty

Government policies may play a crucial role in reducing poverty. Agriculture as a major source of both income and occupations makes this sector particularly interesting as a channel for providing income support to the poor. Added to this is the more immediate goal of increasing agricultural productivity. Over the past decade several governments across Sub-Saharan Africa have reintroduced input subsidy programs in order to achieve both aims (Morris et al., 2007).[12] Jayne and Rashid (2013) take stock of the evidence on the input subsidy programs in Sub-Saharan Africa. Based on a number of studies they claim that national

[10] See Anderson (2007) for a comparison of the bride price versus the more common marriage payment in south Asia, dowry.
[11] I refer to paper 4 for a detailed discussion.
[12] These include Burkina Faso, Ghana, Kenya, Malawi, Mali, Nigeria, Senegal, Tanzania, and Zambia (Jayne and Rashid, 2013).

food production has increased (although less than expected), but that the impacts on households' food security and poverty (and maize prices) are moderate or mixed. The modest impacts stem in part from the unsuccessful targeting. Most of these programs are to target[13] poor farm households, yet the recipients tend to be wealthier households. This limits both the poverty-reducing impact and the increase in overall production due to the crowding out of commercial fertilizer.

Jayne and Rashid (2013) argue that the benefits do not outweigh the substantial program costs.[14] Further, that government spending would be more successful in increasing agricultural productivity and reducing poverty if shifted to other budgets, either within or outside the agricultural department (see Jayne and Rashid (2013) for details). In line with this, Pan and Christiaensen (2012) argue that the multiple goals of targeting the poor and increasing national food security may not be reconcilable. The poor and those with the highest marginal productivity from adding fertilizer or seeds may not be the same group. Yet, Jayne and Rashid (2013) also acknowledge that the input subsidy programs are likely to stay for some time since they are "politically popular among voters and could help win elections" (p. 551). The subsidy programs may in other words be susceptible to political capture that override the program goals (Duflo et al., 2011; Lunduka et al., 2013).

Assuming that the programs are here to stay for a while, then understanding how and at what level political capture is happening is crucial in order to increase the programs' efficiency. The subsidized inputs are often accessed through vouchers with multiple stakeholders involved in the allocation process of both vouchers and inputs, from the central government and down to the village level. For instance, Pan and Christiaensen (2012) provide evidence on local elite capture in Tanzania. In recent years, several papers have assessed whether the program allocations are overridden by electoral goals at the central level (Banful, 2011; Brazys et al., 2015). These build to a varying degree on the theories on tactical redistribution that predict that resources, in this case input vouchers, are either targeted at core or swing voters (or electoral districts) (Cox and McCubbins, 1986; Dixit and Londregan, 1996, 1998; Lindbeck and Weibull, 1987, 1993).

Paper 3 investigates whether fertilizer vouchers from the Malawian Farm Input Subsidy Program[15] were targeted at districts with more core or swing voters in an election season. I identify core and swing voters using past election outcomes, in line with previous work (Cole, 2009), but due to shifting party affiliations I also exploit information on ethnicities' political connectedness and geographical distribution. The paper adds to the existing political economy literature on the Malawian Farm Input Subsidy Program (Holden and Lunduka, 2013; Mason and Ricker-Gilbert, 2013; Brazys et al., 2015; Dionne and Horowitz, 2016), and is to

[13]Some of the input subsidy programs are universal.

[14]These take up a large portion of the government and agricultural budgets. For example, input subsidies accounted for 16 percent of the Malawian government's budget in 2008/09 (Dorward and Chirwa, 2011) and around 40 percent of the Zambian government's annual budget on agriculture over the period 2004-2011 (Mason and Ricker-Gilbert, 2013). Additional costs include the negative externalities of fertilizer overuse and crowding out of commercially bought fertilize and government spending.

[15]See Lunduka et al. (2013) for a review of the impacts of the Malawian program.

my knowledge the first to use panel data on the district-level nation-wide allocations on an input subsidy program in Sub-Saharan Africa.

2.4 Ethnic inequality

Ethnicity is a multifaceted identity (Posner, 2005; Chandra, 2006). Ethnic identity may vary in strength both within and between ethnic groups, and over time (Stewart, 2005; Eifert et al., 2010). In papers 3 and 4 I use ethnicity as a marker in assessing tactical redistribution and the impact of the bride price custom on educational investments, respectively. The former falls into a growing literature on the prevalence of ethnic favoritism in Sub-Saharan Africa. For instance, ethnic favoritism is linked to voting behavior (Bates, 1983; Posner, 2005; Ichino and Nathan, 2013), public good and aid allocations (Jablonski, 2014; Burgess et al., 2015) and clientelistic networks (Wantchekon, 2003), which again have implications for economic outcomes, including education (Kramon and Posner, 2016). Nunn (2012) also assesses differences in educational attainment by ethnicity, but trace these back to the colonial period. Paper 4 is as such a contribution to understanding observed ethnic differences in education. Building on Ashraf et al. (2016), it highlights another channel, namely females' (additional) returns to education in the marriage market for ethnicities practicing the bride price custom. Further, paper 4 provides empirical evidence from four southern African countries allowing for a cross-country comparison within the same region.

3 Summary of papers

In this section I summarize each of the four papers that constitute this thesis. I focus here on the research questions that are addressed and the main findings, leaving a more detailed discussion of the data and methods for the next section.

Paper 1

Exploring technology use under climate risk and shocks through an experimental lens

Increasing agricultural productivity among smallholders is essential in order to improve food security in Sub-Saharan Africa. Growing populations in combination with limits on agricultural land suggest that modern inputs may play a central role in increasing yields. On the other hand, the returns to these technologies, such as inorganic fertilizer, are weather-dependent and therefore also uncertain. In this paper, my co-author and I assess use and potential demand for inorganic fertilizer among predominantly net buyers of cereals in Tigray, Ethiopia. We combine rainfall data with plot data, in addition to a field experiment on fertilizer demand and a hypothetical choice experiment. Specifically, we explore how average rainfall, rainfall risk, lagged rainfall shocks and risk aversion relate to inorganic fertilizer use at the farm plot level. Further, we analyze how these variables and exogenous price variation explain experimentally derived demand for inorganic fertilizer at the household level. As expected, we find that fertilizer use and demand are positively associated with average annual rainfall. Lagged rainfall shocks are negatively associated with the amount of fertilizer applied at the plot level and the demand for fertilizer, and positively associated with the planting of cereals. Rainfall risk, measured in terms of intra-annual variation in rainfall, is negatively correlated with fertilizer use at the plot level and fertilizer demand. However, controlling for rainfall risk, our measure of risk aversion is positively correlated with fertilizer use, whereas the interaction between risk aversion and rainfall risk is negatively associated with fertilizer use. The former result is consistent with Finkelshtain and Chalfant (1991)'s theory for net buyers and their response to output price risk. We do not find a statistically significant relationship between risk aversion and fertilizer demand, whereas our results indicate a positive association between risk aversion and the planting of cereals. In terms of the price responsiveness of fertilizer, we find that around 40 percent of the households prefer fertilizer to cash at the going fertilizer price (7.6 Ethiopian Birr (ETB)/kg)[16] at the time of the survey. Lastly, a one ETB increase in the price per kg of DAP fertilizer reduces the share of households demanding fertilizer over cash by 9.1 to 9.5 percentage points. These findings suggest that shortfall in lagged rainfall may result in binding liquidity constraints. In addition, the relationship between risk aversion and fertilizer use seems to depend on contextual factors.

Paper 2

Learning the hard way? Adapting to climate risk in Tanzania

The impact of repeated shock exposure, such as droughts, on farm households' ability to cope with new shocks is ambiguous. On the one hand, if households responded to previous shocks by depleting assets, then they will be more vulnerable to the impact of a current shock. On the other hand, if households are able to draw upon their experiences from past shocks, then this may enable them to mitigate the impact of a new shock. Climate change is expected to increase the incidence and magnitude of extreme events, such as droughts, thereby making this question particularly relevant. In this paper, my co-author and I use recent panel data on Tanzanian farm households to investigate how previous shock exposure affects the impact of a current shock. Specifically, we investigate the impact of current and past droughts on agricultural yield and children's health, measured by their nutritional status. Our results show that droughts reduce crop yields, with the impact increasing in the severity of the drought. The results also indicate that the more shocks a household has experienced in recent years, the less severe is the impact of a current shock on agricultural yields. However, this only holds for mild droughts. In terms of children's health, severe droughts seems to

[16]The exchange rate in June 2010 was \$1=13.5 Ethiopian Birr (ETB), making this equivalent to \$0.56 per kg.

have a negative impact on short-term nutritional indicators, but there are is also suggestive evidence that households with more previous shock experience are able to mitigate the impacts of less severe shocks on children. We investigate possible mechanisms for these results. We find that households invest in soil- and water conservation facilities in response to more frequent shock exposure, whereas they are less likely to apply fertilizer. Moreover, households seem to engage in off-farm activities as a coping strategy in response to shocks, but this strategy appears less important for households that have more previous shock exposure. These findings suggest that households are able to learn from their past shock experience, and could imply that households, to a certain extent, are able to adapt to climate risk.

Paper 3

Exchanging fertilizer for votes?

Several Sub-Saharan African countries have (re)introduced targeted input subsidy programs over the past decade. The inputs are typically accessed through vouchers that are economically attractive for a large share of the countries' inhabitants. As such, these programs may also serve as instruments for amassing electoral support. I investigate to what extent distributions from the Malawian Farm Input Subsidy Program (FISP) was altered in the last season prior to the presidential election in 2009, relative to other seasons. Specifically, I use a two-way fixed effects estimator and assess how changes in the official district-level allocations in the election season (2008/09) relates to the distribution of core and swing voters. I identify core and swing voters based on past election outcomes and ethnicity shares. The categorization of core and swing voters differs from previous work since I combine both previous election results and ethnicity. This approach is necessary due to shifting party affiliations, which is common in many other developing countries. Importantly, there is no a priori reason for why the districts with more core or swing voters should have a different need for vouchers in the election season relative to other seasons, except that of electoral goals. I do not find evidence of targeting at the incumbent's core voters. Instead, districts with more swing voters receive on average more fertilizer vouchers in the 2008/09 season relative to other seasons, and this comes at the expense of the main opponents' core voters, who receive on average fewer vouchers. Differing between voters by ethnicity only reveals that the incumbent's co-ethnics and the swing voter ethnicities were favored relative to the co-ethnics of one of the main opponents. This paper speaks to the contentious debate on targeted input subsidy programs and political capture.

Paper 4

In school on time to marry?

Girls may be more likely to enroll in primary school on time than boys in southern Africa. I investigate the role of the bride price custom, involving a payment from the groom and his family to the bride's family, in explaining part of this pattern. Previous qualitative and in part quantitative work has suggested that the bride price is increasing in the bride's education, whereas it may be reduced by a bride's non-virginity and previous childbearing, and thus potentially also age. I couple ten cross-sections of the Demographic Health Surveys for Malawi, Mozambique, Namibia and Zambia with Murdock's (1967) Ethnographic Atlas. I compare the likelihood of enrolling on time by bride price custom and gender, while imposing survey and district fixed effects and a battery of ethnicity- and household-level control. As expected, I find that 7-9 year old girls that belong to ethnicities that have historically practiced the bride price custom (bride price girls) are more likely to enroll on time relative to boys from bride price ethnicities. This holds in Malawi and Namibia. In Mozambique and Zambia, girls are less likely to enroll on time than boys, but only among non-bride price ethnicities. Lastly, girls from bride price ethnicities are more likely to enroll on time than other girls in Zambia and Namibia, whereas with the exception of Namibia there is limited evidence that boys differ by the bride price custom. However, bride price teenage girls acquire on average more years of education compared to non-bride price girls in all four countries. I assess a range of alternative explanations that may explain the pattern of results, including the role of child labor, nutritional status, sibling competition and returns in the labor market. None of the alternative explanations seem to explain the female-favored gap in on-time enrollment. Nevertheless, the results on the relationship between this gap and the bride price custom remain inconclusive. In Namibia, individuals belonging to bride price ethnicities do better on all explored outcomes compared to those from non-bride price ethnicities. This suggests that there are other factors correlated with the bride price custom that explain why bride price children are more likely to enroll in school on time and obtain on average more education. On the other hand, the bride price custom does seem to explain the differences in teenage girls' educational attainment in Malawi, Mozambique and Zambia. This paper adds to the ongoing public debate on the bride price custom in Sub-Saharan Africa and its impact on girls' education.

4 Data and methods

In each paper I use econometric methods. Econometrics merges economic theory, mathematics and statistics (Frisch, 1933) and is used to test and contribute to the further development of economic theory and policies (Wooldridge, 2008). The empirical economic methodology seeks to identify causal relationships. The extent to which this is possible depends on the data generating process, the methodological approach, and the theoretical assumptions.

Typically, the researcher wants to identify the impact of a policy or economic condition on an outcome, holding everything else constant (*ceteris paribus*) (Wooldridge, 2008). Selection into that policy or condition is a major threat to establishing a causal relationship. Experimental data typically involves randomly assigning participation or a condition, thus reducing this threat (Angrist and Pischke, 2009). The experimental setting varies greatly, from the laboratory (where the researcher has more or less full control over all aspects of the participants' decision-making) to large-scale randomized control trials. In between there is a large range of approaches in terms of contextual factors, see Harrison and List (2004) and Levitt and List (2009) for a detailed discussion. Movement from the former to the latter typically involves a trade-off between the internal and external validity of the results. Internal validity refers to the extent to which one can claim causality, whereas external validity refers to the generalizability of results to other settings (Roe and Just, 2009). Observational data is to a greater extent ridden with selection and omitted variable bias issues, depending upon the source of variation that the researcher is exploiting. For instance, observational data may offer a source of exogenous variation through natural experiments or quasi-experiments (Cameron and Trivedi, 2009).

I will in the following briefly present the data and methods used in each paper of the thesis, upon which I discuss their potential limitations. I do not attempt a complete description of these, for this I refer to the specific papers, but aim at identifying similarities and differences between the four papers.[17]

4.1 Data and methods

Paper 1 assesses the relationship between fertilizer use and demand, risk aversion and various rainfall measures. We use data from a household survey on 527 households in Tigray in northern Ethiopia. The survey took place in 2010 as a joint collaboration between the Norwegian University of Life Sciences and Mekelle University with my co-author as a key organizer. The survey data consists of both an observational component on household and plot characteristics and an experimental component. The latter includes a framed field experiment on fertilizer and a hypothetical choice experiment on risk aversion. The hypothetical choice experiment is based on Binswanger (1980) and Wik et al. (2004), and is placed within the context of agricultural production (see paper 2 for details). In addition, we create measures on households' exposure to rainfall risk, rainfall shocks and average annual rainfall using rainfall data from meteorological stations in Tigray. These rainfall variables are coupled with households using information on proximity and elevation. We analyze plot-level fertilizer *use* using a bivariate probit and a Cragg (double hurdle) model and fertilizer *demand* using a linear probability model. I refer to paper 1 for a more detailed discussion of the choice of

[17] Paper 1 is subject to a more detailed discussion. This paper is published and the maximum pages allowed limited the discussion of data and method in the paper.

models. The 2010 survey enters into a longer panel, but we limit our focus to this survey due to its broader experimental component. Attrition is therefore an issue that we try to tackle in the analysis using inverse probability weighting. See Hagos and Holden (2002) for details on the initial sampling that took place in 1998.

In paper 2 we investigate whether households are able to adapt to climate risk. We use data from the first two rounds of the Living Standard Measurement Survey (LSMS) for Tanzania (NBS, 2009, 2011). This is a nationally representative survey with information on a broad range of topics. We restrict our focus to farm households and match plots and households across the two survey rounds. The panel data is coupled with gridded weather data from the University of Delaware (Willmott and Matsuura, 2012b,a) using GPS coordinates. This allows us to estimate reduced form impacts of current and past shocks on agricultural yield and children's nutritional status while imposing plot- or grid-specific fixed effects. We define a shock as annual rainfall below a given percentile of the grid-specific historical distribution, whereby all grid cells have equal marginal probability of experiencing a shock in an agricultural season.

Paper 3 assesses tactical redistribution of fertilizer vouchers in Malawi. Specifically, I investigate whether the allocations from the Malawian Farm Input Subsidy Program were altered in an election season (2008/09) relative to other seasons in line with targeting at core or swing voters. These voters are identified using past election outcomes and ethnicity. I combine data from the presidential elections (SDNP, 2004; MEC, 2009), population and ethnicity data from the 2008 census (NSO, 2008), and district level figures on fertilizer voucher allocations from annual reports compiled by the Logistics Unit (LU, 2012). I assess how changes in allocations correlate with the swing and core voter measures while imposing season- and district-specific fixed effects. In addition, I control for time-varying district-specific factors that may impact targeting using data from the Second Integrated Household Survey 2004-05 (NSO, 2005) and gridded monthly rainfall data from the Climatic Research Unit (CRU) (Harris et al., 2014).[18]

In paper 4 I investigate to what extent the bride price custom is driving a female-favored gap in on-time enrollment in southern Africa. I pool ten cross-sectional rounds of the Demographic Health Surveys (ICF International, 2014) for Malawi, Mozambique, Namibia, and Zambia. These are coupled with Murdock's (1967) Ethnographic Atlas using information on the mother's ethnicity. Since ethnicities are not matched perfectly this is a rather data-intensive task. I refer to paper 4 for details on the sources used when matching. I identify whether each ethnicity has historically practiced the bride price custom or not. There is limited quantitative data on the bride price custom in general, and none in the DHS. I therefore also build on qualitative work from economics and other disciplines in order to motivate my hypotheses. I am interested in how the on-time enrollment differs by gender and bride price custom. I assess 7-9 year old children's likelihood

[18] I do not use the same rainfall data as in paper 2, as the University of Delaware data (that was was available at the time of analysis) provides a shorter history of rainfall.

of starting school on time compared to the official enrollment rules using a linear probability model. Children are compared to those within the same district and that are interviewed in the same survey round, while imposing a battery of ethnicity- and household-level controls. The hypotheses on on-time enrollment rests on the assumption that the bride price custom affects educational attainment. I therefore also assess differences in this outcome for teenagers and young adults.

In all four papers I implement some form of fixed effects approach. However, the spatial unit and time dimension of the fixed effects varies greatly across the four papers. Specifically, I use linear panel data models with fixed effects in papers 2 and 3, but these differ considerably in the size of the unit of observation. Paper 2 uses panel data at the level of the plot and the household, whereas paper 3 uses a panel at the district level. Paper 1 is based on cross-sectional data, where the fixed effects are imposed at the level of the geographical zones. Lastly, in paper 4 I use repeated cross-sections[19] where the unit of observation is the individual and where I control for district and survey round-specific factors. This has consequences for the source of variation used in estimating the coefficients of interest and the extent to which I can argue that I am observing a causal relationship.

A key assumption for obtaining unbiased estimates based on cross-sectional analysis is that the error term is uncorrelated with the explanatory variables. These explanatory variables are then characterized as exogenous. This is also called the selection-on-observables or unconfoundedness assumption (Wooldridge, 2008; Angrist and Pischke, 2009). This is a very strict requirement. For instance in paper 4, it requires that I am able to identify and control for the relevant observable factors that correlate with the bride price custom. The panel fixed effects estimator allows us to "weaken" this assumption, as it allows for endogenous variables given that they are only correlated with the time-invariant component of the error term. Specifically, the panel fixed effects estimator removes the unit-specific time-invariant characteristics that may be unobservable to the researcher (for instance plot characteristics in paper 2). This comes at the cost of greater data requirements as it requires observing the same unit, e.g. plot, over time. Further, in order to obtain unbiased estimates using this estimator the strict exogeneity assumption has to hold. It states that the error term is mean-independent of the explanatory variables after conditioning on the unobserved unit-specific effects. I refer to Wooldridge (2008) for a more detailed discussion of these and additional assumptions.

In summary, all four papers rely on secondary data sources (paper 1 is in part an exception as the data is of a primary nature to my co-author). I use primarily observational data, with the exception of paper 1 where my co-author and I couple observational data with experimental data. All four papers strive to analyze reduced form models, in the sense that an endogenous variable is analyzed as a function of exogenous explanatory variables. The extent to which the explanatory variables are exogenous is further discussed in the following section and in more detail in the respective papers.

[19] An exception is the analysis of Mozambique where I only have one survey round available.

4.2 Limitations

In all papers I aim at establishing a credible causal relationship between the explanatory variables and outcomes of interest, with varying degrees of success. This is due both to the nature of the data and methods, and the theoretical underpinnings. An important limitation in all four papers is the lack of explicit theoretical frameworks that allows for pinning down the exact mechanisms.

In paper 1 we use both experimental and observational data and this has consequences for the extent to which we can argue that we are observing a causal relationship. The results from the framed field experiment, i.e. on the probability of choosing fertilizer over a randomized amount of cash, can be interpreted as causal since we have randomly assigned the price. Yet, the exact mechanisms for our results, such as why lagged shortfall in rainfall increases the likelihood of choosing cash over fertilizer, are not clear-cut. This may suggest that the household is liquidity constrained, or that they are adjusting their expectations on future rainfall and thus the returns to fertilizer. Further, the fact that the data is derived from experiments does not necessarily allow for a more causal interpretation. For instance, we relate fertilizer use in the previous season to a measure of risk aversion, yet we measure the risk aversion rank after the decision on fertilizer is taken. This ignores any temporal instability in risk aversion. The method of elicitation also warrants some comments. Harrison and Rutström (2008) describe the experimental set-up as an ordered lottery selection that is attractive due to its simplicity.[20] However, our measure of risk aversion is based on a hypothetical choice experiment, which may yield different results than if real pay-offs were involved (Harrison and Rutström, 2008).

Theoretically, paper 1 builds on the insights from Finkelshtain and Chalfant (1991), but we apply them to a very different setting. Whereas Finkelshtain and Chalfant (1991) focus on the risk-averse producers' production response under output price risk, we investigate instead the role of risk-averse producers input use under rainfall risk. A theoretical framework would have guided our understanding in terms of both how our context differs and the subsequent predictions, yet we are constrained by both time and space in achieving this. Lastly, parts of our sample participate in safety-net programs (i.e. the Productive Safety Net Program (PSNP)). Participation in these programs may affect the relationship between risk aversion and fertilizer use, an issue that we have not been able to examine.

Paper 2 assesses the impacts of past and current shocks on agricultural yield and child health. We construct relative measures of rainfall shocks (rather than absolute measures) so that experiencing a shock should be orthogonal to other factors specific to the plot, household or grid cell. However, as Deaton (2010) argues, our ability to inform policy makers is limited by the extent to which we can identify the driving mechanisms. Although we make some headway by exploring potential mechanisms, we are constrained by both the data available and the lack of a concise theoretical framework.

[20] See Harrison and Rutström (2008) for a detailed discussion of this method versus other approaches.

Paper 1 and 2 are the closest in terms of overlapping topics and to a greater extent complementary. Both examine the relationship between rainfall measures and economic outcomes. Yet, a weakness to the thesis is the inconsistent use of definitions of climate variables. Whereas we in paper 1 treat the coefficient of variation (CV) of inter-annual rainfall across a seven year period as climate risk, we define climate risk as the probability of experiencing a negative climate shock in paper 2. This is in part the result of greater data constraints in the former paper. Still, these do capture a similar concept, since a higher coefficient of variation implies greater variability in total annual rainfall, thus implying a higher risk of a severe drought. However, the extent to which one can claim causality between these measures and an outcome differs. The coefficient of variation is a relative risk measure (paper 1) but it is endogenous. It captures both the range of variation in rainfall over these years and the annual variation, which again is likely to correlate with other factors, such as the placement of safety-net programs. In contrast, the probability of experiencing a shock in a given year (as in paper 2) should be exogenous, given that there is no temporal autocorrelation. That being said, although the shock measures in paper 2 may have a high degree of internal validity in establishing causality, the external validity in terms of extrapolating our findings to other contexts may be more nuanced (see Hsiang (2016) for a detailed discussion).

Paper 3 assesses the extent to which the Malawian Farm Input Subsidy Program is ridden by electoral goals. A strength of the paper is the use of panel data, yet there are also a number of limitations to panel data estimations and underlying assumptions that warrant attention. A downside with panel fixed effects estimates is that these are particularly susceptible to attenuation bias. Especially if there is a strong correlation between, in this case, the actual inter-annual district level allocations as compared to the amount of measurement error. Since I am removing the district-specific mean the coefficient estimates may to a large degree be estimated based on noise (Angrist and Pischke, 2009). This may explain why the coefficient estimates are relatively small, the alternative explanation of course being that there was no targeting at specific groups of voters in the election season. I employ the following empirical strategy: I control for district- and time-specific factors and known time-varying factors, and argue that finding any remaining cross-sectional variation in the voucher allocations in an election season that correlate with the distribution of swing and core voters is difficult to explain by anything other than electoral goals. I am thus attributing any observed changes as due to the incumbent government's goal of re-election, in line with Cole (2009).

I make a number of additional assumptions in paper 3. I assume that the incumbent and his government infer individuals' partisan affinity based on ethnicity. This falls in line with the historical relationship between ethnicity and voter's party affinity prior to the 2009 election (Ishiyama and Fox, 2006; Posner, 2004), but is also the result of data limitations. This is clearly a strong assumption. In addition, the exact mechanism through which the incumbent is expected to influence the voters through vouchers remains unanswered. I assume that the incumbent and his government allocate vouchers based on the proportional distribution of core and swing voters. This in the expectation that receiving a voucher will increase the likelihood of voting for the incumbent. Yet, there is a considerable distance between the incumbent and his government's allocative actions and the actual voters, whereby the assumption that (the increased likelihood of) receiving a voucher can be interpreted as vote-buying remains untested. Similarly, I am unable to address whether and how the incumbent and his government tackles the issues of compliance and monitoring in vote-buying. These issues are fertile ground for future research.

Paper 4 is perhaps the most exploratory in nature. It takes on the bride price custom in explaining differences in on-time enrollment and subsequent differences in educational attainment. The pooled cross-sectional surveys have the advantage of providing detailed data on a wide range of variables, including ethnicity, and are representative at the national- and region/province/district-level. In, addition the surveys are randomly sampled and are less subject to attrition than for instance panel data. However, the data suffers from a number of limitations, including selection issues and measurement error (see paper 4 for details). Added to this the bride price custom is clearly not assigned exogenously and omitted variable bias is a major concern. I try to address this by comparing individuals within the same districts and survey years, and by imposing ethnicity- and household-level controls. Nevertheless, in order to investigate the role of omitted variable bias and shed light on the pattern of results I also explore alternative explanations. As such it results in an expansive paper. A theoretical model may have allowed for a more succinct discussion, but the bride price custom's endogenous nature would still limit the interpretation of results. Assessing the role of bride price custom in view of an education policy, like Ashraf et al. (2016), may improve our understanding of the relationship between the bride price and the timing of educational investments.

In summary, I have tried to assess the empirical questions with the available data and appropriate methods. The above discussion indicates that there is scope for both improvements and extensions, but also identifies paths for future research. I return to the latter in the final section.

5 Conclusion, policy implications and future research

The objective of this thesis is to shed light on households' investment in agriculture and adaptation to climate risk and shocks in Sub-Saharan Africa, and how politicians and local customs may impact individuals' and households' behavior.

Identifying barriers to technology adoption is essential in order to both increase agricultural productivity and ensure food security in Sub-Saharan Africa. This thesis adds to the literature on the determinants of inorganic fertilizer uptake and the scope for adoption under variable rainfall conditions. Not surprisingly, fertilizer use and demand are found to be correlated with local rainfall conditions. On the other hand, controlling for rainfall risk results in a positive relationship between risk aversion and fertilizer use. This positive relationship may be driven by net buyers of food who engage in subsistence-orientation so as to reduce their exposure to (weather-induced) output price fluctuations. However, the current literature on Ethiopia shows both a positive relationship between risk aversion and fertilizer use, and a negative relationship between risk aversion and fertilizer purchases. Future research should aim at disentangling the underlying mechanisms for this pattern. In addition, it would be informative to understand if and how safety-net programs may influence this relationship, and whether these programs influence risk aversion. Similarly, one should explore whether there are complementary inputs in northern Ethiopia that reduce the downside risk related to fertilizer use, and thus crowd in the latter. Lastly, future research should assess the extent to which limited fertilizer adoption in northern Ethiopia is due to low returns rather than market imperfections. In terms of policy implications, expanding weather insurance and safety-nets in years of drought may dampen the negative relationship between rainfall risk and farm households' investments in fertilizer.

Concurrently, the climate is warming and increasing in variability. It is crucial to understand how farm households respond and adapt to climate shocks and risk in order to design better policies today, but also to inform our understanding of possible future responses. The responses to current weather changes cannot be directly extrapolated to the impacts of future events, yet it may give some indications of the potential room for adaptation. This thesis finds that farm households seem to be learning from past shocks, mitigating the impact of current shocks, but that the scope for adaptation decreases with the severity of the shock. These findings indicate that there is room for disseminating knowledge of and access to technologies and techniques that may reduce shortfall in agricultural yield in a drought year. Further, that safety-nets may play a role in years of severe drought by alleviating the most severe impacts. On a similar note, although I cannot establish a causal relationship between malnutrition and on-time school enrollment, the relationship between high levels of stunting and high incidents of delayed enrollment warrant more attention. Improving current food security may as such have important positive externalities on human capital.

Government policies may play a key role in reducing poverty and inequality, but are also susceptible to political capture. This thesis indicates that vouchers from the Malawian Farm Input Subsidy Program were altered favorably towards swing voters at the expense of the opponents' core voters in an election season. There is a growing literature on this program's limited ability to address the intended goals of increasing household and national food security. This thesis provides additional evidence on why this may be the case. Increased transparency at the central level in the distribution process and more clear allocation rules may limit the scope for electorally motivated redistribution. This should be a requirement set forth by donors where their support is relevant. Future research should clarify the extent to which political capture is preventing the fulfillment of program goals. Further, the thesis deals with the 2009 presidential election. Since then, new elections have taken place. An interesting question is whether the calls for increased transparency in allocations have limited the room for politicization of the Malawian input subsidy program.

Furthermore, I contribute to the bulk of research that highlights the role of improving credit- and insurance markets. For instance, fertilizer use is negatively related to lagged shortfall in rainfall, which may imply binding liquidity constraints. Moreover, wealth and parental education remain important determinants of educational investments. Although this may in part be a function of different preferences for education, it also suggests that educational investments are dependent on parents' resources. Improved credit markets may allow children to stay in school for longer. However, reducing the costs of secondary school for the poorest, through for example need-based aid, and expanding the number of secondary schools is likely to lift the education level for a larger share of the population. Nonetheless, these educational policies may only be effective if the parents' incentive structures are fully understood, including the role of customs.

This thesis provides insight into children's education cycle across four African countries and how customs may impact girls' and boys' cycle differently. Most existing studies on children's education in Sub-Saharan Africa indicate that girls are comparably worse off than boys. My findings suggest a more nuanced picture. For instance, I find that girls are more likely to enroll in primary school when they reach the official enrollment age in Malawi and Namibia, relative to boys, yet this only holds for ethnicities that historically have practiced the bride price custom. Moreover, the bride price custom seems to result in higher educational attainment among females belonging to bride price ethnicities relative to other females. Nevertheless, in the long-run young men do comparably better than young women in Malawi, Zambia, and Mozambique, whereas Namibian females acquire more years of education than males, regardless of bride price custom. This latter finding is more in line with the recent drop-out patterns in developed countries. Context clearly matters in shaping parents' decisions. This reaffirms the need for designing context-specific policies. Further, I have taken a purely quantitative view on schooling and disregarded differences in school quality. Future research should explore to what extent parents' investments are sensitive to school quality and how this may differ by gender. Lastly, bride price payments may represent a substantial sum that is ignored in most household surveys. Better data on the amounts and direction of payments may inform our understanding of how the custom affects educational investments and also changes in inequality in society.

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PAPER 1

African Journal of Agricultural and Resource Economics Volume 11 Number 1 pages 47-62

Exploring technology use under climate risk and shocks through an experimental lens

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Abstract
Increasing agricultural productivity among smallholders in developing countries remains essential to improving food security, and one potential avenue for this increase is through stimulating technology adoption. In this paper we combine rainfall data with household survey and field experimental data to assess households' use and potential demand for a risky agricultural input in Tigray, Ethiopia. More specifically, we explore how average rainfall, rainfall variability, lagged rainfall shocks and risk aversion relate to inorganic fertiliser use at the farm plot level. Further, we analyse how these variables and exogenous price variation affect the demand for inorganic fertiliser at the household level. The findings are potentially important for the design of policies to promote agricultural production in semi-arid rain-fed agricultural areas with vulnerable populations facing rainfall risk and shocks.

Key words: rainfall shocks and risk; framed field experiments; risk aversion; technology adoption; Ethiopia

1. Introduction

Increasing agricultural productivity remains a central challenge to reducing poverty and improving food security among smallholders in sub-Saharan Africa. An avenue for achieving this is through technology adoption in agriculture.[1] However, despite improvements in technology supply, adoption rates and continued usage of modern technologies remain low. Proposed explanations include credit constraints and consumption risk (Dercon & Christiaensen 2011), liquidity constraints (Holden & Lunduka 2014), imperfect insurance and input markets (Binswanger & Rosenzweig 1986; Hagos & Holden 2006; Foster & Rosenzweig 2010), labour market imperfections (Lamb 2003; Holden *et al*. 2004), behavioural biases (Duflo *et al*. 2011), limited experience (Conley & Udry 2010), and heterogeneous returns (Suri 2011). Risk and risk aversion are central to several of these factors and may affect households' investment in technologies.

Theoretical work suggests that risk and risk aversion affect farmers' input use. According to Sandmo's (1971) model, risk-averse producers produce less under output price risk than under price certainty. However, risk-averse farmers who are net buyers of food may respond differently to changes in risk and risk aversion in order to protect their consumption needs, instead increasing their production with the level of risk aversion, while the response to increasing risk is ambiguous (Finkelshtain & Chalfant 1991). In addition, the extent to which risk and risk aversion affect farmers'

[1] We use Foster and Rosenzweig's (2010) definition of technology as "the relationship between inputs and outputs".

input choice depends on the factor market access. Higher risk or risk aversion under credit constraints may reduce investments in relatively more risky technologies (Feder, 1980).

Production risk due to rainfall variability and its impact on rain-fed agriculture is central to our context, and is fundamentally related to output price risk due to covariate risk and limited market integration. We focus on one technology, inorganic fertiliser, and its adoption under rainfall risk, rainfall shocks and risk aversion among farmers in the semi-arid Tigray region in northern Ethiopia. We define rainfall risk as inter-annual rainfall variability, whereas a rainfall shock is captured as deviations in annual rainfall compared to the local average.[2] We are not the first to analyse fertiliser adoption in view of risk aversion or rainfall patterns in the Ethiopian context. For instance, risk aversion is positively correlated with fertiliser use in the Tigray region (Hagos & Holden, 2011), recent subjective drought experience and higher risk aversion reduce the probability of purchasing fertiliser in the Amhara region (McIntosh *et al*. 2013), whereas fertiliser use is concavely and convexly related to lagged annual rainfall and current intra-annual rainfall variability respectively (Alem *et al*. 2010). The novelty of our approach is that it combines these issues, assessing fertiliser use under rainfall risk and shocks for different degrees of risk aversion, in an area where the majority of farmers are net buyers of food. More specifically, we aim to answer the following questions. How does risk aversion interact with rainfall risk in their correlation with fertiliser *use* at the farm plot level? How do lagged rainfall shocks affect fertiliser use? Further, how does fertiliser *demand* respond to exogenous variation in fertiliser prices and correlate with average rainfall, rainfall risk, lagged rainfall shocks, and varying risk aversion? And finally, what are the policy implications of these findings?

We combined several methods and data sources to answer these questions. First, we assessed fertiliser *use* under varying levels of average rainfall, lagged rainfall shocks and inter-annual rainfall variability, coupling observational farm plot data with rainfall data from local meteorological stations. We placed particular emphasis on plots planted with cereal crops, given our focus on food security. This was further combined with risk aversion, which was elicited based on hypothetical crop choice scenarios. Second, we experimentally assessed households' *demand* for fertiliser under exogenous price variation and examined how demand correlates with average rainfall, inter-annual rainfall variability, lagged rainfall shocks and risk aversion. We combined fertiliser offers to our random sample of households with randomisation of the amount of cash offered as an alternative to fertiliser, allowing us to assess demand in response to exogenous price variation. This framed field experiment provided us with a wide array of prices within the same area and captured how the share of all households demanding fertiliser changed with fertiliser price. This provided a measure of potential unconstrained demand that was based on the perceived local production potential and was free of access and liquidity constraints. Our main contributions thus are (a) to assess how rainfall (average, variability and lagged shocks) and the interaction between risk aversion and rainfall risk relate to fertiliser use and (b) to assess the potential demand for the risky input at varying exogenous input prices through randomised experimental treatments and to determine whether it correlates with the rainfall variables and risk aversion. We assessed the robustness of our findings by imposing varying sets of controls.

We found that cereal crop planting and fertiliser application at the plot level, which comprise a joint decision, are statistically significantly and positively correlated with average annual rainfall and risk aversion at a given level of risk for the typical net buyers of cereals in the study areas. Further, these were negatively correlated with the interaction between rainfall risk and risk aversion when controlling for plot and household characteristics, irrigation and access to farm credit. For cereal plots, we found that rainfall variability was negatively related to fertiliser use on the extensive margin, that

[2] Our short history of rainfall data to draw upon precludes a more narrow definition of a "shock".

less than average rainfall in the previous season reduced fertiliser on the intensive margin, whereas average rainfall was positively correlated with fertiliser use on both margins. Our results from the framed field experiment reveal a strongly significant negative sign for the price of ,fertiliser and a positive and significant relationship with average annual rainfall. This demonstrates that basic economic theory holds and that average annual rainfall is a good indicator of expected return to fertiliser in this semi-arid area. Further, we found that rainfall variability and lagged rainfall shocks were negatively correlated with the probability of choosing fertiliser in the experiments. Farm input credit appeared not to stimulate fertiliser use in this semi-arid environment.

2. Conceptual framework

We conceptualised a model in which we assumed risk-averse farmers who produce a food crop that is viewed as a normal good and who maximise the expected utility of income and leisure.[3] Input decisions take place under uncertainty in the first period, whereas the amount of rainfall is revealed in the second period, after which output is harvested. For simplicity, we limited the inputs used to labour and fertiliser in addition to land. Farmers' net income follows from the value of the output, subtracting the value of the inputs used in production.

In line with previous work, we assumed that fertiliser is a yield-enhancing, but risky, input (Feder 1980; Dercon & Christiaensen 2011). There are several reasons why this is a realistic assumption in our context. First, Dercon and Christiaensen (2011) found negative net returns to fertiliser at very high and low levels of rainfall in Ethiopia. Second, farmers' ability to assess the net returns is most likely variable (Beaman *et al*. 2013), although previous experience may improve their input management abilities and thus reduce variability (Foster & Rosenzweig 2010). Further, we assumed that expected net returns under adoption were higher than under no adoption, also in line with Dercon and Christiaensen's (2011) findings, but that the realisation of a bad (rainfall) state results in lower net returns than under no adoption. There thus is a trade-off between risk and the expected income.

We organised the factors that affect farm households' adoption of inorganic fertiliser into five categories based on the proposed explanations for limited technology adoption: (1) rainfall risk and shocks, (2) local terms of trade and market access, (3) institutions and policies that stimulate input demand, (4) household composition (labour supply and consumption needs), and (5) preferences.[4] The first three categories are largely exogenous, although actual participation in institutions is not, whereas the latter two are internal to the farm households.[5] We discuss these factors further below.

Assuming that the marginal return to fertiliser is weather dependent, that farmers update their expectations based on past experience, and that agriculture is their main income source, then rainfall shocks and risk may affect fertiliser use, (1). First, higher rainfall risk, measured in terms of the coefficient of variation (CV) of inter-annual rainfall, increases the expected variability of output and output prices in the second period.[6] This may have less of an effect on input use among risk-neutral farmers who produce a normal good, but may influence fertiliser use among risk-averse farmers. We return to this in our discussion of risk aversion. Second, a previous rainfall shock, captured as a shortfall in lagged rainfall compared to the local average, may tighten present liquidity constraints,

[3] Here we assume a unitary model and use farmer and household interchangeably. Utility maximisation implies a trade-off between labour and leisure in the household.

[4] Unfortunately we were unable to assess the role of risk-bearing institutions, in part due to limited access to institutions such as consumption credit, and leave this for future work.

[5] We set aside the question of whether, taking a long-term perspective, a household's decision to remain in a risky environment can also be characterised as endogenous.

[6] Our approach differs from that of Alem *et al*. (2010), as we focused on inter-annual, rather than intra-annual, rainfall variability.

thus reducing fertiliser use.[7] We expected tightened liquidity constraints to affect farm households, regardless of their level of risk aversion. Lastly, we controlled for average rainfall, as higher average rainfall is expected to increase expected returns.

Further, the net return to fertiliser use depends on the relative prices between fertiliser and the output good, (2). Higher local output prices relative to the input cost increase the net return to fertiliser. Market access feeds into this calculation, as longer distances increase transaction costs and are likely to reduce households' market participation. In terms of institutions and policies that stimulate fertiliser use (3), we focused on credit access and irrigation, which are both provided through government programmes. Access to farm credit relaxes the seasonal credit constraint, whereas irrigation both mitigates the impact of rainfall variability on output and enhances land productivity. In a setting with imperfect or missing factor and output markets, fertiliser use also depends on households' characteristics, (4). For instance, household composition conditions the food demanded and the labour available. Labour markets are thin (Bezu *et al*. 2012), and thus farmers are largely reliant on their own labour as input in production. We restricted our focus to household composition, ignoring other endowments that may affect households' ability to tackle downside risk.

Lastly, the fertiliser use decision depends on farmers' preferences, (5). Preferences can refer to, among others, crop and risk preferences. The main crops in our setting are cereals (e.g. teff, wheat and barley), which all respond to fertiliser, and we therefore ignore potential crop differences hereafter. However, risk preferences may affect households' input use decisions. As discussed earlier, more risk-averse pure producers produce less than less risk-averse producers at a given level of output price risk (Sandmo 1971), thus reducing their input use. Higher risk due to higher rainfall variability may also reduce the use of and demand for a risky input. However, risk-averse net buyers of food are less likely to reduce their demand for an input that is used to produce a normal good as risk increases, as shown by Finkelshtain and Chalfant (1991). Further, these authors show that, at a given level of risk, risk aversion is positively correlated with output (and thus input demand) for net buyers as opposed to the negative relationship expected for net sellers and pure producers. Sandmo's (1971) and Finkelshtain and Chalfant's (1991) theoretical predictions are made with regard to output price risk. Our setting is complicated by two factors. First, covariate risk implies that output prices are negatively correlated with rainfall deviations from the average. Lower than usual rainfall in a larger geographical area means lower production and higher market prices for cereals due to limited output market integration. Local demand for cereals may exceed local supply in such years, while an area is more likely to produce a surplus for export in years with good rainfall (Holden & Shiferaw, 2004). Second, net buyers of food have an increased incentive to increase production, thereby enhancing their input demand, but this incentive may be dampened by the riskiness of the input used. We considered such a risky input. We assessed whether the theoretical predictions were consistent with the empirical data in a situation in which households faced covariate production risk. We also assessed how the interaction between risk aversion and rainfall risk were related to fertiliser use and demand. The majority of our households were net buyers of food, and they produced food cereals that can be defined as normal goods.[8]

Given that risk aversion affects the adoption decision, then omitting risk aversion would bias the estimates of correlated observables. Following Binswanger's (1980) seminal study in India, several studies have aimed to elicit farmers' risk aversion using experiments (Wik *et al*. 2004; Harrison *et al*.

[7] Experiencing a rainfall shock may also affect farmers' perceived risk and risk aversion *ex post*, but we were unable to address this.

[8] Overall, approximately 77% of our sample can be considered to be net buyers of cereals, as the quantity of cereals they receive in the form of food aid, through Food-for-Work and purchases, is higher than the quantity sold.

2010). Experimentally deriving risk aversion is not without its challenges,[9] but it is less likely to be confounded by omitted constraints than deriving risk preferences based on observable production behaviour (Just & Pope 2003). Combining behavioural experiments with observational data to understand technology uptake is less common (Herberich *et al*. 2009; Barrett & Carter 2010). Exceptions include Knight *et al*. (2003), who found lower adoption of modern inputs and crops among more risk-averse[10] farmers in Addis Ababa, Ethiopia, and Liu (2013), who found that Chinese farmers with higher risk and loss aversion, measured *ex post*, adopted a modern cotton type later. Further, McIntosh *et al*. (2013) found that more risk-averse[11] household heads were less likely to purchase inorganic fertiliser in the Amhara region of Ethiopia, and Hagos and Holden (2011) found a positive correlation between risk aversion and fertiliser use in Tigray. These contrasting findings from Ethiopia could relate to the larger share of farmers being net buyers in Tigray than in Amhara.[12]

As noted, several studies have assessed fertiliser use following rainfall shocks (Alem *et al*. 2010; McIntosh *et al*. 2013), whereas empirical findings on how rainfall risk affects input use are more limited. Foster and Rosenzweig (2010) attribute this lack largely to the difficulty of capturing a shift in the risk distribution, while at the same time controlling for locality-fixed effects. They argue that a second best approach is to focus on differences in households' ability to tackle risk given their endowments. Rosenzweig and Binswanger (1993) assessed the riskiness of asset portfolios based on differences in inherited wealth and weather risk, whereas Dercon and Christiaensen (2011) investigated fertiliser use under predicted consumption variability. An alternative method is to provide random access to less risky technologies or risk-mitigating mechanisms (Karlan *et al*. 2014). Regardless of the approach, ignoring farmers' risk preferences under rainfall risk may deprive us of important insights with regard to farmers' adoption decisions. Moreover, climate change may increase future rainfall risk (IPCC 2014), further affecting smallholders' scope of action, with potentially large poverty and vulnerability implications. Households may be net sellers of food in years with adequate rainfall and net buyers in years with low rainfall (Holden & Shiferaw 2004). This again has implications for households' liquidity constraints and their input demand in the following year. More research therefore is needed to assess how rainfall risk and shocks interact with risk preferences and relate to the use of and demand for yield-enhancing inputs. A related question is to what extent policies, such as input credit programmes, can stimulate input use in more marginal semi-arid areas, and whether such programmes magnify the severity of shocks for borrowers with unlucky timing in their input loans.

3. Context, data and empirical strategy

3.1 Setting

We analysed the fertiliser use decision among farmers in the semi-arid highlands of Tigray, Ethiopia. Most farmers practise an integrated crop-livestock system, where oxen serve as the main source of traction power. They have on average one hectare of land and the majority are net buyers of food (Hagos 2003). Average rainfall is lower in this region relative to the other highland regions of Ethiopia (Benin *et al*. 2004). In terms of fertiliser, adoption in Ethiopia is low compared to other East African countries, and Tigray ranks low in usage within the country (Rashid *et al*. 2013). The

[9] Experimentally derived risk preferences may place people in a gambling mode because the experimental context is different from their real-life situations. However, incentive-compatible risk preference experiments have an advantage in that they have real consequences for respondents. See, among others, Harrison and Rutström (2008) for a discussion on experimentally derived risk preferences.
[10] Knight *et al*. (2003) categorise farmers into "risk-averse" and "not risk-averse" based on a hypothetical question in which two outcomes are compared.
[11] It is not clear how McIntosh *et al*. (2013) constructed their measure of risk aversion.
[12] Amhara has greater agricultural potential than Tigray due to higher average rainfall and a larger average farm size; further, a larger share of the households in Amhara are net sellers of food (Benin *et al*. 2004).

Ethiopian government has in recent years stimulated input demand through the provision of credit and improved seeds. DAP (basal) and urea (top dressing) are the most common fertiliser types available, and these are typically purchased in 50 kg bags (Spielman *et al*. 2011). Important policy interventions in the region include investments in irrigation, the provision of agricultural credit and the Productive Safety Net Program (PSNP). The latter programme grants members access to a seasonal employment opportunity with payment in kind or cash, and credit (Government of Ethiopia 2009). Credit programmes were first promoted in the region in the mid-1990s, and more than half of the distributed credit is typically allocated for the purchase of farm inputs (Hagos 2003).

3.2 Data

3.2.1 Sample

The survey and experiments covered a stratified random sample of 527[13] households in 17 rural communities (*tabias*) from four zones in Tigray. Communities were stratified based on geographical (agro-ecological) zones, market access, population density and access to irrigation (Hagos & Holden 2002).[14] Households were interviewed in June and July 2010 by a group of researchers, students and enumerators, and the survey is a collaboration between the Norwegian University of Life Sciences and Mekelle University. All questions were asked in the local language, Tigrinya.

3.2.2 Household and plot survey

The survey data include information on household composition, resource endowments and agricultural activities at the plot level, including rented plots. We discuss the relevant variables in more detail below, under summary statistics.

3.2.3 Framed field experiment and hypothetical choice experiment

Our experimental component consisted of a framed field experiment and a hypothetical choice experiment for eliciting risk aversion. Real payoffs were included in the framed field experiment. This was the last question in the experimental component so as to avoid the real payoff generating bias in other responses.

In the framed field experiment, the respondent, either the male head or the wife/female head, was offered the choice between 5 kg fertiliser (DAP) and cash. The cash amount varied from 10 to 60 Ethiopian Birr (ETB), depending on the die outcome (see Appendix A1 for the experimental protocol).[15] We interpreted the responses as random bounds on unconstrained shadow prices, because the fertiliser was obtained without the respondent having to mobilise additional cash, given this choice. This allowed us to identify a price band within which a varying share of the households preferred fertiliser to cash, thus capturing the distribution of shadow prices in our sample and, assuming representativeness, also for the overall population. Constrained shadow prices are typically found to be significantly lower than unconstrained shadow prices (Holden & Lunduka 2014). The latter are likely to offer a better picture of the perceived benefits, unlike constrained shadow prices, which reveal more about affordability.

[13] We have experimental data on 465 households, whereas fertiliser use and household characteristics were captured for 434 and 517 households respectively. The issue of attrition in plot and experimental data is addressed in the analysis.
[14] Sampling took place in 1998 for the baseline survey of 16 communities (Hagos & Holden 2002). Four follow-up surveys were subsequently implemented in 2001, 2003, 2006 and 2010. Only the last survey round included experiments on fertiliser demand, and we therefore restrict our attention to these cross-sectional data. Two communities were included, and one was dropped from 2006. The present data cover communities from two districts (*woredas)* in the Western Zone, three in the Eastern Zone, three in the Central Zone, and three in the Southern Zone.
[15] In June/July 2010, 10 to 60 ETB were equivalent to 0.52 to 3.11 US$. This gives an approximate price variation of 25% to 150% of the local commercial price.

We elicited risk aversion based on a hypothetical choice experiment (see Appendix A2) that was placed in a context that the farmer can relate to easily.[16] Each respondent was asked to compare two crop varieties, where the difference lay in their outcome in good and bad years. They were informed that we assumed that a bad year occurred in one out of five years. The further the respondents moved down the list before they switched, the more risk averse they were assumed to be, as there is a trade-off between risk and expected outcome. Their preferred variety therefore gives a risk-aversion rank that varies between 1 (low) and 6 (high risk aversion). For simplicity, we did not impose any additional assumptions on their utility function by using these ranks. Both the husband/male head and the wife/female head took part in the experiment separately. We used the risk-aversion rank of the husband when present, as it is typically the household head that is responsible for the agricultural production activities, and the wife/female head otherwise.

3.2.4 Rainfall data

Our rainfall variables were constructed based on monthly rainfall data obtained from the Ethiopian National Meteorology Agency (NMA). Continuous time series for all meteorological stations are available only for recent years, viz. 2003 to 2009. Each community (*tabia*) was matched with the nearest station based on elevation and proximity. In total, we used rainfall data from 13 stations. The rainfall data were likely to provide imperfect measures of actual rainfall at our study sites due to differences in distance between the nearest station and each survey village, and differences in elevation. This introduced measurement error into our rainfall variables and created a downward bias in the coefficient estimates. However, as long as this measurement error was not systematically related to any unobservables that enter into the error term, we would still obtain consistent estimates.

We measured rainfall risk in terms of the coefficient of variation (CV) of annual rainfall across the period 2003 to 2009. We used total annual rainfall, as the rain-fed agricultural season in Tigray lasts from May to June to September to October, and thus falls within the same calendar year. A lagged rainfall shock is defined as the shortfall in annual rainfall in the year prior to the decision of interest, i.e. fertiliser use or experimental choice, relative to the seven-year average. Households were surveyed on their input use in the main production season in 2009, whereas the experiments took place in 2010. We therefore constructed annual shortfall measures for 2008 and 2009. Lastly, we constructed a measure of average rainfall over the period 2003 to 2009, which was used as a proxy for the expected profitability of fertiliser use.

3.3 Empirical strategy

3.3.1 Fertilizer *use*

We investigated the relationship between rainfall, risk aversion and fertiliser use at the extensive and intensive margins. We were primarily interested in cereal plots, but as the planting decision and whether to apply fertiliser are likely to be a joint decision, we first applied a bivariate probit when assessing the factors correlated with fertiliser use at the extensive margin. Following this, we applied a Cragg (double hurdle) model to assess the factors correlated with fertiliser use at the extensive and intensive margin on cereal plots.[17] Our dependent variables in the first and second hurdles were whether the plot received fertiliser and the amount of fertiliser (in kg per hectare) respectively. We analysed fertilizer use at the plot level rather than at the household level, because input-use decisions

[16] Hagos and Holden (2006) employ an identical setup using the same initial sample.
[17] There is no consensus on what type of model to use to analyse the fertiliser-use decision. We have compared the results of the Cragg (double hurdle) model to a censored Tobit and found the latter to be inappropriate, as different factors affected the extensive and intensive margins, unlike the findings of Alem *et al*. (2010). An alternative to these approaches may be a selection model, as the decisions on whether to participate in the fertiliser market and how much to purchase may be associated with selection bias. However, using the Heckman selection model requires an identification strategy with a valid instrument (Wooldridge 2010). Unfortunately, we do not have such a variable available.

are likely to be affected by plot-level characteristics, which again are likely to affect expected returns to fertiliser.

We were interested in the relationship between risk aversion and fertiliser use; how average rainfall, rainfall risk and shocks correlate with fertiliser use; and the extent to which credit access and irrigation stimulate fertiliser use on cereal crops in this semi-arid area with high rainfall risk. We expected different responses to rainfall risk, depending on the level of risk aversion, and therefore included an interaction of rainfall risk (the CV of annual rainfall) with risk aversion. While we expected a positive sign for the risk-aversion variable at a given level of risk, given that the majority of respondents were net buyers of cereals, the expectation for the interaction variable was ambiguous. However, we expected lagged shortfall in rainfall to reduce investments in fertiliser due to tightened liquidity constraints, regardless of risk aversion.

The bivariate probit and the Cragg models assume that unobserved plot and household heterogeneity is uncorrelated with the covariates of interest and the dependent variable. This is a strong assumption. By including plot-specific characteristics, such as slope, land quality and soil type, we hoped to minimise such bias. In addition, we controlled for gender, age (including a squared term), whether the household head had received some education,[18] the number of adults (aged 15 to 65) by gender, children (below the age of 15), older adults (above the age of 65), and walking distance (in hours) to an all-year all-weather road. Finally, we introduced access to farm credit[19] and irrigation on plot, where the latter affects households' ability to hedge against rainfall risk. We controlled for whether the wife's risk-aversion rank was used instead of the husband if his was missing, even though the household was not female headed. Zone-specific fixed effects were included throughout, and standard errors were clustered at the meteorological station level. Lastly, we addressed the noted issue of attrition in the plot data by way of inverse probability weighting.[20]

We must be very cautious about making causal inferences based on our plot level models. We can only assess whether our results are consistent or inconsistent with the theoretical models providing causal predictions. Our key variables may be correlated with other confounding factors that affect input use, thus introducing omitted variable bias. Moreover, our use of cross-sectional data inhibits us from controlling for unobservable heterogeneous plot and household characteristics that may be correlated with our variables of interest.

3.3.2 Fertiliser *demand*

Next, we explored the responses to the framed field experiment and how these related to the prices offered, the expected rainfall, rainfall risk, lagged rainfall shocks, and risk aversion. Our workhorse was a linear probability model (LPM), where the dependent variable was set equal to one if the respondent chose fertiliser (DAP) and equal to zero if the respondent chose cash. We included the cash amount indicated by the die outcome (10 to 60 ETB), the timing of the experiment,[21] and whether the wife responded in the absence of the husband, in addition to the covariates described above, which were introduced sequentially. Again, we addressed the issue of data attrition, in this case for the experimental component, by way of inverse probability weighting.

[18] Education includes elementary schooling and higher levels, religious schooling, and adult literacy programmes.
[19] Access to farm credit was captured by whether the respondent responded yes to "If you wish, are you able to obtain credit for farm inputs?"
[20] We used household characteristics to predict the probability that plot data were missing, and used the inverse as weights. Assuming that the household sample was representative, this should reduce the attrition bias.
[21] Rainfall received so far in 2010 may also have influenced the respondents' choices. Unfortunately, we did not have rainfall data for this year, nor did we have data on when fertiliser application took place, thus preventing us from controlling for whether the experiment took place pre- or post-fertiliser application. Instead, we controlled for the week in which the experiment took place in order to capture how far into the production season the households from each village were.

We expected higher average rainfall to increase the likelihood that the respondent chose fertiliser over cash, whereas higher rainfall risk (a higher CV of inter-annual rainfall) was expected to reduce fertiliser demand, as the returns to fertiliser would be more risky. Applying Finkelshtain and Chalfant's (1991) insights on output price risk to rainfall risk, we expected that, at a given level of risk, net buyers would aim to produce more food, and thus use more inputs, the more risk-averse they were. The expected sign on the interaction between risk aversion and risk was again ambiguous. Likewise, we expected a rainfall shock (lagged shortfall in rainfall) to be negatively related to fertiliser demand. However, the intuition differed somewhat for fertiliser *demand* compared to fertiliser *use*, because the alternative now is cash, and the decisions are not constrained by liquidity shortage. Although the decision itself is not affected directly by a liquidity constraint, the tougher liquidity situation that a household faces after a rainfall shock may increase the demand for cash relative to fertiliser. Further, we cannot rule out that recent shocks may affect future weather expectations.

3.4 Summary statistics

In Table 1 we present descriptive statistics at the household and plot levels. One third of the households were female-headed, and less than a third of the household heads had some form of education. Approximately 65% of the households applied inorganic fertiliser on approximately 45% of all plots. The average plot size was close to 0.3 hectares and the plots received on average 59 kg fertiliser per hectare.[22] Among the households that used fertiliser in 2009, just over half purchased fertiliser at the district market, whereas the remaining purchases were made within the village or at the local market. Approximately 40% of the households had purchased fertiliser using their own savings, whereas a similar share acquired fertiliser through credit, which primarily was formal. The average commercial price per kilogram of fertiliser (DAP) was approximately 7.6 ETB, while the prices offered in the experiments varied from 2 to 12 ETB per kg. In terms of risk aversion, approximately 30% of the respondents chose rank 3, while 26% chose rank 4.[23]

Each household received on average 6.65 decimetres of rainfall annually, but there were large variations across the communities. All of the households experienced a shortfall in rainfall in 2008 relative to the seven-year average. The majority also experienced a shortfall in rainfall in 2009, with the exception being households in two communities that received more rainfall than the average.

[22] We dropped outliers by excluding the top one percent of values of fertiliser per hectare. The recommended application rate of fertiliser per hectare in Ethiopia is 200 kg, according to McIntosh *et al*. (2013), which represents 100 kg DAP and 100 kg urea.

[23] Although we did not explicitly impose any structure on risk aversion, rank 3 implies a constant partial risk aversion coefficient (CPRA) in the range of 0.59 to 0.99, while rank 4 implies a CPRA in the range of 0.99 to 2.44. Approximately one quarter of the respondents chose a rank higher than 4, implying CPRA > 2.44, whereas just over 17% chose ranks 1 and 2, equivalent to a CPRA < 0.59. This shows that the distribution of CPRA is in line with other studies using a similar monetary experimental approach (Binswanger 1980; Wik *et al*. 2004).

Table 1: Summary statistics, plot and household level

Variables	Mean	Std. dev.	Min.	Max.	N
Plot characteristics:					
Plot planted with cereal	0.844	0.363	0	1	1775
Fertiliser (in kg) per hectare	59.450	104.937	0	800	1776
Area planted in hectares (self-reported)	0.273	0.250	0.003	2.250	1776
Irrigated plot: 1 = yes, 0 = no	0.105	0.307	0	1	1775
Soil type[24]	2.546	1.129	1	4	1770
Slope[25]	1.311	0.610	1	4	1774
Land quality: 1 = poor, 2 = medium, 3 = good	1.866	0.750	1	3	1774
Household characteristics:					
Female headed household: 1 = yes, 0 = no	0.300	0.459	0	1	517
Age of household head	54.679	14.825	15	100	517
HH head has some education: 1 = yes, 0 = no	0.268	0.443	0	1	515
Number of female adults aged 15–65	1.356	0.896	0	5	517
Number of male adults aged 15–65	1.288	1.160	0	6	517
Number of children aged 0–14	1.697	1.697	0	7	517
Number of HH members above age 65	0.298	0.529	0	2	517
Can access credit for farm inputs: 1 = yes, 0 = no	0.338	0.473	0	1	509
Applied fertiliser in 2009: 1 = yes, 0 = no	0.652	0.477	0	1	434
Distance to all-year all-weather road (hours walking)	0.789	0.770	0	7	510
Risk aversion:					
Husband's (wife/female head if no husband available) risk-aversion rank	3.592	3.592	1	6	515
Framed field experiment:					
Real choice experiment: 1 = fertiliser, 0 = cash	0.529	0.500	0	1	465
Cash price per kg DAP	6.585	3.368	2	12	465
Rainfall (dm) by calendar year:					
Total rainfall in 2008	5.530	1.838	2.869	10.406	527
Total rainfall in 2009	5.532	2.112	2.613	10.375	527
Average rainfall, 2003–2009	6.652	1.556	4.688	10.741	527
Shortfall in 2008 compared to seven-year average	1.122	0.661	0.288	2.675	527
Shortfall in 2009 compared to seven-year average	1.119	1.459	-2.861	3.730	527
CV of annual rainfall, 2003–2009 (%)	23.885	7.416	10.633	35.722	527

4. Results and discussion

4.1 Observational inorganic fertiliser use and cereal production at the plot level

We first assessed households' use of inorganic fertilisers at the plot level and how this related to the rainfall variables and to risk aversion in particular. The results from the bivariate probit[26] and the Cragg models are reported in Table 2. Our results from the joint decision on whether to plant cereals and apply fertiliser show that these are positively correlated with risk aversion, in line with the theory for net buyers of food. Rainfall risk was associated with a lower probability of fertiliser use, as we expected for a risky input, and rainfall risk interacted with risk aversion also was negatively signed and statistically significant (where theory was ambiguous).

[24] 1 = Cambisol (*Baekel*), 2 = Vertisol (*Walka*), 3 = sandy (*Hutsa*), and 4 = Luvisol (*Mekeyih*).
[25] 1 = flat, 2 = foothill, 3 = mid-hill and 4 = steep.
[26] The bivariate probit is appropriate because the covariance between the two error terms is statistically significantly different from zero at the 1% level.

Table 2: Cereal planting and fertiliser use

Model	(1) Bivariate probit		(2) Cragg	
	Cereal planting	Fertiliser use	Hurdle 1: Fertiliser use	Hurdle 2: Fertiliser use intensity
Husband's (wife if no husband) risk aversion rank	0.138**	0.141*	0.147	10.513
	(0.062)	(0.077)	(0.114)	(20.057)
Average annual rainfall (dm) 2003–2009	0.148**	0.251***	0.240***	38.175***
	(0.070)	(0.043)	(0.060)	(5.264)
Shortfall in rainfall (lagged) compared to seven-year average (dm)	0.230***	-0.086	-0.068	-62.596***
	(0.084)	(0.090)	(0.093)	(16.307)
CV of annual rainfall (%), 2003–2009	-0.010	-0.023**	-0.026*	4.201
	(0.013)	(0.010)	(0.015)	(3.252)
CV of rainfall (%) * Risk-aversion rank	-0.005**	-0.006**	-0.007	-1.113
	(0.002)	(0.003)	(0.005)	(0.891)
Irrigated	-1.063***	0.124	0.206	-52.970
	(0.196)	(0.170)	(0.141)	(64.548)
Can access credit for farm inputs	-0.265**	0.185	0.258	-19.566
	(0.128)	(0.212)	(0.276)	(21.930)
Athro	0.426***			
	(0.061)			
Number of observations	1 722	1 722	1 458	693
Mean of dependent variable	0.802	0.448	0.475	61.083

Note: Robust standard errors clustered at station level are in parentheses. Distance to all-year all-weather road, plot and household characteristics, whether wife's risk aversion rank is used in male-headed household, and zone fixed effects are included throughout but not reported. Hurdle 1 refers to the binary fertiliser use decision; hurdle 2 refers to fertiliser intensity on plots that receive fertiliser. Inverse probability weighting is applied to address attrition in plot data.
Source: Own results based on household survey and rainfall data. Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Lagged shortfall in rainfall is associated with a higher probability of cereal planting, while cereals are less likely to be planted on irrigated land. Interestingly, we did not find that credit access was associated with a higher probability of fertiliser use.

Moving on to cereal plots only (Cragg model), we found that fertiliser use was significantly and positively associated with average rainfall at both the intensive and extensive margins, whereas rainfall variability was only negatively correlated with fertiliser use at the extensive margin. We found no statistically significant relationship between risk aversion and its interaction with rainfall variability and fertiliser use on cereal plots at the intensive and extensive margins. However, risk aversion exhibited a statistically significant relationship with fertiliser use intensity when excluding the interaction term (results available upon request), which may suggest that we do not have sufficient variation to estimate both coefficients. Lastly, we found that experiencing a shortfall in rainfall the previous year relative to the seven-year average was negatively correlated with fertiliser-use intensity. We included controls for plot and household characteristics throughout, and excluding these and access to credit and irrigation resulted in the same pattern of results reported in column (2), with the exception of the interaction term, which turned statistically significant at the 10% level in hurdle 2, maintaining its negative sign (results available upon request).

4.2 Framed field experiment: Demand for fertiliser

Next, we explored the households' responses to the real choice experiment[27] and how these varied with the amount of cash offered (the implicit fertiliser price) and the measures of expected rainfall, rainfall risk, lagged rainfall shocks and risk aversion. The results are reported in Table 3, where we

[27] 5 kg DAP fertiliser versus a randomised amount of cash offered at the farm gate.

report results from specifications without and with the interaction between the CV of rainfall and risk aversion. Controls for distance to an all-year all-weather road and household-specific characteristics are included throughout, whereas we added irrigation and credit access in columns (2) and (4).

In terms of price responsiveness, we found that the probability of choosing fertiliser instead of cash declined by approximately 9.1 to 9.5 percentage points when the fertiliser price increased by one ETB per kg. Further, households that resided in areas that received on average more rainfall were more likely to choose fertiliser, showing that expected rainfall affected the expected profitability of fertiliser use. A 100 mm increase in average expected rainfall increased the probability of choosing fertilizer by 5.4 to 5.5 percentage points when introducing the full set of controls. We cannot rule out that average rainfall also correlated with other variables that affected fertiliser adoption, but average rainfall is the best proxy variable we have for expected profitability after imposing other controls. Shortfall in lagged rainfall was negatively signed and statistically significant throughout. A 100 mm increase in shortfall relative to the average reduced the probability of choosing fertiliser over cash by 8.3 to 9.4 percentage points. This may suggest that households face a binding liquidity constraint in terms of satisfying other needs and/or are adjusting their expectations for rainfall and fertiliser profitability in the following year. Similarly, households that experienced more rainfall variability across the seven-year period were less likely to choose fertiliser over cash. We found no statistically significant relationship between the experimental choice and the interaction between risk aversion and rainfall risk, risk aversion by itself, or rainfall risk after including the interaction term.

Table 3: Real choice experiment: Choice of 5 kg fertiliser (= 1) versus cash (= 0), LPM

Variables	(1)	(2)	(3)	(4)
Cash price per kg DAP	-0.095***	-0.091***	-0.095***	-0.091***
	(0.004)	(0.004)	(0.007)	(0.008)
Husband's (wife if no husband) risk-aversion rank	-0.0002	-0.002	0.028	0.037
	(0.015)	(0.018)	(0.064)	(0.066)
Average annual rainfall, 2003-2009 (dm)	0.029*	0.055***	0.028*	0.054***
	(0.016)	(0.015)	(0.015)	(0.015)
Shortfall in rainfall (lagged) compared to seven-year average (dm)	-0.083***	-0.093***	-0.084***	-0.094***
	(0.016)	(0.026)	(0.016)	(0.026)
CV of annual rainfall (%), 2003–2009	-0.014***	-0.010**	-0.011	-0.006
	(0.004)	(0.004)	(0.007)	(0.007)
CV of rainfall (%) * Risk-aversion rank			-0.001	-0.001
			(0.002)	(0.002)
Distance to all-year all-weather road	Yes	Yes	Yes	Yes
Household-specific characteristics	Yes	Yes	Yes	Yes
Credit access and irrigation	No	Yes	No	Yes
Number of observations	456	385	456	385
Mean of dependent variable	0.52	0.55	0.52	0.55

LPM = Linear probability model. Robust standard errors clustered at station level are in parentheses. Week of experiment, enumerator dummies, whether wife's risk-aversion rank is used in male-headed household, and zone fixed effects are included throughout but are not reported. Inverse probability weighting is applied to address attrition in experimental data.

Source: Own results based on household survey and rainfall data. Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5. Conclusion

We have explored how risk aversion, average rainfall, rainfall risk and rainfall shocks correlate with households' use and demand for inorganic fertiliser in the semi-arid highlands of Tigray, northern Ethiopia. We found that fertiliser use and demand were positively associated with average annual rainfall. Lagged rainfall shocks were associated with lower fertiliser-use intensity at the plot level and lower demand for fertiliser, as would be expected. Rainfall risk was negatively related to fertiliser use at the plot level, as well as to the experimentally derived fertiliser demand. However, at a given level of rainfall risk, the risk aversion rank was positively correlated with fertiliser use on plots planted with cereals and non-cereals, when imposing a set of controls, whereas the interaction with rainfall risk was negatively associated with fertiliser use. The former result is consistent with Finkelshtain and Chalfant's (1991) theory for net buyers regarding their response to output price risk. We did not find a similar relationship for risk aversion in terms of the demand for fertiliser captured through the framed field experiment, or in terms of fertiliser use on cereal plots only. We also found that, for our sample, which comprised mainly buyers of cereals, lagged shortfall in rainfall and risk aversion were positively associated with the planting of cereals. Responses to shocks by vulnerable households therefore sometimes can be the opposite of what may be expected from pure producers. Our framed field experiment also allowed us to investigate the price responsiveness of fertiliser. Approximately 40% of the households preferred fertiliser to cash at the going fertiliser price (7.6 ETB/kg) at the time of the survey, and a one ETB increase in the price per kg of DAP fertiliser reduced the share of households demanding fertiliser over cash by 9.1 to 9.5 percentage points.

Our findings have important policy implications. Rainfall is a key constraint to cereal food production in semi-arid rain-fed agriculture. Although we were unable to find any clear relationship between irrigation and fertiliser use, the expansion of irrigation in such areas can be an important measure for reducing the vulnerability to rainfall shocks, provided that irrigation water is available when droughts occur. The provision of credit for rain-fed cereal production has its limitations in stimulating fertiliser use in such areas, as taking credit for input use prior to a rainfall shock may magnify the negative impact of such a shock on vulnerable households. This may explain why we found no significant positive effect from access to farm input credit on fertiliser use in our study. This does not mean that liquidity constraints are not important, as the responses to lagged shortfalls of rainfall may indicate, but instead may point in the direction of safety nets (Food-for-Work, or Work-for-Inputs) as a better option than farm credit for stimulating agricultural production.

Acknowledgements

The authors gratefully acknowledge funding for the fieldwork from NORAD under the NOMA programme, the efforts during the fieldwork by students and enumerators, Hosaena Ghebru, Bethelhem Legesse Debela and staff at the Department of Economics, Mekelle University, the provision of rainfall data by the Ethiopian National Meteorology Agency (NMA), and comments from Erwin Bulte, Maarten Voors and an anonymous reviewer.

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Appendix 1. Survey instrument for real experiment

<table>
<tr><td colspan="2">Experimental component: Extract
The decision should be what the household (head) would prefer to do today (day of interview), given the current resource situation of the household and information that the household has. The household head/representative will throw a die once for the experiment below:</td></tr>
<tr><td>E1</td><td>Choice experiment 1 (Real). Compensation experiment for your time spent on all the interviews: You have the choice between receiving 5 kg basal (DAP) fertiliser and an amount of money that is determined by you throwing the die: The amount of money that you can choose instead of the fertiliser (if you prefer so) is as follows:
Die outcome in Ethiopian Birr (ETB): 1 = 10, 2 = 20, 3 = 30, 4 = 40, 5 = 50, 6 = 60
Choice: 1. Choose the fertiliser, 2. Choose the money</td></tr>
</table>

Appendix 2. Hypothetical choice experiment: Risk-aversion rank

Each respondent is asked the following question, to which choosing Crop 2 results in a re-framing of the question based on the next pair of outcomes: "If you have the choice between a crop that gives 20 quintal[28] in a good year but no yield in a bad year, and a crop that gives 19.5 quintal in a good year and 2 quintal in a bad year, which crop would you prefer to plant? We assume a bad year occurs one out of five years (two out of 10 years are bad)."

	Good year	Bad year	Choice	Expected outcome	Risk-aversion rank
Crop 1	20	0	1	16	1
Crop 2	19,5	2	2	16	
If choice 2, cont.					
Crop 2	19,5	2	1	16	2
Crop 3	18	4	2	15,2	
If choice 2, cont.					
Crop 3	18	4	1	15,2	3
Crop 4	16	6	2	14	
If choice 2, cont.					
Crop 4	16	6	1	14	4
Crop 5	13	8	2	12	
If choice 2, cont.					
Crop 5	13	8	1	12	5
Crop 6	9	9	2	9	6

[28] 1 quintal = 100 kg

PAPER 2

Learning the hard way? Adapting to climate risk in Tanzania

Sofie Waage Skjeflo* and Nina Bruvik Westberg†‡

Abstract

We use recent panel data on Tanzanian farm households to investigate how previous exposure to weather shocks affects the impact of a current shock. Specifically, we investigate the impact of droughts and past drought incidents on agricultural yield and children's health, measured by their nutritional status. As expected, we find that droughts negatively impact yields, with the impact increasing in the severity of the shock, and that severe droughts have a negative impact on short-term nutritional outcomes of children. We also find that households with more shock experience are less affected by current droughts in terms of crop yields and their children's nutritional outcomes. However, this only holds for less severe droughts. This suggests that households are able to learn from their past shock experience, and could imply that households, to a certain extent, are able to adapt to climate risk. We explore mechanisms that could explain our findings.

Keywords: Rainfall shocks, crop yields, adaptation, child health, Tanzania

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‡We would like to thank Daniel Muluwork Atsbeha, Andreas Kotsadam, Jo Thori Lind, participants at the Nordic Conference on Development Economics 2014 and the CSAE Conference 2016, and seminar participants at the Norwegian University of Life Sciences for useful comments and suggestions. All remaining errors are our own.

1 Introduction

The recent report from the Intergovernmental Panel on Climate Change concludes that climate change is likely to have severe impacts on agriculture in Sub-Saharan Africa with large consequences for food security, creating an urgent need for adaptation (Niang et al., 2014). The report finds that although adaptation strategies are already being used to cope with current climate variability, there are considerable institutional, financial, physical, political and informational barriers to adapting to climate change for small-scale farmers in Africa.

This paper uses nationally representative panel data from Tanzania, coupled with gridded weather data, to explore the impact of climate risk on agricultural yield and children's health among farming households. We aim to contribute to the literature on impacts of climate variables on economic outcomes. There is a large literature on the impact of climate shocks on economic and health outcomes using cross-sectional data, such as Miguel (2005), Feng et al. (2015) and Kudamatsu et al. (2012). The more recent literature uses panel data to control for time-invariant factors while exploiting exogenous variation in temperature, precipitation and extreme events (see Dell et al. (2014) for a recent review). A limitation of these studies is that using short-run weather variation to predict long-run impacts of climate change requires out-of-sample extrapolations that may not be valid (Dell et al., 2014). For instance, Burke and Emerick (2016) show that US farmers are unable to adapt to long-run variations in climate, as opposed to findings based on short-term weather variations. Similarly, when assessing the impacts of climate risk, defined as the probability of experiencing a negative climate shock, extrapolating from the impact of one climate shock to impacts of increased climate variability due to climate change may not be valid. Our contribution is to investigate whether the impact of a climate shock, more specifically droughts, depends on a household's previous experience with such shocks. As far as we know, this is the first paper that does this. Understanding how long-run exposure to negative climate shocks affects households can then be used to inform our understanding of the scope of adaption to increased climate variability due to climate change.

We focus on the impact of shocks and previous shock exposure on two outcomes: crop yields and children's health, measured by their short-run and long-run nutritional status. Farmers with previous exposure to shocks may be less severely affected by a new shock if they are able to apply their knowledge derived from previous shocks, for instance through altered crop and input choices, new farming techniques and income diversification. In this case, the impact of a current shock would be decreasing in the number of shocks previously experienced. On the other hand, exposure to repeated shocks could make households more vulnerable to new shocks, for instance if the households cope by depleting assets, including human capital. In this case, we would expect the negative impact of a shock to be increasing in the number of shocks the household has experienced previously.

Several studies have investigated the potential impacts of climate change on agriculture at an aggregated level. An early application of panel data to this task is the study of U.S. agriculture by Deschênes and Greenstone (2007), later discussed by Fisher et al. (2012). Assessing impacts on Sub-Saharan African agriculture, Schlenker and Lobell (2010) match historical country-level yield data on five crops to weather data from 1961 to 2002. They use their estimated parameters to predict crop production losses due to climate change by year 2065, and find that the production of maize, groundnut, sorghum, millet and cassava is expected to decrease by respectively 22, 18, 17, 17 and 8 percent. Relevant to our context, Rowhani et al. (2011) use regional panel data on maize-, rice- and sorghum yields in Tanzania from 1992 to 2005. The data is coupled with observations from weather stations and gridded, interpolated weather data. They find that precipitation variability during the growing season, measured in terms of the coefficient of variation, has a negative impact on all three crops. Ahmed et al. (2011) use the same data to investigate the impact of rainfall and temperature on yields, and the impact of projected future climate variability on poverty distributions. They argue that the uncertainty related to expected climate volatility makes it difficult to quantify expected shifts in poverty distributions in Tanzania.

Panel data evidence of the impact of weather variability on agriculture at the household level seems less common, an important exception being Rosenzweig and Binswanger (1993). Using the ICRISAT village surveys from India, which include daily rainfall data, they find that a delay in monsoon onset significantly reduces crop- and total farm profits. Further, they find that farmers exposed to more weather variability choose less risky and less profitable investments, and that this effect is stronger for poorer households who are less likely to be able to cope with income variability following a shock.

The impacts of climate variability on households is perhaps better understood when broadening the focus beyond agriculture. A few papers look at the impacts of climate variability on consumption (Skoufias and Vinha, 2013; Lazzaroni and Bedi, 2014), whereas several studies have analyzed the effect of weather shocks on health,[1] either implicitly or explicitly assuming an income effect through agriculture. The impact on children's health is seen as particularly important – if parents are unable to maintain investments in their children's human capital (for instance through schooling or health) during shocks, the effect of negative shocks may persist over generations (Dercon, 2002). With this motivation, Hoddinott and Kinsey (2001) investigate the impact of drought[2] on growth in height, and find a slower growth rate among Zimbabwean children aged 12-24 months old. Maccini and Yang (2009) extend the perspective to adult outcomes and focus on positive rainfall shocks rather than negative ones. They find that Indonesian rural females who as infants experienced 20 percent more rainfall than the district mean become taller as adults (0.57 cm on average).

In terms of short-term nutritional status (weight-for-height and weight-for-age), the evidence on impacts of weather shocks is less clear. Jensen (2000) focuses on the impact through reduced income, comparing children's health and educational outcomes in Cote d'Ivoire based on their exposure to a recent weather shock.[3] In the exposed areas, malnutrition (defined as weight-for-height Z-scores more than two standard deviations below the reference median) increased among children aged 0-10 years, school enrollment decreased by more than one third and the use of medical services for children that were ill decreased, without significant difference between the exposed and unexposed children prior to the shock. However, the amount of rainfall will also affect the disease environment. More rainfall can trigger increased risk of disease, through a change in the prevalence of vector- and water borne diseases, that in part counteracts the income effect (a disease channel).[4] Tiwari et al. (2013) investigate the impact of excess monsoon rainfall on short- and long-run nutritional status in Nepal, matching clusters from the Demographic Health Surveys (DHS) with predicted weather patterns based on rainfall and elevation. A positive contemporaneous rainfall shock (disease channel) results in lower weight-for-age for infants, whereas a positive shock in the previous season increases weight-for-age for all age groups below three years old. The latter finding suggests that the income effect dominates over the lagged disease effect from the past season. Height-for-age is

[1] Others again analyze the impact of weather shocks on mortality, which can be viewed as the cumulative result of negative impacts on children's health. For instance, Rose (1999) explores gender differences in child survival following a positive rainfall shock, while Kudamatsu et al. (2012) analyze the impact of droughts on infant mortality among African farming households.

[2] Hoddinott and Kinsey (2001) identify a drought as a season with rainfall below the average historical mean.

[3] Jensen (2000) defines a weather shock as rainfall during the summer months being more than one standard deviation below the historical mean.

[4] See Smith et al. (2014) for an overview. The evidence is mixed with regards to the relationship between diarrhea and rainfall in the dry and wet seasons. Similarly, vector-borne diseases such as malaria and dengue fever are typically more common in periods with more rainfall, but may also show an increase during droughts due to households' methods of water storage.

only positively affected by more rainfall in the second year of life, and only for children aged 12-35 months.[5] Lohmann and Lechtenfeld (2015) widen the focus to self-reported illness among adults and health expenditures, in addition to self-reported anthropometric measures. They assess the effect of a drought severity index[6] on these measures using four rounds of household panel data from rural Vietnam. A higher drought severity index increases the probability of illness and reduces weight among adults and children, whereas they find no significant impact on weight-for-age Z-scores of children below five. They attribute the negative impact on weight to an income effect, through increased agricultural yields.

Although several papers have analyzed the reduced form impact of weather shocks on health, few assess this explicitly through its effect on agriculture - instead implicitly assuming that this is the main channel. A related, and equally important, question is how previous shock exposure may interact with a new shock in explaining differences in both agricultural and health outcomes. We exploit detailed plot level data on crop production and anthropometric measures of respondents in the Tanzania National Panel Survey to explore these questions. Our results show that experiencing droughts negatively affects crop yields, with the impact increasing in the severity of the shock. The results also indicate that the more shocks a household has experienced previously, the less severe is the impact of a current shock on yields, suggesting that households may learn from previous shocks how to mitigate impacts of current shocks. In terms of children's nutritional outcomes, severe droughts seem to have a negative impact on short-term nutritional indicators, but there are also indications that more previous shock experience mitigates impacts of less severe shocks.

In the following we present our conceptual framework in Section 2, Section 3 gives an overview of the setting, while the data and the empirical strategy to be employed are described in Sections 4 and 5. We present the results in Section 6, followed by a discussion of possible causal mechanisms and caveats in Section 7. Section 8 concludes the paper.

2 Conceptual framework

The impact on farming households of repeated shock exposure, for instance droughts or flooding, in the context of a rural developing country, is not obvious. Market imperfections in insurance and

[5]This contrasts to Maccini and Yang (2009), who find a positive effect on stature from more rainfall in the first year of life. However, they use a more long-term outcome, namely adult height.

[6]The drought severity index captures the annually aggregated shortfalls of monthly district level rainfall from the local historical mean (Lohmann and Lechtenfeld, 2015).

savings are often pervasive, leaving households' response to income shocks largely dependent on their own endowments, and linking poverty vulnerability to risk (Dercon, 2002).

The effect of a weather shock, such as a drought, and its interaction with previous shock exposure on households' consumption and welfare is expected to manifest itself through agriculture. The majority of the farming households in our sample rely on rain-fed agriculture,[7] and we would therefore expect rainfall variability to affect their agricultural output. Previous exposure may have led the household to develop techniques to better tackle new shocks, such as shifting the timing of planting or fertilizer application, switching crop varieties and types, or implementing soil- and water conservation technologies (Burke and Lobell, 2010; Di Falco and Veronesi, 2013). We term this adaptation. Alternatively, their ability to invest in (costly) adaptive strategies may be reduced. Previous shock exposure may have triggered asset depletion, such as selling of livestock or other productive assets (Dercon, 2002), reducing their investment capabilities and ability to deal with more recent shocks. Based on this, we expect past shock experiences to influence the impact of a current shock on agricultural yield. Exposure to climate risk is also likely to have an effect on production and yield in non-drought years. The seminal model by Sandmo (1971) predicts that risk-averse firms in an environment with missing insurance and credit markets will produce less than a risk-neutral firm. Dercon and Christiaensen (2011) show that consumption risk reduces the use of fertilizer in Ethiopia. Based on this, one could expect lower use of "risky inputs", such as inorganic fertilizer and high-yielding (but not drought-resistant) improved crop varieties, and lower yields on plots that have frequently been exposed to shocks. This may also be driven by the depletion story discussed above, whereby repeated shock exposure reduces households' ability to invest in farm production. On the other hand, in a setting with volatile food prices and lack of outside income opportunities, subsistence orientation could be a self-insurance mechanism. Taking into account the consumer-producer role of farm households in developing countries, Finkelshtain and Chalfant (1991) show that under certain conditions, output price risk and risk aversion may lead to higher output.[8] Similarly, Fafchamps (1992) shows that with thin food markets causing price volatility, and high correlation between farm output and market prices, farm households use subsistence orientation as a self-insurance mechanism. A first step to understanding potential long-run impacts of climate risk is therefore to investigate the impact of shocks and repeated shock exposure on agriculture, more specifically crop yields.

[7] In a given year less than 5 percent of the households in our sample have one or more irrigated plots.

[8] For instance, a more risk averse net food buyer is shown to increase production in response to more price risk.

Rural households may derive income and consumption from other sources than own farm production. Income diversification (Rose, 2001), asset depletion (Rosenzweig and Wolpin, 1993), self-insurance through savings (Paxson, 1992) and altered labor supply (Kochar, 1995; Rose, 2001) are possible smoothing strategies that farmers use to adapt to fluctuations in agricultural income (Morduch, 1995; Dercon, 2002). The extent to which rainfall variability affects total income and consumption is therefore not readily derived based on own production only. The correlation between own produce and consumption in years of shock may be very weak, in particular for wealthier households, as Townsend (1994) found in India. Moreover, the combined effect of multiple households' responses in a drought year may result in increased food prices and lower wages when markets are poorly integrated (Jayachandran, 2006), which again affects households' consumption depending upon their position in the market. Even if all income sources were identified, measuring households' total income would be problematic. The alternative measure, consumption, is believed to suffer less from measurement error in rural settings, but is also difficult to capture (Deaton, 2005). However, a desirable outcome from income- and consumption smoothing is better child health outcomes. We therefore investigate the effect of a shock and previous exposure to similar shocks on child health, measured by the children's short- and long-run nutritional status.

Rainfall shocks may affect children's nutritional status in two ways. First is the above-mentioned income effect, whereby households' income available for consumption may fall due to lower yields. For households that are net buyers of food, a related increase in food prices will add to this. The extent to which a drought affects child nutrition thus depends on the opportunities for income- and consumption smoothing. If households are able to perfectly smooth consumption when facing agricultural income shocks, then we do not expect any impact on investment in children's health. Second, rainfall shocks can have an additional direct effect on health through access to clean water and the prevalence of vector- and water-borne diseases (Tiwari et al., 2013; Rabassa et al., 2014).

Similar to the discussion of agricultural outcomes, the effect of past shock experiences on the impact of a current shock on child health is not clear a priori. On the one hand, if households learn income- and consumption smoothing methods from previous shocks, and are able to take advantage of these when facing new shocks, then we expect the impact of a current shock on child nutrition to be decreasing in households' previous shock experience. If adaptation mainly occurs through (better) income- and consumption smoothing, we would expect to find adaptation only for child health outcomes, and not through adapting agricultural techniques. If we observe adaptation both for yield and children's health, we cannot disentangle adaptation through agricultural measures from adaptation through income- and consumption smoothing. On the other hand, if we observe that previous shock exposure magnifies the negative impact of a current shock on child nutrition then this could indicate an asset depletion story. In this case we could also expect to see an independent negative effect of past shock experiences on children's outcome in non-drought years. We may also observe adaptation in yield, but depletion or no adaptation in terms of child health. This could indicate that households adapt by producing less risky, but less nutritious crops, or that agricultural adaptation is costly, and that this is taking place at the expense of children's health, for instance in terms of time use (Kim, 2010).

Finally, for both agricultural and health outcomes, we expect the timing of past shocks to affect the total impact of a new shock. Rebuilding the asset stock following a shock may take time. Households' ability to cope with a new shock could therefore be greater the more time has passed since the last shock, implying a negative relationship between the impact of a new shock and the time that has passed since the last shock. On the other hand, it may be easier to learn from a more recent shock than from shocks that happened a long time ago, whereby the negative impact of a new shock would increase with the time that has passed since the last shock experienced by the household. We investigate these scenarios in the empirical analysis below, and start by describing the study context.

3 Climate and agriculture in Tanzania

We focus on farmers' behavioral responses to weather variability in Tanzania. A substantial share of the population relies on agriculture as their main income source, with around 70 percent of the population residing in rural areas (NBS, 2014). Population density is relatively low throughout the country, but birth rates are high, with each woman on average giving birth to just over five children (NBS and ICF Macro, 2011).

The climate is characterized by large regional, inter-seasonal and intra-annual variations. The inland country is dominated by highlands with a temperate climate, while the coastal areas are warm and humid. Northern and eastern regions experience two rainy seasons (bimodal rainfall pattern), while the rest of the country has one single rainy season (unimodal rainfall pattern). These rainfall patterns are largely the result of the Inter-Tropical Convergence Zone (ITCZ) and its movement across the country (McSweeney et al., 2010, 2014). Climate variability is in addition affected by the El Niño Southern Oscillation (ENSO)[9] and La Niña[10] (Camberlin et al., 2001; Wolff et al., 2011).

Cereals such as maize, rice and sorghum are farmed extensively, maize being the most common crop. A large share of the maize production takes place in the southern highlands, whereas sorghum is mostly found in the drier central highlands and rice in southern regions (Rowhani et al., 2011). Given the limited use of irrigation, the timing of agricultural activities is closely linked to the seasonal rainfall patterns. The rainy season in the unimodal areas (*Msimu*) usually starts in October-November and lasts until April-May, with a dry-spell in-between, allowing for harvest from June to August. In the bimodal areas, the short rainy season (*Vuli*) typically lasts from October to December, whereas the long rainy season (*Masika*) occurs between March and June, with harvesting in July-August. Some crops, such as banana and cassava, may be harvested throughout the year (Kaliba et al., 1998a,b,c; Mafuru et al., 1999; Nkonya et al., 1999).

According to historical records, average annual rainfall in Tanzania has decreased over the past decades, whereas mean annual temperature has increased (McSweeney et al., 2010, 2014; Hulme et al., 2001). In terms of extreme rainfall weather events, the pattern is less clear (McSweeney et al., 2010, 2014). Climate model predictions suggest an increase in mean temperature, and particularly so during the dry season, whereas predictions on rainfall are less certain. For instance, Ahmed et al. (2011) note an increase, whereas Hulme et al. (2001) characterize the predictions from climate models for Africa as uncertain due to incomplete and lacking knowledge of the ENSO's effect and the failure to incorporate the interaction between changing land cover and land use, and the atmosphere.

4 Data

4.1 Plot and household panel

We use the Tanzania National Panel Survey (NPS), a panel of nationally representative household surveys from 2008/09 (NPS1) and 2010/11 (NPS2). Households were sampled from 409 populated enumeration areas drawn from the Tanzania Population and Housing Census from 2002. The first round covers 3265 households (2063 in rural areas) and their 4321 farm plots, and was collected in the period October 2008-October 2009. The second round covers 3924 households, 3168 of them

[9]Warmer sea surface temperature in Pacific, that may result in more than average rainfall in the short rainy season but less in the long rainy season (Camberlin et al., 2001).

[10]Cooler sea surface temperature in Pacific, that may result in droughts in the northern parts of Tanzania, whereas more than average rainfall is likely to occur in southern parts (Wolff et al., 2011).

reinterviewed from round 1, and their 3882 farms plots, and was collected between October 2010 and November 2011. The observations are matched at the household- and plot level across the two survey rounds. Around 7 percent of the plots were measured with GPS in the first round and 80 percent in the second round (NBS, 2011).

The NPS has the advantage of providing detailed data on both agricultural production and child anthropometrics. Moreover, the panel nature of the data makes it possible to control for unobservable time-invariant factors that may be correlated with the climate variables as well as the outcomes we are interested in. Data on agricultural activities is gathered for the agricultural season preceding the interview. Thus, for NPS1 the agricultural season of interest when matching with weather data is 2007/08, whereas agricultural data from NPS2 is matched with rainfall for the 2009/10 season. Figure A1 in the appendix shows a map of the enumeration areas from 2008/09 to which we match the weather data.

In some specifications we use the unbalanced plot panel data, which gives us 5416 observations when we include households that reside in the same location across the two survey years and cultivate crops in both seasons. The balanced household panel gives us 2436 observations, covering both years. For children's nutritional outcomes, we pool the data and use nutritional outcome variables on 3189 children that are 60 months or younger residing in farming households.[11] Since we do not have weather data for 2011, we exclude children measured after the harvest from the 2010/11 rainy season, i.e. those measured after April in the unimodal areas and after June in bimodal areas.

4.2 Climate data

We use University of Delaware's (UDel) gridded precipitation and temperature data, described in Willmott and Matsuura (2012a,b). Each grid cell is 0.5 x 0.5 degrees, equivalent to around 55 x 55 km at the equator. The data is interpolated from weather station observations and provides monthly data on precipitation in millimeters and monthly mean air temperature in degrees Celsius.[12] Each set of GPS coordinates at the enumeration area level is matched to a grid cell. This results in the 391 enumeration areas being matched to 149 grid cells covering mainland Tanzania and Zanzibar,

[11] There are unfortunately too few observations on children below 61 months in the same households over the two rounds of the survey to use the panel structure in this case. We are allowing children that are observed in both years to enter twice. We include children of farming households that were excluded in the yield analysis due to outliers or missing observations on agriculture.

[12] The climate data from UDel has been used extensively over the past years. We choose to use this data given its detailed historical and spatial coverage.

whereby several enumeration areas fall within the same grid cell.[13]

4.3 Measuring climate shocks

Previous studies on the impact of climate variability on agricultural output suggests that both precipitation and temperature are important. Precipitation and temperature shocks are of particular interest, as these are perceived to be orthogonal to other factors that may affect the outcome of interest. A shock is a deviation from average conditions within a given area over a certain period, and is typically defined in terms of levels (Rose, 1999), percentages (Maccini and Yang, 2009) or standard deviations. We operate with two guiding criteria in choosing our measure of shocks. First, we need a shock measure that is orthogonal to other factors that may affect the outcome variables. Second, we require a shock measure that can be aggregated across years without the shocks canceling each other out. To this end, Burke et al. (2015)'s approach is the most useful one. They define a shock based on rainfall falling below a percentile threshold of the local historical rainfall distribution.

There is no consensus on below what level (percentile) the received rainfall qualifies as a shock. Burke et al. (2015), for instance, find that rainfall below the 15th percentile of a gamma distribution is particularly harmful to maize yield and GDP growth in Africa. We define a negative precipitation shock in three ways: *(i)* a severe shock, with precipitation below the 10th percentile of the local historical distribution, *(ii)* a moderate shock, with rainfall below the 15th percentile, and *(iii)* a mild shock, with rainfall below the 20th percentile. Basing our definition of a drought period on deviations from the *local* precipitation pattern means that we control for the average local climate, which may be correlated with other characteristics that could influence our outcome variables (Kudamatsu et al., 2012). Moreover, a relative rather than an absolute measure of drought suggests that any deviations from the local historical mean, i.e. rainfall below the 10th, 15th or 20th percentile of the distribution, should be orthogonal to other factors that may affect households' adaptation. In any given year households in a grid cell have a 10, 15 or 20 percent probability of experiencing a shock as defined above.

We proceed by identifying the historical distribution of rainfall in each grid cell based on the monthly precipitation data for the period 1960-2010. We restrict ourselves to this period, as it

[13] We drop 18 enumeration areas due to lack of precipitation data. These are located along the coast or on islands. Given our focus on agricultural production, we do not believe that omitting these enumeration areas will bias our results, as many households in these areas are involved in other occupations than agriculture.

provides a more representative distribution for recent weather patterns while at the same time giving us sufficient data to construct a distribution from which we draw our historical shocks.[14] All measures are constructed for the entire agricultural season, defined as July to June. A timeline describing the timing of the surveys and agricultural shocks is shown in Figure A2. As an alternative measure, we also define shocks based on precipitation in the relevant rainy season in the unimodal and bimodal areas of Tanzania. This is a more precise measure and is likely to reduce measurement error and thus attenuation bias in the estimated shock coefficients, given that we are able to correctly identify the growing season.

Unfortunately, the University of Delaware data only contains monthly mean air temperatures, which prevents us from developing a good indicator of temperature shocks,[15] but we include mean temperature (C°) during the growing season as a control in our analysis of agricultural outcomes.[16]

When investigating the impact of shocks on child health we identify the most recent agricultural season prior to the child's measurement, since this is the season relevant to the child's food consumption before being measured. The relevant season differs between the unimodal and bimodal areas, and we investigate the impact of shocks in the relevant season depending on when the child was measured. For children in households residing in unimodal areas, we use the rainfall shock in 2007/08 for all those measured prior to May 2008 in the first survey round, whereas those measured in May or later are assigned a shock value based on the 2008/09 rainfall season. We set the cut-off to July for the bimodal areas.[17] The same procedure is used for the second survey round.

We identify previous exposure to the shocks by counting the number of similar shocks that have occurred over the last 10-year period, in other words 1997/98-2006/07 for the first survey round, and 1999/00-2008/09 for the second survey round. This measure takes into account the most recent shocks relevant to each survey round. On the other hand, it only exploits variation in shock incidence in the first and last two years of the 10-year time period, as the window of "shock memory" is moved forward from the first to the second survey round, while we are controlling for plot fixed effects. When looking at the timing of past shocks, we count the number of years that

[14]The same approach is taken by Burke et al. (2015).

[15]Schlenker and Lobell (2010) and Lobell et al. (2011) use growing degree days (GDD) as a measure of accumulated temperature exposure for crops during the growing season, and degree days above 30 degrees Celsius as a measure of exposure to extreme heat.

[16]We choose to define the growing season based on the main rainy season, and in accordance with recorded planting times for maize. This latter varies from October to February in the unimodal areas (Kaliba et al., 1998a,b,c) and from January to April in the bimodal areas (Mafuru et al., 1999; Nkonya et al., 1999; Kaliba et al., 1998b). This differs from Ahmed et al. (2011) who use a general growing period for the entire country, i.e. from January to June, for maize, rice and sorghum.

[17]The choice of cut-off is based on the beginning of the main harvest in each area.

have passed since the plot or child was last exposed to a similar shock. For each survey round, we count backwards from the relevant agricultural season or season in which the child was measured.

We set our initial window of shock memory to 10 years, as it both provides enough variation to investigate our hypotheses, while at the same time covering a recent period that the decision-maker is likely to remember, and thus update their decision-making process accordingly. Previous work from Tanzania suggests that farmers remember recent deviant years with too little or too much rainfall, whereas less recent years are, not surprisingly, primarily remembered by older farmers (Slegers, 2008). Similar findings are made among Ethiopian farmers who remembered severe droughts that occurred 15-20 years ago (Meze-Hausken, 2004). We vary the window of shock memory, using 15 and 20 years instead of 10, to investigate whether the results are sensitive to this (results available upon request).

Importantly, since the previous shock exposure variable is based on the local historical distribution of rainfall over the past 50 years, all households across grid cells have an equal probability of experiencing a shock in a given year (withstanding temporal correlation). Consequently, areas that experience more weather shocks in the past decade should not differ systematically from areas that experience more shocks in any other decade of the 50-year period.

4.4 Measuring agricultural yield

We vary our measure of agricultural output, using maize, cereal and total yield (log of output per hectare) at the plot level. Total yield covers all crops from the long rainy season, including legumes, vegetables, roots, tubers and cash crops. Around 60 percent of the plots are planted with mono- or intercropped maize, followed by around 12 percent allocated to rice paddy. Beans, groundnuts and pigeon peas are typical crops used for intercropping, whereas few farmers have cash crops, such as tobacco, cotton and cashew nuts. For each output measure we exclude the lower and upper one percentile, but our results are robust to including these assumed outliers.

Each measure has both disadvantages and advantages. We suspect that using total yield is more likely to bias our results. Households with past shock experience that experience a current shock may be more likely to harvest cassava, which weighs more than cereals and is more drought-tolerant, than those that did not experience a shock, thus resulting in a higher total yield. The five cereals (maize, sorghum, millet (bulrush and finger), wheat and rice) that enter into the cereal yield variable are on the other hand more homogenous in weight, and using maize only provides an even more homogenous crop category.[18] On the other hand, restricting the agricultural yield data to only maize or cereal reduces the number of observations, primarily at the plot level, but also at household level. Further, the sample of households that grow maize in both years may be a select group, that is either unable to switch to alternative crops, or are highly capable maize farmers. The choice of outcome variable also depends on the type of adaptation we expect. Crop switching is captured by using a more aggregate crop group, while focusing on cereals or maize may capture other types of adaptation such as timing of planting, irrigation and soil conservation practices.

4.5 Measuring children's health

We use three measures of children's nutritional status as outcome variables. First, *(i)* weight-for-age, which is referred to as the "classical index" in WHO (1986), capturing underweight. This can be supplemented or replaced by the following two; *(ii)* weight-for-height, which reflects short-run nutrition and recovers quickly after a period of insufficient nutrition (wasting, index of acute malnutrition) and *(iii)* height-for-age, which captures long-run nutrition (stunting, index of chronic malnutrition). Stunting and wasting react differently to the nutritional state, and are distinct biological concepts. Wasting is more prevalent between 12 and 24 months of age, while stunting is more prevalent above 24 months. Growth is a slow process, and cannot be reversed (you cannot lose height), while weight may react quickly to nutrition and disease (WHO, 1986). According to WHO (1986) it is most appropriate to look at these outcome variables for children aged five and younger. The weight-for-age, weight-for-height and height-for-age of the children in our sample are linked to the WHO reference population by creating Z-scores.[19] The standard allows us to create Z-scores for individuals aged 0-60 months. Individuals with a weight-for-age Z-score that is more than two standard deviations below the median are defined as underweight, whereas similar cut-offs apply for categorizing individuals as wasted (weight-for-height) and stunted (height-for-age). In line with Alderman et al. (2006) we drop individuals with Z-scores below -6 or above 6, resulting in the exclusion of 75 observations. In addition, we are forced to drop individuals that were not measured, due to illness or because they were not at home.

[18] Improved maize varieties are typically more drought-tolerant than local varieties.

[19] We subtract the median and divide by the standard deviation of the appropriate sex and age category of the reference population.

4.6 Descriptive statistics

In Table 1 we report descriptive statistics at the plot, household and child level. Maize yields average around 800 kg per hectare, whereas average cereal and total yields are closer to 880 kg per hectare. The household head is on average 49 years of age, and one fourth of the households are female-headed. Four percent of the households experience a severe shock (rainfall below the 10th percentile) in one of the surveyed agricultural seasons, i.e. 2007/08 and/or 2009/10, whereas 11 percent have experienced a mild shock (rainfall below the 20th percentile) in these same seasons. In terms of previous exposure, the households have experienced between zero and four severe shocks over the past decade. The number of years since a similar shock occurred varies between one and 41 years for the severe shocks, and one and 20 years for the mild shocks. In terms of child health, children are on average 1.6 and 0.9 standard deviations below the international reference population for height-for-age and weight-for-age, respectively, whereas they are on average closer to the median of the reference population for weight-for-height. When using the cut-offs of two standard deviations below the median, we find that 36 percent of the children are stunted, whereas 14 and 6 percent are wasted and underweight, respectively.

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Plot level					
Total yield (kg/ha)	875.07	1050.29	18.42	11943.43	5416
Cereal yield (kg/ha)	889.74	930.95	29.16	5991.05	4313
Maize yield (kg/ha)	798.73	764.12	10.16	4447.90	3297
Household level					
Age hh head	48.695	15.345	19	105	2436
Female headed hh	0.250	0.433	0	1	2436
Year 2010/2011	0.5	0.5	0	1	2436
GPS measured plots	0.571	0.495	0	1	2436
Average temp. in growing season (C°)	23.758	3.163	7.34	28.76	2436
Rainfall below 10th percentile this season	0.042	0.201	0	1	2436
No. of seasons with rainfall below 10th perc., last 10 yrs	1.166	1.071	0	4	2436
Years since rainfall below 10th percentile	9.362	9.638	1	41	2436
Rainfall below 15th percentile this season	0.071	0.257	0	1	2436
No. of seasons with rainfall below 15th perc., last 10 yrs	1.829	1.406	0	6	2436
Years since rainfall below 15th percentile	5.697	6.153	1	35	2436
Rainfall below 20th percentile this season	0.112	0.316	0	1	2436
No. of seasons with rainfall below 20th perc., last 10 yrs	2.418	1.552	0	7	2436
Years since rainfall below 20th percentile	3.622	3.265	1	20	2436
Child level					
Length/height-for-age Z-score	-1.646	1.53	-5.91	5.93	2800
Weight-for-age Z-score	-0.895	1.169	-5	5.43	2801
Weight-for-length/height Z-score	0.053	1.274	-5.58	5.65	2795
Age in months	30.151	17.457	0	60	3137
Female	0.5	0.5	0	1	3137

5 Empirical specifications

5.1 Agricultural yield

To investigate the impact of shocks and previous exposure to shocks on agricultural yield, we estimate the following equation:

$$\mathrm{Y}_{phct} = \alpha + \beta_1 \mathrm{Shock}_{ct} + \beta_2 \mathrm{PrevShock}_{ct} + \beta_3 \mathrm{Shock}_{ct} \times \mathrm{PrevShock}_{ct} + \mathbf{X}'_{hct}\boldsymbol{\delta} + \zeta_p + \eta_t + u_{phct} \quad (1)$$

where Y_{phct} is the outcome of interest (log of yield) for plot p in household h in grid cell c at time t. Shock_{ct} is a dummy equal to one if precipitation is below the 10th, 15th or 20th percentile at time t, $\mathrm{PrevShock}_{ct}$ is the number of years a grid cell c was exposed to such a shock in the past, and $\mathrm{Shock}_{ct} \times \mathrm{PrevShock}_{ct}$ is an interaction between the two. We look at the number of shocks experienced over a 10-year period prior to each agricultural season, but vary this time period as a sensitivity analysis using a 15- and 20-year window. We include plot fixed effects, ζ_p, to control for time-invariant plot characteristics, and survey year fixed effects, η_t. u_{phct} is a mean zero error term, and we cluster the standard errors throughout at the grid cell level.

The choice of which control variables to include is not obvious. Following the recommendation by Dell et al. (2014) we only include regressors that can credibly be viewed as exogenous. Controlling for input use or crop choice when looking at agricultural yield would be problematic, since these variables are likely to be influenced by whether or not the household experiences a shock; in fact they may be important channels through which a household may adapt to climate risk. Angrist and Pischke (2009) calls this a "bad control problem" and shows that including regressors that are not exogenous to the weather variables we are interested in would bias the estimates of β_1, β_2 and β_3. The vector $\mathbf{X}_{hct}$ therefore only consists of a set of control variables at the household level, more specifically the age and gender of the household head, whether the households' plots were measured with GPS or not, and the mean temperature in the growing season.

The coefficient β_1 can be interpreted as the effect of being exposed to a shock without having been exposed to similar shocks over the past 10-year period. β_2 is the effect of past shock exposure on yield in a non-drought year, while β_3 is the effect of past shock exposure on the impact of a current shock. The average effect of a current shock is thus $\beta_1 + \beta_3 \times \overline{\mathrm{PrevShock}}$ where $\overline{\mathrm{PrevShock}}$ is the average number of shocks experienced. $\beta_3 < 0$ indicates that previous exposure to shocks makes the household less able to deal with a current shock (depletion), while $\beta_3 > 0$ indicates that households are able to learn from previous shock exposure to mitigate the impact of a current shock (adaptation). Similarly, $\beta_2 < 0$ indicates that more frequent past shock exposure leads to lower yield, while $\beta_2 >$ indicates the opposite. Since we are controlling for plot-level fixed effects, we are only exploiting variation within each plot over time. Any variation in the PrevShock_{ct} variable is thus variation in the number of shocks a plot has been exposed to between the first and the second survey round, and in the first two years that enter into the 10-year period. This means that an increase in previous shock exposure must come from experiencing a shock in the 2007/08 season and/or the 2008/09 season, whereas a decrease in shock exposure would occur when moving the 10-year window forward results in a shock year dropping out.

We also capture the effect of previous shock exposure on the impact of a current shock through LastShock_{ct}, replacing PrevShock_{ct}. This variable is based on counting the number of years since a similar shock, i.e. rainfall below 10th, 15th or 20th percentile, occurred. As described above, we expect that the timing of previous shock exposure may matter for the impact of a current shock. For instance, having recently experienced a similar shock could magnify the negative effect of a contemporaneous shock if households have depleted their asset stock, and adaptation to a new shock is costly. Alternatively, as time passes since the household last experienced a shock, their asset stock may be rebuilt, but knowledge of how to adapt to a shock may dissipate over time. Our second specification is as follows:

$$\text{Y}_{phct} = \alpha + \gamma_1 \text{Shock}_{ct} + \gamma_2 \text{LastShock}_{ct} + \gamma_3 \text{Shock}_{ct} \times \text{LastShock}_{ct} + \mathbf{X}'_{hct}\boldsymbol{\delta} + \zeta_p + \eta_t + u_{phct} \quad (2)$$

where the average effect of a shock is $\gamma_1 + \gamma_2 \times \overline{\text{LastShock}}$. We include the same control variables as in the first specification.

5.2 Child health outcomes

We employ a reduced form model to investigate the impact of shocks and their interaction with previous shocks on child health outcomes:

$$\text{Y}_{ihct} = \alpha + \lambda_1 \text{Shock}_{ct} + \lambda_2 \text{PrevShock}_{ct} + \lambda_3 \text{Shock}_{ct} \times \text{PrevShock}_{ct} + \mathbf{X}'_{ihct}\boldsymbol{\delta} + \xi_c + \varphi_t + u_{ihct} \quad (3)$$

where Y_{ihct} is a measure of the nutritional status for child i in household h in grid cell c at time t. We employ three outcomes: height-for-age Z-score, weight-for-age Z-score and weight-for-height Z-score. $\mathbf{X}_{ihct}$ includes a set of child-specific characteristics on age and gender, in addition to controls for birth- and interview month. Shock_{ct} refers to the last agricultural season prior to child measurement in grid cell c at time t. PrevShock_{ct} and the interaction term are defined as in the empirical specification for agricultural outcomes. We focus on the shock history relevant to the household, and not only shocks that occur in the child's lifetime, as the care-takers in the household are the ones who potentially learn and are able to protect children from shortfalls in income. We include grid-level fixed effects, ξ_c, rather than household or enumeration area fixed effects, as we are not able to use the data on the last children measured in the second survey round and therefore do not have sufficient variation within the household or enumeration area. This means that we are exploiting within grid cell variation to estimate the effects of rainfall shocks on child nutrition. We are thus comparing children from different households and, in some cases, different enumeration areas when several enumeration areas fall within the same grid cell. This should be kept in mind when interpreting the results.

We expect a contemporaneous shock (rainfall below the 10th, 15th or 20th percentile) to have a negative impact ($\lambda_1 < 0$) through income on short-term nutritional outcomes, i.e. weight-for-age and weight-for-height, but less so for height-for-age as this measure does not react quickly to changes in consumption. However, the disease channel may in part counteract this effect, since less rainfall could be beneficial if it reduces the prevalence of vector- and water borne diseases. Similarly, past exposure to rainfall shocks could have an impact on child health (captured by λ_2) if the shocks occur during the lifetime of the child, especially on the long-run nutritional status. Accumulated negative income shocks at the household level could also have a negative impact on children's health, which would imply $\lambda_2 < 0$.

Finding $\lambda_3 < 0$ would indicate that households' repeated previous exposure to droughts makes child health more vulnerable to recent shocks. For short-term nutritional outcomes, we expect the impact mechanism to be through the income of the household, where the impact on household consumption is increasing in previous shock exposure, perhaps due to asset depletion and lack of consumption smoothing mechanisms. A child's previous exposure to shocks is expected to affect height-for-age negatively, which could imply $\lambda_3 < 0$ depending on when the previous shocks occurred. $\lambda_3 > 0$ would, on the other hand, indicate that households are able to take advantage of learning from previous shocks, through improved income- and consumption smoothing and/or through agricultural adaptation, depending on the sign of β_3 from specification 1.

Similar to the specification in eq. (2), we also look at the importance of timing of past shocks for child nutritional outcomes.

6 Results

6.1 Agricultural yield

We start off by presenting our results for agricultural outcomes, in line with the first empirical specification in eq. (1), using the plot-level panel. We report here the results from using log of cereal yield as the outcome variable, and refer to the appendix for the results on log of total yield and maize yield. Plot-level fixed effects are included throughout, and we are therefore exploiting the within-plot level variation. Panel A in Table 2 shows that experiencing a negative rainfall shock reduces cereal yields. The impact of the shock is increasing in the severity of the shock, i.e. the more severe shocks have a larger negative impact on crop yields. More specifically, rainfall below the 10th percentile results in an average reduction in cereal yield of 26 percent, whereas rainfall below the 15th percentile on average reduces yield by 18 percent. The impact of a mild shock suggests an average decrease in yield by 10 percent, but is not statistically significant.

Next, we include an interaction term between the frequency of past shocks and a shock this agricultural season, while controlling for the number of shocks experienced, thus estimating the full specification in eq. (1). When controlling for past shock experience, the impact of a current shock is no longer statistically significant. This may be because we have insufficient plot observations without any previous shock experience to estimate this coefficient. The impact of a current shock is smaller for plots with more previous shock experience, corresponding to $\beta_3 > 0$ in our empirical specification, but only for the least severe shock. The magnitude indicates that an additional shock experience on average reduces the impact of a current mild shock by about 12 percent for cereal yields. Farmers with more shock experience seem better able to cope with a current shock, but only for mild shocks, perhaps because available adaptation strategies are not sufficient to mitigate the impact of severe droughts. It may also be that we are unable to estimate a significant coefficient on the interaction term because there are too few plot observations with past shock experience and a current shock for the more severe, and therefore rarely occurring, shocks. The coefficients on the number of past shocks and the interaction term are jointly significant for the moderate and mild shocks, but not for the severe shock.

The results also show that plots with more shock experience on average have higher yields, corresponding to $\beta_2 > 0$ in the empirical specification. Although we are primarily interested in β_1 and β_3, we do offer some possible explanations for this result. One potential explanation for this finding is that farmers invest in higher-yielding technologies as a self-insurance mechanism to mitigate the impact of shocks and ensure a minimum production level when facing risk. The farmers that continue in farming despite previous droughts[20] appear to increase their effort and investments in response to shocks as an adaptive measure. Those with more frequent shock exposure seem to intensify production more, on average leading to between 15 and 30 percent higher yields depending on the severity of the shock. The difference in yield due to varying the number of shocks experienced is smaller for more severe shocks. This may be because severe shocks have such a large impact on households' income that adjustment is difficult, or because experiencing a severe shock triggers an adjustment in behavior regardless of how many shocks they have experienced. Furthermore, it may also indicate that intensification is costly, if farmers are more reluctant to increase investments and efforts when experiencing only a few moderate or mild shocks. An alternative, or additional, explanation for the large positive effect is that this is driven by households who experienced a drought in the first round. This drought will enter into the 10-year shock window in the second round. Since yield was negatively impacted in the first round and assuming there is no shock in the second round, giving higher yields, then we find by construction a positive impact of the number of recent shocks.

[20]Either because they are especially skilled, or because they lack outside opportunities, as further discussed below.

Table 2: The effect of rainfall shocks on cereal yield

	Severe shock		Moderate shock		Mild shock	
Panel A:						
Shock this season	-0.260***	-0.103	-0.182*	-0.149	-0.106	-0.166
	(0.091)	(0.209)	(0.103)	(0.333)	(0.071)	(0.161)
Number of shocks last 10 yrs		0.149		0.234***		0.308***
		(0.095)		(0.074)		(0.067)
Shock this season * No. of similar shocks last 10 yrs		-0.035		0.082		0.117*
		(0.112)		(0.122)		(0.061)
Panel B:						
Shock this season		-0.451		-0.206		-0.190*
		(0.400)		(0.138)		(0.115)
Years since last shock		-0.021**		-0.030***		-0.043**
		(0.008)		(0.006)		(0.018)
Shock this season * Years since last similar shock		0.070		0.018		0.044*
		(0.118)		(0.027)		(0.026)
Number of Obs.	4313	4313	4313	4313	4313	4313
Mean of Dep. Var.	6.31	6.31	6.31	6.31	6.31	6.31

Notes: Dep. var.: Total cereal yield (log), including maize, sorghum, millet, wheat and rice. Severe shock refers to rainfall below the 10th percentile, moderate below the 15th percentile and mild below the 20th percentile. Shocks based on 12 month rainfall. Plot fixed effects. Survey year, age and sex of household head, GPS measurement of plot and average temperature in growing season included but not reported. Standard errors clustered at grid cell level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

These results are similar when looking at the three different outcome measures, see Table A1 for results on total yield and maize yield. We find the largest negative effects of a severe shock for the more narrow yield definitions, i.e. 28 percent reduction for maize compared to 23 percent reduction in total yield.[21] This may be because the total crops category includes less drought-sensitive crops, and that there is more room for substitution between crops. Further, we do not find evidence that the impact of current shock is smaller for plots with more previous shock experience when looking at total yield, possibly because previous shock experience is less valuable than for a specific crop such as maize. We also vary the "shock memory" in the model, by counting the frequency of shocks over the past 15 and 20 years prior to the relevant agricultural season. The results largely hold (available upon request), but are weaker the longer the time period we take into account. The results are also largely robust to using a more narrow definition of the rainy season, described in Section 4.3, and as reported in Table A2.

In Panel B, Table 2 we show the results from looking at the timing of past shocks. The results demonstrate that the timing of past shocks matters. Plots with more distant shock experience have lower yields, corresponding to $\gamma_2 < 0$, and this effect is declining in the severity of the shock. One way of interpreting this is that a shock has a stock effect on increased investments and effort, and that this stock depreciates more slowly for severe shocks, due to the lasting impression of such a shock. As discussed in the conceptual framework, we expect that more recent shock experience may provide households with the knowledge of how to cope with a new shock, but that this effect may dissipate over time. On the other hand, the household may need time to recover from a shock to be able to cope with a new shock. For the mild shock, the more time has passed since the last shock, the smaller the impact of a current shock, or $\gamma_3 > 0$ in eq. (2), which may indicate that the "recovery" effect dominates. For the moderate and severe shocks, the coefficient on the interaction term is not statistically significant. This could be explained by farmers' inability to mitigate the impact of more severe shocks, or because we do not have sufficient variation to estimate the coefficient. The results for total yield and maize yield are similar, as seen from Table A3.

6.2 Child health outcomes

Next, we investigate the impact of shocks and previous shock exposure on children's health among the same farming households. In Panel A in Table 3, we report the results on weight-for-age, referring

[21]The impact is not statistically significant for the total yield variable.

to the appendix for results on height-for-age and weight-for-height. These are the results when using the more narrow specification of the growing season in defining weather shocks, as described in Section 4.3, while the results for the more general definition are shown in the appendix. The rainfall shocks are defined as rainfall below the 10th, 15th or 20th percentile of the local historical rainfall distribution in the months of the rainy season (the long rainy season in the bimodal areas). Grid cell, birth month- and interview month fixed effects are included throughout but not reported. We are therefore comparing children within the same grid cell, born in the same month (in part accounting for their exposure to rainfall shocks in utero) and interviewed in the same month. The results on children's health should thus be interpreted with caution, since we are not controlling for unobservable household characteristics that may be correlated with the climate variables and children's nutritional outcomes.

Looking first at the impact of a shock without controlling for past shock experience, we find that the most severe shock is associated with a lower weight-for-age Z-score, while we do not find statistically significant results for the less severe shocks. Experiencing rainfall below the 10th percentile of the local historical rainfall distribution in the rainy season prior to being measured is associated with a 0.18 standard deviation lower weight-for-age Z-score of children five years and younger. When we control for past shock experiences of the household to which the child belongs, the coefficients on the shock variables are all negative, but not statistically significant. The results also indicate that in households with more shock experience, a current shock is associated with a smaller decrease in short-run nutritional indicators.[22] The coefficient on the interaction term, λ_3 in the empirical specification in eq. (3), is positive and significant for both moderate and mild shocks for weight-for-age, which could indicate that households are able to use previous shock experiences to better shield their children from current shocks. The coefficient on the number of past shocks, λ_2, is positive but not statistically significant, but it is statistically significant when using weight-for-height as the outcome variable. This could be an indication of a selection mechanism and is further discussed in Section 7.1. Again, the coefficients on past shock experience and the interaction term are only jointly significant for the moderate and mild shocks for weight-for-age Z-scores.

[22]This also holds for the weight-for-height Z-score, as shown in Panel B, Table A4.

Table 3: The effect of rainfall shocks on children's weight-for-age Z-score

	Severe shock		Moderate shock		Mild shock	
Panel A:						
Unimodal/bimodal shock this season	-0.177*	-0.122	0.055	-0.160	-0.023	-0.270
	(0.092)	(0.194)	(0.101)	(0.159)	(0.094)	(0.167)
Number of unimodal/bimodal shocks, last 10 yrs		0.110		0.009		0.050
		(0.086)		(0.059)		(0.064)
Unimodal/bimodal shock this season * No. of unimodal/bimodal shocks, last 10 yrs		0.010		0.101**		0.122**
		(0.096)		(0.050)		(0.049)
Panel B:						
Unimodal/bimodal shock this season		-0.400***		0.325		0.093
		(0.140)		(0.215)		(0.144)
Years since unimodal/bimodal shock		-0.020		-0.000		-0.017
		(0.015)		(0.016)		(0.015)
Unimodal/bimodal shock this season * Years since unimodal/bimodal shock		0.056***		-0.060		-0.019
		(0.015)		(0.043)		(0.029)
Number of Obs.	2801	2801	2801	2801	2801	2801
Mean of Dep. Var.	-0.89	-0.89	-0.89	-0.89	-0.89	-0.89

Notes: Dep. var.: Z-score is deviation of child's weight-for-age from the median, divided by the standard deviation of the appropriate sex and age category of the reference population. Sample: individuals aged 0-60 months from farming households. Severe shock refers to rainfall below the 10th percentile, moderate below the 15th percentile, and mild below the 20th percentile. Shocks based on unimodal/bimodal rainfall. Controls for age, sex, survey year, grid cell, birth- and interview month included but not reported. Standard errors clustered at grid cell in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

As shown in Table A4 in the appendix, there does not seem to be any impact of shocks on the height-for-age Z-score, which is as expected since height-for-age is a measure of long-run nutritional status. Using rainfall over the 12 month period, rather than unimodal/bimodal rainfall, as reported in Table A5, gives similar results, although the shock variable alone is no longer statistically significant for weight-for-age.

Lastly, we investigate the importance of the timing of past shock experience for the impacts on child nutrition. As seen from Panel B in Table 3, when we control for the timing of past shock experiences, a severe shock is associated with a 0.4 standard deviation decrease in the weight-for-age of children five years and younger. The impact of less severe shocks is not statistically significant. We also see that the impact of a severe drought is smaller the more time has passed since the last severe drought the household was exposed to, which could be because the household has had time to recover and rebuild their asset stock. The results are similar when looking at the weight-for-height Z-score, as shown in Panel B in Table A6, but they also indicate that children with more distant shock experience (both for severe and mild shocks) on average have worse weight-for-height Z-scores, which is surprising. One would expect recent shocks to have a negative impact on short-term child nutrition, since these are more likely to have occurred during the lifetime of the child. We discuss this result further below. As before, there are no statistically significant results for the long-run nutritional indicator, height-for-age, as seen in Panel A, Table A6.

7 Discussion and caveats

Our results may suggest that households with more previous exposure to negative rainfall shocks use higher-yielding and, in some cases, less drought-sensitive technologies. They also indicate that households with more past shock experience to some extent are able to mitigate the impacts of current shocks on children's nutrition. They do not, however, say anything about the type of technology or adaptation that takes place, i.e. the mechanisms behind the results. There are also caveats with regards to interpreting the difference in yield, drought-sensitivity and children's nutritional outcomes as being caused by previous shock experience.

7.1 Mechanisms

Previous studies suggest that farm households undertake a range of actions to reduce their vulnerability to weather shocks. Shifting the timing of planting or fertilizer application, switching crop varieties and types, and implementing soil- or water conservation technologies are potential adaptation strategies in agriculture (Burke and Lobell, 2010; Di Falco and Veronesi, 2013). The NPS-data does not contain detailed information on the timing of cropping activities, but we have information on the type of crop grown, as well as what inputs have been used and whether soil- and water conservation technologies have been implemented. Switching crop varieties and implementing soil-and water conservation are actions that may also increase yield (see for instance Banda et al. (1994); Vancampenhout et al. (2006).) Further, if households intensify production as a risk-coping mechanism, i.e. subsistence orientation, then this may take place through increased labor efforts or the use of other inputs. According to Tanzanian farmers interviewed in 2005/06, cultivating and weeding at the appropriate time, both labor-intensive endeavors, are central mechanisms for reducing the impact of droughts (Slegers, 2008).

We investigate potential causal mechanisms by estimating the association between technology choice, past and current shock experiences, and the interaction between the two, similar to the empirical specification for investigating impacts on crop yields (eq. (1)). We first compare the probability of investing in erosion control and water harvesting facilities on plots. As seen from Panel A in Table 4, households with plots that have experienced on average more moderate and mild shocks, are more likely to have these measures in place.[23] Given that these investments increase yields and protect households from shortfall in yield in drought years, this may be one of the behavioral responses that contribute to our previous finding that plots with more frequent previous exposure to shocks on average have higher yield. We find no change in these investments in years of drought, which is as expected since these are likely to be time-consuming measures that do not immediately yield benefits and are therefore unlikely to be implemented in response to a current drought.

Next, we look at the use of inorganic fertilizer, as reported in Panel B in Table 4. Plots with no previous drought experience receive less inorganic fertilizer in years with severe and moderate droughts, whereas the total reduction in inorganic fertilizer on plots with previous exposure to

[23]The most common erosion control and water harvesting facilities reported in both years of the survey are terraces and bunds.

rainfall shocks is smaller. More frequent previous exposure over the past decade reduces the use of inorganic fertilizer, which is in line with the findings of Dercon and Christiaensen (2011). The latter result may also be driven by an income effect triggering a binding liquidity constraint.

We also compare the use of other technologies and inputs, including improved maize varieties, intercropping, and total labor days, but do not find any clear differences based on previous shock exposure and its interaction with current shocks (available upon request). We do however find negative impacts of droughts alone on use of more variable inputs such as labor, measured in terms of total labor days.

Table 4: The effect of rainfall shocks on use of agricultural technologies

	Severe shock	Moderate shock	Mild shock
Panel A: Erosion control/water harvesting, dummy			
Shock this season	0.133	0.086	-0.048
	(0.106)	(0.076)	(0.106)
Number of shocks last 10 years	0.031	0.066***	0.065***
	(0.034)	(0.025)	(0.023)
Shock this season * No. of similar shocks last 10 yrs	-0.064	-0.013	0.019
	(0.042)	(0.020)	(0.027)
Number of Obs.	5403	5403	5403
Mean of Dep. Var.	0.14	0.14	0.14
Panel B: Inorganic fertilizer, dummy			
Shock this season	-0.517**	-0.361**	-0.059
	(0.106)	(0.140)	(0.106)
Number of shocks last 10 years	-0.051*	-0.053**	-0.027
	(0.027)	(0.021)	(0.017)
Shock this season * No. of similar shocks last 10 yrs	0.167**	0.073**	-0.004
	(0.080)	(0.031)	(0.032)
Number of Obs.	5416	5416	5416
Mean of Dep. Var.	0.10	0.10	0.10

Notes: Dep.var.: Panel A: Erosion control/water harvesting facility on plot (1=yes, 0=no). Panel B: Inorganic fertilizer applied on plot (1=yes, 0=no). Linear probability model. Severe shock refers to rainfall below the 10th percentile, moderate below the 15th percentile and mild below the 20th percentile. Shocks based on 12 month rainfall. Plot fixed effects. Survey year, age and sex of household head, and average temperature in growing season included but not reported. Standard errors clustered at grid cell in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The above mechanisms relate to agricultural production, however, we are also interested in possible mechanisms that may explain our findings on child health outcomes. As discussed in the conceptual framework, indications of previous shock experience mitigating current shock impacts on child health may both be due to adaptation in agriculture, that reduces the yield impact of shocks, and adaptation taking place outside agriculture. Potential coping strategies in this context are income diversification, asset depletion and self-insurance through savings, where we hypothesize that households may use their experience with these strategies from previous shock exposure to mitigate impacts of current shocks.[24]

In order to investigate potential mechanisms, we use the same approach as above to estimate the relationship between an indicator of income diversification and shocks, previous shock exposure and their interaction, while controlling for household fixed effects.[25] As an indicator of income diversification we use a dummy variable equal to one if the household head's main occupation was outside agriculture in the 12 months preceding the survey, and zero otherwise.[26] Results in Panel A in Table 5 show that experiencing a severe shock increases the probability of the household head's main occupation being outside agriculture, which may indicate that this is an important strategy to cope with severe shocks that lead to large shortfalls in agricultural income. For all three shocks, more frequent past shock exposure decreases the probability of non-agricultural employment for the household head, and non-agricultural occupation seems to be less important as a coping strategy for households with more previous shock experience. We also look at whether any of the household members engage in self-employment activities outside of agriculture, see Table 5, Panel B. The probability increases when experiencing severe and moderate shocks, but diminishes with the number of previous shocks (interaction effect). These findings may suggest that households opt for subsistence orientation in response to risk exposure. On the other hand, it may also be the result of selection, whereby households with outside income opportunities that have experienced more shocks have left agriculture. We discuss this latter possibility further below.

[24]We are unable to investigate whether they have in fact used these strategies before, and so it may instead reflect a strategy of last resort.

[25]Unfortunately, we do not have access to data on household savings and remittances nor an adequate measure of asset holdings and can therefore not investigate these potential coping mechanisms. Less than two percent take up credit for subsistence purposes in either season. Not surprisingly, we find no impact of shock on this outcome.

[26]For many households the last 12 months will cover the agricultural season following the season to which "shock this year" refers to. If we limit the sample of households to those interviewed early in each survey round, for instance between October 2008 (2010) and May 2009 (2011), the pattern of results remains more or less the same (see Table A7).

Table 5: The effect of rainfall shocks on income diversification

	Severe shock	Moderate shock	Mild shock
Panel A: Head's main occupation is non-agricultural, dummy			
Shock this season	0.252*	-0.047	0.064
	(0.131)	(0.116)	(0.100)
No. of shocks., last 10 yrs	-0.072**	-0.060**	-0.065***
	(0.032)	(0.027)	(0.024)
Shock this season * No. of shocks, last 10 yrs	-0.165***	-0.026	-0.052*
	(0.054)	(0.030)	(0.029)
Number of Obs.	2436	2436	2436
Mean of Dep. Var.	0.53	0.53	0.53
Panel B: HH member operated business/self-employed, dummy			
Shock this season	0.311***	0.161*	-0.018
	(0.075)	(0.086)	(0.063)
No. of shocks., last 10 yrs	-0.007	0.017	-0.023
	(0.028)	(0.025)	(0.023)
Shock this season * No. of shocks, last 10 yrs	-0.120***	-0.042**	-0.010
	(0.039)	(0.021)	(0.019)
Number of Obs.	2436	2436	2436
Mean of Dep. Var.	0.31	0.31	0.31

Notes: Dep.var.: Household head's main occupation is non-agricultural (1=yes, 0=no). Household member operated business/self-employed over past 12 months (1=yes, 0=no). Linear probability model. Severe shock refers to rainfall below the 10th percentile, moderate below the 15th percentile, and mild below the 20th percentile. Shocks based on 12 month rainfall. Household fixed effects. Survey year, age and sex of household head, and average temperature in growing season included but not reported. Standard errors clustered at grid cell in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Difference in characteristics between households who stayed and those who left

Variable	Observed	N	Mean	St. Dev	p-value
Age hh head	Stayed	1218	47.66	15.29	0.000
	Moved/Not tracked	143	42.58	15.30	
Household size	Stayed	1218	5.42	2.95	0.000
	Moved/Not tracked	143	4.46	2.29	
Years of education hh head	Stayed	1218	4.49	3.37	0.198
	Moved/Not tracked	143	4.87	3.35	
Female hh head	Stayed	1218	0.25	0.43	0.128
	Moved/Not tracked	143	0.19	0.39	
Metal roof	Stayed	1218	0.48	0.50	0.224
	Moved/Not tracked	143	0.43	0.50	

Notes: Sample: Households in the unbalanced panel with cultivated plots, characteristics in 2008/09 survey. Comparison of households in first survey round based on whether they moved/were not tracked or not in second round. The majority of those that did not stay fall into the category "Moved" rather than "Not tracked".

7.2 Endogenous placement and selection issues

In the above analysis we have treated previous shock exposure as orthogonal to household characteristics. There are several reasons why this assumption may be problematic. Households may adapt to shocks by migrating, as documented for individuals by Munshi (2003) in the Mexican setting. The households we observe who are still in agriculture after several shocks may be different from the ones that have left agriculture or migrated. For instance, they may be better at agriculture, so that the coefficient on our interaction term is overestimated, or they may be less skilled, and thus unable to find other income sources, in which case we could be underestimating the interaction term.

To shed some light on the potential selection effects, we compare the characteristics of the households that moved between the first and the second survey round, or were not possible to track, with the households that stayed. Results are reported in Table 6. Heads in households that moved or were not tracked down in the second survey round are on average younger, and the household size is on average smaller. There is no significant difference in terms of education, sex of head of household, or quality of housing, measured by the share that have metal roof. If these characteristics are representative of households' ability to farm and adapt to climate variability, then we find no clear indication of neither positive or negative selection into agriculture.

As a second approach, we compare the characteristics of households based on their previous shock exposure over the past 10 years, dividing them into two groups: those that have experienced no shocks and those that have experienced at least one. If our results are driven by positive selection

Table 7: Comparison of households in first survey round by exposure to rainfall shocks

Variable	Risk exposure	N	Mean	St. Dev	p-value
Age hh head	No shock last 10 years	412	50.19	15.19	0.000
	At least one shock last 10 years	806	46.34	15.18	
Household size	No shock last 10 years	412	5.45	2.72	0.772
	At least one shock last 10 years	806	5.40	3.06	
Years of education hh head	No shock last 10 years	412	4.29	3.66	0.141
	At least one shock last 10 years	806	4.59	3.21	
Female hh head	No shock last 10 years	758	0.24	0.43	0.723
	At least one shock last 10 years	806	0.24	0.43	
Metal roof	No shock last 10 years	412	0.62	0.49	0.000
	At least one shock last 10 years	806	0.41	0.49	

Notes: Sample: Households from balanced panel, characteristics in 2008/09 survey. A shock is defined as rainfall below the 10th percentile of the local historical rainfall distribution, "last 10 years" refers to 1997/98-2006/07.

into agriculture, resulting in an overestimated interaction coefficient on adaptation, then we expect the households who are still farming despite repeated exposure to have among other higher levels of education and better housing. We investigate this by comparing households based on their previous shock exposure, as shown in Table 7. The results show that the households with no shock experience are more likely to be headed by an older household head, whereas there is no difference in terms of years of education or gender of household head. However, these are characteristics of households *after* experiencing shocks, and all household characteristics are essentially endogenous to the shocks. Especially in terms of household wealth, we could expect households that have experienced more negative shocks to be less wealthy. Indeed, our results show that households with no shock experience on average have better quality housing, measured by the share that has metal roofing or better versus grass, bamboo and mud.

We would ideally like to observe households before they experience shocks to see whether households that experience shocks are different from those that do not experience shocks. Since each cluster has the same probability of experiencing a shock, there should be no difference between households prior to the shock. We therefore investigate whether households that experience shocks in 2010/11 were different in 2008/09. The results are shown in Table 8. We find that households that experience a shock "next season" are on average smaller, more likely to be headed by a female, and are more likely to have better housing quality.

So far we have assumed that the household that experienced a contemporaneous shock, is the same household that experienced similar shocks over the past 10 years. The estimated effect from previous shock exposure will be biased if the household we observe in the panel is not the same

Table 8: Comparison of households in first survey round by rainfall shock in second survey round

Variable	Risk exposure	N	Mean	St. Dev	p-value
Age hh head	Rainfall below 10th perc. 2009/10	28	48.04	18.79	0.891
	No shock	1190	47.64	15.21	
Household size	Rainfall below 10th perc. 2009/10	28	3.90	2.04	0.006
	No shock	1190	5.46	2.96	
Years of education hh head	Rainfall below 10th perc. 2009/10	28	4.07	3.41	0.506
	No shock	1190	4.50	3.37	
Female hh head	Rainfall below 10th perc. 2009/10	28	0.39	0.50	0.068
	No shock	1190	0.24	0.43	
Metal roof	Rainfall below 10th perc. 2009/10	28	0.75	0.44	0.004
	No shock	1190	0.47	0.50	

Notes: Households in balanced panel, characteristics in 2008/09 survey. Shocks based on percentiles in local historical rainfall distribution. Results are similar for shocks defined as rainfall below the 15th or 20th percentile.

household that operated the observed plots 10 years ago. The survey asks how long each individual has lived in the community, enabling us to assess to what extent this might be affecting our results. Around 73 percent of the households that enter into the plot analysis report to have a household head that has always lived in the given location, and this percentage is similar across both male- and female-headed households. Among the remaining household heads, 75 percent have resided there for 13 years or more. This suggests that the shock history is likely to be relevant to the large majority of the households.

There are also potential selection problems in terms of impacts of shocks on children's health. Since droughts may increase child mortality (Kudamatsu et al., 2012), the children we observe may be more resilient (positive selection). This is the so-called *culling effect* (Almond and Currie, 2011), and could positively bias the estimate of the shock impact. On the other hand, children who have been exposed to droughts may have suffered previous health shocks that make them more vulnerable to a current shock, since the distribution of infant health stock is shifted leftwards (the *scarring effect*) (Almond and Currie, 2011). This would negatively bias the estimate of the shock impact.

Our findings with regards to past shock experience may also be driven by a select sample of children, whereby the positive coefficient on the interaction between a contemporaneous shock and past shock experience, λ_3, is explained by the culling effect, rather than households' adaptation. Past shocks may have shifted the cut-off of the distribution of surviving children rightwards, whereby only the strongest children are observed in our sample. In other words, the households may not themselves have learnt from previous shock, rather the children are more "tolerant" to new shocks. The positive and significant coefficient on past shock experience, λ_2, for weight-for-height falls in line with this selection story, as seen from Panel B, Table A4. Unfortunately, based on the data available we are not able to determine whether selection is driving our results.

7.3 Functional form

In the above regressions, exposure to previous climate shocks is included as a continuous variable interacted with the shock variable. This means that we implicitly assume that the number of shocks a household has previously been exposed to has a linear impact on how much a shock last season affects yields. This may not be a valid assumption. Lack of sufficient variation prevents us from investigating our hypothesis by including a quadratic term. Of those that have experienced a shock in one of the relevant years, the previous exposure to a similar shock is limited to up to three for severe shocks, four for moderate shocks and up to five for mild shocks.

7.4 Using gridded weather data

Auffhammer et al. (2013) discuss common pitfalls when using gridded weather data in econometric analyses. First, the choice of weather data set matters, as data from different sources may agree on average temperatures, but not on the deviations from average values, which is the variation we are using in our analysis. This is issue is particularly important when using weather data from developing countries where the spatial coverage of weather stations may be limited, and it is therefore recommended to use at least one other weather data set to check the robustness of the results. The measurement error may cause attenuation bias that is amplified when using fixed effects, causing potentially large biases to our estimated coefficients (Angrist and Pischke, 2009). Another issue is spatial correlation. Although we have included average temperature as a control variable in addition to the rainfall shocks, there may be other climate variables (Auffhammer et al. (2013) mention wind and relative humidity) that are correlated with the included weather variables. This is an important problem if the goal of the analysis is to extrapolate potential climate change impacts based on the econometric study, as the estimated coefficients will pick up the effect of the omitted variables on the outcome of interest as well. We do not consider this to be a great concern in our study, since our goal is not extrapolation, but we recognize that our measures of "drought" may be picking up the effect of other weather variables. A greater concern is that these omitted weather variables are likely to be spatially correlated,[27] and omitting them causes a spatially correlated error

[27]Both due to physical factors governing the climate, and because of how the data is interpolated. The latter cause of correlation could be even more important if there are few weather stations, and several grid cells are based on data

term. Auffhammer et al. (2013) recommend adjusting the standard errors to account for the spatial correlation, and note that this adjustment is likely to increase the standard errors significantly. Although we have clustered the standard errors in our analysis at the grid cell level, we have not made further steps to account for additional spatial correlation. Using a different climate data set as well as further adjustment of the standard errors to account for spatial correlation remain tasks for further robustness checks.

8 Conclusion

In this paper we have investigated to what extent previous shock exposure affects the impact of contemporaneous shocks on households. We focus on two outcome variables, crop yield and child health outcomes. Our results show that experiencing droughts negatively impacts crop yields, with a larger negative impact of more severe droughts. The results indicate that households with more previous drought experience are better able to handle rainfall shocks, but only less severe shocks, and that the timing of past droughts matters. More previous drought experience is associated with higher yields, which could be due to subsistence orientation and intensification in response to increased risk. These results hold when controlling for plot-level time-invariant unobservables. Exploring the technologies used by the households suggests that households invest in soil- and water conservation facilities in response to more frequent rainfall shocks, whereas they are less likely to apply fertilizer. In terms of children's nutritional outcomes, severe droughts seem to have a negative impact on short-term nutritional indicators, while we find suggestive evidence that more previous shock experience mitigates impacts of less severe shocks. Children are less affected by a severe drought the more time has passed since the household was last exposed to a similar shock. Households seem to use off-farm income sources as a coping strategy when facing shocks, but this strategy appears less important for households that have more previous shock exposure.

Our results have important policy implications. We find large reductions in yield in years of drought, and similar negative effects on short-run nutritional outcomes under severe droughts, suggesting that households are unable to compensate for the shortfall in consumption from own-production with alternative income- and consumption smoothing strategies. Although previous experience with similar shocks seems to mitigate the impact of less severe current shocks, this does not seem to hold for the most severe shocks, suggesting the need for external safety-nets in years of

from the same stations.

severe droughts.

However, the relatively higher yields that we observe for households with more past shock experience, and the related investment in erosion control and water harvesting, highlights the importance of combining targeted safety nets with general improvements in knowledge of and access to technologies and techniques that may reduce shortfall in yield in a drought year. Similarly, the reduced use of inorganic fertilizer following years of drought underline the importance of improving credit- and insurance markets so as to allow farmers to fully partake in agricultural input (and output) markets.

We do not attempt to extrapolate these findings and apply them to long-term changes due to climate change. However, our results indicate that farmers are able to adapt to climate variability, and that they are able to take advantage of previous experiences to reduce the impact of current shocks, but only less severe shocks. This could imply that farmers to a certain extent may be able to adapt to increased climate variability due to climate change. On the other hand, the farmers appear to be vulnerable to severe droughts, and the possibility of adapting to increased frequency of severe rainfall shocks seems limited based on our results.

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Appendix A

Figure A1: Enumeration Areas from NPS1 2008/09

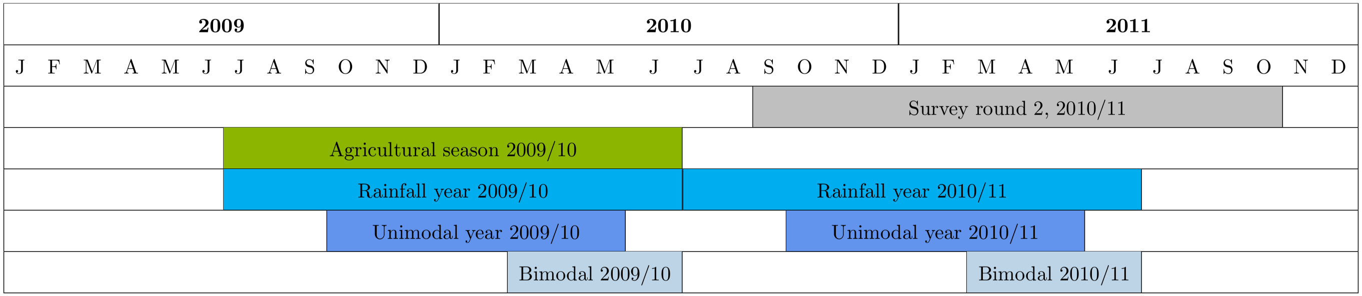

Figure A2: Timeline: Rainfall shocks experienced in the 2009/10 agricultural season, survey round 2 (NPS2).

Notes: Households interviewed in 2010/11 (NPS2) are questioned on the 2009/10 agricultural season.

Table A1: The effect of rainfall shocks on total yield and maize yield, number of shocks

	Severe shock		Moderate shock		Mild shock	
Panel A: Total yield (log)						
Shock this season	-0.231	0.019	-0.208*	0.032	-0.106	-0.042
	(0.150)	(0.242)	(0.108)	(0.250)	(0.080)	(0.159)
Number of shocks last 10 yrs		0.095		0.152**		0.249***
		(0.094)		(0.068)		(0.065)
Shock this season * Number of shocks last 10 yrs		-0.094		-0.026		0.047
		(0.173)		(0.108)		0.047
Number of Obs.	5416	5416	5416	5416	5416	5416
Mean of Dep. Var.	6.21	6.21	6.21	6.21	6.21	6.21
Panel B: Maize yield (log)						
Shock this season	-0.287**	-0.217	-0.207	-0.528	-0.092	-0.253
	(0.130)	(0.343)	(0.138)	(0.384)	(0.082)	(0.180)
Number of shocks last 10 yrs		0.239**		0.215**		0.320***
		(0.121)		(0.091)		(0.078)
Shock this season * Number of shocks last 10 yrs		0.037		0.201		0.163**
		(0.147)		(0.135)		(0.066)
Number of Obs.	3297	3297	3297	3297	3297	3297
Mean of Dep. Var.	6.22	6.22	6.22	6.22	6.22	6.22

Notes: Dep. var.: Total yield (log), includes all crops. Maize yield (log), includes local and improved maize varieties. Severe shock refers to rainfall below the 10th percentile, moderate below the 15th percentile and mild below the 20th percentile. Shocks based on 12 month rainfall. Plot fixed effects. Survey year, age and sex of household head, GPS measurement of plot and average temperature in growing season included but not reported. Standard errors clustered at grid cell level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A2: The effect of unimodal/bimodal rainfall shocks on total yield, cereal yield and maize yield, number of shocks

	Severe shock		Moderate shock		Mild shock	
Panel A: Total yield (log)						
Unimodal/bimodal shock this season	-0.289**	0.166	-0.182*	0.149	-0.109	0.123
	(0.129)	(0.206)	(0.093)	(0.352)	(0.080)	(0.170)
Number of unimodal/bimodal shocks last 10 yrs		0.145		0.272***		0.302***
		(0.107)		(0.071)		(0.065)
Unimodal/bimodal shock this season * Number of unimodal/bimodal shocks last 10 yrs		-0.156		0.000		0.031
		(0.114)		(0.118)		(0.073)
Number of Obs.	5416	5416	5416	5416	5416	5416
Mean of Dep. Var.	6.21	6.21	6.21	6.21	6.21	6.21
Panel B: Cereal yield (log)						
Unimodal/bimodal shock this season	-0.217**	0.153	-0.107	-0.383	-0.124*	-0.207
	(0.103)	(0.191)	(0.091)	(0.380)	(0.070)	(0.176)
Number of unimodal/bimodal shocks last 10 yrs		0.346***		0.387***		0.371***
		(0.096)		(0.072)		(0.064)
Unimodal/bimodal shock this season * Number of unimodal/bimodal shocks last 10 yrs		-0.052		0.238**		0.174**
		(0.090)		(0.117)		(0.068)
Number of Obs.	4313	4313	4313	4313	4313	4313
Mean of Dep. Var.	6.31	6.31	6.31	6.31	6.31	6.31
Panel C: Maize yield (log)						
Unimodal/bimodal shock this season	-0.200*	0.329*	-0.086	-0.578	-0.102	-0.280
	(0.113)	(0.193)	(0.111)	(0.492)	(0.083)	(0.217)
Number of unimodal/bimodal shocks last 10 yrs		0.385***		0.367***		0.404***
		(0.122)		(0.091)		(0.080)
Unimodal/bimodal shock this season * Number of unimodal/bimodal shocks last 10 yrs		-0.131		0.302**		0.228***
		(0.088)		(0.152)		(0.087)
Number of Obs.	4313	4313	4313	4313	4313	4313
Mean of Dep. Var.	6.31	6.31	6.31	6.31	6.31	6.31

Notes: Dep. var.: Total yield (log), includes all crops. Cereal yield (log), includes maize, sorghum, millet, wheat and rice. Maize yield (log), includes local and improved varieties. Severe shock refers to rainfall below the 10th percentile, moderate below the 15th percentile and mild below the 20th percentile. Shocks based on unimodal/bimodal rainfall. Plot fixed effects. Survey year, age and sex of household head, GPS measurement of plot and average temperature in growing season included but not reported. Standard errors clustered at grid cell level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A3: The effect of rainfall shocks on total yield and maize yield, years since last shock

	Severe shock	Moderate shock	Mild shock
Panel A: Total yield (log)			
Shock this season	-0.633	-0.243*	-0.247**
	(0.681)	(0.135)	(0.015)
Years since last shock	-0.009	-0.021***	-0.038**
	(0.011)	(0.006)	(0.015)
Shock this season * Years since last similar shock	0.136	0.015	0.059**
	(0.183)	(0.012)	(0.025)
Number of Obs.	5416	5416	5416
Mean of Dep. Var.	6.21	6.21	6.21
Panel B: Maize yield (log)			
Shock this season	-0.387	-0.051	-0.116
	(0.430)	(0.150)	(0.119)
Years since last shock	-0.032***	-0.030**	-0.036**
	(0.009)	(0.014)	(0.016)
Shock this season * Years since last similar shock	0.045	-0.023	0.024
	(0.151)	(0.025)	(0.023)
Number of Obs.	3297	3297	3297
Mean of Dep. Var.	6.22	6.22	6.22

Notes: Dep. var.: Total yield (log), includes all crops. Maize yield (log), includes local and improved maize varieties. Severe shock refers to rainfall below the 10th percentile, moderate below the 15th percentile and mild below the 20th percentile. Shocks based on 12 month rainfall. Plot fixed effects. Survey year, age and sex of household head, GPS measurement of plot and average temperature in growing season included but not reported. Standard errors clustered at grid cell level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A4: The effect of unimodal/bimodal rainfall shocks on children's height-for-age and weight-for-height Z-score, number of shocks

	Severe shock		Moderate shock		Mild shock	
Panel A: Height-for-age Z-score						
Unimodal/bimodal shock in season before child measured	-0.136	-0.368	0.105	-0.205	0.014	-0.258
	(0.094)	(0.247)	(0.122)	(0.171)	(0.116)	(0.200)
Number of unimodal/bimodal shocks, last 10 yrs		-0.127		-0.139		-0.122
		(0.134)		(0.100)		(0.103)
Unimodal/bimodal shock in season * Number of unimodal/bimodal shocks, last 10 yrs		0.088		0.096		0.074
		(0.136)		(0.073)		(0.064)
Number of Obs.	2800	2800	2800	2800	2800	2800
Mean of Dep. Var.	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65
Panel B: Weight-for-height Z-score						
Unimodal/bimodal shock in season before child measured	-0.139	0.159	0.003	-0.019	-0.024	-0.124
	(0.098)	(0.193)	(0.088)	(0.151)	(0.076)	(0.131)
Number of unimodal/bimodal shocks, last 10 yrs		0.256**		0.132		0.183**
		(0.109)		(0.080)		(0.079)
Unimodal/bimodal shock in season * Number of unimodal/bimodal shocks, last 10 yrs		-0.078		0.053		0.105**
		(0.092)		(0.052)		(0.045)
Number of Obs.	2795	2795	2795	2795	2795	2795
Mean of Dep. Var.	0.05	0.05	0.05	0.05	0.05	0.05

Notes: Dep. var.: Z-score is deviation of child's weight-for-age from the median, divided by the standard deviation of the appropriate sex and age category of the reference population. Sample: individuals aged 0-60 months from farming households. Severe shock refers to rainfall below the 10th percentile, moderate below the 15th percentile and mild below the 20th percentile. Shocks based on unimodal/bimodal rainfall. Controls for age, sex, survey year, grid cell, birth- and interview month included but not reported. Standard errors clustered at grid cell level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A5: The effect of rainfall shocks on children's height-for-age and weight-for-height Z-score, number of shocks

	Severe shock		Moderate shock		Mild shock	
Panel A: Height-for-age Z-score						
Shock in season before child measured	-0.021	0.127	0.144	0.012	-0.012	-0.260
	(0.144)	(0.255)	(0.142)	(0.189)	(0.118)	(0.166)
Number of shocks, last 10 yrs		-0.062		-0.037		-0.089
		(0.110)		(0.096)		(0.086)
Shock in season before child measured * Number of shocks, last 10 yrs		-0.161		0.063		0.102^{*}
		(0.107)		(0.085)		(0.060)
Number of Obs.	2800	2800	2800	2800	2800	2800
Mean of Dep. Var.	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65
Panel B: Weight-for-age Z-score						
Shock in season before child measured	-0.082	0.043	0.090	-0.046	-0.031	-0.304^{**}
	(0.128)	(0.270)	(0.117)	(0.170)	(0.091)	(0.138)
Number of shocks, last 10 yrs		0.085		0.046		0.004
		(0.077)		(0.066)		(0.060)
Shock in season before child measured * Number of shocks, last 10 yrs		-0.055		0.100		0.127^{***}
		(0.134)		(0.063)		(0.042)
Number of Obs.	2801	2801	2801	2801	2801	2801
Mean of Dep. Var.	-0.89	-0.89	-0.89	-0.89	-0.89	-0.89
Panel C: Weight-for-height Z-score						
Shock in season before child measured	-0.101	0.063	0.024	-0.016	-0.025	-0.178
	(0.121)	(0.242)	(0.087)	(0.141)	(0.069)	(0.112)
Number of shocks, last 10 yrs		0.203^{**}		0.128^{*}		0.102
		(0.085)		(0.065)		(0.063)
Shock in season before child measured * Number of shocks, last 10 yrs		-0.018		0.078		0.085^{*}
		(0.129)		(0.058)		(0.044)
Number of Obs.	2795	2795	2795	2795	2795	2795
Mean of Dep. Var.	0.05	0.05	0.05	0.05	0.05	0.05

Notes: Dep. var.: Z-score is deviation of child's weight-for-age from the median, divided by the standard deviation of the appropriate sex and age category of the reference population. Sample: individuals aged 0-60 months from farming households. Severe shock refers to rainfall below the 10th percentile, moderate below the 15th percentile and mild below the 20th percentile. Shocks based on 12 month rainfall. Controls for age, sex, survey year, grid cell, birth- and interview month included but not reported. Standard errors clustered at grid cell level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A6: The effect of unimodal/bimodal rainfall shocks on children's height-for-age and weight-for-height Z-score, years since last shock

	Severe shock	Moderate shock	Mild shock
Panel A: Height-for-age Z-score			
Unimodal/bimodal shock in season before child measured	-0.144	0.304	0.025
	(0.191)	(0.367)	(0.189)
Years since unimodal/bimodal shock	-0.001	0.025	0.003
	(0.015)	(0.022)	(0.022)
Unimodal/bimodal shock in season * Years since unimodal/bimodal shock	0.002	-0.056	-0.004
	(0.032)	(0.071)	(0.036)
Number of Obs.	2800	2800	2800
Mean of Dep. Var.	-1.65	-1.65	-1.65
Panel B: Weight-for-height Z-score			
Unimodal/bimodal shock in season before child measured	-0.441***	0.166	0.105
	(0.127)	(0.217)	(0.127)
Years since unimodal/bimodal shock	-0.030***	-0.023	-0.030**
	(0.010)	(0.018)	(0.015)
Unimodal/bimodal shock in season * Years since unimodal/bimodal shock	0.076***	-0.026	-0.016
	(0.014)	(0.045)	(0.022)
Number of Obs.	2795	2795	2795
Mean of Dep. Var.	0.05	0.05	0.05

Notes: Dep. var.: Z-score is deviation of child's weight-for-age from the median, divided by the standard deviation of the appropriate sex and age category of the reference population. Sample: individuals aged 0-60 months from farming households. Severe shock refers to rainfall below the 10th percentile, moderate below the 15th percentile and mild below the 20th percentile. Shocks based on unimodal/bimodal rainfall. Controls for age, sex, survey year, grid cell, birth- and interview month included but not reported. Standard errors clustered at grid cell level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A7: The effect of rainfall shocks on income diversification, restricted sample

	Severe shock	Moderate shock	Mild shock
Panel A: Head's main occupation is non-agricultural, dummy			
Shock this season	0.342***	-0.097	0.056
	(0.129)	(0.196)	(0.160)
No. of shocks., last 10 yrs	-0.117***	-0.075**	-0.093***
	(0.036)	(0.030)	(0.032)
Shock this season * No. of shocks, last 10 yrs	-0.246***	-0.029	-0.067
	(0.054)	(0.058)	(0.047)
Number of Obs.	1542	1542	1542
Mean of Dep. Var.	0.55	0.55	0.55
Panel B: HH member operated business/self-employed, dummy			
Shock this season	0.539**	0.394**	0.028
	(0.246)	(0.159)	(0.118)
No. of shocks., last 10 yrs	-0.038	0.001	-0.042
	(0.044)	(0.034)	(0.034)
Shock this season * No. of shocks, last 10 yrs	-0.201**	-0.110**	-0.026
	(0.100)	(0.042)	(0.035)
Number of Obs.	1542	1542	1542
Mean of Dep. Var.	0.30	0.30	0.30

Notes: Dep.var.: Household head's main occupation is non-agricultural (1=yes, 0=no). Household member operated business/self-employed over past 12 months (1=yes, 0=no). Linear probability model. Severe shock refers to rainfall below the 10th percentile, moderate below the 15th percentile, and mild below the 20th percentile. Shocks based on 12 month rainfall. Household fixed effects. Survey year, age and sex of household head, and average temperature in growing season included but not reported. Sample: Households in first (second) survey round interviewed between October 2008 (2009) and May 2009 (2011). Standard errors clustered at grid cell in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

PAPER 3

Exchanging fertilizer for votes?

Nina Bruvik Westberg*†

Abstract

Several Sub-Saharan African countries have (re)introduced targeted input subsidy programs over the past decade. These programs often have a centralized structure and the subsidized inputs are attractive to a large share of the population. Therefore, these programs may also serve as instruments for amassing electoral support. I investigate to what extent distributions from such a program, specifically the Farm Input Subsidy Program (FISP), was altered leading up to the presidential election in Malawi in 2009. Core and swing voters are identified based on past election outcomes and ethnicity. I use a fixed effects approach, comparing the official allocations of fertilizer vouchers in the last season prior to the election to other seasons, and how this relates to the distribution of core and swing voters. I do not find evidence of targeting at the incumbent's core voters, whereas districts with more swing voters are found to receive on average more fertilizer vouchers in the 2008/09 season relative to other seasons. This increase comes at the expense of the districts with more of the opponents' core voters, who receive on average fewer vouchers. Differing between voters by ethnicity only reveals that the incumbent's co-ethnics and the swing voter ethnicities were favored relative to the co-ethnics of one of the main opponents.

Keywords: fertilizer subsidies, elections, Malawi, Africa

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†I am grateful to the Logistics Unit for access to data on the Farm Input Subsidy Program, the National Statistical Office of Malawi for sharing census data, to Stein T. Holden, Alain de Janvry, Jo Thori Lind, Knut Einar Rosendahl, Elisabeth Sadoulet, the Kafferanse group at NMBU, participants at the 37th Meeting of the Norwegian Association for Economists, and three anonymous referees for useful comments and suggestions. All errors are my own.

1 Introduction

Several Sub-Saharan African countries have made targeted input subsidy programs an integral part of their policies for improving food security. A number of papers have assessed the impacts of these programs on agricultural production, crop allocation, maize prices, and poverty.[1] The extent to which these programs are overridden by electoral goals is less understood. If these programs are used to garner political support, then this may overshadow the program goals and potentially limit the program's impact on improving food security.

This paper investigates how the distribution of core and swing voters affects the allocations from the Malawian national agricultural input subsidy program in an election season relative to other seasons.[2] The Malawian program is of particular interest as it led to a wave of similar programs in other Sub-Saharan African countries (Jayne and Rashid, 2013). The Agricultural Input Subsidy Program (AISP), henceforth called the later named Farm Input Subsidy Program (FISP), was introduced in 2005 with the aim of improving national and household food security (Dorward and Chirwa, 2011). It targets rural households who are unable to purchase farm inputs by distributing vouchers for subsidized fertilizer and seeds. Given the high dependence on agriculture throughout the country,[3] the large number of beneficiaries,[4] the inputs' significant market value, and the program's vague targeting and allocation rules, the input subsidy program may also serve as an instrument for amassing electoral support.

Politically motivated (re)distribution is categorized as driven by either patronage or tactical redistribution with the aim of winning elections (Cox and McCubbins, 1986; Dixit and Londregan, 1996, 1998; Lindbeck and Weibull, 1987, 1993; Snyder, 1989).[5] Patronage involves access to power that enables the ruling party to favor their own, without necessarily goals of re-election (Cole, 2009).[6] There are two main theories on tactical redistribution for whom the candidate may favorably target

[1] See for instance Lunduka et al. (2013) for a review on the Malawian Farm Input Subsidy Program (FISP).

[2] I operate with agricultural seasons rather than calendar years. Agriculture is largely rain-fed and relies on a single rainy season that lasts from November to April (FEWS Net, 2016). Fertilizer vouchers are usually distributed at the end of the calendar year whereas fertilizer is usually applied between 1-4 weeks after planting, which takes place in November and December (Snapp et al., 2014; FEWS Net, 2016). The presidential election took place in May 2009.

[3] According to the 2008 census 76 percent of the employed rural population report subsistence-farming (*mlimi*) as their employment status, and among unemployed adults the most commonly stated reason for being inactive is "home worker", possibly implying agricultural work (NSO, 2010).

[4] The number of beneficiaries of fertilizer vouchers in a season ranges from 1.4 million to over 1.9 million households. This corresponds to 61-79 percent of rural households and 52-68 percent of all households in Malawi (LU, 2008, 2009, 2010, 2011, 2012; NSO, 2008).

[5] This as opposed to programmatic redistribution, which is more ideologically based (Dixit and Londregan, 1996).

[6] See for instance Miguel and Zaidi (2003).

in an election run-up. Cox and McCubbins' (1986) core supporter model suggests that (promises of) resources will be targeted at areas where the candidate has strong ties (i.e. to core voters). The swing voter model predicts instead that resources are directed at voters without a strong party preference (Dixit and Londregan, 1996, 1998; Lindbeck and Weibull, 1987, 1993).[7] In both cases increased spending on one group under a tight budget constraint will require decreased spending on others (Dixit and Londregan, 1996).

With these models in mind I analyze the following: to what extent were fertilizer vouchers targeted at swing voters or the incumbent's core voters at the expense of the opponents' core voters, in the season prior to the 2009 presidential election? The institutional setting calls for two novel strategies. First, since the incumbent Bingu wa Mutharika changed parties over the studied period I require a more nuanced approach in identifying his core voters.[8] I identify the incumbent's core voters as the share of his previous party's (United Democratic Front (UDF)) past election outcome that can be attributed to his ethnicity's (Lomwe) votes. The same is done for one of the main opponents whose support stems from UDF. Second, I apply the core and swing voter concepts to a setting with more than two dominant parties. This renders the common measure of swing voters, the difference in vote margin between the two main parties, less applicable. I argue instead that the swing voters in this setting are those who previously voted for parties that by the 2009 election had more or less disintegrated.[9] These voters may be more responsive to economic benefits as compared to those with a strong party affiliation. The empirical strategy is otherwise straightforward. I assess the relationship between the distribution of voters and the district level allocations in the election season (2008/09) relative to pre- and post-seasons using a two-way fixed effects estimator.

I do not find that the incumbent's core voters, identified in terms of past election outcomes and ethnicity, are favored. Instead the swing voters are allocated more vouchers at the expense

[7] Additional factors, such as the candidates' risk aversion, their ability to target voters, and turn-out may influence the direction of transfers (Cox and McCubbins, 1986; Dixit and Londregan, 1996; Nichter, 2008). The initial theories dealt with the promises of resources, while empirically they have been applied to campaign spending and vote buying in an election season (e.g. Dahlberg and Johansson (2002) and Cole (2009)) as well as post-election targeting (e.g. Case (2001)). The empirical support for the core and swing models is mixed. Ansolabehere and Snyder (2006) find for instance support for the core supporter model, whereas Dahlberg and Johansson (2002) and Stokes (2005), among others, reveal targeting at swing voters.

[8] A typical strategy is to treat the past election outcome as a measure of the incumbent's core voters, and likewise for the relevant opponent. See Weghorst and Lindberg (2013) for a discussion of this approach versus others.

[9] The falling support for these parties is supported by the 2005 and 2008 Afrobarometers (Khaila and Mthinda, 2005; Tsoka and Chinsinga, 2008). The Afrobarometer is a research project that regularly conducts nationally representative surveys in African countries (Tsoka and Chinsinga, 2008).

of the main opponents' core voters. A one percentage point increase in the share of oppositions' core voters relative to the swing voters corresponds to a 0.41-0.52 percent reduction in vouchers per 100 rural households in the election season relative to the six-season average. Comparing districts based on ethnicities, ignoring past election outcomes, gives similar albeit slightly different results on targeting. Districts with more of the incumbent's co-ethnics, i.e. Lomwe, or more swing voter ethnicities receive, on average more vouchers relative to districts with of the opponents' co-ethnics, specifically the Yaos. The economic magnitudes are however small. Importantly, the results rely on the official distribution of vouchers. This masks potential differences in the unofficial allocations, which may either strengthen or weaken the results.

To my knowledge, this is the first paper to look at how the distribution of core and swing voters relates to the national voucher allocations from the Malawian input subsidy program in an election season relative to other seasons. Other studies have largely focused on a sub-set of seasons and/or districts. Mason and Ricker-Gilbert (2013) instrument for whether a household acquired subsidized fertilizer or seeds using among other whether the "ruling party" won the majority in the household's district in the last presidential election. They find that these households receive on average more fertilizer (and seeds) in the 2006/07 and 2008/09 seasons.[10] Dionne and Horowitz (2016) use individual-level data from three districts. First, they assess whether the vouchers were targeted at specific ethnic groups at the local level in the post-election season (2009/10), which they do not find evidence of. Second, they analyze whether individuals that received a voucher in the 2009/10 season show a larger increase from 2008 to 2010 in stated support to the incumbent's party, relative to non-recipients. They find evidence of this. Most similar to my paper is Brazys et al. (2015). Their hypothesis is that the government "strategically allocated the [FISP] in order to build a (winning) national electoral coalition" (p. 46) and their main analysis is two-fold. First, they analyze the determinants of the share of households within a constituency that received a voucher for fertilizer or seeds in the 2007/08 season. They argue that the Democratic Progressive Party (DPP)[11] government sought to maximize votes by *(i)* allocating to the poor since they will benefit proportionally more from a voucher, and *(ii)* to areas where the program could be expected to have the greatest success in terms of better farm land. Second, they analyze whether

[10]It is not clear how they have addressed the change in the ruling party, from UDF to DPP. Their other instrument is the administratively determined district allocations. They undertake a similar analysis for Zambia (Mason and Ricker-Gilbert, 2013).

[11]This is the incumbent Bingu wa Mutharika's new party.

these same (instrumented) allocations are positively associated with the DPP results from the 2009 parliamentary and presidential elections.[12] Importantly, Brazys et al. (2015) cannot separate the government's goal of re-election from the goal of improving household and national food security.[13] Lastly, it is not clear why Brazys et al. (2015) chose to focus on the 2007/08 season rather than the 2008/09 election season.[14]

This paper adds to the literature on politically motivated redistribution within the context of agricultural development (Cole, 2009; Banful, 2011b; Mason et al., 2013; Brazys et al., 2015; Dionne and Horowitz, 2016). The contribution is primarily empirical. First, I analyze the program distributions over a number of years, unlike Banful (2011b), Brazys et al. (2015) and Dionne and Horowitz (2016) who only have one season of allocations available. I am thus able to control for district-specific factors that affect allocations, whereby the results are less susceptible to omitted variable bias. Second, I analyze the official, nation-wide allocations rather than what the households report having received (Pan and Christiaensen, 2012; Mason et al., 2013; Brazys et al., 2015; Dionne and Horowitz, 2016). Neither the official allocations nor what the households have received are perfect measures when there is diversion and leakage in the allocation process,[15] yet analyzing the official allocations may to a larger extent reflect the incumbent's goals. Finally, I address some of the issues that the establishment of new parties creates by using information on other observable characteristics, i.e. ethnicity, to identify the likely core and swing voters. Contrary to more mature democracies, politicians in Sub-Saharan African countries often change party (Van de Walle, 2003) suggesting a relevance of my approach to other settings. This resembles the empirical approach taken by Gutiérrez-Romero (2014) who identifies Kenyan core and swing voters based on ethnicity. As such, this paper also adds to the literature on electorally motivated ethnic targeting (Jablonski, 2014).

The remaining paper is organized as follows. I first describe the program in question, the electoral background, and why the fertilizer subsidies may be termed political. Next, I give an

[12]To this end, they instrument the voucher shares received using allocation of FAO funds, poverty, and "ethnic intensity". The latter is a district level measure "based on the median response to a Likert scale survey question" from the 2005 Afrobarometer "which asked the participants the degree to which they identified with their ethnic identity vis-à-vis a "Malawian" identity".

[13]Allocating to the poor who are unable to purchase fertilizers and to areas targeted by the FAO that the authors argue are largely rural areas with "good farm land" also falls in line with the program goals.

[14]The same data is available for the election season. This is further discussed in Section 3.

[15]Jayne et al. (2015) describes diversion as diverted fertilizer from the official supply chain, whereas leakage captures households selling their received vouchers or fertilizer to other households.

overview of the data and the empirical strategy. This is followed by the results, and a discussion of these and potential caveats. The final section concludes.

2 The politics of the subsidy program

2.1 Farm Input Subsidy Program

Food security has stood at the forefront of Malawian politics for decades and was a central topic in the 2004 election run-up. The possibility of improving food security with a large-scale subsidy program was incorporated into several party campaigns and the election winners, the United Democratic Front, were among the proponents (Booth et al., 2006). Yet, they did not implement such a program in the following agricultural season, continuing instead the smaller Targeted Inputs Program (TIP) (Chinsinga, 2010; Mpesi and Muriaas, 2012). These mixed signals are likely to have contributed to the lower fertilizer application rates in the 2004/05 season, resulting in lower harvests and reduced food security (Dorward et al., 2008). This, combined with the recent food crisis in 2001/02, led the Mutharika-led government to introduce the Farm Input Subsidy Program (FISP) in 2005 (Booth et al., 2006; Holden and Lunduka, 2013; Mpesi and Muriaas, 2012). The program involves annual distributions of vouchers for fertilizer and seeds.[16] Although initially described as a targeted program it was not until the 2007/08 season that the Ministry of Agriculture and Food Security (MoAFS) put forth a set of targeting, albeit vague, guidelines focusing on vulnerable households (see Appendix A for a description).

Several levels of authority are involved in identifying beneficiaries and distributing vouchers. First, the MoAFS decides upon the initial allocation of vouchers to districts, which are then broken down to the level of Extension Planning Areas (EPA). In some seasons the ministry also disaggregated the allocations further down to the village level (LU, 2008, 2009). From 2007/08 and onwards the allocations were supposed to reflect the share of cropped land allocated to maize and tobacco by EPA and population density. The latter information is gathered through the annual farm family registries, which are meant to provide lists of all possible beneficiary households (Dorward

[16] I focus on fertilizer due to its higher market value. The fertilizer is intended for maize, and in some seasons also tobacco, tea and coffee. The most common fertilizers made available are NPK (basal dressing) and urea (top dressing) (LU, 2007, 2008, 2009, 2010, 2011, 2012). These contain respectively 23 and 46 percent nitrogen. The figures on the average maize yield response to nitrogen vary greatly in Malawi, but data from household surveys indicate that a 1 kg increase in nitrogen on average yields between 7 and 14 kg more of maize (Snapp et al., 2014). In comparison, the average annual per capita consumption of maize among rural residents was 154 kg in 2003/04 (Verduzco-Gallo et al., 2014).

and Chirwa, 2011; Chirwa et al., 2011; Chirwa and Dorward, 2013). Data on allocations suggest, however, that these rules are not followed. The Logistics Unit, an underlying institution of the MoAFS that monitors the program, has repeatedly claimed lack of transparency on behalf of the government with regards to how the allocations are made (LU, 2009, 2010, 2011, 2012). Second, the annual farm family register is compiled through the involvement of multiple stakeholders that may inflate their household numbers in order to induce the government to allocate more vouchers (Holden and Lunduka, 2013). There is a large discrepancy between the number of households identified by the 2008 census (NSO, 2008) and the number of households that exist according to the farm family registers. Dorward and Chirwa (2010) and Chinsinga (2012) argue, among other, that this is due to the listing of households and villages that do not exist, so called "ghost households and villages". Third, the final lists of beneficiaries are determined locally based on the aggregated figures from the MoAFS.[17] Fourth, the actual distribution of vouchers involves several parties, including the MoAFS, local government officials and Traditional Authorities (Dorward and Chirwa, 2011). This complicated program structure may result in differences between the intended and actual allocations.

2.2 Political subsidies

There are several characteristics that make the subsidy program an attractive tool for targeting voters. First, the subsidy program is politically relevant due to its shear size. Dorward and Chirwa (2011) estimate that the combined program costs in 2008/09 amounted to $265.4 million, of which 14 percent was financed by donors. The program costs consumed 16 percent of the national budget and 74 percent of MoAFS's budget.[18] Second, it is relevant to the majority of voters. Around 85 percent of the population are rural residents (NSO, 2008). Most of the subsidized fertilizer is intended for maize production. Maize is a key staple of the Malawian diet; according to a national survey around 97 percent of farming households cultivated maize in the 2002/03-2003/04 seasons (NSO, 2005), and the majority are net buyers of maize (Dorward et al., 2008). Dorward and Chirwa

[17]For instance, the lists over eligible households for the 2008/09 season were set up by the traditional leaders (chiefs) or Village Development Committees. These were then to be verified by the local extension officer and the District Agricultural Development Officers (Holden and Lunduka, 2013). Actual procedures varied, however, and the final lists of beneficiaries were often subject to multiple changes. For a more detailed discussion of the institutional setting, see Appendix A.

[18]The costs were particularly high this season due to increased import costs, in comparison the program costs in 2007/08 amounted to $116.8 (Dorward and Chirwa, 2011).

(2011) estimate that 65 percent of all farm households received a voucher in the 2008/09 season. Third, the centralized organization of the program in combination with the opaque targeting rules leaves the distribution of program vouchers and inputs in part up to the government's discretion.[19] This is exemplified by the second-round allocations made in the beginning of 2009 for which there are few records (LU, 2009). Lastly, the program was an important election promise in 2009 for both the governing and the main opposition parties (Mpesi and Muriaas, 2012), indicating that the program was still at the forefront of Malawian politics.[20]

A number of authors describe the FISP as politicized and in particular leading up to the 2009 election. Dorward and Chirwa (2011) argue that the "pressures to expand the programme and use it for patronage arose prior to the election" (p. 243), referring to the 2009 election. Kelly et al. (2010) further claim that politicians were more often involved in distributing vouchers in the 2008/09 season than in previous seasons. According to informants cited by Chinsinga (2012), the incumbent's stronghold, Thyolo, and neighboring districts of Mulanje and Phalombe, received more vouchers per eligible households and particularly in the 2008/09 election season. Respondents in Karonga district distinguish between the two allocation rounds in 2008/09, stating that the second-round vouchers were more likely to be distributed by "political figures like MPs, party chairpersons" (p.12), than the first-round vouchers (Dorward et al., 2010). This is supported by Mpesi and Svåsand (2012) who claim that the fertilizer subsidies played a key role in the incumbent's party's (DPP) election campaign. They argue that the parliamentary candidates were unable to affect the program, thereby indicating a centralized allocation structure. Mpesi and Muriaas (2012), on the other hand, argue that the program was politicized at the local level and "not on a national scale" (p. 381). They further claim that "fertilisers were distributed rather evenly thorough [*sic*] the country" (p. 381), but that "in some areas the local administrators said that only those who support the government deserve the spoils of the government policies" (p. 387), referring to the subsidies.

Although the above descriptions are primarily anecdotal and highlight different levels of authority they indicate that allocations are to a certain extent politicized. Furthermore, the program's centralized structure implies that the presidential, rather than parliamentary, elections should be the main focus in understanding how the voucher allocations may have been used to mobilize electoral

[19] The president was for instance for some years also the minister of MoAFS.

[20] The program can therefore be described as policy-neutral in the sense that the programmatic content is likely to have appealed to voters from multiple parties (Cox, 2009).

support.

2.3 The 2009 general election

Presidential and parliamentary elections take place every fifth year and party voting had largely fallen in line with regional borders prior to 2009. Voters in the most populous region, the Southern region, gave most of their support to the United Democratic Front (UDF) in the first three multi-party elections. This resulted in a presidential seat for Bakili Muluzi in the first two terms, i.e. 1994 and 1999, and for Muluzi's hand-picked candidate, Bingu wa Mutharika, in the third term. The Central region was, and still is, dominated by Malawi Congress Party (MCP), whereas voters in the most sparsely populated region, the Northern region, have historically given most of their support to AFORD (Alliance for Democracy). I return to these political parties in Section 3.3.

The fourth multi-party election took place on May 19th, 2009.[21] Seven candidates ran for presidential office, among them the incumbent Mutharika. His intention to represent DPP was finalized in October 2008. Mutharika won a majority of the votes in all three regions, and was only surpassed by John Tembo, representing MCP, in five out of 28 districts. This election was therefore historical in the sense that it broke down regional voting patterns.[22]

3 Who are the core and swing voters?

I assume that the incumbent's objective is to maximize the expected voting return from distributing economic benefits, in this case fertilizer vouchers, according to a budget constraint and an assessment of the distribution of likely core and swing voters (Cox and McCubbins, 1986; Dixit and Londregan, 1996). The fertilizer vouchers are distributed at the end of the calendar year, at times into January, making the 2008/09 agricultural season the key period of interest. In line with the political business cycle literature (Nordhaus, 1975), I argue that the election season is of particular interest to the incumbent. This will be the voters' most recent reference point based on which they are likely to judge him (Healy and Lenz, 2014; Kang, 2015) and the vouchers can be more explicitly tied to the upcoming election.

As touched on earlier core and swing voters are often identified based on past election outcomes.

[21] The date is in accordance with the week set by the constitution (Commonwealth Secretariat, 2009). See Appendix A for a more detailed description of the institutional setting, and Table B1 for a timeline of events.

[22] The 2014 presidential election seems to have reaffirmed these regional lines (Dulani and Dionne, 2014).

Most relevant for my purpose are the results from the 2004 presidential election in Malawi. If the incumbent had fronted the same party in both elections a strategy would be to use the vote shares received in 2004 to identify areas with likely core and swing voters. Instead, the incumbent, Mutharika, left UDF and formed a new party, DPP, in between the 2004 and 2009 elections. Some of UDF's core voters in 2004 are expected to be the opposition's core voters in 2009. Moreover, a share of the votes received in 2004 are attributable to AFORD's core voters, since Mutharika was the joint candidate of AFORD and UDF. It is therefore necessary to identify characteristics that were observable prior to the 2009 election and that Mutharika may have exploited in order to target voters.

The presidential election results are based on majority voting. The notion of swing and core districts in a setting with a direct national vote is perhaps less intuitive. However, if the incumbent's objective is to maximize votes and his own core voters are in minority, then distributing economic benefits to the groups perceived as more responsive (i.e. districts with more swing voters) as opposed to the opposition's core voters may be essential in order to be re-elected.[23]

3.1 Voting preferences

I assume that voters derive utility from their affinity to a party and its candidate and from an economic benefit, in this case the fertilizer vouchers. The incumbent is assumed to know the utility that voters derive from the economic benefit, which is increasing in the economic benefit, whereas the utility derived from partisan affinity is not known (Cox and McCubbins, 1986). A larger distance between the voter's individual partisanship and the incumbent's characteristics requires a larger benefit to the voter in order to induce him/her to vote favorably (Cox and McCubbins, 1986; Dixit and Londregan, 1996; Dahlberg and Johansson, 2002; Stokes, 2005) or to vote at all Nichter (2008). In other words, reaching out to the opponents' core voters will be more costly, whereas those voters that lack a clear alternative are expected to be cheaper to sway. The incumbent's own core voters may be even cheaper to buy off than swing voters, possibly excluding the need for economic benefits. On the other hand, if turn-out depends on benefits than this increases the likelihood that the core voters are at the receiving end (Nichter, 2008).

[23] As such, the districts are comparable to the groups in the single-district models (Cox and McCubbins, 1986; Dixit and Londregan, 1996, 1998; Lindbeck and Weibull, 1987, 1993) and the municipalities in Dahlberg and Johansson (2002)'s empirical analysis.

Partisan affinity in Malawi is more likely attached to the parties' and presidential candidates' attributes, such as ethnicity, than to policies or ideologies. According to Kadima (2006) there are no clear ideological differences between the political parties in Malawi,[24] and the increase in the number of political parties seems largely motivated by personal conflicts rather than ideological differences (Booth et al., 2006). Rather, most parties are "identified with specific tribal and elite groups" (p. 115) (Kadima, 2006). Responses to the 1999 Afrobarometer for Malawi confirm a strong relationship between ethnic identity and political parties (Ishiyama and Fox, 2006).[25] In summary, this suggests that ethnicity is a key factor that the candidates may mobilize based on.[26]

The 2008 census distinguishes between 12 ethnicities, in addition to "other", where the Chewa, Lomwe, Yao, Ngoni, and Tumbuka are the largest groups covering respectively 33, 18, 14, 11, and nine percent of the population (NSO, 2008). The ethnic divisions fall more or less in line with the ethnicities of the main candidates, Tembo (MCP), Muluzi (UDF), and Mutharika (DPP) in the 2009 run-up. Tembo is a Ngoni, but has historically had a strong attachment to Chewas through prominent positions during Hastings Kamuzu Banda's Chewa-dominated rule (Libby, 1987).[27] Muluzi is a Yao, whereas the now deceased Mutharika (he died in 2012) was a Lomwe. Mutharika underlined his ethnicity among other through the establishment of the organization "Mulhakho wa Alhomwe", meant to promote Lomwe culture (EU-EOM, 2014). I return to the other ethnicities in Section 3.4.

3.2 Incumbent's core voters

Core voters are defined as those who have a strong attachment to the incumbent. The above discussions highlight the incumbent's ethnic group, the Lomwe, as a likely group of core voters. I separate the UDF's district vote share from 2004 into Lomwe and non-Lomwe, arguing that the former are the incumbent's core voters. Specifically, I hypothesize that: *(H1)* districts in which

[24] Van de Walle (2003) argues that this is common to many African countries. That being said this may be changing. There for instance various accounts on the extent to which programmatic content was more prominent in the last presidential election (2014) in Malawi (Dulani and Dionne, 2014; Patel and Wahman, 2015).

[25] The evidence for African countries in general is more mixed (Ishiyama and Fox, 2006). See Basedau and Stroh (2012) for a more detailed discussion on the country-based evidence. Eifert et al. (2010) highlight instead the temporal aspect and find that ethnic identification increases closer to an election.

[26] There is less qualitative evidence that other characteristics, such as religion, may be exploited for political gain. As of 2008, around 83 percent of the population were Christian, whereas 13 percent were Muslim (NSO, 2008). Although there may be divisions between Muslims and Christians that are relevant, the ethnic group of Yaos and Muslims are largely overlapping.

[27] The MCP leader prior to John Tembo, Gwanda Chakuamba, also received most of his votes from the Chewa-dominated Central region although he is from a Southern district (Hughes, 2001).

a larger population share are Lomwe and voted for Mutharika in the 2004 election receive more fertilizer vouchers relative to other districts in the election season (2008/09). I also investigate a variant of this hypothesis using the ethnicity share only (Lomwe), regardless of past voting outcome. Evidence of the above would suggest that Mutharika favored his expected core voters prior to the 2009 presidential election.

3.3 Opponents' core voters

The task of identifying the incumbent's swing voters is complicated by the changing party affiliations, in addition to the existence of more than two dominant parties. A first step is to identify the main opposition candidates and their core voters.

In the 2005 and 2008 Afrobarometers the UDF and MCP, in addition to the incumbent's party, DPP, were the most popular parties (Khaila and Mthinda, 2005; Tsoka and Chinsinga, 2008).[28] Yet, although MCP and UDF were expected to be the incumbent's main challengers in 2009, around one third of the votes in the 2004 presidential election had gone to other parties. This demands the question of who these past contenders were. Table 1 lists the presidential candidates from 2004 and 2009, their party affiliation, election result and ethnic affiliation. The third main competitor in 2004, Chakuamba, received about a quarter of the votes representing the Republican Party (RP). He did not run on the RP ticket in 2009, but was instead replaced by Stanley Masauli (Lansford, 2014). The fourth and fifth candidates, Brown Mpinganjira (National Democratic Alliance) and Justin Malewezi (independent), each received less than 10 precent of the votes in 2004. Both candidates were the result of internal fighting in UDF.[29] Similar internal squabbling characterized the party leadership of AFORD that had a strong foothold in the Northern region prior to 2004 (EISA, 2004; Mpesi and Muriaas, 2012).[30] The ongoing fights and shifting partnerships may have contributed to reduced trust from voters. Already in the 2005 Afrobarometer only two percent responded that

[28] UDF's candidate, Muluzi, was not allowed to run for a third term, and the UDF-voters were instead urged to vote for the Tembo-led MCP. However, this was not finalized until April 2009, after the distribution of vouchers for the 2008/09 season, and so I treat Muluzi as a separate opposition candidate.

[29] Mpinganjira established NDA in 2003 in opposition towards Muluzi's bid for a third term. The party lasted only past the 2004 election. Malewezi, who was the vice-president during Muluzi's second-term, ran as an independent candidate following Muluzi's appointment of Mutharika as his successor (EISA, 2004; Gloppen et al., 2006).

[30] Several AFORD members broke off to establish new parties in 2004, in part in response to the AFORD leader Chakufwa Chihana's initial bid that they support Muluzi for a third term (Mpesi and Muriaas, 2012), and some united into the Mgwirizano coalition headed by Chakuamba. The remaining branch of AFORD entered into a coalition with UDF in 2004, a collaboration that was further threatened by Muluzi's appointment of Mutharika as their presidential candidate (EISA, 2004; Gloppen et al., 2006).

they felt close to the AFORD party, and one percent would vote for AFORD had there been an election tomorrow (Khaila and Mthinda, 2005). Even fewer gave their support to other parties, such as NDA and RP. Responses were largely similar in 2008 (Tsoka and Chinsinga, 2008). The run-up to the 2009 election was therefore dominated by DPP, MCP and UDF.

Table 1: Presidential candidates 2004 and 2009: ethnicities and political parties

		2004			2009		
Name	Ethnicity	Presidential candidate	Political party	Results (%)	Presidential candidate	Political party	Results (%)
Bingu wa Mutharika	Lomwe	Yes	UDF*	35.8	Yes	DPP	65.98
John Tembo	Ngoni	Yes	MCP	27.0	Yes	MCP	30.69
Gwanda Chakuamba	Sena	Yes	RP**	26.0	No	NRP	
Brown Mpinganjira	Lomwe	Yes	NDA	8.7	No***	UDF	
Justin Malewezi	Chewa	Yes	Indep.	2.5	No		
Kamuzu Chibambo		No			Yes	PETRA	0.79
Stanley Masauli		No			Yes	RP	0.76
Loveness Gondwe		No			Yes	NRC	0.72
James Mbowe Nyondo		No			Yes	Indep.	0.61
Dindi Gowa Nyasulu		No			Yes	AFORD	0.45

Notes: Sources: Libby (1987); EISA (2004); Gloppen et al. (2006); Lansford (2014). I have not been able to identify the ethnicities of the remaining candidates. *Joint coalition with AFORD. **Candidate of Mgwirizano Coalition, representing RP and PETRA, in addition to five other parties. ***Joint coalition with MCP, i.e. Tembo's running-mate.

MCP has historically drawn support from the Chewas, who are primarily found in the Central region.[31] MCP's candidate, Tembo, is himself from the Central district of Dedza. Mutharika and DPP are likely to perceive districts with many previous MCP voters and/or that are primarily resided by Chewas as out of reach. The same goes for areas that have historically voted for UDF and/or that are ethnically linked to Muluzi. Based on the above I hypothesize that: *(H2)* districts in which a larger population share voted UDF in 2004 and are ethnically affiliated with Muluzi (i.e. Yao) receive fewer fertilizer vouchers than other districts in the election season (2008/09). I further expect that: *(H3)* districts in which a larger population share voted MCP in 2004 receive fewer fertilizer vouchers than other districts in the election season (2008/09). Again, I also inves-

[31] MCP was the only party allowed during Hastings Kamuzu Banda's one-party regime prior to 1994, a period during which the Chewas in the Central region were favored. Examples of preferential treatment include the relocation of the capital from the Southern region (Zomba) to the Central region (Lilongwe), the imposition of Chewa as the only African national language (Kaspin, 1995), more agricultural investments channeled to the Chewa-dominated areas, higher exam entry requirements to secondary school for students from the Northern and Southern regions and firing of non-Chewas in the public sector (Vail, 1989).

tigate these hypotheses in terms of ethnicities only. I expect that districts with a larger share of Yaos or Chewas to receive on average fewer vouchers than other districts, regardless of past voting outcomes.

3.4 Swing voters

Several districts are without any clear ties to neither the incumbent nor the main opponents.[32] Yet, the extent to which the different candidates are likely to have perceived these to hold swing voters in 2009 is likely to differ. For instance, the Chewas and the Tumbukas, the latter the largest group in the Northern region, have historically followed different political blocks (Posner, 2004). Voting for MCP as opposed to DPP may incur a higher utility loss for the Tumbukas.[33] Mutharika may expect districts where MCP has previously received a small vote share as more receptive to vouchers from his DPP-led government. The same logic applies to districts where UDF has historically received few votes. Targeting these districts will increase the probability of reaching a persuadable voter.

I employ two measures of swing voters based on past election outcomes. I expect that: *(H4a)* districts in which a larger population share voted "other parties" than MCP or voted UDF but are neither Yao or Lomwe, receive on average more vouchers relative to other districts in the election season (2008/09).[34] Second, I extract the share of UDF-votes from 2004 that can be ethnically aligned to neither Muluzi (Yao ethnicity) nor Mutharika (Lomwe ethnicity), and separate this from the remaining bulk of swing voters. Some of these may be related to UDF for other reasons than ethnicity, whereas others are possibly the core voters of AFORD. Extracting these results in a potentially more homogenous group of swing voters. I thus expect that: *(H4b)* districts in which a larger population share voted for other parties than MCP and UDF in 2004, receive on average more vouchers than other districts in the election season (2008/09). Lastly, I also investigate the swing voter hypothesis in terms of ethnicities only, comparing all "other ethnicities" against the Yao, Chewa, and Lomwe, regardless of past voting outcomes. Finding empirical support for the above suggests that the incumbent's government targeted swing voters in the run-up to the 2009 election.

[32] For example, the Southern districts of Chikhwawa, Nsanje, and Mwanza all gave the majority of votes to Chakuamba or Malewezi in 2004, neither of whom participated in the 2009 election. These three districts are to a large extent populated by Ngoni, Sena, and/or Nyanja. A substantial share of the voters in the Northern region voted instead for Chakuamba's coalition in 2004.

[33] There seems to be less written about the political affiliations of other ethnic groups, such as the Ngoni.

[34] The "other parties" refers to the RP (Mgwirizano Coalition), NDA, and the independent candidate Malewezi.

4 Data and empirical strategy

4.1 Data

Data on the Farm Input Subsidy Program (FISP) is obtained from the Logistics Unit (LU). The LU produces an annual report that includes both the first-round allocations (i.e. the annual beneficiary lists) and any subsequent second-round allocations, such as those that took place in 2007/08 and 2008/09. These "final figures" are only available at the district level. I have accessed reports for the seasons 2006/07-2013/14, but omit the last two seasons due to the death of Mutharika in 2012. The subsidy data are coupled with the population figures from the 2008 census (NSO, 2008) in order to construct the main outcome variable of interest, i.e. fertilizer vouchers per 100 rural households. According to the census there were 2.44 million rural households as of 2008, after excluding reserves and parks. I use the census data and not the farm family registries, as I only have access to the latter for the more recent years. I discuss the possible implications of this in Section 6.3. The census also provides information on the distribution of the ethnic groups. Results from the presidential election in 2004 are obtained from the Sustainable Development Network Programme's (SDNP) website (SDNP, 2004), whereas results for 2009 are accessed through the Malawi Electoral Commission's (MEC) website (MEC, 2009). Both are available at the district level (this the lowest level available) of which there are 28 in total.

I control for possible time-varying confounding factors.[35] First, there are changes in the subsidy program during the studied period. The program included fertilizer for tobacco in some seasons and for tea and coffee in the 2008/09 season. Since there are no district level figures on the distribution of coffee and tea vouchers to include in the analysis, I do not control for this program change. I do control for the district share of households farming tobacco, taken from the Integrated Household Survey 2004/05 (NSO, 2005), and interact this with the relevant tobacco seasons.[36] Second, one may worry that changes in the distribution of poor and vulnerable groups could affect the allocations. It seems unlikely that there are systematic changes in the number of child-, female- or orphan-headed households, or households with individuals with disabilities, that again affect distributions at a more aggregate level. Especially when keeping in mind the mixed adherence to these guidelines. However, since agriculture is largely rain-fed a drought or flood in one season may affect allocations in the

[35]The district fixed effects will capture time-invariant district-specific characteristics that may correlate with the voucher allocations. This is further discussed in Section 4.3.

[36]Fertilizer for tobacco was included in the 2006/07-2008/09 seasons (LU, 2007, 2008, 2009).

following season as a compensation for past loss and the reduced income available to households for purchasing fertilizer commercially.[37] I therefore control for deviations in lagged seasonal rainfall.[38]

4.2 Summary statistics

Summary statistics at the district level are reported in Table 2. Each district received annually on average 134 vouchers per 100 rural households over the period 2006/07-2011/12. The official number received per 100 rural households by district varies between zero and 342.[39] The share of the district population that are Lomwe, Yao or Chewa varies greatly, ranging from almost no inhabitants of the specific ethnicity to 73-98 percent. The presidential vote shares from 2004 also differ largely by district, ranging from almost zero to over 80 percent for a given party.

Table 2: Summary statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Subsidy program					
Fertilizer vouchers per 100 rural HH[a]	134.464	53.571	0	342.283	168
Covariates					
Share tobacco farmers (%) x tobacco season	8.379	16.012	0	64.000	168
Seasonal deviation in rainfall (mm)	-16.518	132.735	-501.215	166.649	168
Ethnicity shares, 2008					
Lomwe share (%)	16.346	26.156	0.018	87.111	28
Yao share (%)	10.762	18.391	0.173	72.774	28
Chewa share (%)	27.411	36.045	0.447	97.880	28
Share that are not Yao/Chewa/Lomwe (%)	45.482	36.670	1.661	99.362	28
Presidential election results, 2004					
MCP's vote share (%)	19.866	28.289	0.566	79.970	28
UDF's vote share (%)	34.511	22.364	1.309	88.207	28
Other parties' vote share (%)	45.623	29.991	4.566	98.124	28
Presidential election results, 2004, by ethnicity					
UDF's vote share (%) x Lomwe share	8.625	14.303	0.004	44.265	28
UDF's vote share (%) x Yao share	6.815	15.122	0.009	60.779	28
Other parties' vote share (%), inc. non-Lomwe and Yao share of UDF	64.693	28.844	19.880	99.412	28

[a]Sources: Logistics Unit's reports for six seasons (2006/07-2011/12), and population figures from 2008 Population and Housing Census.

[37]Experiencing a drought/flood in the same season is unlikely to affect distributions, as the rainy season usually lasts from November to February, with extensions to March-April in the northern parts of the country (McSweeney et al., 2010a,b), whereas fertilizer distributions typically take place by December or January at the latest.

[38]Specifically, I use gridded precipitation data from the Climatic Research Unit (CRU) to create district level figures for lagged seasonal deviations of rainfall from the historical mean. The dataset CRU TS3.22 covers the period 1901-2013, from which I use the years 1961-2013 to create a historical mean. The agricultural season is defined from August to July, as the last harvest typically takes place by July. See Harris et al. (2014) for a detailed description of the data.

[39]The island district, Likoma, is the only district that received zero fertilizer vouchers in a season.

4.3 Empirical specification and identification strategy

I investigate possible targeting at core and swing voters using the following empirical specification:

$$\text{Vouchers}_{ds} = \alpha_0 + \mathbb{1}(s = 08/09)\,(\beta_1 \text{UDF}_d \times \text{Lomwe-share}_d + \beta_2 \text{UDF}_d \times \text{Yao-share}_d + \beta_3 \text{MCP}_d) + \mathbf{X}'_{ds}\boldsymbol{\delta} + \lambda_d + \gamma_s + \mu_{ds}. \quad (1)$$

Vouchers_{ds} denotes the official distribution of fertilizer vouchers per 100 rural household to district d in season s. $\text{UDF}_d \times \text{Lomwe-share}_d$ captures the UDF's district level vote share from the 2004 presidential election that are aligned with Mutharika, as defined by ethnicity (Lomwe). This enters through an indicator function $\mathbb{1}(\cdot)$ set to one for the 2008/09 season, zero otherwise. $\text{UDF}_d \times \text{Yao-share}_d$ is the same vote share now interacted with Muluzi's ethnicity (Yao). MCP_d is the district vote share received by MCP in 2004. The vector $\mathbf{X}_{ds}$ includes seasonal deviation in rainfall from the historical district level mean and a control for whether the subsidy program in season s included distributions of fertilizer for tobacco interacted with the proportion of households farming tobacco in district d. The share of tobacco farmers remains the same, whereas whether the subsidy program included vouchers for tobacco varies across the seasons (i.e. included in the 2006/07-2008/09 seasons). λ_d and γ_s denote district and season fixed effects. μ_{ds} is a mean zero error term and standard errors are clustered at the district level. Inference based on cluster-robust standard errors relies on an asymptotic justification, which may not hold for very few clusters. Cameron et al. (2008) show that cluster-robust standard errors are downward biased when there are few clusters. Whether 28 clusters (districts in Malawi) qualifies as "few" is not clear since the cluster-robust standard errors perform relatively well for 30 clusters (Cameron et al., 2008). Nevertheless, I report the wild cluster bootstrapped standard errors[40] that provide asymptotic refinement in addition to the cluster-robust standard errors, as recommended by Cameron et al. (2008).

I use a two-way fixed effects estimator. The district fixed effects captures time-invariant differences in among other land size, agroecological conditions, ethnicity, and poverty characteristics that may affect allocations. Brazys et al. (2015) find for instance that households in constituencies

[40] Wild cluster bootstrapping resamples the residuals at the cluster level, based on which new values for the dependent variable are constructed. The resample is then used to calculate the coefficient estimates and standard errors that are used for inference. Cameron et al. (2008) recommends to impose the null hypothesis for the residuals and using Rademacher weights (+1 with probability 0.5 and -1 with probability 0.5) when resampling residuals. I perform wild cluster bootstrapping in Stata using cgmwildboot.ado, written by Judson Caskey.

with a higher district level poverty share received on average more vouchers compared to others in 2007/08. The time-invariant component of this poverty share is captured by the district fixed effects. The same goes for the time-invariant component of "ethnic intensity" that Brazys et al. (2015) found to be positively correlated with receiving vouchers.[41] The season fixed effects control for any annual program wide and macroeconomic changes that may affect distributions nation-wide. For instance, the formalization of beneficiary criteria that took place after the 2006/07 season is captured in the fixed effect for this season.

My identification strategy is thus to compare voucher allocations to districts across the six-season period, focusing on the 2008/09 season relative to other seasons, i.e. 2006/07, 2007/08 and 2009/10-2011/12, and how this correlates with the distribution of core and swing voters. I am therefore relying on district-specific changes over time. Past election outcomes and the ethnic composition may be correlated with other factors, such as poverty, that affect the annual distribution of fertilizer vouchers. However, finding that the relationship between the vote measures and the voucher allocations changes in the election season relative to other seasons falls to my knowledge only in line with electorally motivated tactical redistribution (Cole, 2009). The identification strategy relies on the assumption that there are no time-varying unobservables that are correlated with the vote measures and the allocated vouchers. Districts with for instance more swing voters should not be on a different trend relative to other districts, it assumes a common trend. Assuming that this holds, then this will produce unbiased coefficient estimates.[42] Further, since I am looking at the impact of past election outcomes and the ethnic composition on distributions in the 2008/09 season, rather than for instance a policy change that may be affected by past fertilizer voucher allocations, I am less concerned about possible lagged effects. I expect an immediate response, if there is one, on the importance of these variables to fertilizer vouchers allocations.

The expected coefficient sign of β_1 is ambiguous. A positive coefficient will, in line with *(H1)*, indicate that districts largely inhabited by the incumbent's core voters experience an increase in voucher allocation compared to districts with more swing voters (the reference category) in the

[41] This is a district level measure "based on the median response to a Likert scale survey question" from the 2005 Afrobarometer "which asked the participants the degree to which they identified with their ethnic identity vis-à-vis a "Malawian" identity" (Brazys et al., 2015). Eifert et al. (2010) find that the extent to which individuals claim a strong ethnic identity is positively correlated with the timing of presidential elections, suggesting that there is a time-varying component.

[42] Another issue that may violate the fixed effects estimator's assumption of strict exogeneity is feedback from the dependent variable to the explanatory variables (Cameron and Trivedi, 2009). However, I am using the same vote shares, i.e. from the 2004 elections, and not the future election results.

election season (2008/09) relative to other seasons. A negative coefficient would instead indicate that the swing voters are favored, in line with *(H4a)*. The coefficients β_2 and β_3 are expected to be negative, in line with *(H2)* and *(H3)*, indicating that the opponent(s)'s core voters are punished, here relative to the swing voters. Positive coefficients would instead imply that the swing voters are favored, again in line with *(H4a)*. In a second specification I separate the share of UDF votes that are not ethnically aligned with Lomwe or Yao from that of other parties. A positive coefficient on the remaining swing voters would indicate support to *(H4b)*. Lastly, I use a similar specification to the above to investigate the alternative definition of the swing and core voters using ethnicity shares only.

5 Results

5.1 Targeting based on past voting and ethnicity

Table 3 reports the results using past election outcomes and ethnicity as measures of the distribution of core and swing voters. In columns 1-3 the reference category is the distribution of all other voters than what the variable indicates, whereas in columns 4 and 5 the reference category are the swing voters as defined in *(H4a)* and *(H4b)*, respectively.

The empirical specification in eq. (1) is reported in column 4. I do not find support for the hypothesis of more vouchers being allocated to the incumbent's core voters, *(H1)*. Specifically, districts with more of the incumbent's core voters (UDF x Lomwe) do not receive on average more vouchers than districts with more swing voters in the 2008/09 season. The opponents' strongholds are on the other hand found to be disadvantaged in the election season, supporting hypotheses *(H2)* and *(H3)*. Districts in which a larger share voted for UDF in the last election and where there are more Yaos received on average less vouchers per household in the election season compared to districts with more swing voters. A one percentage point increase in the vote share to UDF interacted with the Yao-share corresponds to a decrease in the average number of fertilizer vouchers per 100 rural household by around 0.69 vouchers. A similar result is found for the previous main opposition party, MCP. A one percentage point increase in the vote share to MCP corresponds to a reduction of 0.55 vouchers. Comparing this to the average, a one percentage point increase in MCP's vote share results in a 0.41 percent decrease in fertilizer vouchers per 100 households, whereas a similar increase in the Yao-share of the UDF-votes gives a 0.52 percent decrease. Keeping in mind that the district level MCP vote share varies between 0.6 and 80 percent, then an increase of 20 percentage points in favor of MCP would translate into on average 11 fewer vouchers per 100 rural households.[43]

Importantly, this is in comparison to the reference category "other parties", i.e. the swing voters. Districts with more swing voters received on average more vouchers compared to the opponents in the 2008/09 season relative to other seasons, in support of *(H4a)*. Results are similar when using the alternative definition of swing voters (see column 5), where I exclude the share of previous UDF-voters that are neither Lomwe and Yao. This is in support *(H4b)*.

These results are robust to asymptotic refinement following wild cluster bootstrapping, with the exception of the estimated coefficient for MCP's vote share (as seen from the square brackets). In terms of the control variables, I find consistent evidence that districts with a higher of tobacco farmers receive on average more vouchers in seasons with tobacco vouchers. Less than average rainfall in the previous season is not associated with the allocations in the following season.

For the sake of comparison, I also report the results comparing the swing and oppositions' core voters against the rest, and using the incumbent's core voters as the reference category. As seen from Table B2, districts with more swing voters received on average more vouchers in the 2008/09 season relative to other voter groups (column 1), whereas the oppositions' core voters received comparably less (columns 2 and 3). Again, there is no statistically significant difference between the allocations to the incumbent's core voters versus the swing voters (columns 4 and 5).[44]

[43]If the distribution of vouchers is altered in order to maximize votes, then the incumbent is arguably more interested in voters than households per se. Using the number of potential voting adults (i.e. age 18 and above) instead of households results in largely the same pattern of results (results available upon request).

[44]The first variable in columns 5 in Tables 3 and B2 are simply the mirror image.

Table 3: Targeting of fertilizer vouchers at core and swing voters in an election season

	(1)	(2)	(3)	(4)	(5)
UDF's vote share (%) x Lomwe share	0.063			-0.157	-0.359
x Season 08/09	(0.354)			(0.405)	(0.447)
	[0.344]			[0.437]	[0.480]
UDF's vote share (%) x Yao share		-0.511**		-0.693***	-0.687***
x Season 08/09		(0.198)		(0.212)	(0.194)
		[0.201]**		[0.236]***	[0.218]***
MCP's vote share (%)			-0.432*	-0.546*	-0.527*
x Season 08/09			(0.247)	(0.314)	(0.305)
			[0.272]	[0.356]	[0.348]
UDF's vote share (%) x (1-Yao-Lomwe shares)					-0.798
x Season 08/09					(0.506)
					[0.545]
Share tobacco growers in 2002/03-03/04	0.857***	0.843***	0.979***	0.990***	0.962***
× tobacco season	(0.227)	(0.231)	(0.264)	(0.265)	(0.260)
	[0.318]	[0.323]	[0.334]	[0.338]	[0.328]
Seasonal deviation in rainfall	0.011	0.015	0.005	0.010	0.010
from historical mean (mm)	(0.066)	(0.066)	(0.066)	(0.065)	(0.065)
Number of obs.	168	168	168	168	168
adjusted R^2	0.326	0.335	0.347	0.357	0.361
F-stat	99.863	130.665	99.390	120.975	99.518
Mean Dep. Var.	134.464	134.464	134.464	134.464	134.464

Notes: Dep. var.: fertilizer vouchers per 100 rural households, based on population figures from 2008 census and beneficiary figures from Logistics Unit's reports that include first- and second-round distributions. The unit of analysis is the district. Each column indicates a separate regression. Columns (1)-(4): Comparing distribution of fertilizer vouchers in 2008/09 relative to 2006/07 - 2011/12. Core and swing voters are identified using past election outcomes and ethnicity All vote shares are from the 2004 presidential election. Tembo's core voters are captured by MCP's vote share. Mutharika's and Muluzi's core voters are identified using ethnicity, respectively Lomwe and Yao, and the UDF-election outcome. All specifications include district and season fixed effects. Robust standard errors clustered at district level in parentheses. Wild cluster bootstrapped standard errors in brackets, with null hypothesis imposed, Rademacher weights -1 and 1, as recommend by Cameron et al. (2008), and 1,000 replications. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.2 Targeting at ethnic groups

In Table 4 I identify core and swing voters using ethnicity only. Again, I find no evidence of targeting at the incumbent's core voters, i.e. Lomwe, relative to other ethnicities (column 1) or the swing voter ethnicities (column 4). Instead, I find that districts with a higher Yao-share received on average fewer vouchers, whereas a similar finding is not made for the Chewas. Keeping in mind that the reference category is all "other ethnicities", districts with a higher share of these other ethnicities receive on average more vouchers than other districts in the election season relative to other seasons. Using instead the Lomwe as the reference category, reveals that districts with more Lomwe receive on average more vouchers than districts with more Yaos in the election season (2008/09) relative to other seasons (see Table B3).

Table 4: Targeting of fertilizer vouchers at core and swing voters in an election season
Core and swing identified using ethnicity

	(1)	(2)	(3)	(4)
Lomwe share (%) x Season 08/09	0.038			-0.066
	(0.195)			(0.232)
	[0.164]			[0.475]
Yao share (%) x Season 08/09		-0.496**		-0.606**
		(0.203)		(0.231)
		[0.244]**		[0.261]**
Chewa share (%) x Season 08/09			-0.195	-0.286
			(0.176)	(0.237)
			[0.199]	[0.261]
Number of obs.	168	168	168	168
adjusted R^2	0.326	0.339	0.333	0.343
F-stat	99.793	118.349	96.944	101.000
Mean Dep. Var.	134.464	134.464	134.464	134.464

Notes: Dep. var.: fertilizer vouchers per 100 rural households, based on population figures from 2008 census and beneficiary figures from Logistics Unit's reports that include first- and second-round distributions. The unit of analysis is the district. Each column indicates a separate regression. Columns (1)-(4): Comparing distribution of fertilizer vouchers in 2008/09 relative to 2006/07 - 2011/12. Mutharika's, Muluzi's and Tembo's core voters are identified based on ethnicity, respectively Lomwe, Yao and Chewa. All specifications include district and season fixed effects, an interaction between tobacco subsidy season and share tobacco farming households in 2004/05 and seasonal deviation in rainfall relative to the historical mean. Robust standard errors clustered at district level in parentheses. Wild cluster bootstrapped standard errors in brackets, with null hypothesis imposed, Rademacher weights -1 and 1, as recommend by Cameron et al. (2008), and 1,000 replications. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.3 Robustness checks

I investigate whether the results are robust to using the annual beneficiary lists from the Logistics Unit's (LU), allowing for a more disaggregated analysis. This data is not ideal since I lack lists for the 2006/07 and 2007/08 seasons, and for one district in three of the seasons: Mulanje in 2008/09, Mwanza in 2009/10, and Ntcheu in 2011/12. If the district-specific loss is not random, then this may result in attrition bias. Moreover, this data does not include the second-round allocations made in 2008/09. This reduces the number of seasons available for analysis resulting in a comparison of the 2008/09 season to post-election seasons. I create an unbalanced panel at the level of the Traditional Authority (TA).[45] After dropping TAs where households do not receive vouchers (urban areas, parks and reserves) I am left with 207 rural TAs. Results are reported in Tables B4. I include the district level results that rely on the annual reports for the same four-season period (2008/09 - 2011/12) for the sake of comparison. The district level results are robust to focusing on the four-season period (columns 1-4), whereas I do not find support for the oppositions' core voters being punished relative to the swing voters when using the beneficiary lists (columns 5-8).

I also assess the role of the second-round allocations made in the 2008/09 season, in December 2008 and January 2009, but do not find any statistically significant results.[46]

[45]The use of Traditional Authority (TA) as the level of aggregation is determined by the ability to match the census data with the subsidy program data. The latter data contains allocations by both TA and Extension Planning Areas (EPA) whereas the census only operates with the former delineation. In some instances, the program data is sub-divided into more Traditional Authorities (TA) than those which the National Statistical Office (NSO) operate with in the census. In order to be able to match different data sources, I have identified which old TAs these new TAs previously were registered as part of in the 2008 census data. I have been unable to match information from the FISP and the census data for two TAs (one in Rumphi and one in Nkhata Bay) for the five year period, these vouchers are therefore not included in the analysis. See Appendix A for a more detailed description of the Traditional Authorities.

[46]Dorward and Chirwa (2011) argue that "criteria and systems for subsequent supplementary rounds of voucher allocation and distribution later in the season are less clear but are intended to address problems of unmet demand in first round distribution" (p. 234). What these unmet demands are is not obvious, and the additional allocations are open to executive discretion. I separate the total 2008/09 allocation by rounds, and include round-specific fixed effects. The variables of interest are interactions between the 2004 election outcome, ethnicity shares and the two rounds. None of the core voter coefficients are statistically significantly different from zero below the 10 percent level, nor do I find any difference in terms of the swing voters (results available upon request). All in all, it is difficult to assess whether the first and second rounds differ in terms of how politically motivated they were.

6 Discussion and caveats

6.1 The results in a broader perspective

The district level results show that swing voters were favored at the expense of the oppositions' core voters in the election season (2008/09) relative to other seasons. In particular, districts in which a higher share are Yao and previously voted UDF receive on average fewer vouchers compared to districts with more swing voters. The same pattern of results holds when comparing the Yaos against the swing voter ethnicities. Yet, while I do not find any difference between the incumbent's core voters when using the combination of past election outcomes and ethnicity, I do find that districts dominated by the Lomwe receive on average more vouchers compared to districts with more Yao. In other words, the Yao seem in particular to be punished. A possible reason for the different findings on the incumbent's core voters, identified based on the interaction between the incumbent's 2004 election outcome and ethnicity versus ethnicity only, may stem from the competition from a co-ethnic candidate in the 2004 election (see Table 1).

Given these results, a central question to ask is what Mutharika would have achieved had he only targeted his core voters in an election season. The 2009 election was the first election for Mutharika and his party, DPP, rendering the notion of core voters as less settled. Distributing additional vouchers could be an effective mechanism to signal their credibility and the promising nature of the incumbent as a patron (Keefer and Vlaicu, 2008; Kramon, 2011). On the other hand, those ethnically affiliated with Mutharika may have had little alternative but to vote for him. In settings where access to government resources has historically fallen along ethnic lines voters may favor their own ethnic representative more so because of the belief that the other ethnic candidate will favor his/her ethnicity, than in the expectation that they will benefit (Van de Walle, 2003). Keeping past ethnic favoritism in mind, the Lomwe were probably unlikely to benefit from a power shift to Tembo and his Chewa-dominated MCP or to Muluzi and his Yao-dominated UDF. Lastly, securing support from Mutharika's co-ethnics only would not be sufficient to win the election. Allocating additional fertilizer vouchers to districts with more swing voters was more likely to maximize votes.

How do these results compare to that of Brazys et al. (2015) and Dionne and Horowitz (2016)? Brazys et al. (2015) found that households that reside in constituencies that are located in districts with a higher share of Lomwe receive on average more vouchers relative to areas with more Yaos.[47]

[47] This does however not hold when they control for the amount of aid allocated, resulting in the opposite sign.

This is in line with my findings for the 2008/09 season, but not for the 2007/08 season that they focus on.[48] Further, they also find that areas with more Chewas and Nkhonde/Tumbuka households are more likely to report having received vouchers than areas with more Lomwe. Yet, the distribution of Chewas and Tumbuka is correlated with tobacco farming. Since they have not controlled for the relevance of the tobacco vouchers these estimates are likely to be upward biased (I find that the interaction between a tobacco season and the share tobacco farmers is positive and statistically significant).[49] Note that my interpretation of the Chewas differs from Brazys et al. (2015). Whereas they treat them as swing voters, I treat them as the oppositions' core voters, in line with Dionne and Horowitz (2016). In summary, while Brazys et al. (2015) argue that the DPP government targeted the "up for grabs" ethnicities (Chewas, Ngoni, Tonga and Nkhonde/Tumbuka) at the expense of the "safe" (Lomwe, Nyanja) and "impossible" (Yao) ethnicities, I only find evidence of reduced targeting at the Yaos relative to others. Dionne and Horowitz (2016), on the other hand, found no evidence of local targeting at specific ethnic groups in the districts of Rumphi, Mchinji and Balaka in the 2009/10 season. This is however not so surprising when taking into account that they are imposing village fixed effects and thereby rely on within-village variation in ethnicity.[50] The authors further acknowledge that their study does not address whether the program targeted based on ethnicity or partisanship at the national level.

Importantly, my results only indicate small adjustments in the allocation of vouchers. The small magnitudes may either reflect, *(i)* that the incumbent and his government did not adjust voucher allocations at the margin, or *(ii)* the data does not adequately reflect the incumbent's intended allocation of vouchers. I return to the latter explanation in Section 6.3. Assuming instead that the former explanation holds, one may further argue that the considerable increase in program expenditures in 2008/09 suggests that a binding budget constraint was not a central issue. This would preclude the need for reducing allocations to some groups in order to favorably target others. However, assuming that the incumbent instead increased allocations overall, regardless of past voting outcomes and ethnic affiliations, then all districts should have experienced an increase in

[48] Interacting the swing and core voter measures with the 2007/08 season renders none of these variables statistically significantly different from zero (results available upon request).

[49] Interestingly, Brazys et al. (2015) also claim that the votes from the Chewas (in addition to the Ngoni, Tonga and Nkhonde/Tumbuka) "were essential in securing a national electoral majority" in the parliamentary elections, yet the share of Chewas in a district is strongly negatively correlated with the DPP's presidential election outcome in 2009.

[50] The authors state that "[i]n the villages in Rumphi 94.5% of respondents were Tumbuka; in the villages in Mchinji 89.6% of respondents were Chewa; and in the villages in Balaka 78% of respondents were Yao" (p. 10).

voucher allocations. This is not found to be the case with the data at hand, season 2008/09 did not involve on average more vouchers relative to the other seasons. Moreover, although the program costs were considerably higher in 2008/09 this was largely due to higher import costs, the actual amount of fertilizer made available was higher in the preceding season (Dorward and Chirwa, 2011; LU, 2008, 2009).

A natural follow-up question is whether voters were influenced by the altered allocation of vouchers. The incumbent Mutharika and his party, DPP, won a landslide victory, receiving between 26 and 97 percent of the votes in a given district. This may in part be attributed to the exchange of vouchers for votes. Then again, other campaign spending may also have been instrumental in amassing electoral support, voters may have approved of the incumbent's general economic policies and/or voted for Mutharika more as a statement against the opposition (Mpesi and Muriaas, 2012). Unfortunately, I am not able to provide a convincing analysis of the relationship between the voucher allocations in 2008/09 and the subsequent 2009 voting outcome, neither in terms of voting nor turn-out. I have no exogenous variation in the subsidy program to exploit and there are likely to be omitted variables (e.g. government benefits) that are correlated with both the voting outcome and fertilizer distributions, thus biasing the estimated coefficients.[51]

The exact mechanism through which the incumbent is expected to influence the voters by allocating vouchers remains unanswered. I have assumed that the incumbent and his government allocate vouchers based on the proportional distribution of core and swing voters. This in the expectation that receiving a voucher will increase the likelihood of voting for the incumbent, including in the form of increased turn-out (Nichter, 2008). With the exception of the second-round allocations in the 2008/09 season, there is a considerable distance between the incumbent and his government's allocative actions and the actual voters. The assumption that (the increased likelihood of) receiving a voucher can be interpreted as vote-buying remains untested. It is however

[51] I can only provide correlations between the voucher allocations in 2008/09 and the incumbent's district level vote share in 2009. These are reported in Table B5. The raw correlation between the two variables without controlling for any confounding factors is presented in column (1). A marginal increase in fertilizer vouchers per 100 rural households corresponds to 0.15 percentage points more votes to the incumbent. The magnitude remains more or less unchanged when introducing controls for the rural population share, the number of potential voters, and district shares of households with access to improved sanitation and safe water as reported in the 2008 census (columns 2-3). These latter two measures serve as proxies for poverty. Introducing separate controls for the shares of farmers that grow maize and tobacco do not alter the results either (column 4). However, controlling for average literacy rates and/or past election outcomes (columns 5-7) renders the coefficient on fertilizer vouchers no longer statistically significant at the 10 percent level. Still, whether receiving more vouchers affected voting behavior remains unanswered.

plausible that the voucher allocations involved a message of favorable voting, as suggested by the anecdotal evidence discussed in Section 2.2.[52] Further, as Banful (2011b) argues, the finding that allocations follow political considerations at the district level suggests that similar considerations are likely to have influenced allocations at the farm level. Nevertheless, I am unable to address whether and how the incumbent and his government tackles the issue of compliance and monitoring in vote-buying (Stokes, 2005) in the Malawian context, leaving this for future research.

6.2 Were voters rewarded?

An equally interesting question is to what extent political support in 2009 was rewarded by the provision of more vouchers in the following season, i.e. 2009/10. Results from the district level analyses are reported in Table 5. I do not find that districts with a higher vote share to DPP in 2009 received on average more vouchers. Instead they received on average fewer vouchers compared to others (column 1). Similarly, districts in which the winning margin (between DPP and MCP) was larger received on average fewer vouchers (column 2). Lastly, districts in which the incumbent experienced a larger increase in the vote share in 2009 relative to 2004 are also disfavored in 2009/10 (column 3).

These results fall in line Banful (2011a) who find reduced allocations of government grants to districts where the election was won by a higher vote margin in Ghana. Miguel and Zaidi (2003), on the other hand, find that Ghanian government funds are targeted at districts won by a large majority. Neither study looks at the post-election season.

[52] Additional support to this argument stems from the government's requirement that recipients in 2009/10 show a voter registration card (LU, 2010).

Table 5: District level: Distribution of fertilizer vouchers to incumbent's core voters in the post-election season

	(1)	(2)	(3)	(4)	(5)
DPP's vote share (%) [2009] x Season 09/10	-0.334*				
	(0.179)				
	[0.163]**				
Vote share margin (%) [2009], between DPP and MCP x Season 09/10		-0.166*			
		(0.090)			
		[0.082]**			
Diff. between DPP's [2009] and UDF's [2004] vote shares (%) x Season 09/10			-0.206**		
			(0.099)		
			[0.089]**		
DPP's vote share (%) [2009] x Lomwe share x Season 09/10				0.146	
				(0.099)	
				[0.101]	
Lomwe share (%) x Season 09/10					0.147
					(0.089)
					[0.092]
Number of obs.	168	168	168	168	168
adjusted R^2	0.333	0.333	0.328	0.328	0.335
F-stat	108.848	109.634	100.878	101.801	113.364
Mean Dep. Var.	134.464	134.464	134.464	134.464	134.464

Notes: Dep. var.: fertilizer vouchers per 100 rural households, based on population figures from 2008 census and beneficiary figures from Logistics Unit's reports that include second-round distributions. Each column indicates a separate regression. Columns (1)-(2): comparing district level distribution of fertilizer vouchers in 2009/10 relative to 2006/07 - 2011/12. Vote shares refer to presidential elections in 2004 and 2009, with the election year indicated in squared brackets. All specifications include district and season fixed effects, an interaction between tobacco subsidy season and share tobacco farming households in 2004/05 and seasonal deviation in rainfall relative to the historical mean. Robust standard errors clustered at district level in parentheses. Wild cluster bootstrapped standard errors in brackets, with null hypothesis imposed, Rademacher weights -1 and 1, as recommend by Cameron et al. (2008), and 1,000 replications. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6.3 Measurement error

Measurement error is a potential problem in a setting where decisions are politicized and data are imperfect. First, there is likely to be measurement error in terms of whom actually received vouchers, as compared to the intended allocations.[53] This may be due to displacements of vouchers or diversion of fertilizer. For instance, rent-seeking by local government officials and village chiefs (Holden and Lunduka, 2013) may have diluted or intensified the incumbent's electoral goals. This measurement issue would be more problematic if my intention was to analyze the impact of receiving subsidy vouchers on voting behavior. My main interest has instead been the incumbent and his government's allocative actions. In this regard, the official intended figures are less prone to measurement error compared to the final figures on recipients, assuming that the official figures are a good proxy for his intentions.

The above results rely on data that excludes the extra allocations made to tea and coffee production in 2008/09. These were allocated to districts with proportionally more of the incumbent's core voters and swing voters, and so their inclusion may have altered the results.[54] On the other hand, reports of additional vouchers being in circulation, particularly in the first seasons, suggest that the government made more vouchers available than officially reported. Sales figures indicate that an additional 0.92 million fertilizer vouchers were distributed in 2008/09, an increase of roughly 27 percent compared to the initial 3.4 million (LU, 2008). Unfortunately, there are no reliable sales figures to investigate the distribution from this angle.

Measurement error in the dependent variable may also arise from misconceptions around the number of households in a district. The beneficiaries were supposed to be selected based on the annual farm family registries and the beneficiary criteria. I have only been able to access the registries for some seasons and therefore resorted to using the census data instead. The information

[53] A comparison between the dependent variable in the main analysis and the share of households that received vouchers for fertilizer and seeds in the 2008/09 season, as reported in the Welfare Monitoring Survey (WMS) from 2009 (NSO, 2009), confirms this. The relationship between the number of fertilizer vouchers per 100 rural households, and the share of households reported to have received vouchers in 2008/09 is depicted in Figure B1. As expected, there is a positive relationship between the two measures. More fertilizer vouchers per 100 rural households predicts a higher share of households reported to having received vouchers. Yet, it is by far a perfectly linear relationship. This may be attributed to measurement error issues, in the addition to the fact that the Welfare Monitoring Survey only includes the share of households receiving vouchers. This may mask differences in the number of vouchers received.

[54] An additional 11,000 fertilizer vouchers for tea were distributed in January 2009 to the districts of Mulanje and Thyolo (LU, 2009), where more than 70 percent are Lomwe (NSO, 2008). Including these may have altered the findings on the incumbent's core voters. On the other hand, the northern districts, where the defined swing voter measure is high, received 4,000 fertilizer vouchers for coffee in 2008/09, adding to the findings that the swing voters were targeted.

that enters into the construction of the dependent variable may therefore not reflect the information used by the decision maker of interest, i.e. the incumbent and his government. The census took place in June 2008 and the preliminary report was finalized in September 2008, making it possible that these figures could have entered into the government's decision-making process for the 2008/09 season and onwards. These figures have, however, also been used to construct the dependent variable for the 2006/07 and 2007/08 seasons, which is possibly misleading, and for the following seasons, thus ignoring any population growth. Nevertheless, the pattern of results is robust to using the four-season period (see Tables B4), which excludes the first two seasons. Another possible concern is migration to areas that are perceived to receive more vouchers, thus affecting the number of vouchers available per household. However, the requirement that recipients own land and the limited existence of markets for selling and buying land suggest that this is an unlikely tactic.

More important is how the census figures compare to the farm family registries. The former may underestimate the number of households in 2008, as suggested by Dorward et al. (2010).[55] Since I am using the same population figures across the seasons then any variation in the dependent variable is attributable to the fertilizer program and not to changes in the population figures. On the other hand, if over- or underreporting of the number of farm families as compared to the census is correlated with my covariates, then this would be problematic. For instance, if areas with more swing voters systematically reported more farm families in 2008/09, then this would introduce upward bias in the estimated coefficients for the swing voter variables. Chirwa and Dorward (2013) compare the discrepancy between the number of farm families and the census figures over time. They note a sharp increase in the number of farm families in the Central region in the period 2005/06-2009/10. The growth rates in the Northern and Southern regions were, respectively, highest from 2005/06 to 2007/08 and from 2008/09 to 2009/10. The relatively stable number of farm families from 2008/09 and onwards in the Northern region suggests that the number of vouchers allocated in 2008/09 should not be comparably higher than in later seasons. The defined swing voters are to a large degree located in the Northern region. Thus my findings of more vouchers being allocated to districts with more swing voters in 2008/09 compared to later seasons may still hold had the farm family registries been used instead. Nevertheless, it is difficult to assess the extent to which

[55] The underestimation of the number of farm households in the census is based on estimates incorporating the reported voucher receipts from a 2009 household survey covering 14 districts, with the number of redeemed vouchers and perceived availability of vouchers (Dorward et al., 2010).

measurement error in the number of households compared to the number farm families is affecting my results without more detailed data.

A possible severe issue is measurement error in the covariates of interest, leading to biased and inconsistent estimates if this is correlated with any unobservables that enter into the error term. If the measurement error is uncorrelated with unobservables affecting the fertilizer allocations, then this will result in attenuation bias only. In other words, the estimated coefficients are biased towards zero, and this may be particularly pronounced when using the fixed effects estimator (Angrist and Pischke, 2008). The independent variables of interest are interactions between season, ethnicity and past election outcomes. Ethnicity, like population, is drawn from the 2008 census data[56] and is based on the share of people and not the share of households. Ethnicity is expected to be correctly captured in the 2008 census. Although there is some migration between districts[57] the requirement that the recipients should own land, which is predominantly accessed through inheritance, likely limits measurement error in the share of rural households that align with an ethnicity. Finally, another source of measurement error pertains to the method of identifying the core voters using the interaction between ethnicity and vote share. This assumes equal voting participation from all ethnic groups within a given district, which may not be a viable assumption. Unfortunately, I am unable to assess this as I lack individual-level data.

7 Conclusion

This paper examines how the distribution of core and swing voters relates to the national voucher allocations from the Malawian Farm Input Subsidy Program in an election season relative to other seasons. The subsidized fertilizer vouchers are of interest to the majority of the population and may therefore be an attractive tool for the incumbent to sway voters to re-elect him. I find that the incumbent's government alters the distribution of subsidized fertilizer vouchers in the last season prior to the presidential election compared to other seasons. This falls in line with possible electoral motives. Specifically, districts with potentially more swing voters receive on average more vouchers at the expense of districts with more of the opponents' core voters. I do not find evidence of the incumbent's core voters being favored relative to swing voters, whereas districts with more of the

[56] The previous census from 1998 does not include data on ethnicity.

[57] In the year prior to the census in 2008, 41.4 percent of inter-district migration involved migration from rural districts to cities, the remaining being between districts (NSO, 2008).

incumbent's co-ethnics received on average more vouchers compared to districts inhabited by more of main opponent's co-ethnics. Importantly, there is no a priori reason for why these districts should have a different need for vouchers in the election season relative to other seasons, indicating that electoral motives rather than program goals underlie the allocations. The categorization of core and swing voters differs from previous work, in that I combine both past election outcomes and ethnicity to identify core and swing voters. This approach is made necessary due to shifting party affiliations, which is common in many developing countries.

I have not assessed whether the Farm Input Subsidy Program has been successful in achieving its overall goals of improving food security at the household and national level. Previous studies indicate the impacts on agricultural production, maize prices and poverty are modest (see Lunduka et al. (2013) for a review on Malawi). My findings, albeit small in magnitude, may suggest that these limited impacts are in part due to the program being overridden by electoral goals. Future research should clarify the extent to which this is the case. Increased transparency at the central level in the distribution process and more clear allocation rules may limit the scope for electorally motivated redistribution. This should be a requirement set forth by donors where their support is relevant. In general, informing the population about the drawbacks and costs related to the program and how these may be dealt with, is crucial in order to allow voters assess politicians' behavior and policy platforms. This paper deals with the 2009 presidential election. Since then, new elections have taken place. An interesting question is whether the calls for increased transparency in allocations have limited the room for politicization of the Malawian input subsidy program.

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Appendices

Appendix A: Institutional details

Agricultural/Farm Input Subsidy Program

Guidelines: Prior to the 2007/08 season the program targeting emphasized that beneficiaries were to be "full time smallholder farmers who cannot afford to purchase one or two bags of fertiliser at prevailing commercial prices, as determined by local leaders in their areas" (p. 23) (Dorward et al., 2008). More detailed guidelines followed that emphasized vulnerable households: *(1)* A Malawian that owns a piece of land and should be cultivated, *(2)* Guardians looking after physically challenged persons, *(3)* Resident of the village, *(4)* Only one beneficiary per household will be registered, and *(5)* The vulnerable group, such as child-headed, female-headed, or orphan-headed households (MoAFS, 2008).

Subsidized inputs: In the program's first season each eligible household was to receive three vouchers, two for 50 kg fertilizer and one for 2-4 kg seeds. The seed package has changed since then and likewise has the size of the subsidy. When the program was initiated in 2005/06, a 50 kg bag of fertilizer for maize or tobacco required the payment of MKW 950 or MKW 1450, respectively. This was reduced to MKW 950 for both types in the 2006/07 season, and later to MKW 900 and MKW 800, in the 2007/08 and 2008/09 seasons, respectively. In 2009/10 the maize top-up price was reduced to MKW 500, and this was the going price up until the 2014/15 season (LU, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014). The 2015/16 season saw an increase to MKW 3500 per bag of fertilizer. The degree of subsidization was highest in the 2008/09 season, following spikes in oil prices, and corresponded to less than 10 percent of the commercial price (Holden and Lunduka, 2013), as opposed to 25 percent in the first seasons (Ricker-Gilbert et al., 2011).

Access to inputs: The Ministry of Agriculture and Food Security (MoAFS) organizes the printing of vouchers. Inputs have in recent years been accessed at the local depots, administered by the two government parastatals (LU, 2008, 2009, 2010, 2011, 2012). Households are reported to have had to share their vouchers with another household in the village. This may be driven by equality preferences and/or that fewer than the intended number of vouchers were distributed locally (Holden and Lunduka, 2013).

Political and traditional institutions

Malawi's institutional power structure consists of elected representatives, government bureaucrats and the Traditional Authorities. General elections are held every fifth year, when a president, a vice-president and Members of Parliament (MPs) are elected. Each parliamentary member represents one constituency, and are elected based on a first-past-the-post single-member system. The Ministry of Agriculture and Food Security (MoAFS) is the ministry most closely involved in the subsidy program, followed by the Ministry of Finance. As of 2009, MoAFS was divided into six centralized departments, under which there are eight Agricultural Development Divisions (ADDs). The next level of authority is the District Agricultural Development Officer (DADO) (Chinsinga, 2009b; Masangano and Mthinda, 2012). These play a central role in providing information to the farm family registries and compiling the beneficiary lists. Each district's agricultural services are further broken down into Extension Planning Areas (EPA), covering several sections which again each are headed by an Agricultural Extension Development Officer (AEDO) who is responsible for several villages (Masangano and Mthinda, 2012).

In an attempt to decentralize power, each district also has a district council to which local councillors are elected (Patel et al., 2007; Cammack et al., 2007; Chiweza, 2010). These are further subdivided into Area Development Committees (ADC) and Village Development Committees (VDC). The ADCs and VDCs have over time become involved in identifying program beneficiaries. Each district is also divided into Traditional Authorities, which are further subdivided into villages, each headed by a Village Headman (Patel et al., 2007). The Traditional Authorities are chosen based on kinship, are paid by the government and play a central role in local decision-making (Patel et al., 2007). According to Cammack et al. (2007) they are often affiliated to political parties. Moreover, they often exert influence over the local MPs, and may influence whom the villagers vote for in the general elections (Patel et al., 2007; Chinsinga, 2009a).

Appendix B: Tables and Figures

Table B1: Timeline of events

1994	Hastings Kamuzu Banda's one-party rule (Malawi Congress Party (MCP)) ends
	Bakili Muluzi (United Democratic Front (UDF)) is elected president in first multi-party election
1999	Bakili Muluzi (UDF) is re-elected president
2004	Bingu wa Mutharika (UDF) is elected president
2005	Bingu wa Mutharika leaves UDF and forms Democratic Progressive Party (DPP)
	Agricultural Input Subsidy Program is introduced, later renamed Farm Input Subsidy Program
2009	Bingu wa Mutharika (DPP) is re-elected president
2011	Joyce Banda leaves DPP and creates People's Party (PP)
2012	Bingu wa Mutharika dies and vice-president Joyce Banda (PP) becomes president

Table B2: Targeting of fertilizer vouchers at core and swing voters in an election season. Incumbent's core voters as reference category

	(1)	(2)	(3)	(4)	(5)	(6)
Other parties' (than MCP and UDF) vote share (%) x Season 08/09	0.575**				0.359	
	(0.264)				(0.447)	
	[0.283]**				[0.478]	
UDF's vote share (%) x Yao share x Season 08/09		-0.511**			-0.328	-0.536
		(0.198)			(0.359)	(0.334)
		[0.201]**			[0.454]	[0.494]
MCP's vote share (%) x Season 08/09			-0.432*		-0.168	-0.389
			(0.247)		(0.308)	(0.273)
			[0.272]		[0.342]	[0.387]
UDF's vote share (%) x (1-Yao-Lomwe shares) x Season 08/09				-0.799*	-0.439	
				(0.433)	(0.459)	
				[0.465]*	[0.511]	
Other parties' vote share (%), inc. non-Lomwe and non-Yao share of UDF x Season 08/09						0.157
						(0.405)
						[0.433]
Number of obs.	168	168	168	168	168	168
adjusted R^2	0.370	0.335	0.347	0.336	0.361	0.357
F-stat	107.869	130.665	99.390	104.008	99.518	120.975
Mean Dep. Var.	134.464	134.464	134.464	134.464	134.464	134.464

Notes: Dep. var.: fertilizer vouchers per 100 rural households, based on population figures from 2008 census and beneficiary figures from Logistics Unit's reports that include second-round distributions. District-level analysis. Each column indicates a separate regression. Columns (1)-(4): Comparing distribution of fertilizer vouchers in 2008/09 relative to 2006/07 - 2011/12. All vote shares are from the 2004 presidential election. Mutharika's and Muluzi's core supporters are identified based on ethnicity, Lomwe and Yao respectively. All specifications include district and season fixed effects. Robust standard errors clustered at district level in parentheses. Wild cluster bootstrapped standard errors in brackets, with null hypothesis imposed, Rademacher weights -1 and 1, as recommend by Cameron et al. (2008), and 1,000 replications. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B3: Targeting of fertilizer vouchers at core and swing voters in an election season
Incumbent's core voters as reference category. Core and swing identified using ethnicity

	(1)	(2)	(3)	(4)
Share that are not Yao/Chewa/Lomwe (%) x Season 08/09	0.287			0.066
	(0.215)			(0.232)
	[0.230]			[0.279]
Yao share (%) x Season 08/09		-0.496**		-0.540***
		(0.203)		(0.191)
		[0.190]**		[0.336]
Chewa share (%) x Season 08/09			-0.195	-0.220
			(0.176)	(0.171)
			[0.191]	[0.237]
Number of obs.	168	168	168	168
adjusted R^2	0.343	0.339	0.333	0.343
F-stat	98.645	118.349	96.944	101.000
Mean Dep. Var.	134.464	134.464	134.464	134.464

Notes: Dep. var.: fertilizer vouchers per 100 rural households, based on population figures from 2008 census and beneficiary figures from Logistics Unit's reports that include second-round distributions. Each column indicates a separate regression. Columns (1)-(4): Comparing distribution of fertilizer vouchers in 2008/09 relative to 2006/07 - 2011/12. All vote shares are from the 2004 presidential election. Mutharika's and Muluzi's core supporters are identified based on ethnicity, Lomwe and Yao respectively. All specifications include district and season fixed effects. Robust standard errors clustered at district level in parentheses. Wild cluster bootstrapped standard errors in brackets, with null hypothesis imposed, Rademacher weights -1 and 1, as recommend by Cameron et al. (2008), and 1,000 replications. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B4: District and Traditional Authority level: Targeting of fertilizer vouchers at core and swing voters in an election season

Level of analysis	District				Traditional Authority			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Election outcomes and ethnicities								
UDF's vote share (%) x Lomwe share x Season 08/09	-0.170			-0.334	0.301			0.214
	(0.398)			(0.389)	(0.264)			(0.264)
	[0.511]			[0.498]				
UDF's vote share (%) x Yao share x Season 08/09		-0.624**		-0.803***		0.037		-0.048
		(0.237)		(0.216)		(0.094)		(0.116)
		[0.325]*		[0.271]***				
MCP's vote share (%) x Season 08/09			-0.553**	-0.749**			-0.217	-0.194
			(0.244)	(0.296)			(0.192)	(0.212)
			[0.256]**	[0.330]**				
Number of obs.	112	112	112	112	811	811	811	811
adjusted R^2	0.564	0.589	0.606	0.654	0.211	0.206	0.215	0.216
Mean Dep. Var.	133.094	133.094	133.094	133.094	135.110	135.110	135.110	135.110
Panel B: Ethnicities								
Lomwe share (%) x Season 08/09	-0.092			-0.190	0.215			0.209
	(0.219)			(0.225)	(0.150)			(0.170)
	[0.309]			[0.284]				
Yao share (%) x Season 08/09		-0.603**		-0.704***		0.068		0.058
		(0.234)		(0.239)		(0.094)		(0.120)
		[0.286]**		[0.274]**				
Chewa share (%) x Season 08/09			-0.238	-0.395*			-0.057	-0.012
			(0.194)	(0.222)			(0.152)	(0.177)
			[0.209]	[0.269]				
Number of obs.	112	112	112	112	811	811	811	811
adjusted R^2	0.564	0.599	0.576	0.625	0.214	0.207	0.207	0.213
F-stat	31.991	36.816	49.485	47.273	24.828	21.243	24.015	23.152
Mean Dep. Var.	133.094	133.094	133.094	133.094	135.110	135.110	135.110	135.110

Notes: Dep. var.: fertilizer vouchers per 100 rural households. Based on population figures from 2008 census and beneficiary figures from Logistics Unit's reports that include second-round distributions (district level), and beneficiary figures from Logistics Unit's beneficiary lists that exclude second-round distributions (Traditional Authority level). Each column indicates a separate regression. Columns (1)-(4): comparing district level distribution of fertilizer vouchers in 2008/09 relative to 2009/10 - 2011/12. Columns (5)-(8): comparing Traditional Authority-level distribution of fertilizer vouchers in 2008/09 relative to 2006/07 - 2011/12. All vote shares are from the 2004 presidential election. Mutharika's and Muluzi's core voters are identified using ethnicity, Lomwe and Yao respectively. All specifications include district/Traditional Authority and season fixed effects, an interaction between tobacco subsidy season and share tobacco farm households in 2004/05 by district and seasonal deviation in rainfall relative to the historical mean. Robust standard errors clustered at district level in parentheses. Wild cluster bootstrapped standard errors in brackets, with null hypothesis imposed, Rademacher weights -1 and 1, as recommend by Cameron et al. (2008), and 1,000 replications. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B5: Relationship between fertilizer voucher allocations in the election season (2008/09) and the incumbent's vote share in 2009 presidential election

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fertilizer vouchers per 100 rural household [2008/09]	0.145**	0.115*	0.128*	0.158*	-0.002	0.061	0.003
	(0.065)	(0.063)	(0.065)	(0.079)	(0.098)	(0.045)	(0.057)
Share rural inhabitants (%) [2008]		0.618	0.735	0.654	0.706	0.923	0.910*
		(0.831)	(0.905)	(0.981)	(0.935)	(0.620)	(0.521)
Total number of individuals aged +18 '1000 [2008]		-0.087***	-0.078**	-0.068**	-0.052**	-0.032	-0.029
		(0.027)	(0.033)	(0.031)	(0.023)	(0.019)	(0.017)
Share with improved sanitation (%) [2008]			1.400	0.672	-1.274	0.763	-0.106
			(3.312)	(3.993)	(2.734)	(1.634)	(1.726)
Share with safe water (%) [2008]			0.208	-0.066	-0.037	-0.164	-0.138
			(0.343)	(0.441)	(0.431)	(0.362)	(0.379)
Share maize growers (%) [2002/03-2003/04]				0.069	0.256	0.362**	0.405**
				(0.326)	(0.301)	(0.155)	(0.141)
Share tobacco growers (%) [2002/03-2003/04]				-0.281	-0.292	0.039	-0.009
				(0.238)	(0.227)	(0.227)	(0.223)
Literacy rate (%) [2008]					1.647***		0.726*
					(0.548)		(0.414)
UDF's vote share (%) [2004]						-0.613***	-0.532***
						(0.139)	(0.120)
MCP's vote share (%) [2004]						-0.602***	-0.522***
						(0.113)	(0.121)
Number of obs.	28	28	28	28	28	28	28
adjusted R^2	0.143	0.280	0.230	0.193	0.415	0.699	0.728
F-stat	4.874	6.919	3.990	3.218	7.346	15.947	23.224
Mean Dep. Var.	71.712	71.712	71.712	71.712	71.712	71.712	71.712

Notes: Dep. var.: Mutharika's (DPP) district level vote share from 2009 presidential election. Each column indicates a separate regression. Fertilizer vouchers per 100 rural households to district, based on population figures from 2008 census and beneficiary figures from Logistics Unit's reports that include second-round distributions. All shares are district level shares from the year(s) referred to in the squared brackets. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

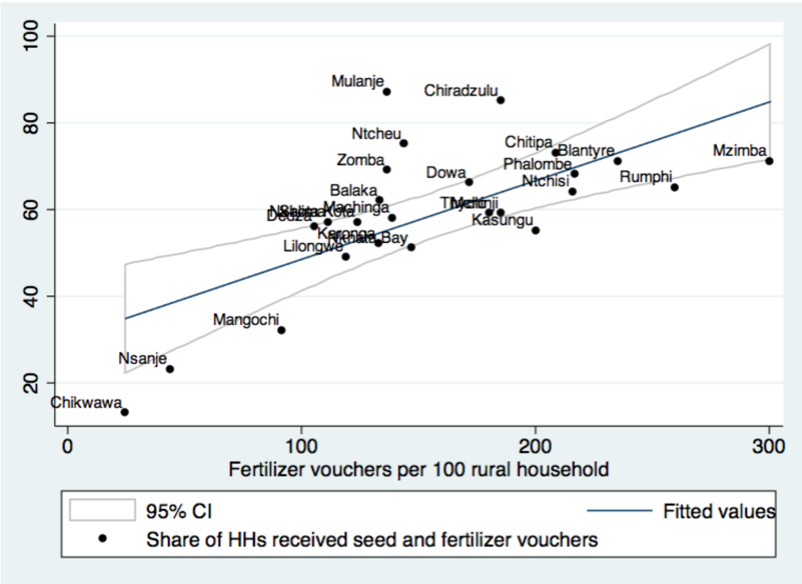

Figure B1: Correlation between official district allocations and share of households receiving vouchers in 2008/09

Notes: This figure shows the correlation between (i) the official 2008/09 district level distribution of vouchers per 100 rural household and (ii) the reported share of households that received fertilizer vouchers in the 2008/09 season. Sources: (i) Logistics Unit (LU, 2009) and 2008 Population and Housing Census (NSO) (NSO, 2008) and (ii) 2009 Welfare Monitoring Survey (NSO, 2009). Districts excluded: Likoma, Neno and Mwanza.

PAPER 4

In school on time to marry?

Nina Bruvik Westberg*†

Abstract

Girls are more likely to enroll in school on time than boys in southern Africa. I investigate the role of the bride price custom, a payment from the groom's family to the bride's family, in explaining part of this. Previous qualitative and in part quantitative work has suggested that the bride price is increasing in the bride's education, whereas it may be decreasing with non-virginity and previous childbearing, and thus potentially also age. I couple several rounds of the Demographic Health Surveys for Malawi, Mozambique, Namibia and Zambia with Murdock's (1967) Ethnographic Atlas. I find that 7-9 year old girls that belong to ethnicities that have historically practiced the bride price custom are more likely to enroll on time relative to boys from bride price ethnicities. This holds in Malawi and Namibia and is robust to ethnicity- and household-level controls. In the two other countries, girls from non-bride price ethnicities are less likely to enroll on time relative to boys. I find less evidence of girls from bride price ethnicities enrolling earlier than other girls. However, bride price teenage girls acquire on average more years of education compared to non-bride teenage price girls in all four countries, whereas there is no difference for teenage boys, with the exception of in Namibia. I assess a range of alternative explanations that may explain the pattern of results, including the role of child labor, nutritional status, sibling competition and returns in the labor market.

Keywords: on-time school enrollment, bride price, southern Africa

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†I would like to thank seminar participants at the Norwegian University of Life Sciences, University of Oslo, and the Nordic Conference in Development Economics 2016, as well as Øyvind Nystad Handberg, Stein T. Holden, Jo Thori Lind, Eivind Hammersmark Olsen, Knut Einar Rosendahl, Sofie Waage Skjeflo and Andreas Bruvik Westberg for useful comments and suggestions. All errors are my own.

1 Introduction

Primary school enrollment rates have increased dramatically over the past decades in Sub-Saharan Africa. Despite this achievement a large share of children fail to enroll in school on time. This share is smaller for girls than for boys in several southern African countries. For instance, 68 and 65 percent of Zambian eight year old girls and boys, respectively, were enrolled in school when censused in 2010. Similar differences are found in Lesotho, Malawi, Namibia, Tanzania and Zimbabwe (NSO, 2008; ZimStat, 2012; ICF International, 2014).[1] Even though these differences are small and simply based on raw averages, they still raise the question: what drives this enrollment pattern?

This paper examines the role of the bride price custom in explaining girls' earlier enrollment. A bride price is a payment from the groom's family to the bride's parents, and possibly her extended family.[2] There are two underlying assumptions for why the bride price custom may influence the timing of school enrollment. First, the bride price payment is expected to be increasing in a girl's level of education (First, 1977; Mulder, 1995; LAC, 2005; MHRC, 2006; CREAW, 2013; Ashraf et al., 2016). Parents adhering to the bride price custom may therefore face higher returns to investing in their daughter's education. Second, if the bride price is also decreasing with non-virginity and previous childbearing, which previous studies suggest (LAC, 2005; Justiniano et al., 2005; MHRC, 2006; Mann et al., 2015; Ashraf et al., 2016), then it will also be advantageous to send the girls to school *on time*. Based on this, *(H1)* I expect that girls belonging to an ethnicity that historically has practiced the bride price custom (bride price girls) are more likely to enroll on time compared to boys from the same bride price ethnicities and *(H2)* compared to other girls (non-bride price girls). Lastly, *(H3)* I do not expect the bride price custom to affect boys.

I couple several rounds of the Demographic Health Surveys (DHS) from Namibia, Malawi, Mozambique, and Zambia (ICF International, 2014) with information on ethnicities' historical customs from the Ethnographic Atlas (Murdock, 1967; Gray, 1999). The choice of countries is selected based on the following conditions. First, in all countries there are ethnicities that practice the bride price custom and others that do not. Second, there exists individual-specific information on

[1] Mozambique seems to be an exception in southern Africa, the enrollment rate for girls aged 7-8 years is between one and two percentage points lower than boys' (INE, 2007; MPC, 2015). According to the most recent Demographic Health Survey for the individual countries, the female-favored gap in on-time enrollment is less common in western and central Africa, although with some exceptions. In East Africa girls are more likely to enroll on time in Burundi, Rwanda, Kenya, Madagascar and Tanzania, whereas not in Ethiopia. The bride price custom is the predominant marriage custom in these countries, with some exceptions. I discuss the choice of analyzed countries later in this section.

[2] The bride price custom is further discussed in Section 3.

ethnicity.[3]

I assess the likelihood of enrolling on time in primary school for 7-9 year old children. Specifically, I compare children within the same geographical areas[4] and survey rounds, while controlling for ethnicity- and household-specific factors. First, I find that 7-9 year old girls that belong to ethnicities that have historically practiced the bride price custom are more likely to enroll on time relative to boys from the same ethnicities in Malawi and Namibia. This is in line with *(H1)*. Second, for Mozambique and Zambia I find that girls are *less* likely to enroll on time than boys, but this only holds for the *non*-bride price ethnicities. Further, I find that bride price girls are more likely to enroll on time than other girls in Zambia and Namibia, which is in support of *(H2)*. Yet, Namibian boys belonging to bride price ethnicities are also more likely to enroll on time than other boys. Boys do not differ by the bride price custom in Zambia and Mozambique, in line with *(H3)*, whereas children from bride price ethnicities in Malawi are slightly less likely to enroll on time than other children. An underlying assumption for the bride price custom to affect the on-time enrollment decision is that girls from bride price ethnicities face higher returns to education in the marriage market compared to other girls. In consequence, they should also acquire more years of education. In line with this, I find that bride price teenage girls acquire on average more years of education compared to non-bride price teenage girls in all four countries. Importantly, the bride price custom may be correlated with other factors that affect education, whereby omitted variable bias is a potential threat. I therefore also assess whether there are other factors than the bride price custom that may explain the results.[5]

To my knowledge, this is the first paper to empirically assess whether the female-favored gap in on-time enrollment is driven by the bride price custom. A few studies have addressed this gap. Hoogeveen and Rossi (2013) hypothesize that Tanzanian girls enroll earlier due to a lower opportunity cost of time relative to that of boys, or that girls are more physically and mentally mature. They do not assess either explanation empirically.[6] Bommier and Lambert (2000) suggest

[3] To be precise, I use ethnicity for Malawi and Zambia and language for Namibia and Mozambique. The potential downside of using language is discussed in Section 7.4 and Appendix C. I hereon use the label ethnicity for convenience. According to the Ethnographic Atlas, there is also variation in the bride price custom in other African countries, such as Ethiopia, DR Congo, Nigeria, Madagascar and Zimbabwe. Information on ethnicity is however either lacking (e.g. Madagascar and Zimbabwe), or it has proven difficult to match ethnicities from the DHS with the Ethnographic Atlas (e.g. Ethiopia), or there is a limited number of ethnicities reported in the DHS (e.g. DR Congo) or too little variation in the share who do not practice the bride price custom (e.g. Nigeria).

[4] I use district borders from GADM (Global Administrative Areas) (http://gadm.org/) for Malawi and Zambia, provinces for Mozambique, and regions for Namibia. I will hereon refer to them all as districts.

[5] These are described in more detail in Sections 3 and 7.2.

[6] The role of physical and mental maturity is further discussed in Section 7.2.

two alternative explanations for the Tanzanian setting where the bride price custom is common. First, that boys face higher returns from out-of-school experience, such as farming and informal work. Parents therefore delay boys' enrollment so that they can accumulate more of this experience. Second, that the bride price custom induces girls' earlier enrollment. Bommier and Lambert (2000) assume that parents discount the future receipt of the bride price, whereby the present value of the bride price is higher when received earlier in life.[7] Based on this, the authors expect and find that parents enroll daughters earlier in school and keep them there for a shorter duration, relative to that of sons. They are unable to distinguish between whether these results are driven by the boys' experience hypothesis or the bride price-hypothesis, in part due to lack of variation in the bride price custom within Tanzania.

In a recent working paper Ashraf et al. (2016) examine girls' education in relation to the bride price custom. They distinguish between girls that belong to ethnic groups that have historically practiced the bride price custom (bride price girls) or not (non-bride price girls). Following an increase in the number of schools they find that the school enrollment for Zambian bride price girls aged 5-12 increases comparably more than for other girls. They make similar findings for Indonesia with regards to primary school completion.[8] Ashraf et al. (2016) argue that the stronger response is due to the bride price increasing in the level of education, which they confirm running a hedonic regression, thereby giving parents an additional incentive to invest in these girls' education. The same hedonic regression reveals that the bride price amount is decreasing in the bride's age. My analysis differs from Ashraf et al. (2016) on two main accounts. First, they investigate whether Zambian females aged 5-12 are more likely to be enrolled in school if they belong to a bride price ethnicity following school constructions. My focus is instead on the timing of the school enrollment decision, as well as the educational attainment. The large majority now enroll in school[9] and as such the results may be more relevant for policy-makers. The policy implications are discussed in the final section. Second, I examine this in four southern African countries, including Zambia, whereas Ashraf et al. (2016) focus on Zambia and Indonesia.

My contribution to the literature is twofold. First, the paper speaks to the literature on the timing of human capital investments (Moyi, 2010; Akresh et al., 2012; Seshie-Nasser and Oduro,

[7]They make no assumptions on the impact of eduction and age on the bride price amount, treating it as a lump-sum.

[8]As an aside they also compare boys and find a slight increase in enrollment for bride price boys relative to other boys in Zambia, and higher primary school completion rates for non-bride price boys in Indonesia.

[9]Between 93-96 percent of individuals aged 11-14 have ever attended school in the sample at hand.

2016). Second, it contributes to the literature on the impact of marriage practices on economic outcomes in Sub-Saharan Africa (Jacoby, 1995; Tertilt, 2005, 2006; Gaspart and Platteau, 2010; Ashraf et al., 2016).

The paper is organized as follows. I first describe the bride price custom in southern Africa and how it relates to education, upon which I outline a conceptual framework. This is followed by a description of the data and the empirical specification. Next, I present the main results. I continue with a discussion of these, as well as possible alternative explanations for the observed patterns and related caveats. The final section concludes.

2 The bride price custom and education

A bride price (or bride wealth) is a payment from the groom and his family to the bride's parents, and possibly her extended family. The custom has historically been observed in a wide range of settings and is still common in Asia and Africa. It is particularly widespread throughout Africa, where around 80 percent the ethnic groups in Sub-Saharan Africa have historically practiced this custom (Murdock, 1967; Gray, 1999).[10] Dowry, a payment from the bride's family to the groom's family, is more common in South Asia (Anderson, 2007).[11]

The bride price, commonly known as *lobola* in southern Africa, is typically paid in the form of cattle or other livestock, although there is a move towards paying in cash (First, 1977; SALC, 1998; ZLDC, 2002; LAC, 2005). Historically, the bride price has been instrumental in securing ties between families and has also reflected the rights transferred in terms of the woman's labor and reproductive capacity (Anderson, 2007). The groom and his family, at least in patrilineal societies, can also claim the right to keep the children upon divorce. In addition, men and women highlight the respect that a couple acquires as a result of the bride price being paid (MHRC, 2006; Tschirhart et al., 2016). That being said, the custom is also highly contentious,[12] and has been linked to domestic violence (Hague et al., 2011; Platteau and Gaspart, 2007). Nonetheless, over the past decades the custom has to a large degree been described as a means for compensating the parents

[10]Among the remaining ethnic groups in Sub-Saharan Africa, around 8 percent have historically practiced token bride price (i.e. a small gift), 6 percent have practiced bride service, and 4 percent are recorded as having practiced exchange of another woman for the bride.

[11]See Anderson (2007) for a detailed description of bride price- and dowry-paying societies. Typical differences pertain to the role of females in agriculture (Boserup, 1970) and polygyny (Tertilt, 2005), which is in line with Becker (1981)'s model on marriage markets, whereas both are positively associated with patrilineal descent rules. Patrilineal descent means that descent and possibly inheritance is traced through the father's kin.

[12]For instance, female respondents in Malawi were likely to compare the bride price custom to that of "buying a woman" (MHRC, 2006).

for raising and investing in their daughter (Mulder, 1995; CREAW, 2013; Ashraf et al., 2016).

Investment in education is one factor that the parents may be compensated for. According to various sources, individuals across southern Africa state that a more educated girl fetches a higher bride price, including in Namibia, Malawi, Mozambique, South Africa, Zambia and Zimbabwe (First, 1977; OMM, 1984; Ansell, 2001; Arnfred, 2001; Kaufman et al., 2001; LAC, 2005; MHRC, 2006; Shope, 2006; Thomas, 2007; Mushibwe, 2014; Ashraf et al., 2016).[13] These remarks are typically made with the understanding that the parents are compensated for their educational investments. When asked directly about the benefits of female education respondents in Zambia stated among other that it added value to the bride price (Mushibwe, 2014). A limited number of quantitative studies confirm that the bride price increases in education (Ashraf et al., 2016; Corno and Voena, 2016).

There are few studies that explicitly look at why education should matter in determining the bride price. Ashraf et al. (2016) is an important exception. They asked their respondents in Zambia on why the bride price increases with education. When unprompted, 55 percent responded along the lines that the "bride's parents should be compensated for investments", followed by around 15 percent that stated along the lines that it "improves the bride's skills in the house" or that it "improves the woman's earnings potential".[14] In line with this, Kaufman et al. (2001) conclude that a better educated woman is valued higher in part due to her improved opportunities in the labor market in South Africa. Likewise, Thomas (2007) attributes the increase in the bride price since 1990 in Namibia to women being better educated and facing more employment opportunities.

The relationship between age and bride price is less clear-cut. In addition to education, respondents also highlight the role of virginity, pregnancy, previous childbearing, and the girl's behavior and values in influencing the bride price (LAC, 2005; Justiniano et al., 2005; MHRC, 2006; Browning, 2013; Mann et al., 2015; Ashraf et al., 2016). Similarly, individuals also hold the view that too much education is undesirable as it delays marriage (Mushibwe, 2014). If the bride price increases if the bride is virgin and is reduced with previous childbearing, then this is more likely to be secured for younger brides, giving the parents an incentive to marry off early. Again, the quantitative

[13]For instance, a Mozambican respondent in the 1980s stated that "[w]hen a person thinks of the cost of raising the daughter, of sending her to school, to hospital, when calculating the lobolo he stipulates very exaggerated prices, with the aim of being compensated for the expenses he has incurred" (OMM, 1984; Arnfred, 2001).

[14]Around 12 percent state along the lines that it "improves the bride's knowledge and skills as a mother", and around 6-8 percent state along the lines that it "improves the literacy of children" and "is associated with her parents being rich". When probed specifically about each reason, 51 percent state that education increases the earning potential and 53 percent state that it improves children's literacy.

evidence is more limited. Hoogeveen et al. (2011) claim a negative relationship between bride price and age in Zimbabwe. Corno and Voena (2016)'s raw data from Tanzania shows no clear pattern, but after imposing controls the data indicates a positive, concave relationship. Ashraf et al. (2016) find instead that the bride price amount is decreasing in the bride's age in Zambia.

The size of the bride price varies across ethnic groups and settings, but may represent a substantial source of income. Dekker and Hoogeveen (2002) estimate that the bride price payment among resettled households in Zimbabwe constituted two to four times of household's annual gross income. In Kagera, Tanzania, the average bride price payment was around 43 USD, and the maximum at 468 USD (Corno and Voena, 2016). Recent data from Zambia indicate an average bride price payment equivalent to "182 percent of per capita GDP in the year of marriage", whereas the median was 72 percent of per capita GDP (Ashraf et al., 2016).[15] Households seem acutely aware of this potential source of income. For instance, a 25-year old respondent in Mzimba, northern Malawi, states that "[w]hen you bear female children, you count that you have a lot of cows" (C-Change, 2012). Respondents in Zambia state that receiving a bride price payment may relieve resource constraints, potentially also benefitting younger siblings' access to education (Mann et al., 2015). Further, Corno and Voena (2016) find an increased likelihood of early marriage for girls when households face a negative rainfall shock, and argue that the bride price payment is used to smooth consumption.

In general it is difficult to quantify the size of payments and how widespread the custom is today across southern Africa due to the paucity of data. Further, there is no clear pattern in terms of the custom's perseverance. Anderson (2007) claims that the prevalence of bride price payments has been on the decline in Africa following the end of the colonial rule, particularly in urban areas. On the other hand, Resnick (2015) finds that women, better educated individuals and urban residents are more likely to support the concept of bride price (*lobola*), although wealthier respondents are less likely to support it. MHRC (2006) conclude that around 60 percent of their sample of Malawian individuals support the bride price custom, while it is not clear how this differs in terms of socioeconomic characteristics. What one can ascertain is that the bride price custom is legal, despite hefty debates, and is an integral part of customary marriage law.

[15] Other examples include Casale and Posel (2010), who state that the average bride price payment between 1985-1998 was equivalent of close to 13 times the average monthly earnings of black men in South Africa in 1998. Average payments among Ugandan respondents constituted around 14 percent of household income (the authors do not state whether this is annual or monthly) (Bishai and Grossbard, 2006, 2008; Anderson, 2007).

3 Conceptual framework

The following builds largely on Glewwe and Jacoby (1995) and Bommier and Lambert (2000), and Becker (1993)'s seminal human capital model. The decision-makers on whether and when a child enrolls in school are the parents.[16] Parents rely on their children's future earnings upon retirement.[17] I am interested in when and for how long they send a specific child to school in order to maximize the child's discounted future income stream, after deducting school costs. The time-specific cost of schooling are school fees[18] and the opportunity cost of time, i.e. time foregone to income-generating activities. Credit markets are assumed to be perfect thus enabling parents to borrow if necessary. The child has no earnings prior to schooling, whereas the grown child is assumed to work from the age of school completion and up until retirement age. Earnings are then an increasing function of the education level and experience acquired after leaving school.

Upon leaving school the grown child is assumed to marry. Parents belonging to bride price ethnicities expect an additional source of income, i.e. the bride price payment, when their daughter marries. I assume that the parents belonging to a bride price ethnicity receive a bride price that will be increasing in their daughter's years of completed schooling. I also assume that the bride price is higher if the daughter is a virgin, which again is likely negatively related to age. In summary, parents face an incentive to send a daughter to school on time, so that by the time of marriage the daughter has maximized the number of years of schooling.[19] Hence, not only will the parents be willing to invest more in a daughter's education if they belong to a bride price ethnicity, but the timing of this investment is also important. Parents that do not belong to a bride price ethnicity do not face the same monetary returns to their daughter's education in the marriage market.[20] Similarly, parents do not face the same incentives for initiating an early investment in their sons'

[16]Although primary school is compulsory in many developing countries, it is often not enforced, as evident from the high share of children not enrolled in school on time.

[17]They have few other inter-temporal assets than their children's human capital to invest in.

[18]Officially there are no primary school fees in Mozambique and Malawi over the studied period, whereas there were fees during the early years for Zambia, and for the entire period for Namibia. However, parents report having to make voluntary payments, as well as financing school materials, and at times school uniforms. Continuation into secondary school involves a school fee in all four countries in the studied period.

[19]Data from the DHS confirms this. Less than two percent of the females aged 15-19 that are in school are married. These figures are in line with other studies (Baird et al., 2011).

[20]In the case of inter-ethnic marriages, at least in Zambia, the woman's customs typically apply in the marriage process (ZLDC, 2002). Further, the share of inter-ethnic couples is high. I identify the share of couples that involve two individuals from the same ethnicity based on the husband's and wife's reported ethnicity. Around 88, 61, 69, and 84 percent of these co-resident couples consist of co-ethnics in respectively Mozambique, Zambia, Malawi, and Namibia. Note that this refers to the share of cohabitant couples, they may not be married. An even higher share of the co-resident couples belongs to ethnicities that adhere to the same bride price custom (i.e. bride price or no bride price). This holds for 96, 84, 95, and 95 percent of the co-resident couples in respectively Mozambique, Zambia, Malawi, and Namibia.

education, regardless of bride price custom. Based on this, *(H1)* I expect girls belonging to an ethnicity that historically has practiced the bride price custom to be more likely to enroll on time compared to boys from the same bride price ethnicities, and *(H2)* compared to other girls. I do not expect the bride price custom to affect boys, *(H3)*.

Previous studies indicate that a number of the above explicit and implicit assumptions may not hold. First, I have characterized the parents as acting in their own pure self-interest. Yet, individuals are likely motivated by other preferences, such as altruism (see Fehr and Schmidt (2006) for a detailed discussion). Parents may choose to endow their child with human capital because they care about their child's future welfare, regardless of their own returns through old-age support.

Second, the timing of the enrollment decision may depend on other factors, such as children's physical and mental readiness at the age of official enrollment (Glewwe and Jacoby, 1995). Moreover, children may face (different) returns to work experience prior to attending school, i.e. out-of-school experience (Bommier and Lambert, 2000). More importantly, credit markets are not perfect in developing countries (Conning and Udry, 2007). If resources are scarce and parents are unable to borrow to finance education, then one child's education will depend on available resources (Jacoby and Skoufias, 1997) and other children and their received education (Jacoby, 1994; Glewwe and Jacoby, 1995; Bommier and Lambert, 2000).[21] Specifically, a child's birth order and the spacing between her and the previous birth may affect on-time enrollment if credit constraints are binding. Higher birth order children may benefit from older siblings' income, and possibly also that of the parents if this increases in the life cycle. More closely spaced siblings may on the other hand compete for the same resources. More broadly, the number of siblings may impact an individual's educational attainment, due to credit constraints/resource dilution and the trade off between the quantity of children and the quality of their human capital (Becker and Lewis, 1973; Becker and Tomes, 1976).

Third, parents may be unable to keep an individual in school due to supply side constraints. Fourth, the returns to education may be more nuanced. For instance, the extent to which parents expect to rely on old-age support may differ (Björkman-Nyqvist, 2013; Bau, 2014). Further, individuals may face different actual and perceived returns to schooling in the labor market, which again affect how much education the parents are willing to invest in (Jensen, 2010). The returns to education may also extend beyond the labor market, due to positive assortative mating in the mar-

[21] The sociology literature identify this as resource dilution, which also captures restrictions on the amount of parental time available (see Blake (1989)).

riage market (Becker, 1981; Boulier and Rosenzweig, 1984). Lastly, whether or not the grown child will marry may vary, thus introducing uncertainty into the returns to education in the marriage market, in particular for parents from bride price ethnicities.

I do not set up any explicit hypotheses regarding the above. Instead I address some of these issues in the main empirical analysis and discuss other issues in more detail in Section 7.

4 Data

4.1 Demographic Health Surveys

I use data from ten Demographic Health Surveys (DHS) (ICF International, 2014) to investigate my hypotheses. The DHS are randomly sampled cross-sectional national surveys that provide representative information at the region/district/province level. These have the advantage of observing a large number of individuals within the age category of interest. In addition, the DHS often include questions on ethnicity or language, yet this is only asked for women, aged 15-49, and a subsample of men in the same or a similar age group.[22] I refer to Appendix B for a further description of the ten DHS surveys used.

My main focus is on the children who reside with their mother. These children are assigned the same ethnicity or language as their mother.[23] This is done for three reasons. First, to reduce potential measurement error in terms of what ethnicity a child belongs to. Second, the bride price is largely given to the daughter's parents.[24] The incentives for sending girls to school may be less clear-cut for other relatives, such as grandparents or aunts and uncles. Third, I need information on the birth month to determine whether an individual is delayed or not, and this information is only available through the mother. However, results are largely unchanged when using a less strict measure for on-time enrollment and including all children that can be assigned an ethnicity based on the responses of household members that fall within the interviewed age category (see Section 6.2 and Appendix C). Selection issues are further discussed in Section 7.3.

[22]Whether all men or a subsample of men are interviewed in an age group varies between surveys. See Appendix B for details on the sampled age groups.

[23]Again, I hereon refer to both as ethnicity. Potential measurement error in ethnicity and language is further discussed in Section 7.4. I also refer to Appendix B for a discussion of the use of language where ethnicity is lacking and its appropriateness. On a different note, in the analysis I control for whether they report different ethnicities within the household.

[24]Historical claims indicate that the bride price went primarily to the parents, yet detailed data is rare. Data from Tanzania suggests that the parents received 57 percent of the payments made as part of a formal marriage process, whereas aunts, uncles, grandparents and brothers received 39 percent. Notably over 60 percent was paid in cash, followed by around 10 percent in livestock (De Weerdt et al., 2010).

For each survey round I identify the cohort of children for whom it is possible to ascertain whether they have started school on time or not. Children often repeat grades and therefore I cannot deduce starting age based on current grade. Instead, I combine information on the academic calendar, interview month, and birth month. The academic calendar follows the calendar year in all of the sampled countries, except for in more recent years in Malawi (EPDC, 2014a,b,c,d). From 2009 and onwards school in Malawi started in September and lasted until July in the following year. Children are supposed to enter school at the age of six, thus in the year they turn seven, in Namibia, Malawi and Mozambique, and at the age of seven in Zambia. I therefore limit my focus to those aged seven in the countries where the starting age is six, and to eight year olds in Zambia. In some surveys, they also ask about the previous school year, allowing an expansion of the age cohort to age eight (nine) in the countries where children start at age six (seven).

I employ the following approach for Namibia and Mozambique (Zambia): an individual who entered primary school prior to turning seven (eight) years old is defined as being on time.[25] Individuals who have turned seven (eight) years old and have entered school and will turn eight (nine) that year (birth month precedes interview month) are defined as on time. Individuals who have turned seven (eight) years old and are interviewed after the school year started (i.e. after January) and have not entered school yet, are defined as delayed.[26] Those who begin school for the first time in the year they turn eight (nine) are defined as delayed. For Malawi, I also have to take into account the shifting academic calendar. I use the same approach as above to identify who is on time or not for the two first surveys. For the third survey (year 2010), those born in September or earlier, are defined as delayed if they have not started primary school by the age of seven, whereas those born after September are delayed if they have not started school by the age of six.[27]

4.2 Ethnographic Atlas

Murdock's (1967) Ethnographic Atlas (EA) includes information on a large number of ethnicities and their customs across the world. The atlas is previously used within the economics discipline by among other Nunn and Wantchekon (2011); Fenske (2013); Michalopoulos and Papaioannou (2013) and Ashraf et al. (2016). I am primarily interested in the question on bride price. I use the latest

[25] I do not differ between individuals that started school on time and those that started earlier than the official age.

[26] Those that are born and interviewed in January, and thus have just turned seven (eight), and have not yet started school, may still intend to do so. These are excluded from the analysis (20 individuals).

[27] It has been difficult to ascertain what the current official age enrollment policy is in Malawi. I also use January as the cut-off (rather than September) to see whether results are robust to this. See Appendix C for details.

version, compiled by Gray (1999). Using the question on "mode of marriage", I separate between ethnicities that practice "bride price or wealth, to bride's family" from the remaining ones. These encompass the "bride price" versus the "no bride price" samples. This is in line with Ashraf et al. (2016)'s approach. The ethnicities that enter into the "no bride price" sample either pay token price (a small symbolic payment), undertake bride service or a gift exchange, or are registered with "absence of consideration". Obviously, the Ethnographic Atlas is not without its issues, including that the customs may no longer apply to my sample and/or that ethnicities are wrongfully coded at the time of its making. I return to these issues in Section 7.4.

The bride price may correlate with other factors that affect parents' investments in girls' and boys' education. In line with Ashraf et al. (2016), I use information from the Ethnographic Atlas (Murdock, 1967; Gray, 1999) to control for whether an ethnicity is matrilineal[28] and whether females are central in agricultural production. Matrilineal descent is correlated with matrilocality[29], which again is found to be positively associated with more girls than boys being enrolled in school in Indonesia (compared to neo- and patrilocality) (Bau, 2014).[30] The bride price custom is also correlated with females' participation in agriculture, as the value of adding or losing a woman to the household is greater (Boserup, 1970; Anderson, 2007). I create the variable *Female agriculture* that is set equal to 1 for the alternatives "females appreciably more" and "females only", whereas the other responses for the sampled ethnicities ("males appreciably more" and "differentiated but equal participation") are coded as 0. Polygyny is also argued to correlate with the bride price custom, since there may be greater competition for women in the marriage market (Anderson, 2007). All the ethnicities matched with the sampled households, with the exception of three ethnicities of European descent, are found to practice some form of polygyny (Murdock, 1967; Gray, 1999). These exceptions are also the only ethnic groups that practiced plow aboriginally. This is important to control for as the practice of plow may reduce the value of women relative to men (Boserup, 1970; Alesina et al., 2013). I include a control variable for polygyny. Since the role of matrilineal descent, female's involvement in agriculture and polygyny is likely to differ by gender, I also interact these with the female variable.

[28] Descent and possibly inheritance is traced through the mother's kin.

[29] Upon marriage, the couple settles in or around the wife's, rather than the husband's, village.

[30] The opposite pattern is found for those adhering to patrilocality (versus neolocality) in Ghana and Mexico (Bau, 2014).

4.3 Combining the Demographic Health Surveys and the Ethnographic Atlas

I use several sources of data in order to match the ethnicities reported in the DHS with those recorded in the Ethnographic Atlas (Murdock, 1967; Gray, 1999). I first attempt a direct match. Next, I consider Nunn and Wantchekon (2011)'s match between the 2005 Afrobarometer surveys and Murdock's (1959) map. Third, I consider Fenske's ethnicity matches between the EA and the DHS. Fourth, I use the Ethnologue catalogue (Lewis et al., 2016), the Glottolog (Hammarström et al., 2013) and the New Updated Guthrie List (Maho, 2009). Lastly, if unsuccessful in matching based on the above, I use country-specific sources, such as Kaplan and Baldauf (1999).

I am able to match all but four of the unique ethnicities reported in the DHS to an identical or related ethnicity in the EA. For Malawi, I match all 12 ethnicities in the DHS to nine ethnicities in the EA; eight of which I have information on female's involvement in agriculture. For Zambia, there are 62 different ethnicities reported, of which I am able to match all but one to 27 ethnicities in the EA (including those who claim English descent).[31] For Mozambique, I match 19 out of 20 language groups with 13 ethnicities in the EA (including the Portuguese-speakers).[32] For Namibia, I match seven out of nine language groups to six in the EA (including Boers and those of English descent). Seven ethnicities are observable in two different countries. I am thus left with the ethnicities from the DHS being matched with 48 different ethnicities in the EA. Three of the four ethnicities that are unaccounted for cover less than one percent of the country sample for whom I know the mother's ethnicity. The fourth group, the Kwangali-speakers in Namibia, is relatively large and is further discussed in Section 6.2. In addition, there are individuals who have reported an ethnicity that is categorized as "other" in the DHS. The share of adults reporting this varies between 1 and 5 percent depending upon the country and survey round in question.

4.4 Descriptive statistics

Summary statistics for the pooled sample are reported in Table 1. For country-specific summary statistics I refer to Tables A1 and A2.[33] Although primary school is compulsory in three out of

[31] I have information on female's involvement in agriculture for 22 of these. In comparison, Ashraf et al. (2016) state that they match 53 out of 65 ethnic groups with 30 ethnicities in the EA. They use the same DHS surveys for Zambia in addition to an earlier round.

[32] I have information on females' involvement in agriculture for eight of these.

[33] The information on customs for the sample whose ethnicity is identified through the parent is incomplete. In the case of Malawi, these are coded with ethnicity "other" in the DHS. In the Mozambican and Zambian samples, the Ethnographic Atlas lacks information on female's involvement in agriculture for several ethnicities. In the case of Namibia, over half of those with missing information belong to one ethnic group, a small share with a second ethnicity, whereas the remaining are coded as "other". See Section 6.2 and Appendix C for a discussion of the Namibian sample.

four countries (Zambia is the exception), only 73 percent enroll in the year that they are expected to. Around one-quarter of the individuals belong to ethnic groups that have historically adhered to the bride price custom,[34] whereas 63 percent belong to an ethnicity that has historically followed matrilineal descent rules. Around 78 percent of the children belong to ethnicities where females contribute substantially in agriculture ("female agriculture"), keeping in mind that this information is lacking for some ethnicities. In total, around 76 percent of the observed children reside in rural areas. The pooled sample is dominated by individuals from Malawi,[35] followed by Zambia.

Table 1: Summary statistics, pooled sample

Variable	Mean	Std. Dev.	Min.	Max.	N
On-time enrollment	0.731	0.443	0	1	18575
Age*	7.634	0.628	7	9	18575
Female	0.501	0.5	0	1	18575
Household head's years of education*	5.676	4.085	0	20	18565
Wealth index*	2.953	1.393	1	5	18575
Child of head	0.877	0.328	0	1	18575
Grandchild of head	0.06	0.238	0	1	18575
Female household head	0.246	0.431	0	1	18575
Rural	0.762	0.426	0	1	18575
Bride price	0.244	0.43	0	1	17771
Matrilineal	0.625	0.484	0	1	17771
Female agriculture	0.784	0.411	0	1	15768
Polygyny	0.977	0.151	0	1	17771
Mozambique	0.078	0.268	0	1	18575
Malawi	0.538	0.499	0	1	18575
Namibia	0.111	0.315	0	1	18575
Zambia	0.273	0.445	0	1	18575

Notes: All variables are binary (1=yes, 0=no) with the exception of *. These are continuous.

There is substantial variation in terms of the share of children belonging to bride price or non-bride price ethnicities within a given district. Around two percent of the observed children reside in districts where none of the children are identified as belonging to a bride price ethnicity, whereas just over four percent reside in districts where all are identified as belonging to bride price ethnicities. The remaining reside in districts with children from both bride price customs.

The overall selection issues are discussed in Section 7.3.

[34]Among those who do not practice the bride price custom, around 40 percent belong to ethnic groups that have historically paid bride service upon marriage, whereas around 24 percent have paid token bride price.

[35]This is in part because the initial sample size of households is larger, but also because all three surveys include questions on schooling in both the current and the previous year.

5 Empirical specification

I use a linear probability model to analyze the on-time enrollment decision:[36]

$$\begin{aligned} \text{on-time}_{ieds} = \alpha_0 + \alpha_1 \text{female}_{ieds} + \alpha_2 \text{BP}_e + \alpha_3 \text{BP}_e \times \text{female}_{ieds} \\ + \mathbf{Z}_e' \boldsymbol{\theta} + \mathbf{X}_{ieds}' \boldsymbol{\delta} + v_d + \lambda_s + \mu_{ieds}, \end{aligned} \tag{1}$$

where on-time$_{ieds}$ is a binary variable set equal to 1 if an individual i belonging to ethnicity e in district d in survey s is enrolled in school on time, and 0 if not. female$_{ieds}$ is an indicator set equal to 1 for females, 0 otherwise. BP$_e$ is a binary variable capturing whether an individual belongs to a bride price ethnicity (=1) or not (=0), and BP$_e$x female$_{ieds}$ is an interaction between the two. $\mathbf{Z}_e$ is a vector of ethnicity-specific control variables, including female's historical involvement in agriculture, whether the ethnicity has historically followed matrilineal descent rules, whether the ethnicity has practiced polygyny, and interactions between these and the female variable. I also include a binary variable for whether information on females' involvement in agriculture is missing. $\mathbf{X}_{ides}$ includes a set of controls, such as the individual's age, a dummy for rural residence and whether household members report different ethnicities. I also step-wise include controls for other characteristics that may impact the household's incentives for investing in children's schooling. These are education level and gender of household head, a household wealth index[37] and whether the child in question is the child or grandchild of the head. v_d are district fixed effects[38] and λ_s are survey fixed effects. μ_{ieds} is a mean zero error term, and standard errors are clustered at the ethnicity level so as to allow for correlations within ethnicities.[39] The fixed effects approach ensures that I am comparing girls and boys residing in the same district and interviewed in the same survey round. District-specific characteristics, such as access to schools, and general changes in school costs[40] across the survey years should therefore not affect the results. Further, the district fixed effects also capture differences in the average expected marriage age within these geographical areas.

In terms of the hypotheses stated in Section 3, I expect girls from bride price ethnicities (bride price girls) to be more likely to enroll on time compared to boys from bride price ethnicities (bride

[36] Results are similar when using a logit (available upon request).

[37] The wealth index is created by the DHS using information on assets owned, housing material, and sanitation and water access. It ranges between 1 (poorest) and 5 (richest).

[38] These differ between 11 (provinces) in Mozambique, 13 (regions) in Namibia, 26 in Malawi and 72 in Zambia.

[39] As noted, there are at the most 27 ethnicities in a country.

[40] Only Zambia experienced a change in school fees over the studied period. Controlling for the year interviewed rather than survey round does not alter the results (available upon request).

price boys), i.e. $\alpha_1 + \alpha_3 > 0$ *(H1)*, and compared to other girls, i.e. $\alpha_2 + \alpha_3 > 0$ (*H2*). I do not expect boys to differ by the bride price custom, i.e. $\alpha_2 = 0$ *(H3)*. Since I expect $\alpha_2 = 0$, hypothesis *(H2)* can also be boiled down to $\alpha_3 > 0$.

6 Results

6.1 On-time enrollment

The relationship between the bride price custom and on-time enrollment may differ across countries and I therefore run separate country-specific regressions.[41] Results are reported in Table 2. Simply regressing female on on-time enrollment confirms the female-favored gap in Zambia, Malawi and Namibia (Panels B, C and D, columns 1 and 2). Column 1 consists of the entire sample of children for whom it is possible to ascertain whether they are enrolled on time or not (standard errors are clustered at the district level), whereas column 2 consists of all children for whom I know the ethnicity of the mother (standard errors are clustered at the ethnicity level). Importantly, these initial results are robust to controlling for household-level variables (see Table A4). Next, I differentiate by bride price custom (column 3 and 4) and impose ethnicity- (column 5) and household-level (column 6) controls, thereby reducing the sample size to those for whom this information is available. The specification from eq. (1) is reported in column 6.

I expected bride price girls to enroll earlier than bride price boys *(H1)* ($\alpha_1 + \alpha_3 > 0$). The estimated coefficients on female and the interaction between female and bride price are jointly significant for all four countries (column 6). However, the coefficient signs are opposite from what I expected in the case of Mozambique and Zambia (Panels A and B). Specifically, bride price girls are *less* likely to enroll on time than bride price boys. On the other hand, the female-favored gap remains in Malawi, but it seems to hold regardless of bride price custom (Panel C). Girls are around 2.6 percentage points more likely to enroll on time compared to boys in Malawi. Interestingly, the opposite relationship emerges in Mozambique (Panel A). Whereas I previously found no difference by gender in on-time enrollment, I find a male-favored gap when controlling for bride price custom. Lastly, the female-favored gap seems to vanish in Namibia, although the variables' joint significance may imply that bride price girls enroll earlier than bride price boys (Panel D).

[41] In order of comparison the results from the pooled sample are reported in Table A3.

Table 2: Probability of enrolling in primary school on time, by country

Sample	Bride price (BP) and non-bride price (no BP) ethnicities						BP	No BP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Mozambique								
Female	0.006	0.006	0.003	0.006	0.006	-0.027***	-0.056	-0.035***
	(0.032)	(0.033)	(0.032)	(0.033)	(0.008)	(0.008)	(0.081)	(0.004)
Bride price			0.020	0.118*	0.100*	0.030		
			(0.044)	(0.065)	(0.050)	(0.037)		
Female x Bride price					0.027	0.027		
					(0.048)	(0.050)		
Number of Obs.	1447	1447	1431	1431	1431	1429	528	901
Mean of Dep. Var.	0.69	0.69	0.69	0.69	0.69	0.69	0.84	0.60
Panel B: Zambia								
Female	0.028**	0.031*	0.031*	0.031*	-0.130***	-0.115***	-0.002	-0.092*
	(0.012)	(0.017)	(0.017)	(0.017)	(0.017)	(0.021)	(0.011)	(0.044)
Bride price			0.017	0.022	0.000	-0.011		
			(0.019)	(0.015)	(0.021)	(0.013)		
Female x Bride price					0.042**	0.041**		
					(0.017)	(0.017)		
Number of Obs.	6580	5062	4968	4968	4968	4966	1371	3595
Mean of Dep. Var.	0.64	0.66	0.65	0.65	0.65	0.65	0.69	0.64
Panel C: Malawi								
Female	0.035***	0.034***	0.032***	0.032***	0.041***	0.026**	0.052***	0.019
	(0.007)	(0.005)	(0.005)	(0.005)	(0.012)	(0.009)	(0.004)	(0.011)
Bride price			0.039**	0.012	0.015	-0.014*		
			(0.016)	(0.012)	(0.013)	(0.007)		
Female x Bride price					-0.007	-0.006		
					(0.005)	(0.005)		
Number of Obs.	13268	9997	9532	9532	9532	9531	1478	8053
Mean of Dep. Var.	0.77	0.78	0.78	0.78	0.78	0.78	0.89	0.76
Panel D: Namibia								
Female	0.025**	0.044***	0.042***	0.041***	0.038	0.035	0.040***	0.041
	(0.010)	(0.009)	(0.008)	(0.008)	(0.026)	(0.025)	(0.001)	(0.024)
Bride price			0.055*	0.093***	0.110***	0.091**		
			(0.027)	(0.020)	(0.027)	(0.027)		
Female x Bride price					-0.032**	-0.021		
					(0.011)	(0.014)		
Number of Obs.	4181	2322	1840	1840	1840	1836	953	883
Mean of Dep. Var.	0.66	0.69	0.68	0.68	0.68	0.68	0.70	0.66
Ethnicity level controls	N	N	N	Y	Y	Y	Y	Y
Household level controls	N	N	N	N	N	Y	Y	Y

Notes: Linear probability models. Dep.var.: Enrolled in primary school on time (yes=1, no=0), compared to country's official starting age. All reported variables are binary (1=yes, 0=no). *Bride price* indicates that the child's mother is part of an ethnicity that has historically practiced the bride price custom or not, identified using Murdock's (1967) Ethnographic Atlas. Samples of 7-9 year old children: column 1: all, column 2: whose ethnicity is identifiable through the mother, columns 3-6: whose mother's ethnicity is matched to a bride price custom, column 7: whose mother's ethnicity practices the bride price custom, column 8: whose mother's ethnicity does not practice the bride price custom. Standard errors clustered at district level in column 1, and clustered at ethnicity level in columns 2-8. Controls for age, district, rurality, and survey round are included throughout. Ethnicity level controls are matrilineal descent (except in Panel A), whether females are central in agriculture, polygyny, interactions with these and female, and a control for missing information on females' involvement in agriculture. Household level controls are gender and education of household head, whether individual is child or grandchild of head, and the wealth index. Source: DHS surveys for Mozambique, Zambia, Malawi and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Column 6 also indicates that girls belonging to bride price ethnicities (bride price girls) are more likely to enroll in school on time relative to other girls in Zambia (Panel B) and Namibia (Panel D). This lends support to *(H2)* ($\alpha_2 + \alpha_3 > 0$). The estimated coefficients on bride price and the interaction between bride price and female are jointly significant for both Zambia and Namibia. Yet, Namibian bride price boys are also more likely to enroll on time than other boys, resulting in a rejection of the hypothesis that boys do not differ by the bride price custom, i.e. *(H3)* ($\alpha_2 = 0$). There is in others limited evidence on bride price girls being more likely to enroll on time than other girls.

I examine the pattern in more detail by splitting the sample by bride price custom (columns 7 and 8). The results suggest that the male-favored gap in Mozambique and Zambia is driven by children in the non-bride price sample (Panels A and B), whereas the female-favored gap in Malawi seems to be driven by the bride price sample (Panel C). Similarly, a statistically significant female-favored gap emerges in Namibia in the bride price sample (Panel D). Thus, there seems to be support for *(H1)* in Malawi and Namibia. Moreover, although I do not find that bride price girls enroll earlier than bride price boys in Mozambique and Zambia, it is striking that the male-favored gap only emerges in the *non*-bride price sample.

An important caveat with the analysis for Mozambique is that it does not include a control for matrilineal descent. Patrilineal descent is perfectly correlated with the bride price custom for the ethnicities that practice polygyny. How descent rules may affect on-time enrollment (and education) is not clear-cut, as there is no clear pattern across the other three countries. It is therefore difficult to establish whether the coefficient on bride price and the interaction between female and bride price is over- or underestimated.

6.2 Robustness checks

I undertake a number of robustness checks that are discussed in detail in Appendix C. The results are robust to *(i)* excluding the few children who left school early, *(ii)* including the Kwangali-speakers in Namibia,[42] *(iii)* controlling for the mother's education, which may influence their preferences for education, *(iv)* controlling for district-specific school feeding programs targeting girls, and *(v)* controlling for ethnic affiliation with the president. *(vi)* Changing the definition of on-time in Malawi

[42] This is the relatively large group that I was unable to match with the Ethnographic Atlas.

in the year with an altered school calendar[43] results in the female-favored gap being no longer statistically significant in the pooled Malawian sample, but remains so in the bride price sample (see Appendix C for more details). The gap in on-time enrollment may be driven by differences in the likelihood of ever enrolling *(vii)*, but I find that there are few systematic differences by gender and bride price custom (see Appendix C). The results are robust to *(viii)* using a less strict measure of on-time enrollment, where all children who attend school at the age of seven (eight) in Namibia, Malawi and Mozambique (Zambia) are defined as on time, whereas those that do not are delayed. This allows for including children regardless of information on birth month. Specifically, I include individuals who reside with their father only, thereby identifying the ethnicity through him. Lastly, *(ix)* the results are robust to identifying the bride price custom through another household member's ethnicity than that of the mother or father. The exception is Namibia. I previously only found a statistically significant female-favored in the bride price sample, whereas now this also emerges in the non-bride price sample (see Appendix C).

6.3 School progression by gender, mother fixed effects

I seldom observe multiple siblings around the official age enrollment rule. As a consequence, the results reported so far rely on differences between households rather than within. Households with girls in the age group of interest may differ from households with boys. I therefore explore whether the female-favored gap holds for siblings as the children progress through primary school. If girls and boys have the same distribution of age-specific abilities and face the same likelihood of repeating grades, then any observed difference in the likelihood of being on track is likely related to the on-time enrollment decision. In other words, those that are on track are also more likely to have started on time. I use the entire sample of primary school individuals[44] and investigate whether girls are more likely to be on track, controlling for mother fixed effects.[45] I define an individual as being on track if the current grade minus seven is lower or equal to the highest year completed, and as not

[43]As stated in Section 4.1, the academic calendar changed over the course of the studied period, from January-December to September-July. It has been difficult to ascertain what the official rules are for enrollment under the new rules, i.e. whether children are supposed to enroll in school in the year they turn seven, or by for instance September.

[44]Children aged 7-14 (8-15) in Mozambique, Malawi and Namibia (Zambia). To be precise, I use children aged 8-15 in two out of three surveys for Zambia, since the first one (ZM4) only identifies the mother of children below age 15.

[45]The reduction in sample size from the "All" column to the combined "BP" and "No BP" columns within a given country is due to the following: (i) either because the mother reported "other" or an unmatched ethnicity, or (ii) that the child's mother is claimed to reside in the household, but the mother is not identified in the women's questionnaire, which is the source of information on ethnicity. Excluding the children of mothers who were not identified using the women's questionnaire (ii), or using household fixed effects rather than mother fixed effects, results in the same pattern of results (available upon request).

on track if it exceeds the highest year completed. I use age eight instead of seven for Zambia.

Results are reported in Table A5. As seen from column 1, girls are more likely to be on track in school relative to their brothers in Zambia, Malawi and Namibia. There is no statistically significant difference by gender in Mozambique. Next, I split the sample by the mother's bride price custom (columns 2 and 3). The female-favored gap is only observed for the bride price sample in Zambia and Namibia, whereas there is a gender difference in both the bride price and non-bride price samples in Malawi. Further, there is suggestive evidence that bride price girls are more likely to be on track than their brothers in Mozambique. In summary, the female-favored gap in on-time enrollment does not seem to be an artifact of comparing boys and girls from different households. Moreover, girls seem to be more prioritized in households that are likely to adhere to the bride price custom than in other households.

6.4 Educational attainment

I expected bride price girls to be more likely to enroll on time than boys and non-bride price girls under the assumption that the parents want to maximize these girls' years of education prior to marriage. In consequence, I would expect girls from bride price ethnicities to acquire more years of education at a given age than other girls. The difference between bride price girls and boys is more complex. Educational investments by gender will also depend on other factors, such as preferences and returns in the labor market.

I compare the number of years of completed schooling for the age group 15-19.[46] These individuals should have completed primary school had they enrolled on time and progressed through school as intended. Country-specific results are reported in Table 3. In all four countries I find that teenage girls belonging to bride price ethnicities have acquired on average more education relative to other girls (column 2). This is robust to controlling for household-level characteristics (column 3). The estimated coefficients on bride price and the interaction between bride price and female are jointly significant for Mozambique, Zambia, Malawi, and Namibia. However, whereas there is no difference by bride price custom for teenage boys in Mozambique, Zambia and Malawi, the teenage boys from bride price ethnicities in Namibia have acquired on average more years of education compared to other boys. In other words, there is a systematic difference in years accumulated by bride price custom in Namibia. This falls in line with the previous findings on on-time enrollment.

[46] In order to reduce potential sample selection bias I only include individuals that are themselves interviewed, excluding those for whom I only know the ethnicity through their mother.

Namibian children from bride price ethnicities, regardless of gender, were more likely to enroll on time than other children.

Interestingly, there is only a statistically significant male-favored gap among 15-19 year olds in Zambia, whereas Namibian teenage girls have acquired more years than their male counterparts (column 3). Splitting the samples by bride price custom confirms this pattern (columns 4 and 5).[47]

I have compared individuals aged 15-19 that live within the same district. Yet, they may have moved between districts and thus been exposed to different school supply. On the other hand, examining those who have always resided in the same location may result in a very select sample of individuals. Individuals may for instance have moved in order to pursue a higher level of education, whereby only the least educated are staying behind. Nevertheless, restricting the age group 15-19 to those who have resided in the same location since the age of five (thus prior to official school start) results in largely the same results, see Table A6.[48]

7 Discussion and caveats

7.1 Does the bride price custom explain the pattern of results?

There is suggestive evidence that the initial female-favored gap in on-time enrollment is driven by the bride price custom in Malawi and Namibia. Further, although I do not find that bride price girls in Mozambique and Zambia are more likely to enroll on time than bride price boys, I do not find that they are disfavored either, as is the case for the non-bride price samples. The bride price custom may as such be canceling out other disadvantages that girls face in terms of enrolling on time. On the other hand, girls are more likely to be on track relative to their brothers in the bride price samples in all four countries (and in the non-bride price sample in Malawi). Whether this is due to an active prioritization by the parents or other reasons remains unanswered. Nevertheless, by ages 15-19 girls and boys have acquired on average the same years of education in Mozambique, whereas girls are lagging behind in Zambia and leading in Namibia. Thus, although girls may be leading initially, boys are still likely to catch up and possibly surpass girls, in terms of final educational attainment.

[47]Males are more likely to remain in school past this age in Mozambique, Zambia and Malawi (see Table A7). Examining those aged 20-24 reveals a male-favored gap in educational attainment in Mozambique, Malawi, and in the Zambian bride price sample (see Table A8). Namibian women have acquired on average half a year more of education than men. The differential pattern for women by bride price custom remains largely unchanged.

[48]Information on how long an individual has resided in a location is not available for Mozambique.

Table 3: Number of years of completed schooling, by country, ages 15-19

Sample	Bride price (BP) and non-BP ethnicities			BP	No BP
	(1)	(2)	(3)	(4)	(5)
Panel A: Mozambique					
Female	-0.246***	-0.248***	0.054	-0.190	0.084
	(0.030)	(0.030)	(0.044)	(0.123)	(0.058)
Bride price	0.670*	0.072	-0.256		
	(0.334)	(0.312)	(0.225)		
Female x Bride price		0.797***	0.809***		
		(0.228)	(0.162)		
Number of Obs.	3820	3820	3797	1326	2471
Mean of Dep. Var.	5.73	5.73	5.71	6.07	5.52
Panel B: Zambia					
Female	-0.753***	-0.754***	-0.306***	-0.392**	-0.332***
	(0.044)	(0.044)	(0.047)	(0.132)	(0.064)
Bride price	0.210*	0.092	-0.023		
	(0.103)	(0.088)	(0.087)		
Female x Bride price		0.205*	0.266**		
		(0.109)	(0.121)		
Number of Obs.	12009	12009	11979	3366	8613
Mean of Dep. Var.	6.92	6.92	6.92	7.04	6.87
Panel C: Malawi					
Female	-0.046	-0.176	-0.163	-0.135*	-0.077
	(0.166)	(0.142)	(0.124)	(0.036)	(0.167)
Bride price	0.678	0.490	0.100		
	(0.386)	(0.353)	(0.223)		
Female x Bride price		0.246**	0.357***		
		(0.091)	(0.064)		
Number of Obs.	12905	12905	12883	2287	10596
Mean of Dep. Var.	5.95	5.95	5.94	7.13	5.69
Panel D: Namibia					
Female	0.168***	0.168***	0.170***	0.144***	0.154***
	(0.015)	(0.015)	(0.032)	(0.011)	(0.033)
Bride price	0.130**	0.718***	0.177***		
	(0.168)	(0.161)	(0.122)		
Female x Bride price		-0.267	-0.281*		
		(0.161)	(0.130)		
Number of Obs.	6780	6780	6753	4327	2426
Mean of Dep. Var.	7.73	7.73	7.72	7.56	8.01
Ethnicity level controls	Y	Y	Y	Y	Y
Household level controls	N	N	Y	Y	Y

Notes: OLS. Dep. var.: Number of years of completed schooling. All reported variables are binary (1=yes, 0=no). Sample: 15-19 year old individuals whose reported ethnicity is matched with the Ethnographic Atlas. *Bride price* indicates that the individual's ethnicity has historically practiced the bride price custom (BP) or not (No BP), identified using Murdock's (1967) Ethnographic Atlas. Standard errors clustered at ethnicity level in parentheses. Controls for age, district, and survey included throughout. Ethnicity level controls are matrilineal descent (except in Panel A), whether females are central in agriculture, polygyny, interactions with female and a control for whether information on females' involvement in agriculture is missing. Household level controls are gender and education of household head, whether individual is child or grandchild of head, and the wealth index. Source: DHS surveys for Mozambique, Zambia, Malawi and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

As expected, I find that bride price girls are more likely to enroll on time than other girls in Zambia and Namibia. Yet, bride price boys are also enrolling earlier than other boys in Namibia. Further, there is suggestive evidence that bride price children are less likely to enroll on time than other children in Malawi. The limited support for (*H2*), i.e. that bride price girls enroll earlier than non-bride price girls, may relate to the risk of pregnancy. Girls that have reached puberty are at risk of becoming pregnant. Further, a daughter's pregnancy will affect her educational attainment as dropping out is still the norm, despite changes in the official policy.[49] The risk of pregnancy in preventing continued education increases with age, giving all parents an incentive to send daughters to school on time. Males do not face the same risk. If they impregnate a girl then this is less likely to result in school drop-out.[50] Then again, girls are less likely to enroll on time than boys in the non-bride price samples in Mozambique and Zambia. If the pregnancy-hypothesis applies, then there must be other factors that overshadow this effect.

I hypothesized that the bride price custom does not affect boys' enrollment, i.e. *(H3)*. As noted, I find support for this in Zambia and Mozambique, but not in the two other countries. An underlying assumption is that the investment in boys' education is unaffected by the bride price custom. There is no evidence to suggest that mens' age itself affects the size of the bride price payment, but the age at which males leave school may impact their marriage age. It is difficult to ascertain whether a son's early marriage is a desirable outcome for the parents. However, the age for first cohabitation, which often involves marriage,[51] is on average 2-6 years later for men than for women in a given country (see Table A9).[52] This may suggest that men are in less of a hurry to marry. On the other hand, men's education level may impact both their ability to finance the bride price payment, especially if they are expected to finance this themselves, and possibly also the final bride price amount. Yet, with the exception of Namibia, I do not find that males from bride price ethnicities acquire on average more years of education than other males. There is thus less reason to suspect

[49]Evidence from Kenya and Malawi support this claim (Baird et al., 2011; Duflo et al., 2015). In the pooled sample, 4 percent of girls aged 15-19 that are currently in school have given birth, whereas 11 percent of those that have given birth are in school. According to the most recent DHS for each country, 38.7, 25.7, 21.7, and 17.5 percent of 17 year olds have begun childbearing in respectively Mozambique, Zambia, Malawi, and Namibia, respectively. These figures on childbearing do not reveal whether the pregnancy is followed by school drop-out, or whether girls first leave school and then become pregnant. However, they do indicate that teenage pregnancy is a common phenomenon, potentially affecting parents' decision on when to send their daughters to school.

[50]Girls are more likely to drop out due to pregnancy than boys in all four countries (INE, 2008; CSO, 2010; EMIS, 2013a,b).

[51]The DHS does not ask at what age an individual married, only at what age they first cohabited.

[52]Females do not seem to differ by bride price custom (if anything they are slightly older in Malawi and Namibia), whereas men belonging to bride price ethnicities in Malawi and Namibia are on average older when they first cohabit compared to other men (Table A9). This latter finding may relate to the need to accumulate savings for the bride price payment, in line with Casale and Posel (2010).

that the bride price custom is affecting males' education.

Moving on to females' educational attainment, I find that Zambian bride price teenage girls have acquired on average more years of education relative to other bride price teenage girls. This is in line with the findings on on-time enrollment. However, I also find the same pattern on educational attainment in Mozambique and Malawi. This may imply that the bride price girls face higher returns in the marriage market, but that the timing of the investment is less of an issue. Importantly, a similar pattern is not found for the males in these three countries. Again, Namibian bride price teenagers acquire on average more education than others, regardless of gender.

In summary, there is mixed evidence on the extent to which the bride price custom explains the pattern of results. I continue by examining other possible explanations for the observed patterns in on-time enrollment and educational attainment. I do not attempt an exhaustive analysis of all the factors that are associated with these outcomes, but focus on those that may pertain to gender and the bride price custom.

7.2 Alternative explanations

7.2.1 Out-of-school experience

Bommier and Lambert (2000) propose that boys face higher returns to out-of-school experience, such as farming or pastoralism, causing parents to delay boys' school enrollment in Tanzania. Historically, African ethnicities have paid the bride price in the form of cattle. Cattle-keeping is typically a responsibility delegated to boys. If bride price ethnicities are more likely to have cattle,[53] and boys are responsible for these animals, then this may in part explain bride price boys' slightly higher probability of being delayed in Malawi.[54] I investigate the out-of-school experience hypothesis for Malawi by assessing the amount of time that 7 and 8 year olds spend on different activities while imposing the same set of controls as in the main analysis.[55] Results are reported in Table A10.[56] Girls spend on average 1.5 hours more per week on work than boys, whereas bride

[53]The last DHS survey rounds include information on livestock ownership. In all four countries, households headed by individuals belonging to bride price ethnicities are more likely to have livestock, relative to others. This also holds when controlling for district fixed effects (results not reported).

[54]As seen from Table 2, boys do not differ in their on-time enrollment based on bride price status in Mozambique and Zambia, whereas in Namibia the relationship is positive.

[55]Two of the three surveys for Malawi (MW3 and MW4) include a component on child labor. This is lacking from the other country surveys. Unfortunately, these same two surveys lack information on cattle ownership, so I cannot assess whether boys are working more in households that own cattle. The survey (MW5) that includes information on cattle ownership does show a larger likelihood of cattle ownership among household heads belonging to bride price ethnicities relative to others.

[56]Results are reported using the sample of individuals whose ethnicity is identified through the mother. Using the

price boys spend on average around 1.7 hours more per week working, relative to non-bride price boys (column 4). The small number of hours spent per week seems unlikely to explain why bride price boys are sightly more likely to be delayed than non-bride price boys. Further, splitting the sample by bride price custom reveals that bride price girls work on average more than bride price boys (column 5). This suggests that the out-of-school experience is not driving the female-favored gap in on-time enrollment in the bride price sample in Malawi.

7.2.2 Nutritional status

Previous studies show that individuals with worse health are more likely to be delayed or never enroll in school (Glewwe and Jacoby, 1995; Alderman et al., 2009; Akresh et al., 2012, 2016). If this differs systematically by gender or bride price custom, then this may be driving the observed pattern in on-time enrollment.[57] The DHS does not include anthropometric data on children of school age. I compare instead the nutritional status of younger children (36-59 months old) under the assumption that their nutritional status is likely to more or less persist up until the official school starting age. Specifically, I assess the likelihood of being stunted, i.e. having a height-for-age score two standard deviations below the median of the reference population (WHO, 1986). Results are reported in Table A11.[58] Notably, between 24-52 percent of the children are found to be stunted in a given country. I find that girls are less likely to be stunted than boys in three out of four countries (column 5). The exception is Namibia, where girls are slightly more likely to be stunted. In addition, bride price children are less likely to be stunted than others in Mozambique and Namibia. The latter finding falls in line with the better outcomes for bride price individuals in general in Namibia. Next, I split the sample by bride price custom (columns 6 and 7). The higher likelihood of stunting for boys seems to be driven by the non-bride price samples in Mozambique and Zambia, whereas boys are worse off in both the bride price and non-bride prices sample in Malawi. This may imply that the female-favored gap among bride price ethnicities in Malawi is

entire sample, including those whose ethnicity is identified through another household member, does not alter the pattern of results (available upon request).

[57]An alternative yet related explanation for why boys are more likely to be delayed, is that girls are on average more mature than boys at the legal age of enrollment (Hoogeveen and Rossi, 2013). It is not clear why this should differ across bride price ethnicities. It may, however, explain part of the remaining gender gap in on-time enrollment. Then again, it is not clear why this should be the case for Malawi and Namibia, but not Mozambique and Zambia.

[58]In column 1 I employ all children whose ethnicity is identified through the mother, whereas in columns 2-5 the children whose bride price custom is unidentified are dropped. The results (available upon request) remain largely the same when controlling for mother's height (this is unavailable for the first Namibian survey) and to using the continuous measure height-for-age (Zambian bride pride girls have a slightly higher height-for-age than bride price boys).

driven by girls' better nutritional status. Yet, these findings do not explain why there is not also a female-favored gap in on-time enrollment in the non-bride price samples in Malawi, Mozambique, and Zambia.

7.2.3 Sibling rivalry: birth order, birth spacing and sibship size

If resources are scarce and parents are unable to borrow to finance education, then one child's education may depend on other children and their received education (Jacoby, 1994; Glewwe and Jacoby, 1995; Bommier and Lambert, 2000). First, if credit constraints are an issue, then bride price children that have an older sister may benefit from her marriage. However, I do not find that the association between on-time enrollment and having an older sister that has left the household differs by bride price custom, nor does it alter the main pattern of results (available upon request).[59] Second, if the sibship size differs by bride price ethnicity then this may impact children's educational attainment. I compare the number of living children born to women and men aged 26-45 years.[60] As seen from Panel A in Table A12, women belonging to bride price ethnicities give birth to on average fewer (more) children in Mozambique and Malawi (Namibia). Men belonging to bride price ethnicities have fathered slightly more children relative to other men in Zambia and Namibia (Panel B). This may imply that the bride price teenage girls' higher level of education relative to other girls is due to less sibling competition in Mozambique and Malawi. On the other hand, the same pattern was not observed for boys (Table 3). Lastly, controlling for the number of months between the birth of the child and the preceding and succeeding child (and whether the child is the last or first born) does not alter the main pattern of results (available upon request). I leave it for future research to investigate whether there are more nuanced differences in birth order and birth spacing that differ systematically by gender and/or bride price custom, which again affect education.

[59] I compare individuals' probability of on-time enrollment, controlling for whether the child in question has an older sister that has left the household, thus likely having married, and including separate interactions with this variable and gender and bride price custom. Since daughters might stay in the household upon marriage in matrilineal societies, I also include the few children who have a married sister in the household. The DHS does not ask this directly, but I use information on the relationship to the head and the marital status, assuming that all individuals with the same relationship to the head are siblings (i.e. children or grandchildren). This introduces some measurement error, as this may not hold true for all. I also control for the relative birth order to capture possible birth order and sibship size effects.

[60] I use this age range so as to make the results comparable to Ashraf et al. (2016).

7.2.4 Returns in the labor market

The gap in educational attainment between bride price and non-bride price females may be due to different returns to education in the labor market rather than in the marriage market. The DHS does not include information on wages, so I resort to using current labor market participation.[61] I examine the likelihood of working for a given level of education by bride price custom for adults aged 26-45.[62] Results are reported in Table A13 for women and men separately. Between 50 and 65 percent of all women are working in each country and the probability of working increases with education. Women in Mozambique and Zambia do not differ by the bride price custom (columns 1 and 2), whereas better educated bride price women in Malawi are actually less likely to be working than other women (column 3). I can only speculate about the reasons for this, but one possible explanation is that these women are better educated in order to reap returns in the marriage market rather than in the labor market. Lastly, Namibian bride price women are more likely to be working given secondary education or higher, relative to non-bride price women (column 4). Turning to the men (columns 5-8), the average labor market participation is considerably higher than that of women. Further, I find that Namibian men from bride price ethnicities are also more likely to be working for a given level of education, than other men. There is in other words a systematic difference by bride price custom in Namibia, in line with the findings on education and stunting.

7.2.5 Supply side constraints

I have treated the education decisions as being up to the parents. This ignores possible supply side constraints and school policies on who is allowed to enroll first when there are limited spots available. As long as schools do not enroll individuals based on gender (which I do not have reason to believe that they do) then I am less worried with regards to the findings on gender. Children from bride price ethnicities may however be residing in specific parts of a district that differ systematically in terms of school supply from other areas within the district. I have in part addressed this by controlling for ethnic connections to the president (see Appendix C), but this is far from sufficient. Unfortunately, I have not been able to assess this further.

[61] I use the DHS's definition for who is currently working. Current refers to the last seven days, and working refers to work other than housework. I control for interview month so as to take into account differences across seasons.

[62] I use the same age group as Ashraf et al. (2016), making them comparable.

7.2.6 Likelihood of marriage

The proposed argument for sending girls to school on time is that parents from bride price ethnicities expect a higher bride price. This warrants the question of whether parents can expect their daughter to marry. In the most recent DHS surveys 19.5, 16.5, and 23.3 percent of 15-19 year olds are married in respectively Malawi, Zambia, and Mozambique. A considerable lower share is married in Namibia. Even by the ages 20-24 (25-29) only 5 (13.8) percent of Namibian women are married.[63] The comparable figures for those aged 20-24 is 65.3, 55.4, and 47.2 percent in respectively Malawi, Zambia, and Mozambique.[64] Assuming that these marriage patterns are observable to the parents, then parents in Zambia, Malawi, and Mozambique are more likely to expect their daughter to marry than in Namibia.[65]

7.3 Selection bias

7.3.1 Children not living with their mother

There are two main sources of possible selection bias. First, I have used information on birth month to identify whether an individual was on time or not. This is only available for the sample of children whose mother is interviewed. Second, and relatedly, I have used the ethnicity of the mother to identify what bride price custom a child can be expected to be affected by. I am thus excluding 7-9 year old children who reside with their father only (this constitutes as small number of children) or with other relatives/non-relatives such as grandparents. However, as noted, the findings on on-time enrollment were largely unchanged when *(viii)* using a less strict definition of on-time enrollment, thus including children whose birth month is unknown, and *(ix)* using the sample of children whose ethnicity is identified through someone other than a parent (see Appendix C).

Nonetheless, I compare the children for whom I have information on ethnicity through the mother to the children for whom this is lacking. Results on mean differences are reported in Table A14.[66] There are statistically significant differences on all accounts, except for the education of

[63]High marriage costs is one cited reason for the low share of marriages observed in urban (Tvedten, 2011) and rural Namibia (Frank, 2015).

[64]Including the separated/divorced women, then the share of 15-19 (20-24) year olds who have engaged in marriage are 27.2 (59.4), 22.3 (74.1), 18.2 (63), and 7.2 (18.6) in respectively Mozambique, Zambia, Malawi, and Namibia.

[65]Comparing the likelihood of ever having married (i.e. currently married, divorced or widowed) among individuals aged 26-45, I find that there is no difference for women by bride price custom. The exception is Namibia, where bride price women are slightly more likely to marry (results available upon request).

[66]Including those for whom birth month is missing and the bride price custom is identified through the father or another household member results in the same pattern in mean differences (see Table A15).

the household head. However the differences are in general not large. As expected, the included children are more likely to be children of the household head, while the excluded children are more likely to be living with older female heads, often the grandmother. Hence, the results may not be extrapolated to these children, and to those whose ethnicity I am unable to match to a bride price custom. Yet, since the bride price is largely bestowed upon the parents, and other family members' incentives may be more complex, then the incentive structure for investing in education that I have investigated may be less relevant.

7.3.2 Select sample of children due to different descent rules

The bride price custom is positively correlated with patrilineal descent, whereby children belong to the father's lineage (Anderson, 2007). Upon divorce or death of the father, children in patrilineal ethnicities are therefore less likely to live with their mother, unlike what is the case in matrilineal ethnicities. Since I am primarily using children whose ethnicity is identified through the mother, I may therefore be observing a more select sample of children from bride price ethnicities than from non-bride price ethnicities. Importantly, results were largely unchanged when I included children whose ethnicity is assumed the same as another household member (see Table D6). Also, contrary to what I expected, I observe a higher share of female-headed households with children among bride price ethnicities, as compared to non-bride price ethnicities.[67] I am therefore less concerned that I am observing a more select sample of children from the bride price ethnicities.

7.4 Measurement error

The variables of interest are likely measured with error. First, I use self-reported measures of school enrollment. The questions on schooling refer to recent years and so recall is unlikely to be a problem. Self-reported enrollment may on the other hand differ from actual enrollment (Baird et al., 2011). I use information on school enrollment from the DHS, which does not involve a program component nor does the survey focus on education. There are in other words no obvious incentives for why respondents should intentionally misreport. Second, whether an individual is defined as on time or not is based on the reported age and in part birth month. Any measurement error in these variables will follow through to the dependent variable, reducing the precision of the estimates. Particularly

[67]In the sample of 7-9 year olds around 30 and 23 percent of the bride price and non-bride price samples, respectively, reside in a female-headed household.

problematic in my case would be if over- or under-reporting was correlated with gender or bride price. It is not obvious why this should be the case.[68]

There is also likely to be measurement error in whether the child and his/her parents practice the bride price custom or not. Measurement error may stem from *(i)* the use of language rather than ethnicity in the case of Namibia and Mozambique (see Appendix B for a further discussion), *(ii)* the matching of an ethnicity from the DHS to a similar ethnicity in the Ethnographic Atlas, *(iii)* misrepresentation of ethnicities in the Ethnographic Atlas and *(iv)* an alteration of the customs after the atlas was compiled.[69] However, as long as this measurement error is not systematically related to my variables of interest, i.e. educational investments, then this will only result in downward bias my estimates. Likewise, if ethnicities that have historically not practiced the bride price custom are now adopting it and this affects the investments in their daughters' education, then this will attenuate my estimates.

7.5 Standard errors

Standard errors are clustered at the ethnicity level. There are at the most 27 ethnicities in a country. Cameron et al. (2008) show that cluster-robust standard errors may be downward biased when there are few clusters and recommends using wild cluster bootstrapped standard errors. The issue of few clusters remains to be addressed.

8 Conclusion

Girls are more likely to enroll on time in primary school than boys in southern Africa. I have investigated the role of the bride price custom in driving this gap. The bride price custom may incentivize parents to enroll their daughter in school on time so as to maximize the number of years of education prior to the desired marriage age. I expected girls from ethnicities that have historically practiced the bride price custom to be more likely to enroll on time relative to boys from

[68]In line with the DHS data, annual reports from Namibian, Malawian and Zambian primary schools show that more girls are entering into school at the official age as compared to boys (EMIS, 2013a,b, 2016), whereas the opposite is found in Mozambique (Ministério da Educação, 2014).

[69]There is suggestive evidence of the latter. A claimed pattern in several of the countries is the so-called commercialization of the bride price, as well as the adoption of the custom by other ethnic groups. Already in the 1980s, Arnfred (2001) noted that "[a]ccording to sources in the OMM, lobolo is now found in all provinces of the country, especially in the cities where the influence of modern life is strongest." Respondents in the Zambian Customary Law Project note that a "problem was the commercialization of lobola by parents and guardians. It was agreed that this was contrary to the old customary law that required a token payment like a chicken as symbol of the families' agreement to the marriage" (ZLDC, 2002). Findings from Namibia also suggest that the bride price custom is gradually taken up by ethnic groups that historically have not followed this custom (LAC, 2005; Tvedten, 2011).

the same bride price ethnicities. I find evidence of this in Malawi and Namibia. For Mozambique and Zambia I find instead that girls are *less* likely to enroll on time than boys, but this only holds for the *non*-bride price ethnicities. I also expected girls from bride price ethnicities to be more likely to enroll on time relative to other girls, and that boys do not differ by the bride price custom. The results indicate that the former holds for Zambia and Namibia, yet in Namibia boys belonging to bride price ethnicities are also more likely to enroll on time than other boys. I also assess a number of alternative explanations that may explain the above results, yet none seem to be satisfactory. In summary, the empirical evidence on the bride price custom in driving the female-favored gap in on-time enrollment is inconclusive.

Turning to educational attainment, I find that teenage girls belonging to bride price ethnicities are on average more educated than other females in all four countries. This falls in line with higher returns to education in the marriage market due to the bride price custom. However, individuals from bride price ethnicities, regardless of gender, are comparably better of on all examined outcomes in Namibia, including stunting and labor market participation. In addition, the likelihood of marriage is very low in Namibia. In other words, there are likely to be other confounding factors than the bride price custom that explain the results in Namibia. Importantly, none of the alternative explanations seem to explain the observed pattern in educational attainment in the three other countries.

This paper speaks to the contentious role of the bride price custom in southern Africa today.[70] Policy-makers should be aware of possible incentive structures induced by the bride custom, and what a possible abolishment may imply.[71] The public debate has focused on the bride price custom as being detrimental to girls' education, yet this paper provides a more nuanced picture. Girls from bride price ethnicities are progressing more quickly through school compared to their brothers, and may be acquiring more years of education than other girls. One question that arises is whether credit constrained parents are favoring girls at the expense of boys in order to reap benefits from their daughters' marriage. Further, the custom is argued to be contribute to child marriages, yet on average females from bride price ethnicities are not found to marry earlier than other females. This may imply that there are other important factors, such as lack of labor market opportunities and access to secondary education, that are influencing women's earlier marriage age. That being said,

[70] See for instance http://thisisafrica.me/lobola-bride-price-custom-gone-bad/

[71] Namibia was for example recently recommended by the UN Human Rights Committee to abolish the custom, see http://allafrica.com/stories/201604080120.html.

the bride price custom may have important negative side-effects. Opponents argue for instance that it instigates domestic violence. Uganda's recent ban on the refund of the bride price upon divorce be an important step in the right direction.[72] On a broader level, the bride price custom as it operates today may limit the role of education as a vehicle for social mobility if only the more wealthy can afford to pay a high bride price, thereby cementing inequality in society. More data is needed on the amounts exchanged and the source of financing. This may inform the broader debate on the bride price custom and its future in Sub-Saharan Africa.

This paper has made a number of other findings that deserve more scrutiny. Wealth is still an important predictor for on-time enrollment. Need-based targeting that exempt parents from financing school materials may be an effective mechanism for reaching the most disadvantaged. On the other hand, wealth and parental education may also reflect a lack of knowledge about the returns to education and the potential costs of delaying enrollment. Disentangling this is one path for future research. Further, the high levels of stunting, in particular among boys, suggest a role for targeted nutrition programs. School feeding programs may give parents an additional incentive to send children to school, and improve children's nutritional status. Future research should focus on the extent to which the recently implemented programs are functioning as intended.

[72] https://www.theguardian.com/global-development/2015/aug/17/uganda-court-rules-against-refund-bride-price-divorce

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APPENDIX A: Tables

Table A1: Summary statistics, Mozambique and Zambia

Variable	Mean	Std. Dev.	Min.	Max.	N
Panel A: Mozambique					
On-time enrollment	0.688	0.464	0	1	1447
Age⋆	7	0	7	7	1447
Female	0.513	0.5	0	1	1447
Household head's years of education⋆	3.876	3.551	0	19	1445
Wealth index⋆	3.099	1.424	1	5	1447
Child of head	0.86	0.347	0	1	1447
Grandchild of head	0.071	0.257	0	1	1447
Female household head	0.35	0.477	0	1	1447
Rural	0.673	0.469	0	1	1447
Bride price	0.37	0.483	0	1	1431
Matrilineal	0.574	0.495	0	1	1431
Female agriculture	0.36	0.48	0	1	1431
Missing info on female agriculture	0.488	0.5	0	1	1431
Polygyny	0.945	0.228	0	1	1431
Panel B: Zambia					
On-time enrollment	0.656	0.475	0	1	5062
Age⋆	8.297	0.457	8	9	5062
Female	0.506	0.5	0	1	5062
Household head's years of education⋆	6.872	3.908	0	20	5059
Wealth index⋆	2.871	1.374	1	5	5062
Child of head	0.904	0.295	0	1	5062
Grandchild of head	0.051	0.219	0	1	5062
Female household head	0.178	0.383	0	1	5062
Rural	0.65	0.477	0	1	5062
Bride price	0.276	0.447	0	1	4968
Matrilineal	0.497	0.5	0	1	4968
Female agriculture	0.779	0.415	0	1	4968
Missing info on female agriculture	0.114	0.318	0	1	4968
Polygyny	0.995	0.071	0	1	4968

Notes: All variables are binary (1=yes, 0=no) with the exception of ⋆. These are continuous.

Table A2: Summary statistics, Malawi and Namibia

Variable	Mean	Std. Dev.	Min.	Max.	N
Panel A: Malawi					
On-time enrollment	0.784	0.411	0	1	9997
Age⋆	7.446	0.497	7	8	9997
Female	0.497	0.5	0	1	9997
Household head's years of education⋆	5.173	3.875	0	19	9996
Wealth index⋆	2.938	1.384	1	5	9997
Child of head	0.898	0.302	0	1	9997
Grandchild of head	0.043	0.203	0	1	9997
Female household head	0.216	0.411	0	1	9997
Rural	0.875	0.331	0	1	9997
Bride price	0.155	0.362	0	1	9532
Matrilineal	0.741	0.438	0	1	9532
Female agriculture	0.745	0.436	0	1	9532
Missing info on female agriculture	0.047	0.212	0	1	9532
Polygyny	1	0	1	1	9532
Panel B: Namibia					
On-time enrollment	0.688	0.464	0	1	2322
Age⋆	7.354	0.478	7	8	2322
Female	0.503	0.5	0	1	2322
Household head's years of education⋆	6.346	4.816	0	20	2318
Wealth index⋆	3.009	1.451	1	5	2322
Child of head	0.732	0.443	0	1	2322
Grandchild of head	0.156	0.363	0	1	2322
Female household head	0.469	0.499	0	1	2322
Rural	0.574	0.495	0	1	2322
Bride price	0.52	0.5	0	1	1840
Matrilineal	0.411	0.492	0	1	1840
Female agriculture	0.476	0.5	0	1	1840
Polygyny	0.830	0.375	0	1	1840

Notes: All variables are binary (1=yes, 0=no) with the exception of ⋆. These are continuous.

Table A3: Probability of enrolling in primary school on time, pooled sample

	Bride price (BP) and non-bride price (no BP) ethnicities						BP	No BP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Female	0.031***	0.032***	0.030***	0.045***	0.045***	0.030*	0.012	0.039**
	(0.006)	(0.006)	(0.006)	(0.009)	(0.009)	(0.016)	(0.018)	(0.019)
Bride price			0.038***	0.037**	0.030*	0.013		
			(0.012)	(0.014)	(0.016)	(0.015)		
Female x Bride price					0.015	0.015		
					(0.016)	(0.015)		
Ethnicity level controls	N	N	N	Y	Y	Y	Y	Y
Household level controls	N	N	N	N	N	Y	Y	Y
Number of Obs.	25476	18828	17771	17771	17771	17762	4330	13432
Mean of Dep. Var.	0.71	0.73	0.73	0.73	0.73	0.73	0.78	0.71

Notes: Linear probability models. Dep.var.: Enrolled in primary school on time (yes=1, no=0), compared to country's official starting age. All reported variables are binary (1=yes, 0=no). *Bride price* indicates that the child's mother is part of an ethnicity that has historically practiced the bride price custom or not, identified using Murdock's (1967) Ethnographic Atlas. Samples: Column 1: all 7-9 years old children, column 2: 7-9 years old children whose ethnicity is identifiable through the mother, columns 3-6: 7-9 years old children whose mother's ethnicity is matched to a bride price custom, column 7: mother's ethnicity practices the bride price custom, column 8: mother's ethnicity does not practice the bride price custom. Standard errors clustered at district level in column 1, and clustered at ethnicity level in columns 2-8. Controls for age, district, rurality, and survey round are included throughout. Ethnicity level controls are matrilineal descent, whether females are central in agriculture, polygyny, interactions with these and female, and a control for missing information on females' involvement in agriculture. Household level controls are gender and education of household head, whether individual is child or grandchild of head, and the wealth index. Source: DHS surveys for Mozambique, Zambia, Malawi, and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A4: Probability of enrolling in primary school on time, by country
Excluding ethnicity-level variables

Sample	W/ and w/o info on bride price custom				W/ info on bride price custom			
	Mozambique	Zambia	Malawi	Namibia	Mozambique	Zambia	Malawi	Namibia
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Female	-0.000	0.026**	0.032***	0.023**	-0.003	0.028**	0.028***	0.039***
	(0.033)	(0.012)	(0.006)	(0.010)	(0.033)	(0.013)	(0.007)	(0.011)
Household head's years of education⋆	0.020***	0.018***	0.016***	0.003*	0.020***	0.019***	0.015***	0.002
	(0.006)	(0.002)	(0.001)	(0.002)	(0.006)	(0.002)	(0.001)	(0.002)
Wealth index⋆	0.098***	0.093***	0.040***	0.036***	0.098***	0.097***	0.044***	0.042***
	(0.016)	(0.008)	(0.003)	(0.008)	(0.016)	(0.008)	(0.004)	(0.013)
Child of head	0.106**	0.080***	0.033**	0.052***	0.104**	0.079***	0.046**	0.023
	(0.037)	(0.017)	(0.013)	(0.016)	(0.038)	(0.028)	(0.018)	(0.025)
Grandchild of head	0.150**	0.064**	0.023	0.037**	0.163**	0.128***	0.070***	0.010
	(0.063)	(0.024)	(0.015)	(0.013)	(0.063)	(0.036)	(0.018)	(0.025)
Female household head	0.008	0.062***	0.041***	0.010	0.011	0.051***	0.028**	0.027
	(0.019)	(0.014)	(0.010)	(0.020)	(0.019)	(0.017)	(0.011)	(0.022)
Number of Obs.	1445	6575	13261	3917	1429	4966	9534	1836
Mean of Dep. Var.	0.69	0.64	0.77	0.66	0.69	0.65	0.78	0.68

Notes: Linear probability model. Dep.var.: Enrolled in primary school on time (yes=1, no=0), compared to country's legal starting age. All reported variables are binary (1=yes, 0=no), except ⋆ which are continuous. Sample: columns 1-4: 7-9 year old children, columns 5-8: 7-9 year old children whose mother's ethnicity is matched to a bride price custom. Standard errors clustered at district level. Controls for age, district, rurality, and survey round are included throughout. Source: DHS surveys for Mozambique, Zambia, Malawi, and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A5: Probability of being on track in primary school, by country
Mother fixed effects

	All	BP	No BP
	(1)	(2)	(3)
Panel A: Mozambique			
Female	0.011	0.060*	-0.011
	(0.029)	(0.030)	(0.024)
Number of Obs.	8845	3132	4633
Mean of Dep. Var.	0.41	0.57	0.30
Panel B: Zambia			
Female	0.034**	0.053**	0.023
	(0.017)	(0.026)	(0.020)
Number of Obs.	20330	4824	13053
Mean of Dep. Var.	0.58	0.63	0.57
Panel C: Malawi			
Female	0.050***	0.067**	0.045***
	(0.011)	(0.028)	(0.015)
Number of Obs.	34798	4489	23840
Mean of Dep. Var.	0.35	0.51	0.33
Panel D: Namibia			
Female	0.071**	0.110***	0.048
	(0.028)	(0.036)	(0.044)
Number of Obs.	10429	3719	4220
Mean of Dep. Var.	0.59	0.61	0.62

Notes: Linear probability model. Dep.var.: On track in primary school (yes=1, no=0). Age minus official starting age is lower or equal to highest grade completed (1) or not (0). All reported variables are binary (1=yes, 0=no). Sample: individuals aged 8(9)-14(15) years; DHS surveys for Mozambique, Malawi and Namibia (Zambia). Mother fixed effects. Standard errors clustered at district level. Control for age and whether head is father of child included throughout. BP and No BP indicates that the individual's mother is part of an ethnicity that has historically practiced the bride price custom or not, respectively, identified using Murdock's (1967) Ethnographic Atlas. The reduction in sample size from the "All" column to the combined columns for "BP" and "No BP" within a given country is either due to dropping children of mothers who reported "other" or an unmatched ethnicity, or that the child's mother is claimed to reside in the household, but the mother is not identified in the women's questionnaire. Source: DHS surveys for Mozambique, Zambia, Malawi, and Namibia * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A6: Number of years of completed schooling, by country
Individuals ages 15-19, resided in same location since age 5

	Zambia (1)	Malawi (2)	Namibia (3)
Female	-0.246*	-0.048	0.074
	(0.124)	(0.229)	(0.044)
Bride price	-0.079	-0.098	0.351**
	(0.140)	(0.270)	(0.130)
Female x Bride price	0.376***	0.374*	-0.332**
	(0.127)	(0.198)	(0.103)
Ethnicity level controls	Y	Y	Y
Household level controls	Y	Y	Y
Number of Obs.	5933	7630	5268
Mean of Dep. Var.	6.76	5.61	7.75

Notes: OLS. Dep. var.: Number of years of completed schooling. All reported variables are binary (1=yes, 0=no). Sample: 15-19 year old individuals whose reported ethnicity is matched with the Ethnographic Atlas, and who have resided in the same location since age 5. Standard errors clustered at ethnicity level in parentheses. "Bride price" indicates that the individual's reported ethnicity has historically practiced the bride price custom (=1), or not (=0), identified by Murdock's (1967) Ethnographic Atlas. Controls for age, district, and survey included throughout. Ethnicity level controls are matrilineal descent, whether females are central in agriculture, polygyny, interactions with female and a control for whether information on females' involvement in agriculture is missing. Household level controls are gender and education of household head, whether individual is child or grandchild of head, and the wealth index. Source: DHS surveys for Zambia, Malawi and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A7: Probability of currently attending school, by country and age group

	Mozambique		Zambia		Malawi		Namibia	
Age group	15-19	20-24	15-19	20-24	15-19	20-24	15-19	20-24
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Female	-0.041***	-0.042***	-0.108***	-0.036***	-0.207***	-0.125***	0.004	0.023
	(0.006)	(0.003)	(0.011)	(0.011)	(0.018)	(0.022)	(0.008)	(0.029)
Bride price	-0.076	-0.134**	-0.023*	-0.008	0.039*	0.101***	0.188***	0.088***
	(0.044)	(0.044)	(0.011)	(0.010)	(0.020)	(0.022)	(0.016)	(0.015)
Female x Bride price	0.064	0.091**	0.041**	0.015	-0.037**	-0.096***	-0.051**	-0.010
	(0.062)	(0.034)	(0.016)	(0.014)	(0.015)	(0.022)	(0.017)	(0.015)
Ethnicity level controls	Y	Y	Y	Y	Y	Y	Y	Y
Household level controls	Y	Y	Y	Y	Y	Y	Y	Y
Number of Obs.	3801	3100	11889	9185	12795	11672	6680	5591
Mean of Dep. Var.	0.49	0.17	0.60	0.15	0.57	0.09	0.70	0.18

Notes: Linear probability model. Dep.var.: Currently attending school (yes=1, no=0). All reported variables are binary (1=yes, 0=no). Sample: 15-19 year old individuals (columns 1, 3, 5 and 7) and 20-24 year olds (columns 2, 4, 6 and 8) whose ethnicity is matched to a bride price custom. Standard errors clustered at ethnicity level. "Bride price" indicates the individual is part of an ethnicity that has historically practiced the bride price custom or not, as identified by Murdock's (1967) Ethnographic Atlas. Controls for age, district, rurality and survey round are included throughout. Ethnicity level controls are matrilineal descent (except in Panel A), whether females are central in agriculture, polygyny, interactions with female, and a control for missing information on females' involvement in agriculture. Household level controls are gender and education of household head, whether individual is child or grandchild of head, and the wealth index. Source: DHS surveys for Mozambique, Zambia, Malawi and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A8: Number of years of completed schooling, by country, ages 20-24

	BP and No BP		BP	No BP
	(1)	(2)	(3)	(4)
Panel A: Mozambique				
Female	-0.731***	-0.731***	-1.461**	-0.812***
	(0.060)	(0.059)	(0.320)	(0.045)
Bride price	1.296**	0.686		
	(0.430)	(0.418)		
Female x Bride price		0.774***		
		(0.250)		
Number of Obs.	3111	3111	1186	1925
Mean of Dep. Var.	5.82	5.82	6.18	5.60
Panel B: Zambia				
Female	-0.134	-0.130	-1.253***	-0.101
	(0.089)	(0.087)	(0.109)	(0.090)
Bride price	0.353	0.194		
	(0.224)	(0.164)		
Female x Bride price		0.260		
		(0.167)		
Number of Obs.	9615	9615	2668	6947
Mean of Dep. Var.	7.68	7.68	7.91	7.60
Panel C: Malawi				
Female	-1.495***	-1.856***	-1.337***	-1.816***
	(0.281)	(0.187)	(0.028)	(0.280)
Bride price	1.139**	0.604		
	(0.399)	(0.384)		
Female x Bride price		0.678***		
		(0.075)		
Number of Obs.	12122	12122	1956	10166
Mean of Dep. Var.	5.94	5.94	7.81	5.59
Panel D: Namibia				
Female	0.522***	0.522***	0.714***	0.584***
	(0.041)	(0.041)	(0.008)	(0.050)
Bride price	0.754*	0.503**		
	(0.321)	(0.200)		
Female x Bride price		0.361		
		(0.275)		
Number of Obs.	5922	5922	3732	2190
Mean of Dep. Var.	8.77	8.77	8.70	8.89
Ethnicity level controls	Y	Y	Y	Y

Notes: OLS. Dep. var.: Number of years of completed schooling. All reported variables are binary (1=yes, 0=no). Sample: 20-24 year old individuals whose reported ethnicity is matched with the Ethnographic Atlas. Standard errors clustered at ethnicity level in parentheses. "Bride price" indicates that the individual's reported ethnicity has historically practiced the bride price custom (=1), or not (=0), identified by Murdock's (1967) Ethnographic Atlas. Controls for age, district, and survey included throughout. Ethnicity level controls are matrilineal descent (except in Panel A), whether females are central in agriculture, polygyny, interactions with female and a control for whether information on females' involvement in agriculture is missing. Source: DHS surveys for Mozambique, Zambia, Malawi and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A9: Age at first cohabitation, by country

	Mozambique (1)	Zambia (2)	Malawi (3)	Namibia (4)
Female	-3.937***	-4.379***	-4.704***	-1.590***
	(0.084)	(0.059)	(0.153)	(0.045)
Bride price	-0.144	0.059	0.497***	0.706**
	(0.498)	(0.101)	(0.122)	(0.245)
Female x Bride price	0.662	0.210	-0.222***	-0.634***
	(0.481)	(0.130)	(0.063)	(0.130)
Ethnicity level controls	Y	Y	Y	Y
Number of Obs.	7875	23676	26877	9383
Mean of Dep. Var.	20.28	20.23	18.59	24.42

Notes: OLS. Sample: women and men aged 26-45 years. All reported variables are binary (1=yes, 0=no). Standard errors clustered at ethnicity level. Fixed effects for age, district, rurality and survey year included throughout but not reported. "Bride price" indicates that the individual is part of an ethnicity that has historically practiced the bride price custom or not, identified by Murdock's (1967) Ethnographic Atlas. Ethnicity level controls are matrilineal descent (except in column 1), whether females are central in agriculture, polygyny, interactions with female, and a control for missing information on females' involvement in agriculture. Source: DHS surveys for Mozambique, Zambia, Malawi and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A10: Are "bride price boys" delayed due a higher work load? Malawi

	Bride price (BP) and non-bride price (no BP) ethnicities				BP	No BP
Hours spent last 7 days on	HH chores	Farm/Business	Non-family work	All work	All work	All work
	(1)	(2)	(3)	(4)	(5)	(6)
Female	1.130***	0.236	0.234	1.488**	2.557**	1.043
	(0.303)	(0.348)	(0.408)	(0.603)	(0.283)	(0.689)
Bride price	0.038	1.287*	0.471*	1.747***		
	(0.523)	(0.558)	(0.227)	(0.346)		
Female x Bride price	-0.102	-1.272**	-0.206	-1.558***		
	(0.236)	(0.504)	(0.439)	(0.430)		
Ethnicity level controls	Y	Y	Y	Y	Y	Y
Household level controls	Y	Y	Y	Y	Y	Y
Number of Obs.	4991	5066	5070	5082	731	4351
Mean of Dep. Var.	4.19	1.34	0.71	6.15	7.17	5.98

Notes: OLS. Dep.var.: Hours spent on different activities over last seven days. All reported variables are binary (1=yes, 0=no). Sample: 7-8 year old children in Malawi. Standard errors clustered at ethnicity level. "Bride price" indicates that the individual's mother is part of an ethnicity that has historically practiced the bride price custom or not, as identified by Murdock's (1967) Ethnographic Atlas. Controls for age, district, rurality, and survey round are included throughout. Ethnicity level controls are matrilineal descent, whether females are central in agriculture, polygyny, interactions with female, and a control for missing information on females' involvement in agriculture. Household level controls are gender and education of household head, whether individual is child or grandchild of head, and the wealth index. Source: DHS surveys for Malawi; MW3 (2000) and MW4 (2004/05). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A11: Are individuals delayed due to lower nutritional status?
Probability of being stunted for children aged 36-59 months, by country

	Bride price (BP) and non-bride price (no BP)					BP	No BP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Mozambique							
Female	-0.023	-0.021	-0.021	-0.054***	-0.036***	0.017	-0.036***
	(0.017)	(0.018)	(0.017)	(0.003)	(0.004)	(0.039)	(0.008)
Bride price		-0.028	-0.088**	-0.090**	-0.069**		
		(0.018)	(0.031)	(0.038)	(0.032)		
Female x Bride price				0.006	0.011		
				(0.044)	(0.043)		
Number of Obs.	3381	3346	3346	3346	3346	1209	2137
Mean of Dep. Var.	0.36	0.36	0.36	0.36	0.36	0.24	0.42
Panel B: Zambia							
Female	-0.035***	-0.036***	-0.037***	-0.025**	-0.061***	0.005	-0.064***
	(0.008)	(0.008)	(0.008)	(0.010)	(0.013)	(0.030)	(0.019)
Bride price		-0.000	-0.002	-0.012	-0.009		
		(0.018)	(0.017)	(0.015)	(0.013)		
Female x Bride price				0.020	0.024*		
				(0.014)	(0.013)		
Number of Obs.	8292	8119	8119	8119	8118	2297	5821
Mean of Dep. Var.	0.41	0.41	0.41	0.41	0.41	0.38	0.42
Panel C: Malawi							
Female	-0.028***	-0.029***	-0.029***	-0.066***	-0.073***	-0.132***	-0.052***
	(0.005)	(0.005)	(0.005)	(0.016)	(0.018)	(0.009)	(0.005)
Bride price		-0.060*	-0.038	-0.045	-0.023		
		(0.030)	(0.039)	(0.043)	(0.040)		
Female x Bride price				0.016	0.018		
				(0.015)	(0.017)		
Number of Obs.	7841	7442	7442	7442	7442	1141	6301
Mean of Dep. Var.	0.52	0.52	0.52	0.52	0.52	0.46	0.54
Panel D: Namibia							
Female	0.005	0.004	0.004	0.035***	0.019**	0.043***	0.016
	(0.016)	(0.018)	(0.019)	(0.008)	(0.006)	(0.001)	(0.008)
Bride price		-0.122**	-0.192***	-0.216***	-0.225***		
		(0.046)	(0.044)	(0.031)	(0.022)		
Female x Bride price				0.047	0.054		
				(0.037)	(0.032)		
Number of Obs.	2776	2563	2280	2280	2280	1199	1081
Mean of Dep. Var.	0.24	0.25	0.24	0.24	0.24	0.21	0.28
Ethnicity level controls	N	N	Y	Y	Y	Y	Y
Household level controls	N	N	N	N	Y	Y	Y

Notes: Linear probability model. Dep.var.: Probability of being stunted (=1), i.e. height-for-age 2 standard deviations below the WHO's median reference population. All reported variables are binary (1=yes, 0=no). *Bride price* indicates that the individual's mother is part of an ethnicity that has historically practiced the bride price custom or not, identified based on Murdock's (1967) Ethnographic Atlas (EA). Sample: children 36-59 month olds whose mother's reported ethnicity is matched with the EA. Standard errors clustered at ethnicity level. Controls for age, district, rurality, and survey included throughout. Ethnicity level controls are matrilineal descent (except Panel in A), female agriculture, polygyny, interactions with female, and a control for whether information on females' involvement in agriculture is missing. Household level controls are gender and education of household head, whether individual is child or grandchild of head, and the wealth index. Source: DHS surveys for Mozambique, Zambia, Malawi and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A12: Number of children by mother and father, by country

	Mozambique (1)	Zambia (2)	Malawi (3)	Namibia (4)
Panel A: Number of children born by women				
Bride price	-0.608***	0.043	-0.266***	0.337***
	(0.084)	(0.040)	(0.055)	(0.058)
Number of Obs.	6743	14948	21589	11282
Mean of Dep. Var.	3.42	3.96	3.84	2.75
Panel B: Number of children by father				
Bride price	-0.132	0.171**	0.109	0.183**
	(0.255)	(0.075)	(0.131)	(0.056)
Number of Obs.	1615	10461	5826	3275
Mean of Dep. Var.	3.33	3.51	3.42	2.22
Ethnicity level controls	Y	Y	Y	Y

Notes: OLS. Dep.var.: Number of living children born by women aged 26-45 (Panel A), and fathered by men aged 26-45 (Panel B). All reported variables are binary (1=yes, 0=no). Sample: women and men aged 26-45 old. Standard errors clustered at ethnicity level. Fixed effects for age, district, rurality, and survey year included throughout but not reported. "Bride price" indicates that the woman/man is part of an ethnicity that has historically practiced the bride price custom or not, identified by Murdock's (1967) Ethnographic Atlas. Ethnicity level controls are matrilineal descent (except for Mozambique), whether females are central in agriculture, polygyny, and a control for whether information on females' involvement in agriculture is missing. Source: DHS surveys for Mozambique, Zambia, Malawi, and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A13: Probability of currently working, by country

	Women				Men			
	Mozambique	Zambia	Malawi	Namibia	Mozambique	Zambia	Malawi	Namibia
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Bride price	0.051	-0.025	0.084**	-0.047	-0.024	0.024	-0.153	-0.142***
	(0.031)	(0.040)	(0.034)	(0.026)	(0.043)	(0.038)	(0.149)	(0.026)
Primary school	0.008	0.048**	0.053***	0.069***	0.002	0.039	0.039***	-0.104***
	(0.022)	(0.019)	(0.009)	(0.016)	(0.019)	(0.029)	(0.007)	(0.022)
Primary school x Bride price	0.031	0.003	-0.051	0.020	-0.002	-0.022	0.124	0.064**
	(0.034)	(0.035)	(0.036)	(0.034)	(0.031)	(0.038)	(0.136)	(0.026)
Secondary school	0.157***	0.077***	0.114***	0.197***	0.042	0.045	0.054***	-0.095***
	(0.031)	(0.023)	(0.012)	(0.018)	(0.038)	(0.030)	(0.010)	(0.020)
Secondary school x Bride price	-0.086	-0.022	-0.041	0.039	0.002	-0.012	0.101	0.104**
	(0.059)	(0.037)	(0.042)	(0.029)	(0.050)	(0.036)	(0.137)	(0.041)
More than secondary school	0.331***	0.297***	0.322***	0.382***	0.028	0.062*	0.066***	0.027
	(0.042)	(0.037)	(0.026)	(0.041)	(0.055)	(0.032)	(0.017)	(0.019)
More than secondary school x Bride price	0.030	0.005	-0.220***	0.129*	-0.020	-0.023	0.203	0.161***
	(0.055)	(0.050)	(0.058)	(0.058)	(0.078)	(0.045)	(0.153)	(0.018)
Ethnicity level controls	Y	Y	Y	Y	Y	Y	Y	Y
Number of Obs.	6678	14883	21542	11148	1575	10426	5813	4442
Mean of Dep. Var.	0.47	0.65	0.65	0.55	0.94	0.91	0.83	0.74

Notes: Linear probability model. Sample: women and men aged 26-45. Standard errors clustered at ethnicity level. Fixed effects for age, interview month, rurality, district, and survey year included throughout but not reported. "Bride price" indicates that the individual is part of an ethnicity that has historically practiced the bride price custom or not, identified by Murdock's (1967) Ethnographic Atlas. Ethnicity level controls are matrilineal descent, whether females are central in agriculture, polygyny, and a control for whether information on females' involvement in agriculture is missing. Source: DHS surveys for Mozambique, Zambia, Malawi and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A14: Mean differences between sample with bride price custom known (included) and not known (excluded)

Variable	Included		Excluded		Difference	
	N	Mean	N	Mean	Diff.	St.erorrs
On-time enrollment	17771	0.730	7452	0.677	0.053**	(0.006)
Age⋆	17771	7.638	7452	7.626	0.012**	(0.009)
Female	17771	0.500	7452	0.522	-0.022**	(0.007)
Household head's years of education⋆	17762	5.664	7433	4.806	0.858	(0.058)
Wealth index⋆	17771	2.963	7452	2.879	0.084*	(0.019)
Child of head	17771	0.878	7452	0.302	0.576**	(0.005)
Grandchild of head	17771	0.060	7452	0.433	-0.373**	(0.005)
Female household head	17771	0.246	7452	0.396	-0.150**	(0.006)
Mother alive	17771	0.997	7427	0.883	0.114**	(0.004)
Father alive	17750	0.946	7424	0.905	0.042**	(0.008)
Rural	17771	0.761	7452	0.776	-0.015**	(0.006)

Notes: Sample: 7-9 year old children in rural and urban households who is identified as on time or not. All variables are binary (1=yes, 0=no) with the exception of ⋆. These are continuous. "Bride price known" indicates that the individual's mother's ethnicity is matched with an ethnicity in Murdock's (1967) Ethnographic Atlas. The excluded group encompasses those that are not residing with their mother, that lack information on ethnicity in the household, their reported ethnicity is coded as "other", or the reported ethnicity is not matched with an identical or similar ethnicity in the Ethnographic Atlas. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A15: Mean differences between sample with bride price custom known (included) and not known (excluded). Using a less strict measure of on-time enrollment

Variable	Included		Excluded		Difference	
	N	Mean	N	Mean	Diff.	St.erorrs
On-time enrollment	22209	0.721	3267	0.665	0.056**	(0.008)
Age⋆	22209	7.638	3267	7.589	0.049*	(0.012)
Female	22209	0.505	3267	0.516	-0.011**	(0.009)
Household head's years of education⋆	22193	5.621	3255	3.990	1.631	(0.078)
Wealth index⋆	22209	2.979	3267	2.592	0.387*	(0.026)
Child of head	22209	0.749	3267	0.438	0.310**	(0.008)
Grandchild of head	22209	0.129	3267	0.451	-0.323**	(0.007)
Female household head	22209	0.274	3267	0.401	-0.126**	(0.008)
Mother alive	22192	0.972	3259	0.902	0.070**	(0.006)
Father alive	22169	0.935	3257	0.928	0.007*	(0.011)
Rural	22209	0.753	3267	0.849	-0.096**	(0.008)

Notes: Sample: 7-9 year old children in rural and urban households who is identified as on time or not, using a broader definition of on-time enrollment (i.e. individuals whose birth month is missing are identified as on time if enrolled in school at the official age of enrollment, and as delayed if not). All variables are binary (1=yes, 0=no) with the exception of ⋆. These are continuous. "Bride price known" indicates that the individual's mother's, father's or other household member's ethnicity is matched with an ethnicity in Murdock's (1967) Ethnographic Atlas. The excluded group encompasses those who either lack information on ethnicity in the household, their reported ethnicity is coded as "other", or the reported ethnicity is not matched with an identical or similar ethnicity in the Ethnographic Atlas. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

APPENDIX B: Demographic Health Surveys

The DHS surveys included are as follows: Namibia (NM4, NM5, NM6), Malawi (MW3, MW4, MW5), Mozambique (MZ6), and Zambia (ZM4, ZM5, ZM6). These were implemented in the following years: Namibia: 2000, 2006/07, 2013. Malawi: 2000, 2004, 2010. Mozambique: 2011. Zambia: 2001/02, 2007, 2013/14. I am unable to use previous rounds of DHS. Either because ethnicity or language is not available, and/or because the previous rounds do not enable merging the birth recode file, which includes mother's ethnicity and birth month, with the household member recode file.

The surveys on Namibia and Mozambique only provide information on language used (or what they first learnt to speak with) and not ethnicity. Whereas the use of language as a proxy for ethnicity would be problematic in Malawi, since some ethnic groups are to a large extent using other languages than their "own",[73] I am not aware of a similar pattern in Mozambique and Namibia. Unfortunately, the Namibian and Mozambican censuses are also limited to the use of language, making it difficult to establish the overlap between ethnicity and language. If an ethnic group reports another language than their own, and as long as this is not correlated with the explanatory variables of interest, then this should only result in attenuation bias.

The age group and the share of men interviewed varies across countries and survey years, with older cohorts being included in the more recent surveys. In the last survey in Namibia (NM6) all women aged 50-64, and half of all men aged 50-64 are also interviewed. Similarly, all men in the age group 15-59 were interviewed in the last survey from Zambia (ZM6). Men in 1/3 of the households in the age group 15-64 were interviewed in Mozambique (MZ6) and 1/3 of the men in households who fell in the age group 15-54 were interviewed in Malawi (MW6).

[73] According to the 2008 census for Malawi, the Chewa, Lomwe, Ngoni, and Tumbuka constitute the largest ethnic groups with respectively 33, 18, 14, and 11 percent of the population (NSO, 2008). These shares are more or less the same for the interviewed women and men in the DHS for Malawi. The Third Integrated Household Survey, on the other hand, only reports the language used. Among the household heads, 55, 5, 4, and 11 percent report to use respectively Chewa, Lomwe, Ngoni, and Tumbuka (NSO, 2012). Language does not adequately reflect ethnicity and the related customs.

APPENDIX C: Robustness checks

(i) Children who left school early

Across the four countries, there are 144 children who are reported to have attended school previously, but are presently not attending (whose mother's ethnicity is known). These children may have dropped out already, or they are the result of miscoding. Excluding them from the analysis (they were previously coded as being on time) does not alter the results (available upon request).

(ii) Namibian sample

One out of the two unmatched groups in Namibia, the Kwangali-speakers, covers a relatively large share of the Namibian sample. They are deemed similar to the Ovambo, both begin matrilineal, whereas the Kavango practice bride service rather than bride price payments (Becker and Hinz, 1995; Ambunda and de Klerk, 2008). I lack information on females' involvement in agriculture, coding it accordingly. As seen from Table D1, the results are robust to including the Kwangali-speakers. Specifically, bride price girls are more likely to enroll on time than non-bride price girls, despite the negatively signed interaction now being statistically significant.

(iii) Mothers' education

If the education of girls is more valued among bride price ethnicities than non-bride price ethnicities, and this has been the case for some years, then bride price households will consist of better educated mothers. This again may affect their preferences for education. As seen from Table D2, controlling for the mother's education does not alter the results.

(iv) School feeding programs targeted at girls

If school feeding programs are targeted specifically at girls and/or bride price ethnicities, then this may be driving the results. At a first glance these programs seem to be targeted at districts, and whereby the district fixed effects should in part address this. Further, most of these programs target all children, and not girls specifically.[74] The Malawi School Feeding Programme, run by the World Food Program, is an exception in terms of the gender focus. This program has two components, targeting all children in the first grades in the participating districts, and targeting girls and orphans in the upper primary school grades Standard 5-8. The school feeding program in Malawi was first introduced in Dedza in 1999, followed by Salima and Ntcheu in 2000, and was

[74] In Zambia the World Food Programme (WFP) runs the Home Grown School Feeding Programme, previously the School Feeding Program, and Mary's Meal recently started up. Mary's Meal has operated in Malawi since 2002, and provides all students at participating schools with a daily meal. Namibia has had a school feeding program since 1992, and none of these have had an explicit gender component (Ellis, 2012). Mozambique did not acquire a school feeding program until 2012, after the survey took place.

then scaled up in 2008 to an additional 10 districts (WFP, 2009). The Malawian DHS surveys took place in 2000, 2004/05 and 2010. Therefore, Dedza, Salima and Ntcheu are assumed to be participating throughout, whereas the ten districts that were added in 2008 are only participating in the last survey. Including this as a control, and with and without an interaction with the gender variable, does not alter the results for Malawi with regards to on-time enrollment (neither variable is statistically significantly different from zero, results available upon request).

(v) Politically connected ethnicities

Previous studies have shown that presidents favor their ethnicity in terms of allocation of public goods, including that of primary school education in Zambia and Malawi (Kramon and Posner, 2013). I assess whether the results on on-time enrollment are robust to controlling for ethnic affiliation. Specifically, I create a variable using the originally reported ethnicity in the DHS and information on whether the sitting president during a given survey is of the same ethnic group.[75] Results are robust to controlling for ethnic affiliation (results available upon request). The coefficient on ethnic affiliation with the president is positive and statistically significant for Mozambique, but as there is no variation across the studied period, one cannot infer whether there is in fact ethnic favoritism in terms of access to education. The estimated coefficient on ethnic affiliation is negative and statistically significant for Namibia.

(vi) Changing school calendar in Malawi

As noted in Section 4.1, I may have incorrectly coded a child as on time or not due to the changing school calendar in Malawi. At the time of the last survey, the school calendar starts in September. I have interpreted the rules such that those born in September or earlier are defined as delayed if they have not started primary school by the age of seven, whereas those born after September are delayed if they have not started school by the age of six. The official rules may however instead be that a child is supposed to enroll in school in the calendar year that they turn seven, thus the cut-off should be in January like in previous years. Results are reported in Table D3. The female-favored gap is not statistically significant in the pooled sample, whereas it remains statistically significant in the bride price sample.

(vii) On-time enrollment confounded with ever enrollment

The gap in on-time enrollment among the 7-9 year olds may reflect whether they are ever likely to attend school. I cannot ascertain this for the individuals that I have analyzed so far, but assuming

[75] In the case of Mozambique I use the ethnicity of both the president's mother and father.

that older cohorts are comparable to the younger ones, I can look at whether non-bride price girls and bride price boys are less likely to ever enroll in school. I limit the focus to individuals aged 11-14 and 15-19, so as to make them as comparable as possible to the younger cohort while at the same time ensuring that the individuals are likely to have started school if they ever were to do so. Country-specific results are reported in Table D4. There are few systematic differences in ever having attended school in the four countries.

(viii) Children without information on birth month

In the main results I use a strict definition of on-time enrollment, using information a child's birth month. As seem from Table D5, the results are largely robust to using a less strict measure of on-time enrollment, where all children for whom I lack information on birth month and who attend school at the age of seven (eight) in Namibia, Malawi and Mozambique (Zambia) are defined as on time, whereas those that do not attend are defined as delayed. This allows for including children who reside with their father only, thereby identifying their ethnicity through him.

(ix) Ethnicity from other household member than mother or father

As discussed in Section 4, the main results exclude children who do not live with their mother. The pattern of results may not hold for children not residing with a parent (as seen from *(viii)*, the results were robust to including children residing with an interviewed father). In order to assess this, I add children who reside with a female household member in the age category 15-49 and/or a male member in the age category 15-49/54/59/64 (depending on the survey). Preferably I use the ethnicity of the household head, under the assumption that they are the decision-makers in terms of when a child is sent to school, and if not available I use that of another household member. I maintain a control for whether several ethnicities are observable in the household, and in addition add a control for whether the child is assigned the ethnicity of someone other than the mother or father. The largest increase in sample size is observed in Namibia, both in relative and absolute terms. Results are reported in Table D6. The results are largely robust to the inclusion of these children, with one exception. Whereas I previously found bride price girls were more likely to enroll on time than bride price boys in Namibia, this female-favored gap is now observed in the non-bride price sample as well.

Table D1: Probability of enrolling in primary school on time, Namibia, including Kwangali-speakers

	Bride price (BP) and non-bride price (no BP) ethnicities						BP	No BP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Female	0.025**	0.044***	0.046***	0.043***	0.039	0.036	0.040***	0.042
	(0.010)	(0.009)	(0.009)	(0.009)	(0.025)	(0.024)	(0.001)	(0.021)
Bride price			0.057**	0.089***	0.107***	0.088***		
			(0.023)	(0.024)	(0.024)	(0.023)		
Female x Bride price					-0.034***	-0.026**		
					(0.006)	(0.009)		
Ethnicity level controls	N	N	N	Y	Y	Y	Y	Y
Household level controls	N	N	N	N	N	Y	Y	Y
Number of Obs.	4181	2322	2093	2093	2093	2089	953	1136
Mean of Dep. Var.	0.66	0.69	0.68	0.68	0.68	0.68	0.70	0.66

Notes: Linear probability model. Dep.var.: Enrolled in primary school on time (yes=1, no=0), compared to country's legal starting age. All reported variables are binary (1=yes, 0=no). These are continuous. Column 1: all children aged 7-8 years, column 2: children aged 7-8 whose ethnicity is identifiable through the mother, columns 3-6: children aged 7-8 whose mother's ethnicity is matched to a bride price custom,column 7: mother's ethnicity practices the bride price custom, column 8: mother's ethnicity does not practice the bride price custom. Standard errors clustered at district level in column 1, and clustered at ethnicity level in columns 2-8. "Bride price" indicates that the individual's mother is part of an ethnicity that has historically practiced the bride price custom or not, as identified by Murdock's (1967) Ethnographic Atlas. Controls for age, district, rurality, and survey round are included throughout. Ethnicity level controls are matrilineal descent, whether females are central in agriculture, polygyny, interactions with female, and a control for missing information on females' involvement in agriculture. Household level controls are gender and education of household head, whether individual is child or grandchild of head, and the wealth index. Source: DHS surveys for Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D2: Probability of enrolling in primary school on time, by country
Control for mother's years of education

	Mozambique (1)	Zambia (2)	Malawi (3)	Namibia (4)
Female	-0.005	-0.111***	0.028**	0.037
	(0.014)	(0.021)	(0.009)	(0.022)
Bride price	0.025	-0.016	-0.025***	0.076**
	(0.036)	(0.013)	(0.005)	(0.024)
Female x Bride price	0.027	0.044**	-0.008	-0.009
	(0.049)	(0.017)	(0.005)	(0.012)
Ethnicity level controls	Y	Y	Y	Y
Household level controls	Y	Y	Y	Y
Number of Obs.	1891	5215	9532	1848
Mean of Dep. Var.	0.69	0.67	0.78	0.69

Notes: Linear probability model. Dep.var.: Enrolled in primary school on time (yes=1, no=0), compared to country's legal starting age. All reported variables are binary (1=yes, 0=no). Sample: 7-9 year old children whose ethnicity is identifiable through the mother. Standard errors clustered at ethnicity level. "Bride price" indicates that the individual's mother is part of an ethnicity that has historically practiced the bride price custom or not, as identified using Murdock's (1967) Ethnographic Atlas. Controls for age, district, rurality, and survey round are included throughout. Ethnicity level controls are matrilineal descent (except in Panel A), whether females are central in agriculture, polygyny, interactions with female, and a control for missing information on females' involvement in agriculture. Household level controls are gender and education of household head, whether individual is child or grandchild of head, the wealth index, and mother's education. Source: DHS surveys for Mozambique, Zambia, Malawi and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D3: Probability of enrolling in primary school on time, Malawi
Altered interpretation of new school calendar

	Bride price (BP) and non-bride price (no BP) ethnicities						BP	No BP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Female	0.038***	0.037***	0.036***	0.036***	0.023**	0.006	0.029***	0.008
	(0.009)	(0.004)	(0.004)	(0.004)	(0.009)	(0.008)	(0.002)	(0.009)
Bride price			0.060**	0.030	0.023	-0.007		
			(0.021)	(0.016)	(0.016)	(0.016)		
Female x Bride price					0.012**	0.010		
					(0.005)	(0.008)		
Ethnicity level controls	N	N	N	Y	Y	Y	Y	Y
Household level controls	N	N	N	N	N	Y	Y	Y
Number of Obs.	10894	10888	10403	10403	10403	10402	1579	8823
Mean of Dep. Var.	0.75	0.75	0.75	0.75	0.75	0.75	0.87	0.73

Notes: Linear probability model. Dep.var.: Enrolled in primary school on time (yes=1, no=0), compared to country's legal starting age. All reported variables are binary (1=yes, 0=no). In survey round with new school calendar (MW6) a child is defined as on time if enroll in year child turns seven (cut-off in January and not September). Column 1: 7-8 year old children, column 2: 7-8 year old children whose ethnicity is identifiable through the mother, columns 3-6: 7-8 year old children whose mother's ethnicity is matched to a bride price custom, column 7: 7-8 year old children whose mother's ethnicity practices the bride price custom, column 8: 7-8 year old children whose mother's ethnicity does not practice the bride price custom. Standard errors clustered at district level in column 1, and clustered at ethnicity level in columns 2-8. "Bride price" indicates that the individual's mother is part of an ethnicity that has historically practiced the bride price custom or not, as identified by Murdock's (1967) Ethnographic Atlas. Controls for age, district, rurality, and survey round are included throughout. Ethnicity level controls are matrilineal descent, whether females are central in agriculture, polygyny, interactions with female, and a control for missing information on females' involvement in agriculture. Household level controls are gender and education of household head, whether individual is child or grandchild of head, and the wealth index. Source: DHS surveys for Malawi. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D4: Probability of ever attending school, by country

	Ages 11-14			Ages 15-19		
	All	BP	No BP	All	BP	No BP
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Mozambique						
Female	-0.004	-0.024	-0.005	0.013*	-0.042*	0.016
	(0.003)	(0.031)	(0.004)	(0.007)	(0.019)	(0.011)
Bride price	-0.019			-0.039		
	(0.015)			(0.027)		
Female x Bride price	0.017			0.057		
	(0.024)			(0.033)		
Number of Obs.	4024	1717	2307	3803	1328	2475
Mean of Dep. Var.	0.93	0.96	0.90	0.92	0.95	0.90
Panel B: Zambia						
Female	0.006**	-0.041	0.012***	-0.050***	-0.016	-0.057***
	(0.003)	(0.030)	(0.002)	(0.006)	(0.013)	(0.009)
Bride price	0.001			-0.002		
	(0.007)			(0.004)		
Female x Bride price	-0.019			0.003		
	(0.011)			(0.007)		
Number of Obs.	10789	2883	7906	11987	3369	8618
Mean of Dep. Var.	0.94	0.95	0.94	0.97	0.97	0.96
Panel C: Malawi						
Female	0.005	-0.003*	0.003	-0.008	-0.016***	-0.004
	(0.006)	(0.001)	(0.007)	(0.009)	(0.000)	(0.010)
Bride price	0.014***			-0.006		
	(0.003)			(0.005)		
Female x Bride price	-0.011***			0.013**		
	(0.003)			(0.004)		
Number of Obs.	14328	2331	11997	12899	2293	10606
Mean of Dep. Var.	0.96	0.99	0.96	0.96	0.99	0.95
Panel D: Namibia						
Female	0.002	-0.002	-0.001	0.004	-0.029***	0.004*
	(0.003)	(0.003)	(0.005)	(0.003)	(0.002)	(0.002)
Bride price	0.001			0.021		
	(0.017)			(0.012)		
Female x Bride price	-0.010			-0.046***		
	(0.011)			(0.013)		
Number of Obs.	3789	2009	1780	6764	4336	2428
Mean of Dep. Var.	0.96	0.96	0.96	0.96	0.97	0.96
Ethnicity level controls	Y	Y	Y	Y	Y	Y
Household level controls	Y	Y	Y	Y	Y	Y

Notes: Linear probability model. Dep.var.: Individual has ever attended school (yes=1, no=0). All reported variables are binary (1=yes, 0=no). Sample: columns 1-3: 11-14 year old individuals, columns 4-6: 15-19 year old individuals. Standard errors clustered at ethnicity level. "Bride price" indicates, for those aged 11-14, that individual's mother is part of an ethnicity that has historically practiced the bride price custom (=1), or not (=0), identified by Murdock's (1967) Ethnographic Atlas. The individual's own reported ethnicity is used for ages 15-19. Controls for age, district, and survey included throughout. Ethnicity level controls are matrilineal descent (except in Panel A), whether females' are central in agriculture, polygyny, interactions with female, and whether information on female's involvement in agriculture is missing. Household level controls are gender and education of household head, whether individual is child or grandchild of head, and the wealth index. Source: DHS surveys for Mozambique, Zambia, Malawi and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D5: Probability of enrolling in primary school on time, by country
Less strict measure of on time, bride price custom identified through mother or father

	Bride price (BP) and non-bride price (no BP) ethnicities						BP	No BP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Mozambique								
Female	0.008	0.004	0.000	0.004	0.009	-0.028***	-0.044	-0.038***
	(0.025)	(0.031)	(0.031)	(0.032)	(0.008)	(0.007)	(0.056)	(0.005)
Bride price			0.004	0.088	0.066	0.007		
			(0.040)	(0.062)	(0.053)	(0.042)		
Female x Bride price					0.036	0.033		
					(0.039)	(0.040)		
Number of Obs.	2180	1614	1595	1595	1595	1593	595	998
Mean of Dep. Var.	0.71	0.71	0.71	0.71	0.71	0.71	0.85	0.63
Panel B: Zambia								
Female	0.030***	0.031*	0.031*	0.031*	-0.125***	-0.112***	-0.010	-0.090*
	(0.011)	(0.016)	(0.016)	(0.016)	(0.016)	(0.020)	(0.014)	(0.045)
Bride price			0.018	0.023	0.001	-0.009		
			(0.019)	(0.016)	(0.020)	(0.013)		
Female x Bride price					0.041**	0.040**		
					(0.015)	(0.016)		
Number of Obs.	7398	5357	5261	5261	5261	5258	1455	3803
Mean of Dep. Var.	0.68	0.67	0.67	0.67	0.67	0.67	0.71	0.66
Panel C: Malawi								
Female	0.035***	0.034***	0.032***	0.032***	0.038**	0.024**	0.052***	0.018
	(0.006)	(0.005)	(0.005)	(0.005)	(0.013)	(0.010)	(0.004)	(0.013)
Bride price			0.041**	0.014	0.016	-0.013**		
			(0.015)	(0.010)	(0.011)	(0.005)		
Female x Bride price					-0.004	-0.005		
					(0.004)	(0.006)		
Number of Obs.	13827	10021	9553	9553	9553	9552	1482	8070
Mean of Dep. Var.	0.76	0.78	0.78	0.78	0.78	0.78	0.89	0.76
Panel D: Namibia								
Female	0.015	0.036***	0.035**	0.034**	0.031	0.028	0.046***	0.035
	(0.015)	(0.010)	(0.010)	(0.010)	(0.022)	(0.021)	(0.001)	(0.021)
Bride price			0.063*	0.102***	0.117***	0.096**		
			(0.028)	(0.025)	(0.032)	(0.030)		
Female x Bride price					-0.029**	-0.018		
					(0.012)	(0.015)		
Number of Obs.	4802	2397	1896	1896	1896	1892	979	913
Mean of Dep. Var.	0.65	0.69	0.69	0.69	0.69	0.69	0.71	0.66
Ethnicity level controls	N	N	N	Y	Y	Y	Y	Y
Household level controls	N	N	N	N	N	Y	Y	Y

Notes: Linear probability model. Dep.var.: Enrolled in primary school on time (yes=1, no=0), compared to country's legal starting age. All reported variables are binary (1=yes, 0=no). A child is defined as on time if she/he is in school at the age of the official enrollment age, regardless of birth month. Sample of 7-9 year old children: column 1: all, column 2: whose ethnicity is identifiable through the mother, and if not the father, columns 3-6: whose mother (or father's) ethnicity is matched to a bride price custom, column 7: whose mother 's (or father's) ethnicity practices the bride price custom, column 8: whose mother 's (or father's) ethnicity does not practice the bride price custom. Standard errors clustered at district level in column 1, and clustered at ethnicity level in columns 2-8. "Bride price" indicates that the individual's mother (or father) is part of an ethnicity that has historically practiced the bride price custom or not, as identified by Murdock's (1967) Ethnographic Atlas. Controls for age, district, rurality, and survey round are included throughout. Ethnicity level controls are matrilineal descent (except in Panel A), whether females are central in agriculture, polygyny, interactions with female, and a control for missing information on females' involvement in agriculture. Household level controls are gender and education of household head, whether individual is child or grandchild of head, and the wealth index. Source: DHS surveys for Mozambique, Zambia, Malawi, and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D6: Probability of enrolling in primary school on time, by country
Including children w/ethnicity identified through other than mother or father

	Bride price (BP) and non-bride price (no BP) ethnicities						BP	No BP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Mozambique								
Female	0.008	0.014	0.009	0.013	0.008	-0.029***	-0.011	-0.036***
	(0.025)	(0.029)	(0.030)	(0.030)	(0.008)	(0.006)	(0.066)	(0.006)
Bride price			0.019	0.097*	0.072	0.027		
			(0.039)	(0.051)	(0.041)	(0.027)		
Female x Bride price					0.039	0.042		
					(0.036)	(0.037)		
Number of Obs.	2180	1983	1910	1910	1910	1908	755	1153
Mean of Dep. Var.	0.71	0.71	0.71	0.71	0.71	0.71	0.84	0.63
Panel B: Zambia								
Female	0.030***	0.027*	0.026*	0.025*	-0.111***	-0.102***	-0.008	-0.094**
	(0.011)	(0.014)	(0.015)	(0.015)	(0.014)	(0.014)	(0.022)	(0.037)
Bride price			0.020	0.024	0.003	-0.000		
			(0.018)	(0.016)	(0.017)	(0.013)		
Female x Bride price					0.040***	0.034**		
					(0.013)	(0.016)		
Number of Obs.	7398	6855	6718	6718	6718	6714	1816	4898
Mean of Dep. Var.	0.68	0.68	0.68	0.68	0.68	0.68	0.72	0.67
Panel C: Malawi								
Female	0.035***	0.032***	0.032***	0.032***	0.031*	0.021	0.037**	0.020
	(0.006)	(0.004)	(0.005)	(0.005)	(0.016)	(0.013)	(0.007)	(0.016)
Bride price			0.027	-0.004	-0.003	-0.031***		
			(0.016)	(0.008)	(0.008)	(0.006)		
Female x Bride price					-0.002	-0.001		
					(0.005)	(0.004)		
Number of Obs.	13827	12072	11525	11525	11525	11520	1856	9664
Mean of Dep. Var.	0.76	0.78	0.78	0.78	0.78	0.78	0.88	0.76
Panel D: Namibia								
Female	0.015	0.005	0.003	0.003	0.031**	0.026**	0.034***	0.036***
	(0.015)	(0.014)	(0.014)	(0.014)	(0.012)	(0.011)	(0.001)	(0.008)
Bride price			0.047	0.084**	0.097**	0.078**		
			(0.032)	(0.030)	(0.029)	(0.024)		
Female x Bride price					-0.028**	-0.016		
					(0.012)	(0.012)		
Number of Obs.	4802	4295	3641	3641	3562	3555	2213	1342
Mean of Dep. Var.	0.65	0.66	0.65	0.65	0.64	0.64	0.64	0.64
Ethnicity level controls	N	N	N	Y	Y	Y	Y	Y
Household level controls	N	N	N	N	N	Y	Y	Y

Notes: Linear probability model. Dep.var.: Enrolled in primary school on-time (yes=1, no=0). A child is on time if she/he is in school at the age of the official enrollment age, regardless of birth month. All reported variables are binary (1=yes, 0=no). Sample of 7-9 year old children: column 1: all, column 2: whose ethnicity is identifiable through mother/father/other household member, columns 3-6: whose mother/father/other household member is matched to a bride price custom, column 7: whose mother/father/other household member's ethnicity practices the bride price custom, column 8: whose mother/father/other household member's ethnicity does not practice the bride price custom. Standard errors clustered at district level in column 1, and clustered at ethnicity level in columns 2-8. "Bride price" indicates that the individual's mother/father/other household member is part of an ethnicity that has historically practiced the bride price custom or not, identified using Murdock's (1967) Ethnographic Atlas. Controls for age, district, rurality, and survey included throughout. Ethnicity level controls are matrilineal descent (except in Panel A), whether females are central in agriculture, and polygyny, interactions with female, and a control for missing information on females' involvement in agriculture. Household level controls are gender and education of household head, whether individual is child or grandchild of head, and the wealth index. Source: DHS surveys for Mozambique, Zambia, Malawi, and Namibia. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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Thesis number: 2016:73
ISSN: 1894-6402
ISBN: 978-82-575-1390-0

Nina Bruvik Westberg was born in Oslo, Norway, in 1985. She holds a BSc. Degree of Social Sciences in Economics from the Norwegian University of Science and Technology (2007) and a MSc. Degree in Development and Natural Resource Economics from the Norwegian University of Life Sciences (2010).

The thesis consists of an introductory chapter and four independent research papers. The four papers can all be placed within the broad realm of development economics, and scratch at the role of climate variability, ethnic customs and government policies in shaping the future.

The first paper assesses empirically the use and demand for inorganic fertilizer among smallholders in northern Ethiopia. The findings indicate that the relationship between risk aversion and fertilizer use depends on contextual factors, and that fertilizer use and demand seems to be both a function of liquidity constraints and rainfall conditions.

The second paper uses panel data on Tanzanian farm households to investigate how previous drought exposure affects the impact of a current drought on agricultural yield and children's health. The results indicate that the impact of a drought on agricultural yields increases in the severity of the shock. The negative impact is mitigated by previous shock exposure, yet this only holds for milder shocks. Severe droughts seem to have a negative impact on children's short-term nutritional status.

The third paper returns to fertilizer and its role in politics. It investigates to what extent the allocations of fertilizer vouchers from the Malawian Farm Input Subsidy Program (FISP) were altered leading up to the presidential election in Malawi in 2009. The results suggest that districts with more swing voters receive on average more fertilizer vouchers. This increase comes at the expense of districts with more of the oppositions' core voters.

The fourth paper focuses on the bride price custom and its role in explaining a female-favored gap in on-time school enrollment in four southern African countries. Previous work has suggested that the bride price is increasing in the bride's education, whereas non-virginity and previous childbearing may reduce it. The paper explores how these two forces may shape the timing of enrollment and educational attainment.

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