Gender Equality in the Family Can Reduce the Malaria Burden in Malawi

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Abstract: We provide the first empirical evidence that increasing equality between decision makers in a family reduces malaria transmission in Malawi. International organizations and the Malawi government have invested more than one hundred million dollars to reduce the disease burden in the past decade, successfully reducing malaria prevalence by innovating, and scaling up impactful interventions. Additional progress is possible: we show that integrating women's empowerment programs into malaria control efforts would reduce the disease burden further. We measure power in three different ways: we estimate two separate collective models of the family, one with outside options and one without, and we construct a reduced form index as a proxy. The average female decision maker has 25% of their partners' decision-making power in the model with outside options — our preferred model for this data. We instrument bargaining power with the percent of families in a community that adhere to a matrilocal relocation, and matrilineal inheritance, tradition. We find that a one standard deviation increase in women's bargaining power decreases the likelihood that a family member contracts malaria by about 40%, using our preferred model. (JEL D1, I14, I15)
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1 Introduction

In the last three decades in Malawi, malaria is estimated to have killed more than half a million people (Murray et al, 2012). Despite decades of intense efforts to control the disease, and despite the scale up of effective methods of control, infection rates remain high (Bhatt et al, 2015; Adepoju, 2019; Chipeta et al, 2019). Roughly 30% of Malawi's population is infected annually, which poses serious morbidity costs (Fernando, Rodrigo, and Rajapaksem, 2010; World Health Organization, 2018). Developing new approaches to lower malaria rates is paramount to further reducing the disease burden (Hay et al, 2004; Griffin et al, 2010; World Health Organization, 2019). Such approaches may, in fact, already have a motivation in various literatures: devising new methods of control may be a matter of drawing connections between malaria contraction and various facets of human behavior.

Across the world, social scientists have documented a positive relationship between family health and gender equality between parents. In theory, parents with more equal bargaining power may allocate more resources to public goods within the family — like indoor residual spraying against mosquitoes — and less equal parents allocate more resources to private goods, like clothing or cigarettes (Blundell, Chiappori, and Meghir, 2005). This theory is empirically supported.[1] This relationship might also hold in Malawi with respect to malaria, though this specific hypothesis has not yet been tested. It seems especially likely to hold with respect to malaria because the probability of infection for any family member is higher when other family members are sick. Investment in one person's health is investment in a public good, since it generates a positive externality. As such, increasing equality between decision makers in the family may reduce malaria transmission.

In this paper, we show that increasing women's bargaining power in the family increases gender equality, and reduces malaria transmission in Malawi. In particular, a standard deviation increase in women's bargaining power would result in a 45% decrease in the likelihood that any family member contracts malaria.

Our analysis has two steps. We first document substantial gender inequality in the family by generating point estimates of parents' bargaining power. Next, we model malaria contraction as a function of parents' decision-making power, instrumenting for power using the percent of families in a community that adhere to a matrilocal relocation and matrilineal inheritance tradition. We find a causal, negative relationship between mother's bargaining power and the likelihood that family

[1] See, for instance, Thomas (1990), Beegle, Frankenberg, and Thomas (2001), Duflo (2003), Attanasio and Lechene (2010), Li and Wu (2011), Lépine and Strobl (2013), Calvi (2017), Calvi, Lewbel, and Tommasi (2017), Sraboni and Quisumbing (2018), Holland and Rammohan (2019), Klein and Barham (2019), and Tommassi (2019). See Richards et al (2013) and Doss (2013) for literature reviews that discuss family members' health and power dynamics between household heads.

members contract malaria. To our knowledge, we are the first to use quantitative methods to study the relationship between power and malaria transmission in any context.[2]

To measure gender inequality in the family in Malawi, we estimate three models of power and family decision making using Malawi's Integrated Health Survey (IHS) data from 2010 and 2013. We use the three primary methods that economists have at their disposal to generate point estimates of bargaining power from observational data: modeling outside options, modeling demand, and constructing a proxy index measure. As explained below, each approach has advantages and disadvantages. By using three methods, we can assess how robust our findings are to various modeling assumptions. The three models map from fundamentally different domains[3] to power estimates, but all three models show that women have statistically less bargaining power than men.

The first model we estimate was developed by Klein and Barham (2019). They construct a collective model of the family with limited commitment, and identify the expected value of women's bargaining power for each family under the assumption that partners' utility functions are random variables. This approach explicitly models each partners' choice of whether to divorce at any point in time — a particularly salient feature of the data generating process. About half of marriages in Malawi end in divorce within twenty years (Reniers, 2003; Cherchye et al, 2018). This estimation strategy has the advantage of incorporating how gender discrimination in institutions outside of the family, such as agricultural and wage labor markets, is reproduced within the household via the relative value of partners' outside options. Because divorce is common in Malawi, and because this is the only model that is able to explicitly incorporate divorce decisions, this is our preferred model to recover bargaining power estimates from this data.

The second model we estimate was developed by Browning, Chiappori, and Lewbel (2013, BCL from here on) and further elaborated by Dunbar, Lewbel, and Pendakur (2013, DLP from here on). This collective model with full commitment allows us to understand consumption inequality within a household by recovering the family's sharing rule. Each member's resource share tells us how much of the family's total surplus that member consumes, giving a direct estimate of inequality in col-

[2]There are, however, many qualitative studies on this relationship, all of which document the role of household bargaining dynamics in malaria prevention and treatment-seeking behaviors. See Ewing et al (2016) for a qualitative study of gendered decision-making power and treatment-seeking behavior for febrile children in Chikwawa, Malawi. See Molyneux et al (2002) for a qualitative study using data from Kenya. See Tolhurst and Nyonator (2006) and Tolhurst et al (2008) for qualitative studies using data from Ghana. See al-Taiar et al (2009) for a qualitative study using data from Yemen. See Williams and Jones (2004) for a brief literature review of earlier ethnographic studies.

[3]Those are earnings profiles for the Klein and Barham (2019) method; household demand for private assignable goods for the Dunbar, Lewbel, and Pendakur (2013) method; and demographic characteristics of the household heads for the PCA proxy variable

lective settings. It also permits the construction of a bargaining power measure as in Tommasi (2019), which is the ratio of the female decision maker's resource share to the parents' summed shares. In families with children, this measure captures the amount that each partner sacrifices so that their dependents can consume family surplus. This model is built on sample-level estimates of Engel curves for private assignable goods and explicitly accounts for positive consumption externalities and economies of scale in households.[4]

The third model we estimate is a simple index of relevant proxy variables that are weighted by loadings from a principal components analysis (PCA). This approach relies on fewer, but stronger, assumptions than those of the two structural models. However, it is more similar to the measurement methodology that can be found in the typical study on power in the family.[5]

Across all three methods, we find robust evidence of gender inequality between parents in the IHS data. We consistently reject the null hypothesis that men and women in the typical family have equal bargaining power, in favor of the alternative hypothesis that women have less power. Using the outside option approach of Klein and Barham (2019), we find that the median female decision maker in our sample has about 25% of the bargaining power that her partner has. The index measure approach suggests that wives have 73% of their partners' power. Using the resource share approach, we find that women in families with more than one child have about 80% of the bargaining power that their partners have.[6] We discuss the epistemic gains from estimating three independent models of power, as well as the fundamental differences in the models' domains and estimates, below. The differences between the mean power estimates from these three models suggest that incorporating divorce decisions into the estimation process provides a drastically different, and likely more accurate, picture of power in the family.

Next, we use an instrumental variables approach to estimate the marginal effect of an increase in each of these three variables on the likelihood that a family member contracted malaria in the last two weeks. We instrument for power using the share

[4]Engel curves are demand functions of income that hold prices constant. See Lewbel (2008) for a history of the topic, and full definition.

[5]Recent examples of studies using indices include those by Saha and Sangwan (2019), who study women's power and access to microfinance; Schaner (2017), whose index and qualitative verification strategy is the only survey-based method to measure power that is referenced in the Abdul Latif Jameel Poverty Action Lab's "A Practical Guide to Measuring Women's and Girls' Empowerment in Impact Evaluations" (Glennerster, Walsh, and Diaz-Martin, 2018); and Mishra and Sam (2016), who use an index created from reported decision making patterns. Mishra and Sam (2016) provide additional examples and ground their index in Agarwal's (1997) conception of women's power and agency. See Ewerling et al (2017) for an example of a study that uses principal components analysis to generate weights for a bargaining power index.

[6]In addition, we find that women sacrifice their own consumption for their children to a greater degree than men do. The resource share measure declines with the number of children, as DLP also document using the 2004 IHS data.

of families in a community that adhere to a tradition of matrilocal post-marriage relocation and matrilineal inheritance.[7] Daughters in families that practice this tradition inherit land and other assets from their parents, as opposed to sons inheriting assets (Peters, 1997; Reniers, 2003; Takane, 2008). Under matrilocal arrangements, men relocate to their wife's community at the time of marriage. Ewing et al (2016) find support for the positive relationship between women's autonomy and this tradition in focus group interviews from the Chikwawa district. Walther (2018) shows that these practices influence family labor allocation and investment decisions by increasing women's bargaining power. Since malaria transmission is unlikely to be related to prevailing inheritance and post-marriage relocation traditions in a community, the works of Ewerling et al (2016) and Walther (2018) appear to provide the basis for a valid instrument.

In fact, across all three models, we find a positive relationship between the percent of families that practice a matrilineal and matrilocal tradition in a community, and gender equality in the family. Our estimates of this relationship range from 0.014 - 0.044, suggesting that about a 1% increase in the percentage of families practicing this tradition in a community corresponds to more than a 1% increase in the typical wife's bargaining power in that community.

We find that the instrument is strong for the bargaining power measures generated from the Klein and Barham (2019) and PCA index approaches. However, we find that the prevalence of these traditions in a community is a weak instrument for the measure of power we construct from the resource shares model. As such, we fit our two-stage least squares model using the Klein and Barham (2019) and PCA model estimates of power, but not the DLP model estimates of power.

Our two-stage least squares results indicate that a one standard deviation increase in women's bargaining power would reduce the likelihood that a family member contracts malaria from 27% to 16% and 8%, for the Klein and Barham (2019) and PCA models respectively. We find that government and NGO interventions could empower women, and that this empowerment would subsequently reduce the likelihood of malaria infection. Further, we calculate naive (biased) correlations between malaria contraction and the DLP model power estimates using logistic regressions. We find a negative correlation using this approach as well, lending additional credence to instrumented results.

Our primary contribution is to show that another policy lever could reduce the malaria burden in Malawi. Programs aimed at reducing the malaria burden, like the new vaccination scale-up endeavor, could be combined with gender-equality interventions for increased effect. For example, a cash transfer to mothers conditional on

[7] The Chichewa word for this tradition, and the way that this tradition is reported in the community module of the IHS data, is "chikamwini."

having vaccinated their children could combat malaria through two routes: increasing vaccine uptake, and empowering mothers by improving their outside options. Our secondary contribution is to estimate three distinct models of power in the family on the same data set and compare the outcomes. While we reject that men and women have equal bargaining power, using all three measures, we also reveal substantial heterogeneity in the estimate distributions across models. Incorporating limited commitment in collective models of family decision making is important in contexts where the divorce rate is high.

The main shortcoming of our analysis is that the data do not permit a lengthy investigation of the mechanisms underlying our results. We test two hypotheses, and propose several more, to explain the negative, causal relationship between gender equality and malaria contraction. The first is the use of a private latrine: women with more bargaining power are far more likely to have a family that uses a private bathroom. Families with less equal parents are more likely to share a bathroom with other families. It is possible that this sharing increases exposure to mosquitoes carrying the *Plasmodium falciparum* parasite. The second is that more equal parents are more likely to enforce bed net use. However, we find no relationship between bargaining power and family bed net use. This is likely because the massive bed net distribution campaigns of the last decade did not target bed net distribution based on gender equality. This is good for reducing the malaria burden but is unhelpful in explaining our results.

The rest of this paper is structured as follows. In Section 2, we summarize the IHS data on malaria, individuals, families, and traditions in Malawi. In Section 3, we provide our instrumental variables approach as if we had bargaining power estimates available. In Section 4 we discuss the theory and practice of bringing each of our three models of power to the IHS data. We present the results in Section 5, explore mechanisms in Section 6, and conclude in Section 7. We provide additional technical details on the theoretical and econometric derivations of the DLP and Klein and Barham (2019) estimators of power in two appendices. We display tables with nuisance parameters in Appendix C.

2 Setting: Malaria and Household Dynamics in Malawi

We study publicly available data from 2010 and 2013, documented in the Living Standards Measurement Study data set — the Integrated Household Panel Survey.[8] These data come from a period of high malaria transmission in Malawi. In this section, we first discuss the public health setting we study. Then, we describe

[8]Download data from the National Statistical Office of Malawi and the World Bank here: https://microdata.worldbank.org/index.php/catalog/2248.

households' and parents' characteristics, which we use to estimate bargaining power in each family. Finally, we discuss the inheritance and martial traditions practiced across the country.

2.1 Malaria in Malawi

Malaria is one of the most common and lethal diseases in Malawi. From 1980 to 2010, the estimated annual number of deaths from malaria increased from 6,089 to 13,953 (Murray et al, 2012). The population tripled in that time frame, and so the incidence of malaria deaths increased by about one-third over thirty years, from 48 to 67 per 1,000. In 2010, the prevalence (number of cases divided by the population size) of malaria in Malawi was 43% (Malawi Ministry of Health, 2014). Over the next four years, the government and NGOs scaled up antimalaria campaigns, and prevalence fell to 33% in 2014 (Malawi Ministry of Health, 2014). In our sample, 27% of families reported that at least one household member contracted malaria in the last two weeks. Prevalence rates are similar today.

Multiple mosquito populations carry the *P. falciparum* infection in Malawi. Mzilahowa et al (2012) study the number of infected bites per year — the entomological inoculation rate — that people in the Chikwawa district of Malawi suffer. They find that *Anopheles funestus* and three species of *A. gambiae* can pass the disease to humans, and that people typically get 15 infected bites per month. These different types of mosquitoes exhibit different behaviors, so that one type of intervention (e.g., interventions targeted to reduce biting within the home) cannot completely reduce the entomological inoculation rate to zero. Multiple different types of interventions are required.

The human relationship to the *P. falciparum* parasite is complex. In general, people can be in any one of five possible states of infection: susceptible; partially immune; infected with symptoms and not receiving treatment; infected without symptoms and not receiving treatment; or infected and currently being treated, typically with symptoms (Griffin et al, 2010). The movement from one status to another depends on a large number of environmental factors, as well as a huge variety of choices that individuals and families make. These environmental factors and human decisions influence the likelihood and rate at which people pass from one state to another via three mechanisms: the etymological inoculation rate, the transmission efficiency (the likelihood of contracting malaria when bitten by an infected mosquito), and the time required to clear the disease (Smith et al, 2005).

Contemporary control and elimination strategies in Malawi influence malaria prevalence via all three channels. The primary methods of control over the last decade have been the rollout of insecticide-treated bed nets, indoor residual spraying, and artemisinin-based combination therapy, often abbreviated ACT (World Health Organization, 2018). In 2015 and 2016 alone, international organizations and the government distributed more than 10 million nets to the people of Malawi, more than one net for every two people (World Health Organization, 2018). Now, the government is working in tandem with the World Health Organization to rollout the RTS,S malaria vaccine (van den Berg et al, 2019). Bednets and spraying influence the etymological inoculation rate; the vaccine influences transmission efficiency; and ACT influences the rate of recovery. The take-up of all of these technologies might also be a function of decision-making power, since they promote public health within the family.

In addition to understanding transmission as a function of malaria prevention campaigns, we can understand the disease prevalence as a function of family decision-making patterns. Decisions that parents make jointly can also influence all three key mechanisms that mediate malaria transmission. Decisions like where to live, the degree of investment in the dwelling structure, and whether to share a latrine with a neighbor or use a private latrine, can all influence the etymological inoculation rate. Decisions concerning nutrition[9] can influence transmission efficiency. Infants enjoy a brief period of immunity from chemicals inherited from their mothers (Sehgal, Siddiqui, and Alpers, 1989). The extent of this brief immunity may be a function of family decisions that influence maternal health. Decisions about when to seek medical help and how much to invest in treatment can influence the rate of clearing the disease.

Ewing et al (2016) provide an important glimpse into the multidimensional relationship between malaria contraction and gender equality in the family in Malawi. They conduct focus group interviews in the southern Chiwawa district and find that couples bargain over when to send a child for medical attention. Women with more bargaining power are able to quickly mobilize family resources to seek medical help for sick children. This reduces the likelihood of superinfection, and speeds the child's transition from "sick with symptoms" to "sick and receiving treatment" to "temporarily immune." Ewing et al (2016) report that families with less equal partners often wait longer, to see whether a child will recover, before taking them to a doctor, sometimes waiting so long that the child collapses. The timing of medical treatment is just one of the many ways in which bargaining dynamics are salient in understanding who contracts malaria, who suffers from superinfection, and who in the population might be temporarily immune or susceptible.

[9] There are strong and positive links between gender equality in the family, and quality of diet (e.g., Sraboni and Quisumbing, 2018; Klein and Barham, 2019). There are strong and negative links between nutritional attainment and malaria contraction. There are two pathways for this connection: better health reduces the time required to clear the disease and the likelihood of contracting malaria from an infected bite (Lakkam and Wein, 2015).

Several more public health features are relevant to the malaria burden in Malawi, and are directly linked to women's bargaining power. One is the prevalence of HIV/AIDS, which can severely increase morbidity and mortality from malaria. Conversely, malaria increases the likelihood of HIV/AIDS transmission (Kublin et al, 2005). In 2004, an estimated 10% of the population of Malawi had HIV/AIDS (Greenwood et al, 2019). There is a direct link between power dynamics and risky sexual behavior, and Gerritzen (2014) documents that more equal partners are more likely to use safety precautions to reduce the spread of infections in Malawi.

In addition, pregnant women are more likely to contract malaria than others. Malaria contracted during pregnancy can cause newborn death. Women who receive regular antimalarial treatment during their pregnancies are more likely to have heavier, healthier babies, and to be healthier themselves (World Health Organization, 2018). In 2013, about 60% of pregnant women in Malawi received two or more antenatal treatments (Mathanga et al, 2012). The recommended number of treatments is three or more. Increased ACT use during pregnancy may reduce malaria rates further, and the allocation of family resources to pregnant women's medication may be a function of women's bargaining power.

2.2 Families in Malawi

Roughly 80% of Malawi's population lives in agricultural communities. GDP per capita was around 630 USD in 2010, the year of our first wave of data, and life expectancy was about 57 years. Malawi was, and is today, one of the poorest countries worldwide.

In Table 1, we present summary statistics for the Malawi IHS at the family level in 2010 and 2013. We study the subset of families in the data that have a male and female household head who are married. The typical family in this sample has five members, including a boy and a girl under the age of 16. A majority of family expenditures are on food. Most families get their water from a public source as opposed to having it piped into their homes. The most common type of floor in a dwelling is mud, and the most common type of roofing material is grass. Education rates are low, particularly for women. This is reflected in greater literacy rates for men than women, in both Chichewa and English.

Many elements of family life in this sample remained constant over time. The average, real family expenditures remained constant at around 5,000 USD per year.[10]

[10]Expenditures are calculated by the World Bank and provided for each family as constructed variables in the IHS data. The maximum reported expenditure in this sample is 18,304,290 MWK per year, or about 111,000 USD per year. The median is around 500,000 MKW per year. They are the sum of reported family expenditures on food, alcohol and tobacco, clothing and footwear, furnishings, health care, transportation, communication technologies, recreation, education, hotels and restaurants, and miscellaneous purchases. The fact that the World Bank-calculated expendi-

Table 1: Household Variable Means (with Standard Deviations in Parentheses)

	2010	2013
% Families with Malaria in Last 2 Weeks	29.73%	25.72%
% Live in Rural Area	74.71%	74.84%
Total Expenditures (in 10,000s MWK, 2010)	81.44 (98.58)	81.28 (88.75)
Food Expenditure Share	58.02% (14.57)	59.91% (13.92)
PAG Expenditure Share	0.26%	0.61%
Plot Size in Acres	1.68 (1.58)	1.60 (1.60)
Family Characteristics		
Family Size	4.97 (2.25)	5.18 (2.26)
# of Boys	1.07 (1.08)	0.94 (1.05)
# of Girls	1.1 (1.06)	0.96 (1.05)
# of Children Ages 0-5	0.74 (0.81)	0.62 (0.74)
Fathers		
Age	40.08 (14.30)	40.68 (14.24)
Education (in Years)	6.94 (4.83)	7.35 (5.01)
Chichewa Literacy	76.71%	81.75%
English Literacy	48.03%	51.77%
Mothers		
Age	37.25 (15.58)	37.78 (15.37)
Education (in Years)	4.71 (4.29)	5.24 (4.51)
Chichewa Literacy	59.42%	66.71%
English Literacy	29.34%	33.65%
Water Access		
% of Families w/ Water in House	16.20%	16.85%
% of Families w/ Water Public	77.33%	78.53%
% of Families w/ Water Natural	5.85%	4.03%
% of Families w/ a Private Latrine	65.53%	71.5%
Dwellings		
% of Families w/ Grass Roof	59.09%	53.87%
% of Families w/ Iron Roof	40.63%	45.73%
% of Families w/ Mud Floor	65.36%	62.29%
% of Families w/ Cement Floor	31.80%	34.81%
% of Families w/ Earth Wall	15.16%	10.40%
% of Families w/ Brick Wall	29.02%	27.98%
% of Families w/ Fired Brick Wall	45.22%	54.6%

Table 2: Household Head Earnings Summaries (in 2010 Kwacha) by Gender (Percentage of Individuals with Positive Earnings in Parentheses) with Test Statistics for Gender Differences

	Female Head		Male Head	T-Statistic
Total Individual Income	97,284.65	<	237,657.5	-8.85
	(77.16%)		(94.64%)	(-29.72)
Income from Labor Market	125,613.88	<	210,320.7	-5.26
	(28.74%)		(53.55%)	(-28.96)
Income from Rainy Season Crop Sales	20,782.35	<	88,240.49	-6.95
	(38.62%)		(66.88%)	(-33.00)
Income from Entrepreneurship	92,561.59	<	239,016.16	-2.09
	(12.49%)		(17.89%)	(-8.36)
Income from Other Sources	27,734.09	<	29,339.1	-0.36
	(34.97%)		(34.29%)	(0.80)
Income from Livestock Sales	3,135.95	<	4,013.76	-0.75
	(15.71%)		(16.91%)	(-1.82)
Income from Livestock Products	1,010.28	<	1,219.04	-0.20
	(3.36%)		(3.32%)	(0.12)
Income from Dry Season Crop Sales	198.28	<	392.05	-2.81
	(2.48%)		(3.07%)	(-2.01)
Income from Tree Crop Sales	265.68	<	527.96	-1.81
	(6.36%)		(5.89%)	(1.11)

Cities and rural areas grew at similar rates. The average family was headed by a 40-year-old father and a 37-year-old mother in both years.

However, educational attainment, literacy rates, and dwelling characteristics improved from 2010 to 2013. The cohort of parents in 2013 has slightly higher educational attainment levels than does the cohort in 2010. Literacy rates reflect this, with increases for mothers and fathers in both Chichewa and English over these three years. Dwellings also improved, with more families living in homes with metal roofs, cement floors, and fired brick walls. Fewer families obtained water from natural sources like rivers and springs. Families were less likely to share a latrine, and more likely to have a private bathroom. All of these improvements likely contributed to the declining prevalence of malaria from 2010 to 2013.

In order to calculate resource shares with the DLP model, we study three-month recall data on clothing and shoes expenditures. These are "private" goods since only one member can use them, and they are "assignable" since we can observe who clothing and shoes belong to. The DLP method maps from variation in expenditures on private assignable goods (PAGs) across family members to their resource shares. In Malawi, families spend only small amounts on PAGs. While the budget share

tures are higher than the GDDPPC in the country is owing to the price scaling in the calculation process.

going to PAGs doubled from 2010 to 2013, it remained lower than 1%.

In Table 2 we present some summary statistics on earnings profiles of male and female household heads, pooled across years. The first variable is the total individual earnings for the male and female household heads who earn some positive amount. We calculate this by summing the earnings from the eight sources listed in the rest of the table. In parentheses, we include the percentage of household heads, by gender, who earn some positive amount from a particular source. As such, we report conditional mean earnings. The conditional means reported in the first row are, in some cases, lower than the conditional means reported in the constituent rows because more people are engaged in lower-earning endeavors than in higher-earning endeavors.[11]

A majority of household heads (77% of women and 95% of men) earn some amount of income from at least one of the eight sources listed in Table 2. The most common sources of earnings are rainy season agricultural sales. About 38% of women and 67% of men earn income by selling crops like corn, rice, and tobacco. The next most common is earning a wage in the labor market, and after that, "other sources" is the most common.

The most lucrative occupation for women is as a wage earner. The typical woman who works in the labor market earns far more than the typical woman who earns income from any other source. The next most lucrative profession for women is being an entrepreneur. For men, entrepreneurship has the highest return, followed by earning wages. In general, interacting with the labor market generates more earnings than selling agricultural products, like livestock or tree crops.

The *t*-tests in Table 2 demonstrate that from all sources men have more opportunities to earn than women do, and when men enter the market, they earn more than women do. These gendered differences in earnings and opportunities could manifest in gendered power dynamics in the family. This phenomenon is documented elsewhere, for example, in Mexico City (Benería and Roldán, 1987). It is possible that the three estimates of bargaining power will reflect the greater degree of opportunity for men outside the family. Of the three measures, the PCA index and the Klein and Barham (2019) measures are the most likely to pick up on these differences. They are directly (for the index) or indirectly (for the Klein and Barham method) based on earnings profiles. The DLP method is the least likely to reflect these differences since resource shares in that model are not directly a function of earnings or gendered market conditions. Structural inequality in the labor market and other institutions might not be reflected in the very small amount of the budget share

[11] All crop information is compiled from the agricultural module of the IHS survey at the plot level, and linked to individuals by their reported plot management. We calculate agricultural earnings as the amount of revenue generated from a plot minus the value of inputs on the plot. Labor market information comes from the household survey module.

spent on PAGs.

To model power in the family using Klein and Barham's (2019) method, an understanding of divorce is also required. Divorce is common in Malawi, with one in two families dissolving within twenty years (Reniers, 2003). Individuals often marry when young. As of 2004, the median age-at-first-marriage was 18 for women, and 23 for men (Cherchye et al, 2018). About 40% of women remarry within two years of divorce, and about 45% of marriages are between individuals living in the same village. An additional 25% are between individuals living in the same district, a slightly larger geographic unit (Cherchye et al, 2018).[12] How well off an individual would be in the case of divorce is likely a key element of a partner's bargaining position in the family. The gender discrepancies reported in Table 2 suggest that men will, in general, be better off than women in the case of divorce.

2.3 Traditions in Malawi

In our model of malaria contraction, we instrument women's bargaining power in the family with the percent of families in a community that adhere to a particular kinship tradition. In this section, we briefly give some background on this set of practices.[13] The key assumption in our model is that the prevalence of these practices in a community is only related to malaria transmission through women's bargaining power in the family, conditional on the controls we include in our models. We outline these models explicitly in the next section.

In matrilineal kinship groups, people trace their descent through their mothers. In partilineal, people trace descent through their fathers. In general, these systems of belonging can have complex social ramifications, including particular labor obligations, political succession, and the distribution of authority in society (Schneider and Gough, 1961). These descent and belonging practices may influence the conditions under which men and women may seek divorce without stigma (Schatz, 2002). Furthermore, it is more likely in patrilineal cultural groups that womens' families are expected to repay wedding gifts to mens' families in the case of divorce (Schatz, 2002), adding a large additional cost to divorce.

Across the world, far more societies observe patrilineal descent traditions than matrilineal descent traditions. However, in Malawi and the greater Zambezi River region, matrilineal descent is relatively common (Davison, 1997). Within the country,

[12] There are 28 districts in Malawi. The country has 36,324 square miles of land and so is about the same size as the American states of Indiana and Maine. The largest district in Malawi is Mzimba, which has about 4,000 square miles.

[13] See Phiri (1983) for a more comprehensive treatment of the history of matrilineal practices among the largest ethnic group in Malawi, the Chewa. This work analyzes how cultural forces — like the slave trade, missionaries, colonialism, and the expansion of capitalism — influenced norms and practices from the 1800s to the mid 1900s. Today, the practice of matrilieanlity and matrilocality are shaped by this historical context.

both cultural practices are observed, with a greater adherence to matrilineal and matrilocal traditions in the south. In our sample, 42% of families practiced the matrilineal and matrilocal tradition in the average community, with a standard deviation of 29 percentage points.

Gottlieb and Robinson (2016) study the relationships between gender, political engagement, and kinship traditions. They construct an index of political engagement and show that women in matrilineal communities have higher index values. They also summarize the link between household bargaining power and kinship traditions succinctly:

> "Finally, women in matrilineal societies are likely to have greater intra-household bargaining power vis-a-vis their spouses. This is certainly true when a couple resides matrilocally and a women is surrounded by her family. But it is also likely to be the case no matter the residence location, since matrilineal women have greater exit options than patrilineal women, for whom bridewealth would have been paid, effectively limiting a woman's ability to return home after a failed marriage or spousal death (Schatz, 2002, 2005). As a result, marriage bonds tend to be weaker and divorce rates higher in matrilineal groups (Schatz, 2002), presumably allowing women more power within the marriage (Phiri, 1983)."

Kerr (2005) studies power in Malawi as well. She conducted interviews and focuses on a case study involving a single family. Kerr draws a connection between gendered institutions and traditions, and bargaining power in the household, writing "Wives' unequal position is thus due to a lack of entitlements, such as land, access to employment, support from kin and the state. Some differences between this area of northern Malawi and other studies from central and southern Malawi are due to the different entitlements, particularly control over land and income, which speaks to the enduring implications of different lineage systems in the region."

3 Estimating the Marginal Effect of an Increase in Equality Between Parents on the Likelihood of a Family Member Contracting Malaria

In this section, we develop our causal inference framework. We first present a schematic diagram that portrays our modeling approach, and then we detail the specific empirical model. The strength of our modelling approach is that we can recover causal results even with an incomplete model of malaria transmission. We

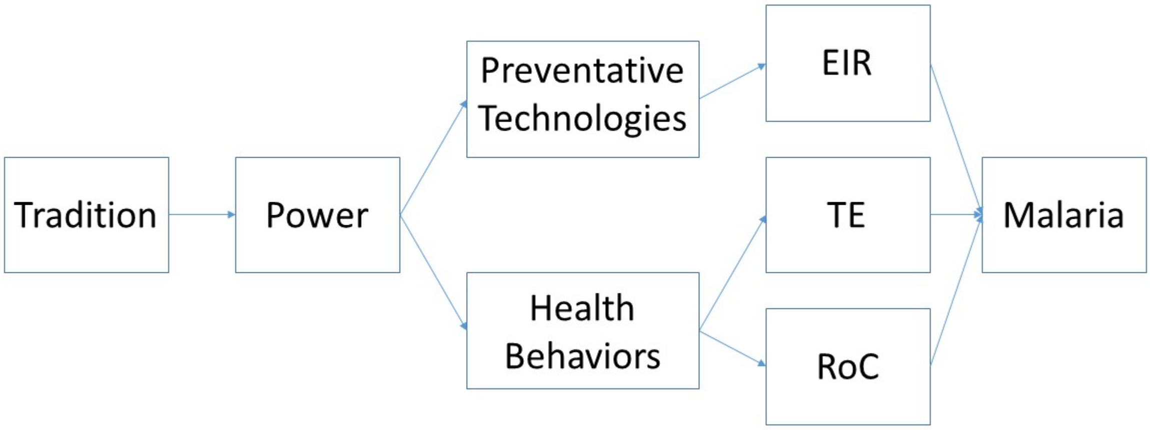

Figure 1: Model of Tradition, Power Dynamics, and Malaria Transmission. The assumption required in order for our results to have a causal interpretation is that, conditional on observables, the instrument — the percent of families adhering to a matrilineal and matrilocal tradition in a community — has no effect on malaria transmission, other than the effect it has via changing bargaining power in the family.

proceed here as if we had an estimate of bargaining power in hand, then discuss how we generate these estimates in the next section.

3.1 Instrumental Variables Approach

Culture and tradition determine who inherits assets, and the size of individuals' immediate social network. Relative assets holdings and social network strength influence power dynamics in the family by improving individuals' relative outside options. Power dynamics in the family influence joint allocations in many domains, such as where to live, when to take a sick child to a doctor, and whether to invest in preventative health care technologies. These choices can affect the etymological inoculation rate, the transmission efficiency, and the rate of clearing *P. falciparum*. These three factors determine whether someone contracts malaria. The relationship between culture, power, household choices, parasite-human relations, and malaria contraction are summarized in the directed acylic graph in Figure (1).

A complete mathematical model would capture all of the steps in this causal chain. Let $Y_{i,h,t}$ be a dummy variable for individual i, in household h, in year t, equal to one if that person was ill with malaria at any time in the last two weeks. Denote the number of times that individual was bitten by an infected mosquito as EIR_i, the likelihood that infection is transmitted from the mosquito to the individual as TE_i, and the rate at which an individual clears infection as RoC_i. If we were to model the malaria prevalence in a population, we would use the $\int SI^oS$ model of these three variables, developed by Ross (1911) and McDonald (1957), and benchmarked by Smith et al (2005). In a model of individual contraction, we can use a linear model:

$$Y_{i,h,t} = \beta_1 EIR_{i,h,t} + \beta_2 TE_{i,h,t} + \beta_3 RoC_{i,h,t} + X'_{i,h,t}\beta + \epsilon_{i,h,t} \tag{1}$$

where $X_{i,h,t}$ is a set of individual and household characteristics, like age, and region fixed effects, and β is a vector of regression coefficients. This model could be extended so that the three principal explanatory variables are explicitly functions of the choices that the family makes, such as whether to invest in indoor residual spraying, or what level of nutritional attainment each individual in the family achieves. Denote investments in preventative technologies as $I_{h,t}$, and the family's health behaviors (like amount of time parents delay before going to the doctor) as $b_{h,t}$. Then the three explanatory variables in (1) can be modeled as functions of family choices:

$$EIR_{i,h,t} = \beta_{1,EIR} I_{h,t} + \beta_{2,EIR} b_{h,t} + X'_{i,h,t}\beta_{EIR} + \nu_{EIR,i,h,t} \tag{2}$$

$$TE_{i,h,t} = \beta_{1,TE} I_{h,t} + \beta_{2,TE} b_{h,t} + X'_{i,h,t}\beta_{TE} + \nu_{T,i,h,t} \tag{3}$$

$$RoC_{i,h,t} = \beta_{1,RoC} I_{h,t} + \beta_{2,RoC} b_{h,t} + X'_{i,h,t}\beta_{RoC} + \nu_{RoC,i,h,t} \tag{4}$$

where ν is an error term in this second layer of models.

These choices are a function of income, prices, and the bargaining power dynamic between decision makers. As Blundell, Chiappori, and Meghir (2005) show, power will influence the purchase of public goods to the extent that parents' marginal rates of substitution between private consumption and public consumption differ. In addition, power will matter more in families with higher degrees of caring preferences. We can model $I_{h,t}$ and $b_{h,t}$ in terms of income, prices (including the losses associated with becoming sick), and parents' bargaining power. Denote the female decision maker's power as $\eta_{h,t}$, income as $y_{h,t}$ and prices as p_t. Then, we can model family level decisions as the functions:

$$I_{h,t} = \beta_{I,h,t}\eta_{h,t} + \beta_{I,h,t} y_{h,t} + \beta_{I,h,t} p_t + X'_{i,h,t}\beta_{I,h,t} + \nu_{I,h,t} \tag{5}$$

$$b_{h,t} = \beta_{B,h,t}\eta_{h,t} + \beta_{B,h,t}y_{h,t} + \beta_{B,h,t}p_t + X'_{i,h,t}\beta_{B,h,t} + \nu_{B,h,t} \tag{6}$$

Finally, we can model women's bargaining power in the family as a function of inheritance and marital traditions. An even more direct model would incorporate another step, explicitly linking matrilineal and matrilocal traditions to the value of women's outside options, relative to their partners' outside options, as an explanatory mechanism. We take this step below, in our application of the Klein and Barham (2019) model of family decision making with limited commitment. For now, denote the percent of families in household h's community that adhere to a matrilineal and matrilocal tradition as $M_{h,t}$.

$$\eta_{h,t} = \beta_{M,h,t}M_{h,t} + X'_{i,h,t}\beta_{M,h,t} + \nu_{M,h,t} \tag{7}$$

Equations (1) - (7) form a full model of malaria transmission as a function of women's bargaining power and matrilineality. If we observed all of the data required to estimate these models, then we could recover a causal estimate of the relationship between power and malaria using ordinary least squares (OLS) to calculate the regression coefficients, under the assumption that the models are correctly specified. However, we do not observe several key variables. For instance, EIR and TE are rarely recorded at the individual level. Worse, RoC is unobservable, though it can be estimated. As such, it is not possible to estimate this full model of malaria contraction. In order to obtain causal estimates of the relationship between power and malaria transmission we need to rely on an alternative assumption.

Our feasible model of power and malaria transmission is a standard two-stage least squares model. Instead of individual level contraction, we analyze a dummy variable equal to one when at least one member of a family was ill with malaria in the past two weeks, $Y_{h,t}$. The first stage of our feasible model is given by (7). We estimate (7) using OLS, and then use the fitted values from this equation to estimate

$$Y_{h,t} = \beta_1\hat{\eta}_{h,t} + X'_{h,t}\beta_{h,t} + \epsilon_{h,t}. \tag{8}$$

Our identifying assumption is that $cov(\epsilon_{h,t}, M_{h,t}) = 0$. That is, the only way that our instrument is related to malaria transmission is through bargaining power. Once we have modeled the relationship between power and matrilineality, we can exclude the instrument from equation (8). Under this assumption, and conditional on instrument strength, the estimate $\hat{\beta}_1$, calculated by fitting equation (8) using OLS, can be interpreted as the causal effect of an increase in women's bargaining power on the likelihood that anyone in the family was ill with malaria in the last two weeks. We block bootstrap $\hat{\beta}_1$ to form the confidence intervals that we use for causal inference.

Our instrumental validity assumption rests on two features of this model. First, we can link power and malaria transmission in the full model (1) - (7). This full model, and the schematic representation in Figure (1), show how a change in power leads to a change in malaria contraction rates. Second, we can add in additional control variables in our feasible model, given by equations (7) and (8), to change the definition of $\epsilon_{h,t}$ in (8). By including regional fixed effects, for instance, we can control for the coincidental covariance across the country of malaria contraction (related to swampy terrain more prevalent in the south) and matrilineality (more frequently practiced by cultural groups located in the south). In total, we include the following control variables in both stages of our feasible model: the percentage of a family's neighbors that contracted malaria in the last two weeks, family size, the log of monthly family income divided by family size, the number of children under five, fixed effects for what kind of dwelling the family lives in, the number of rooms in a family's dwelling, a dummy variable for whether there is a clinic or hospital in a community, and district-year fixed effects. These controls are similar to those found in standard models of malaria transmission in Malawi (e.g., Lowe, Chirimbo, and Tompkins, 2013) and in other areas of sub-Saharan Africa (e.g., Roberts and Matthews, 2016). Now, the only task remaining is to model the family decision-making processes in order to recover an estimate of women's bargaining power for each family, in each year.

4 Recovering Estimates of Women's Bargaining Power in the Family

Families make many decisions jointly, like where to live, what to eat, which school to send a child to, and when to send a child to the doctor. All of these choices affect family members' health, and the likelihood of someone in the family contracting malaria. Modeling how parents' preferences, and their decision-making power, relate to observed choices is important in understanding the take-up of preventative measures, investment in children, and ultimately, the likelihood that any family member becomes ill. To model power in the family, economists can use the collective model of household behavior (Apps and Rees, 1988; Chiappori, 1988, 1992).[14]

In this section, we briefly provide a summary of the basic collective model of the

[14] This model is elaborated on by Browning et al. (1994), Browning and Chiappori (1998), Blundell, Chiappori, and Meghir (2005), and Chiappori and Ekeland (2006).

family, as well as the extensions of DLP[15] and Klein and Barham (2019).[16] We also describe the bargaining power index that we construct using PCA. After explaining each extension, we describe how we fit them to the IHS data. The histograms of the three measures are given in Figure (2). After recovering estimates of women's bargaining power in each family, we can fit the two-stage least squares model in equations (7) and (8).

4.1 The Collective Model

Consider a family with two decisions makers, indexed f and m, and a child, indexed c, who may or may not participate in the decision-making process. The statistician observes household-level data. Let households purchase a $k-$vector of goods, denoted $z = (z^1, \ldots, z^K)$ with prices $p = (p^1, \ldots, p^K)$. Families have total income y.

Each family has a distinct production function that converts these household-level purchases into consumption goods for each family member. Denote the amount that each person consumes of each good $x_\tau = (x_\tau^1, \ldots, x_\tau^K)$ for individuals of type $\tau \in \{c, f, m\}$. Each family member gets utility $U_\tau(x_\tau)$. Denote the family-specific production function $A(z)$ such that $x_f + x_m + x_c = A(z)$.

This production function captures economies of scale that result from cooperation. There are public goods within the family. It is cheaper to heat one home than it is to heat many, for example. There may be less spillage when one person cooks for the family, compared to each member cooking separately. Since individuals are consuming household-level public goods (like heat, internet, shelter, indoor residual spraying against mosquitoes, etc.), people face Lindahl prices for consumption, instead of market prices.[17]

Assume that the family chooses z so that no alternative allocation can be made that makes someone better off, and everyone else at least as well off; in other words, the family reaches a Pareto efficient allocation. Assume that families consider real prices instead of nominal prices (no money illusion). Then there exists some family-specific social welfare function, $\tilde{U}(U_f(x_f), U_m(x_m), U_c(x_c))$, that is twice differentiable and strictly increasing in each of its arguments, so that the family's problem

[15]See Calvi (2017) for a pedagogically useful example of how to use the DLP method to recover resource shares.

[16]We provide additional details for how to derive the bargaining power estimates from the two structural models in Appendices A and B. See the original essays for complete derivations and identification proofs.

[17]Lindahl prices clear individual-level markets in a public goods setting. See Lindahl (1919) for the original treatment of this topic, and Mas-Colell, Whinston, and Green (1995) for a modern summary of the concept.

is:

$$\max_{z,x_f,x_m,x_c} \tilde{U}(U_f(x_f), U_m(x_m), U_c(x_c)) \text{ such that } p'z = y \text{ and } x_f + x_m + x_c = A(z) \quad (9)$$

The solution to this program gives demand functions for each individual, $x_\tau^*(p/y)$. When valued at the Lindahl prices and compared to total family consumption, these demand functions give important analytical objects: resource shares. Denote each family members' resource share as η_τ^{rs}. The set of a family's resource shares is called the family's sharing rule. In this essay, one way that we think about inequality in the family is by recovering the sharing rule for each family. In addition, we can transform the sharing rule, as did Tommasi (2019), to recover an estimate of bargaining power. This transformation is simply the ratio of the female decision maker's resource share to the parents' total resource share.

Power and resource shares are slightly different objects of analysis. Power is the degree to which one person's preferences are reflected in the collective allocation. Resource shares are the amount of the collective surplus that someone consumes. The sharing rule is a function of bargaining power.

Consider two examples that illuminate the difference between power and the sharing rule. First, suppose one parent has a strong preference for taking the family to soccer matches, while the other parent is indifferent about how many soccer matches the family attends. The more powerful the soccer enthusiast is, the more matches the family will go to. Since attending a soccer match is a public good (all members equally observe the sporting event, even if they derive different levels of enjoyment from it), the family members will have more equal resource shares. The more powerful the soccer enthusiast is, the larger the fraction of family surplus that is split equally among the members. This mechanically reduces the enthusiast's resource share (since it increases the other members' shares). As the enthusiast's power increases, the enthusiast's resource share decreases.

Sokullu and Valente (2018) document a real-world example of this sort. They find that Progresa, a Mexican cash transfer targeted to women, reduced women's resource shares while increasing their children's. They suggest that Progresa increased women's bargaining power, increasing gender equality in the family and prompting larger family expenditures on children's well-being. This increased children's resource shares, mechanically decreasing mothers' shares (since resource shares sum to one). They find that men's resource shares were not as responsive to Progresa, suggesting that the proxy that Tommasi (2019) uses appropriately captures power dynamics. More powerful mothers would likely be able to enforce a trade-off between men's resource shares and children's resource shares, as opposed to making a unilateral sacrifice for their children.

Figure 2: Distribution of Bargaining Power Estimates from Three Models. We use a Gaussian kernel density with bin width equal to four times the standard deviation of the distribution (Wickham, 2016). The distribution from the PCA method is displayed in green. The distribution from the DLP method is displayed in red. The distribution from the Klein and Barham (KB) method is displayed in blue.

4.2 Using Predicted Outside Option Values to Measure Power

We can measure power by relaxing the implicit assumption in the model in program (9) that family members fully commit to the collective allocation. In Klein and Barham's (2019) extension, only parents are assumed to be involved in decision making. Children take their parents' decisions as given, and parents take their children's preferences into account when bargaining over an allocation. As described by Mazzocco (2007), each decision maker has an outside option. In Malawi, this outside option can be modeled as divorce (see, for instance, Cherchye et al, 2018). As such, individuals choose whether to divorce. If both partners choose to stay married, they decide jointly how to allocate resources to solve (9). The relative value of the outside options determines the strength of each partner's bargaining position within the marriage.

The first key assumption that Klein and Barham (2019) make is that the economist can model individuals' earnings based on available data. Researchers must predict each parent's earnings in the case of divorce — a key component of the value of each partner's outside option. Bargaining power is a function of these predictions, and of additional scaling parameters like the gendered stigma attached to divorce or the potential to improve one's position through remarriage.

The second key assumption is that parents' utility functions are random variables. This is in direct contrast to typical parametric identification strategies that assume that a particular utility function (like the log of consumption) describes individuals' preferences. Parents' utility functions are unknown to the researcher but known to be elements of the set of all increasing, quasi-concave, and twice differentiable functions. For tractability, Klein and Barham (2019) assume that there is some (arbitrary) partition on the set of all possible utility functions, and that the partners' pair of utility functions are conditionally uniformly distributed on the same subset of permissible functions. Since the partition can take any form, this is a weak "similarity between partners" assumption. This allows Klein and Barham (2019) to semiparametrically identify the expected value of women's bargaining power for each family.

Under these assumptions, the econometrician can recover point estimates of bargaining power from a set of family-specific equations. There are three steps in the estimation process. First, the econometrician must predict partners' earnings, potentially using a control function approach to account for censoring in the earnings. Denote the prediction for partner τ in household h in time period t as $F(X_{\tau,h,t}, \psi_{\tau,h,t})$, where X is a matrix of individuals', families', and settings' characteristics; and $\psi_{\tau,h,t}$ denotes latent ability.

Second, the econometrician must fit a fixed effects model with constraints. The sample estimates of family-specific intercepts capture differences in partners' linearly additive costs and benefits of divorce - that is, the differences in the "stock" of wealth each partner would get in the case of divorce. This fixed effects model is:

$$y = \beta_{0,h} + \beta_1(F(X_{f,h,t}, \psi_{f,h,t}) - F(X_{m,h,t}, \psi_{m,h,t})) + \epsilon_{h,t}, \tag{10}$$

$$\text{such that } \beta_1 + \frac{\epsilon_{h,t}}{F(X_{f,h,t}, \psi_{f,h,t}) - F(X_{m,h,t}, \psi_{m,h,t})} \in [-1, 1]$$

The constraints in this regression model ensure that the parameter estimates do not violate the condition that $\eta_f \in [0, 1]$.[18] Estimating this model gives enough information per household to recover the expected value of bargaining power for each family. Denote the intercept estimates from the constrained fixed effects model as $\tilde{\beta}_0$. The expected value of bargaining power for a family is a function of the parents' predicted earnings in the case of divorce, family income, and the intercept estimate:

$$\hat{\eta}^{KB}_{f,h,t} = \frac{1}{2} + \frac{1}{2}\frac{F(X_{f,h,t}, \psi_{f,h,t}) - F(X_{m,h,t}, \psi_{m,h,t})}{y_{h,t} - \tilde{\beta}_{0,h}} \tag{11}$$

The primary advantage of this approach is that economists can make a weaker assumption on utility functional forms than in other methods, and that the researcher does not need to assume that partners can commit to the collective allocation. The researcher must still make a weak "similarity between partners'" utility functions assumption but does not need to assume a particular functional form for utility. There is a rich tradition to draw from in modeling earnings (e.g., Mincer, 1974; Heckman, 1979), and new tools are regularly emerging to facilitate parameter selection (e.g. Tibshirani, 1996). The econometrician can use standard model comparison methods, like the Akaike information criterion, to compare whether one model describes the earnings process better than another. It is not possible to do this when estimating utility functions.

The primary disadvantage is that power itself is not identified in this model. Rather, the expected value of power for each family is identified. The choice to treat utility functions as random variables, then, has a theoretical disadvantage; it identifies the expected value of power, not power. However, it offers additional empirical tractability, because researchers estimate earnings models instead of demand for private assignable goods, where censoring is typically an issue. Another disadvantage to this approach is that the econometrician needs panel data, as opposed to one or more cross sections, to account for the household-specific intercepts in (5), which contain information like the relative expected utility from remarrying, and the relative gains from using the production technology within the marriage.

[18] See Appendix A for additional details, and see Klein and Barham (2019) for a complete derivation.

4.3 Applying the Klein and Barham (2019) Method to the Malawi Panel Data

To apply the Klein and Barham (2019) method for estimating bargaining power, we first estimate two Heckman selection regressions using full information maximum likelihood. Modeling selection into any earnings-generating activity is important since about 20% of women earn nothing at all. It is likely that women who do not earn anything are substantially different from women who choose to earn something. We want to accurately predict earnings for women who do not earn, and so we model the unobserved difference between women who chose to earn some amount, and those who do not. Modeling the selection problem for men is not as urgent, since 97% of men earn some positive amount. We model this problem regardless, for the sake of symmetry.

We fit the first Heckman selection model on the set of women ages 16-65 in our sample, and the second model fit on men ages 16-65. By estimating two separate models, we allow all parameter estimates to vary by gender, including the unobserved selection parameters. These models are given by the pair of selection and earnings regressions, where i indexes the individual, and $\tau \in \{f, m\}$ indexes type:

$$P_{i,g,t} = \beta^{P}_{i,g,t} X_{i,g,t} + \epsilon_{i,g,t} \tag{12}$$
$$ln(E_{i,g,t}) = \beta^{E}_{i,g,t} X_{i,g,t} + \epsilon_{i,g,t}$$

These regressions include time and district fixed effects; age and age squared; the size of plots an individual manages; a dummy for whether the person is the head of the household; family size; the number of men, women, boys, and girls in the family; literacy dummies for English and Chichewa; a dummy variable for whether the individual is currently living where he or she was born; and a dummy variable equal to one for individuals living in rural areas. To meet the exclusion restriction for Heckman models, we also include the male to female ratio in a community, the number of children under the age of five in the family, and these variables interacted with the year fixed effects. To increase the precision of the predictions, we winzorize the earnings variable, and drop the top 5% of land holders.

We present the selection and earnings regression results in in Appendix C. The results for women and men are in Table 8 and 9, respectively. In general, we see the same patterns in these regression results as in the summary statistics given in Tables 1 and 2. Women are less likely to earn than men, household heads are more likely to earn some positive amount, individuals with larger plots of land are more likely to earn a positive amount, and older individuals are more likely to earn something. Family structure also predicts earnings decisions. Household heads earn more, those with more education earn more, families in rural areas have lower earnings, and entrepreneurs earn more. The inverse Mills ratio is positive and significant for women, and negative and significant for men. This suggests that women who choose not to earn would earn less than their peers who do choose to work, if they entered the labor market. They may be incentivized to do so if they choose to divorce. The inverse Mills ratio for men is negative and significant, suggesting that men with more human capital choose not to earn, perhaps demanding that their family members earn instead of them, allowing them to consume more leisure. The exclusion restrictions for women are significant, and so these estimates are identified off of the instrument. This is not true for men, but censoring is not a major characteristic of the data generating process for men. These estimates are identified based on the same normality assumptions in typical OLS regressions.

The average fitted value for women who earn some positive amount is 18,981 Kwecha per year. The average for women who do not earn is 14,337. The corresponding values for men are 54,919 and 59,630.[19] The fact that men's predicted outside options are much higher suggest that the mean bargaining power variable will be less than 0.5, since the numerator of the fraction in (11) will be negative. We set the predicted earnings for each household head in each wave equal to the fitted values from the earnings regressions in (12):

$$F(X_{f,h,t}, \psi_{f,h,t}) = e^{\hat{\beta}^{E}_{f,t} X_{f,t}}$$
$$F(X_{m,h,t}, \psi_{m,h,t}) = e^{\hat{\beta}^{E}_{m,t} X_{m,t}}$$

Then, we plug in these decision-maker-specific predicted earnings into (10), and estimate the fixed effects model using the simulated method of moments (SMM, see McFadden [1989] for derivation details). This estimation process is as follows. First we fit an unconstrained OLS model to the regression in (10). The constraint in (10) will bind for any family whose OLS intercept estimate falls into the region of parameter estimates that imply $\eta \notin [0, 1]$. We assume that the distribution of each intercept is a truncated normal, centered on the OLS estimate but with a support that includes only permissible intercept estimates. The standard deviation of these truncated normal variables is equal to the standard error from the OLS estimation. We assume the slope estimate is normally distributed around the OLS estimate, with standard deviation equal to the standard error from the OLS estimation. That is, we specify one truncated normal distribution per family, and one sample-specific normal distribution for the slope estimate. We run 1,000 simulations (since we also have to

[19]These averages are lower than those that we report in Table 2 because we drop outliers in this analysis. The median individual incomes and the median predicted individual incomes are similar for both men and women, and are similar to the averages reported here. The median female income is only 7,491, and for men it is only 64,824.

bootstrap the entire model, adding to the number of simulations is costly). The SMM-estimates are those that minimize the sum of squared errors in (10). Denote the household-specific SMM intercept estimates as $\tilde{\beta}_{0,h}$. Then the bargaining power estimate for each family is given by (11).

We estimate $\hat{\eta}^{KB}_{f,h,t}$ for 2045 families in our pooled sample (45% of families headed by a married couple).[20] The median bargaining power measure in this model is 0.26 and the standard deviation is 0.15. This means that the typical wife has 25% of the power that her partner has. A woman with a standard deviation more power than the median woman has about 33% of the power that her husband has. We reject the null hypothesis that men and women have equal bargaining power in favor of the alternative hypothesis that women have less power. The t-statistic for this test is -69.75.

An interesting feature of this model is that we can recover the intrahousehold differences in the sums of the partners' additive, one-time costs and benefits of divorce. If we can think of predicted earnings as the flow of wealth in the outside option, we can think of these costs and benefits as the stocks of wealth given divorce. For instance, if the government gave one partner a large welfare cash transfer at the time of divorce, then that partners' "stock" benefits from divorce would increase, his or her threat point would be more credible, and his or her bargaining power would increase.

We model these within-couple relative linear benefits and costs as the parameter γ. If $\gamma = 0$, the male and female decision makers in the family have the same summed costs and benefits from divorce, and their power dynamics will be completely determined by their relative earnings potentials. If the sign of γ is positive, it indicates one of two things for each family. Either men have a larger expected linear benefit from divorce than women, or both partners would be harmed by divorce, but men would be harmed less. The value of γ indicates that the magnitude of the difference, valued in 2010 dollars. The estimator of γ takes the form

$$\hat{\gamma}_{h,t} = \tilde{\beta}_{0,h}(2\hat{\eta}^{KB}_{f,h,t} - 1).$$

We plot the intrahousehold differences in the individuals' summed, linear costs and benefits in Figure 3. The median value of this parameter in the population is 17,541 Malawian Kwacha, or roughly 110 dollars (at 2010 currency values). This indicates that either men are better off than their partners in divorce, or at least they are harmed less by negative phenomena like mental duress and the loss of use of the communal consumption technology. The magnitude of $\hat{\gamma}$ in the median family is economically meaningful, roughly equal to the median annual income for women.

[20] We observe all of the information required to estimate $\hat{\eta}^{KB}_{f,h,t}$ for some families in both waves of our data, so that the total number of family-year observations we have is 2,881.

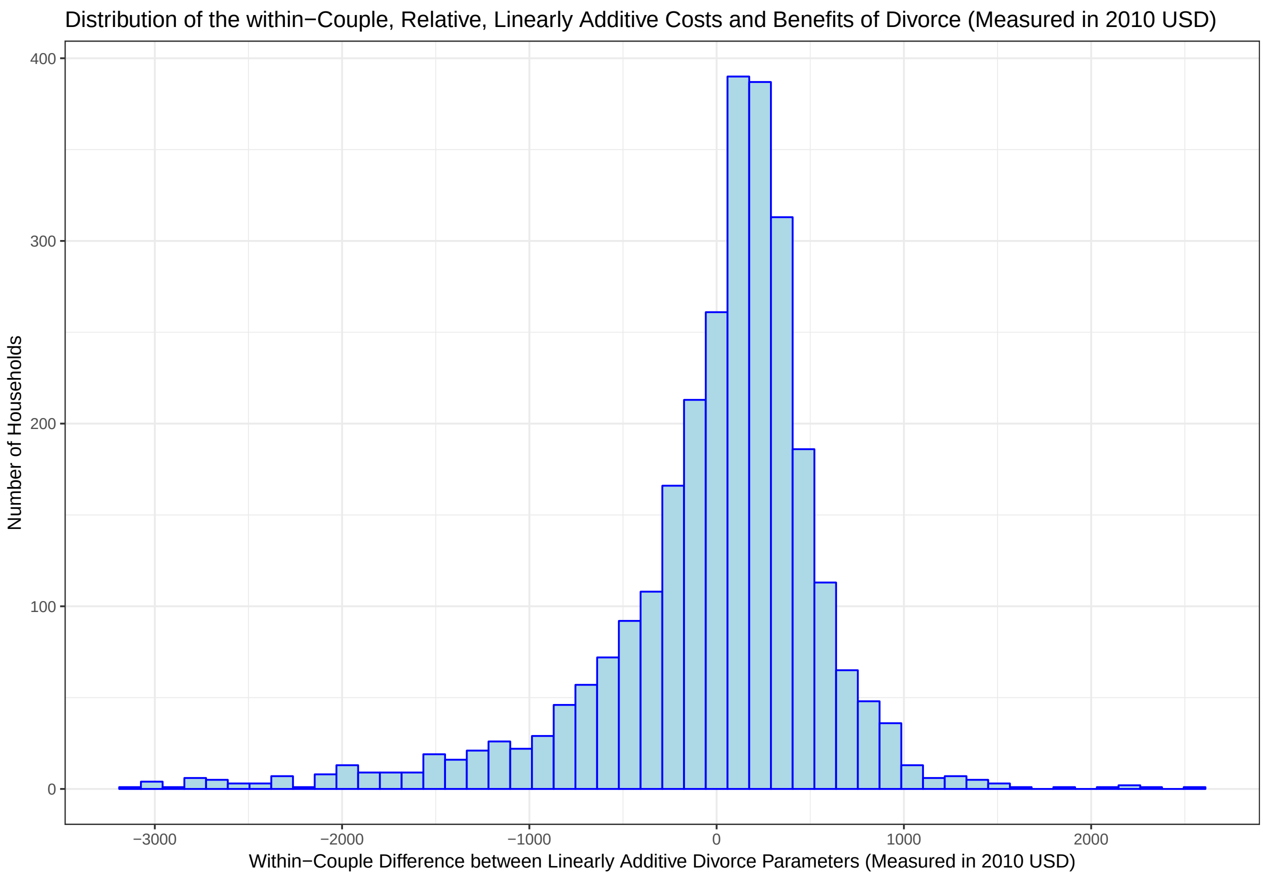

Figure 3: Distribution of $\hat{\gamma}$ estimates. The units are 2010 USD. Positive values indicate that men are better off than women in the case of divorce, not accounting for earnings flows. The husband in the median family would have a more valuable (or less damaging) one-time gain (or one-time loss) than his wife if they chose to get a divorce.

For many families, $\hat{\gamma}$ takes a negative value. The tails in the distribution are large. This could be because the family consumption technology is particularly valuable for some individuals, compared to consuming at market prices. For instance, if one partner got to keep the family house in the case of divorce, the family $\hat{\gamma}$ value would be skewed in that person's favor, and divorce would be a relatively more credible threat. In the tails, these differences will determine power dynamics to a greater extent, since they will make divorce more or less credible threats for one partner relative to the other.

In addition, we can test how matrilocal relocation practices influence the relative costs of divorce. The $\hat{\gamma}$ estimates should be lower in communities where men, on average, move to their wives' communities. At the time of divorce a man would, all else equal, have a larger distance to travel to his new post-divorce home. This should translate to a (relatively) worse negative shock than what his ex-wife experiences, at least along this relocation dimension. We test the null hypothesis that communities wherein more than 50% of the families practice matrilocal relocation have the same mean γ as communities where fewer than 50% of the families practice matrilocal relocation. We reject this null hypothesis ($p = 0.003$) in favor of the alternative hypothesis that the $\hat{\gamma}$ values are different. The mean value of $\hat{\gamma}$ is almost 10,000 Kwecha lower in primarily matrilocal communities, and the mean is negative, favoring females relative to males. This suggests that costs associated with relocating after marriage are a significant determinant of the relative values of outside options. In turn, we should expect to find a strong relationship between female bargaining power and matrilocal relocation. We report such findings in Section 5.

4.4 An Index Using PCA

Our second approach to measuring power in the family is to create a proxy variable from information about partners. We can select variables to include in the index by following studies on which characteristics influence power dynamics (e.g. Agarwal, 1997; and Doss, 2013). In our measure, we combine five commonly used proxy variables: individuals' educations, earnings, land holdings, literacy, and age.

We construct the bargaining power proxy variable in four steps: (1) calculate (two) within-couple, normalized values of relative land holdings, income, education, (English) literacy, and age; (14) use PCA to calculate the weights for female household heads and calculate index values for them in each year in the sample; (3) repeat the second step for male household heads; (4) take the ratio of the female decision maker's values to the sum of couple's values.

We carry out the normalization in step (1) in the following way. Let $x_{f,h}$ and $x_{m,h}$ be the vector of descriptive variables for male and female household heads in a family h. We calculate two family-specific values, one for the father and one for the mother. The values of each element of this vector of five variables, for $t \in \{f, m\}$, are:

$$\chi_{t,h} = \begin{cases} 1 & \text{if } x_{t,h} >= x_{-t,h} \\ \frac{x_{t,h}}{x_{-t,h}} & \text{if } else \end{cases}$$

Partners get values 1 if they have a higher variable value, and some value between zero and one otherwise. We set the value of the element of χ relating to literacy to one-half when partners have the same literacy. We then fit a PCA model for men and women separately, generating loadings for each gender.

Let $\hat{\beta}_f^{PCA}$ and $\hat{\beta}_m^{PCA}$ be the vector of loadings from the first PCA. We calculate a value for each female and male decision maker that most efficiently aggregates information about them $\hat{\beta}_f^{PCA}\chi_{f,h}$ and $\hat{\beta}_m^{PCA}\chi_{m,h}$. Then, we let our measure of bargaining power from this exercise be:

$$\hat{\eta}_h^{PCA} = \frac{\hat{\beta}_f^{PCA}\chi_{f,h}}{\hat{\beta}_m^{PCA}\chi_{m,h} + \hat{\beta}_f^{PCA}\chi_{f,h}} \tag{13}$$

A key advantage of this approach is that we do not need any assumptions on utility functions, or the functional forms of earnings models or demand functions. A key disadvantage is that we have made a very strong assumption about the functional form of bargaining power. To use this method, we must assume that the functional form in (13) is exactly correct. We must assume that the estimate is not missing any relevant information, and the ratio is the correct functional form. This reduced form approach to measuring power is relatively easy to construct and can inform us broadly about gender inequality in the family, but should be used with caution. In tandem with our two structural methods for recovering power, it is a useful tool for exploring bargaining power inequality and malaria incidence in Malawi.

4.5 Applying the PCA Index Method to the Malawi Panel Data

We displayed the summary statistics for the variables that we use to construct the PCA index for bargaining power in Tables 1 and 2. Men in this sample are older and have higher incomes, more educational attainment, and a higher likelihood of being literate. In addition, men manage twice as much land as women.[21]

The loadings we estimate for women are 0.37 for land, 0.40 for income, 0.59 for education, 0.16 for age, and 0.58 for literacy. For men, these values are 0.26, 0.22,

[21] The test statistic on the difference between men's and women's land management is 4.93.

0.67, 0.01, and 0.65. For both men and women, the variance across families in the values of χ are largely driven by income and literacy. For men, these two variables explain more of the variation, relative to the values for women.

The average index value for men is 0.78 and for women is 0.56. The mean of the bargaining power variable is 0.41. We calculate this index for 98% of the families in our sample with a married male and female household head (4,487 families pooled across both 2010 and 2013). Using this method, we reject the null hypothesis that men and women have equal values of bargaining power, in favor of the alternative hypothesis that women have less bargaining power than men. The t-statistic on this test has value -63.78. The corresponding 95% confidence interval on the difference between men's and women's PCA index values is [-0.16, -0.17].

4.6 Dunbar, Lewbel, and Pendakur's (2013) Extension

Our third approach to measuring women's bargaining power in the family is to apply DLP's model to recover the sharing rule for each family. In DLP's (2013) extension, family members are assumed to have "price-independent generalizable log" (PIGLOG) utility functions and are assumed to fully commit to household decisions (divorce and noncooperative behaviors are not possible). The family production function is assumed to be linear so that some matrix A relates household-level purchases to individual consumption equivalents, $z = A[x_f + x_m + x_c]$. The matrix A is such that the Lindahl prices that family members face are weakly less than market prices (to account for the positive consumption externalities within households).

Families are assumed to consume some private assignable goods.[22] If a family consumes some positive amount of a private assignable good for each member, then that family meets the data requirements for the DLP method. Typical examples of private assignable goods are clothing and shoes. For private assignable goods, the need to address the problem of externalities when calculating resource shares is obviated: the matrix A simply has a 1 on the diagonal for private goods, and 0's elsewhere. As such, demand functions for private assignable goods are invariant to changes in the family-specific matrix, A. One of the primary contributions of DLP is to extend the BCL model so that the researcher does not need to estimate A.

DLP consider the family's Engel curves (demand functions that do not depend on prices) for private assignable goods. They are able to recover resource shares from a family's system of Engel curves given one of two additional assumptions. The first is that Engel curves have the same shape across people within in a family, at least at low levels of y. This is their "similarity across people" (SAP) assumption. The second is that individuals in families of the same size have similar preferences. This

[22] Recall that a private good is one that only one member can consume. An assignable good is one that the econometrician can ascribe with certainty to a certain individual.

is their "similarity across types [of families]" assumption. We assume the former in our analysis and so do not provide the functional forms for Engel curves under the latter. Under these assumptions on utility functional forms, the Engel curves for private assignable goods in the household are

$$W_m(y) = \eta_m(\delta_m + \beta ln(\eta_m)) + \eta_m \beta ln(y), \tag{14}$$
$$W_f(y) = \eta_f(\delta_f + \beta ln(\eta_f)) + \eta_f \beta ln(y),$$
$$W_c(y) = \eta_c(\delta_c + \beta ln(\eta_c)) + \eta_c \beta ln(y),$$

where $W_t(y)$ is the family's budget share devoted to the private assignable good for a person of type t. The SAP assumption lets a single β describe the slopes of the Engel curves. As such, fitting (14) using the system of seemingly unrelated regressions gives slope parameters that vary only by an individuals' resource share. The first component of the right-hand side of the Engel curve is set equal to the intercept, a nuisance parameter. The system of equations to fit to demand data, then, is:

$$W_m(y) = \beta_{0,m} + \beta_{1,m} ln(y) + \epsilon_m, \tag{15}$$
$$W_f(y) = \beta_{0,f} + \beta_{1,f} ln(y) + \epsilon_f$$
$$W_c(y) = \beta_{0,c} + \beta_{1,c} ln(y) + \epsilon_c$$

Fitting this model gives sample-level estimates of the population parameters for each Engel curve. The econometrician is left with a system of sample-level and family-level observed parameters, plus the resource share values, and one nuisance parameter. This system is:

$$W_m(y) = \hat{\beta}_{0,m} + \hat{\beta}_{1,m} ln(y) \text{ s.t. } \hat{\beta}_{1,m} = \hat{\eta}_m \beta, \tag{16}$$
$$W_f(y) = \hat{\beta}_{0,f} + \hat{\beta}_{1,f} ln(y) \text{ s.t. } \hat{\beta}_{1,f} = \hat{\eta}_f \beta,$$
$$W_c(y) = \hat{\beta}_{0,c} + \hat{\beta}_{1,c} ln(y), \text{ s.t. } \hat{\beta}_{1,c} = \hat{\eta}_c \beta,$$
$$\hat{\eta}_m + \hat{\eta}_f + \hat{\eta}_c = 1.$$

The sharing rule and some additional nuisance parameter, β, are identified in (16). For each family, there is an Engel curve per "type" of person, and the additional equation dictating that resource shares sum to one. For instance, in a family with no children, there are three total equations, and partners' resource shares can be recovered. For a family with five children, there will be four total equations, and the sharing rule can be recovered between the mother, the father, and the group of children collectively. Additional "types" (e.g., "daughters" and "sons") can be added to the model as long as the econometrician observes positive family spending on private assignable goods for them. That is, the survey must ask families about expenditures on "daughter-specific" and "son-specific" goods, in addition to "mother-specific" and "father-specific" goods.

We construct a measure of power from these resource shares: the ratio of women's resource shares to men's and women's summed resource shares. This measure captures the division of the gains from trade in a marriage:

$$\hat{\eta}^{RS} = \frac{\hat{\eta}_f}{\hat{\eta}_f + \hat{\eta}_m}.$$

There are reasons to be cautious when using this method. The first is that censoring in reported private assignable goods consumption threatens identification (Tommasi and Wolf, 2018). In general, most families do not meet the data requirements for the resource share method. In the 12-month recall data that DLP study, 75% of families do not meet the requirements to estimate the sharing rule. In Tommasi's (2019) application to Progresa data, almost 90% of families are censored. Likewise, in our Malawi data, about 90% of families are censored. This degree of censoring can lead to flat Engel curves, and weak identification of the sharing rule (Tommasi and Wolf, 2018).

In addition, families that meet the data requirements are likely to be systematically more wealthy than families who do not. Therefore, sharing rule estimates may not be externally valid for families that do not purchase a positive amount of PAGs for each type of member. This has several downsides. One is that studying program effects on the sharing rule is limited to studying the local effects to these systematically wealthier families. More directly, the sharing rule cannot be recovered or studied for the majority of the population. Third, as shown by Bargain, Lacroix, and Tiberti (2018), resource share estimates may not be robust to different choices of private assignable goods. While the DLP method can tell us a great deal about distribution of resources and power within the family, it is perhaps best interpreted as one measure of power among several. Estimating additional models of decision-making power, as we do, is thus valuable in assessing the robustness of our analysis of women's empowerment and malaria transmission.

4.7 Applying the DLP Method to the Malawi Panel Data

We pool observations across sample years to estimate resource shares, and use the IHS-prepared expenditure value as our right-hand side variable in (15). We assume that clothing and shoes are private assignable goods, and use the budget share spent on the sum of these goods as left-hand side variables for the system in (15).

We estimate this system of nonlinear equations using three-stage least squares, instrumenting for household consumption with the community's averaged labor market wages (following Attanasio and Lechene, 2010, 2014; Sokullu and Valente, 2018; and Tommasi, 2019).[23] Instrumenting for consumption allows us to plausibly identify the causal relationship between budget shares going to private assignable goods and household consumption. Following Calvi (2017), we include the food budget share in our system of equations. This increases stability in the regressions, since the errors in the regressions of private assignable goods are likely to be similar to each other but (relatively) dissimilar to the errors in the regression on the food budget share.

We scale the intercept and slope parameters by the PCA index power measure, so that our regressions include underlying preference parameters. As such, the intercept and slope of each Engel curve varies by the household's index value, which depends on ten underlying preference parameters.[24] That is, households with the same BP index value have the same slope and coefficient estimates in the system of equations we solve. Letting $\hat{\eta}_h^{PCA}$ represent a household's index value, the system we estimate is given by

$$\begin{aligned} W_{food}(y) &= \beta_{0,food}\hat{\eta}_h^{PCA} + \beta_{1,food}\hat{\eta}_h^{PCA}ln(y) + \epsilon_{food} \\ W_f(y) &= \beta_{0,f}\hat{\eta}_h^{PCA} + \beta_{1,f}\hat{\eta}_h^{PCA}ln(y) + \epsilon_f \\ W_m(y) &= \beta_{0,m}\hat{\eta}_h^{PCA} + \beta_{1,m}\hat{\eta}_h^{PCA}ln(y) + \epsilon_m \\ W_g(y) &= \beta_{0,g}\hat{\eta}_h^{PCA} + \beta_{1,g}\hat{\eta}_h^{PCA}ln(y) + \epsilon_g \\ W_b(y) &= \beta_{0,b}\hat{\eta}_h^{PCA} + \beta_{1,b}\hat{\eta}_h^{PCA}ln(y) + \epsilon_b. \end{aligned} \tag{17}$$

We report the regression results for the most common family type in Table 10, Appendix C. The slope coefficients are significantly different from zero for all of the private assignable goods, and so we can be sure that resource shares are identified in this data. In addition, we learn that the budget share spent on food is decreasing in income, as is generally observed (Attanasio and Lechene, 2014). We also observe that the budget shares spent on private assignable goods are decreasing in family income. By assumption, they bring utility to only one person. It may be a more

[23] We use R's systemfit to estimate the 3SLS model (Henningsen and Hamann, 2007). Three-stage least squares is simply a way to fit a system of seemingly unrelated equations where the same endogenous variable is present in each equation, and an instrumental variables approach is used to identify the corresponding regression coefficients.

[24] Different authors use different preference parameters. For instance, Calvi (2017) uses a linear index of 25 preference parameters in her model of families with children, and an index with 22 parameters for childless couples. Tommasi (2019) uses an index with ten demographic controls plus time and location fixed effects. DLP estimate their model with 18 preference parameters incorporated into each regression in their system (under their assumption of similarity across types of people within the family). See the appendix for details on scaling the Engel curve estimates by preference parameters.

efficient aggregate welfare maximization strategy to spend more money on public goods as family income increases.

Then, we plug in the sample-specific 3SLS estimates, and the family-specific expenditures, structure, and $\hat{\eta}_h^{PCA}$ into the system of equations given in (17). Denote the number of women in a family as F, of men as M, of boys as B, and of girls as G. We solve this system for each household using the generalized method of moments to minimize the sum of squared differences of the left-hand sides from zero:

$$
\begin{aligned}
W_f(y) - \hat{\beta}_{0,f}\hat{\eta}_h^{PCA} - \hat{\beta}_{1,f}\hat{\eta}_h^{PCA} ln(\frac{\eta_f y}{F}) &= 0 \\
W_m(y) - \hat{\beta}_{0,m}\hat{\eta}_h^{PCA} - \hat{\beta}_{1,m}\hat{\eta}_h^{PCA} ln(\frac{\eta_m y}{M}) &= 0 \\
W_g(y) - \hat{\beta}_{0,g}\hat{\eta}_h^{PCA} - \hat{\beta}_{1,g}\hat{\eta}_h^{PCA} ln(\frac{\eta_g y}{G}) &= 0 \\
W_b(y) - \hat{\beta}_{0,b}\hat{\eta}_h^{PCA} - \hat{\beta}_{1,b}\hat{\eta}_h^{PCA} ln(\frac{\eta_b y}{B}) &= 0 \\
1 - \eta_f - \eta_m - \eta_g - \eta_b &= 0
\end{aligned} \tag{18}
$$

The set of parameter estimates $\{\hat{\eta}_f, \hat{\eta}_m, \hat{\eta}_g, \hat{\eta}_b\}$ that minimizes the sum of squared distances from zero is the set of resource share estimates for each household. System (18) is specifically for families with some positive number of men, women, boys, and girls. When a family has a different structure, we study the corresponding subset of the equations in system (18). For instance, in a household without boys, we would drop the fourth of five equations in (18), as well as the boys' resource share term in the fifth equation.

We can recover the sharing rule for a total of 821 families in our pooled sample (11% of all families in our sample, and 18% of families headed by a married couple). The median resource shares are 24.63% for women, 31.02% for men, 24.44% for girls, and 11.94% for boys. In the household that has the median resource share for women, the female household head has a resource share of 24.63%, the male household head has a resource share of 33.9%, the single boy has a resource share of 17.69%, and the two girls split a resource share of 23.7%. In this family, women consume less surplus than men, and girls consume less than boys.

Analyzing resource shares by family size reveals that women sacrifice more consumption as their family grows than men do. The ratio of the female decision maker's resource share to the male decision maker's resource share in the median family with no children is 1.08. In these 67 families, women have slightly higher point estimates of resource shares, but we fail to reject the null that these 67 men and women have equal resource shares (with p-value 0.51). As the number of children grows, this value drops substantially. With one and two children, these ratio values are 0.81 and 0.82, respectively. With three children, this value is 0.76. With four, it is 0.61.

This same pattern is documented by Dunbar, Lewbel, and Pendakur (2013) using Malawi IHS data from 2004.

The vast majority of families in our sample have children. For these families, the average female resource share is 0.24. The average male resource share is 0.28. The t-statistic for the test that the distributions of men's and women's resource shares are the same is -4.78. We reject the null hypothesis that men and women in families with children have equal resource shares, in favor of the alternative hypothesis that women have small resource shares. The bargaining power measure we construct, $\hat{\eta}^{RS}$, has a median of 0.45. We reject the null hypothesis that men and women have an equal proxy value on average. The t-statistic for this test is -4.68.

4.8 Learning from Three Models of Power in the Family

We reject the null hypothesis that men and women have equal decision-making power using all three modeling approaches. Since the approaches are quite different, this is strong and robust evidence of gender inequality within the family in Malawi.

There are epistemic gains from using three distinct models to measure power. The fact that such different learning methods give a similar result — that women have less power than men — is compelling. The key to this epistemic improvement is in how different the three measurement techniques are along two dimensions: what type of data we use to learn about power in the family, and what assumptions are required to reduce the data into a single measure of women's power in each family. The DLP method identifies power using information on clothing and shoes for each family member, in addition to the scaling parameters. This method point identifies the sharing rule, under the strong assumptions that outside options do not influence power dynamics, and that utilities take a particular functional form. The Klein and Barham model relaxes these assumptions but identifies only the expected value of bargaining power for each family. This method uses individual-level earnings data — which tends to be very different in nature from PAGs purchasing data. It is more varied, and less censored. The final method is to simply combine proxy variable information about individuals. This is a more commonly used method and has a strong assumption that bargaining power takes a particular form, instead of deriving the functional form from microeconomic foundations. We can read the same story from each of these extremely different methods. This suggests that the true distribution of bargaining power in the population is likely close to the distributions presented in Figure 2. It is very likely to have a mean and median lower than 0.50.

5 Results: Women's Empowerment Reduces the Likelihood of Malaria Transmission

We conduct inference using percentile confidence intervals, constructed using a block bootstrapping algorithm. This is because the typical standard errors in the 2SLS model in equations (7) and (8) will be incorrect since we use estimates, not observed values, of power as dependent variables. We use a slightly different algorithm for each of the three measurements of power. In the first, we recalculate the Heckman selection models and fixed effect regression in (10), construct the $\hat{\eta}^{KB}$ values in (11) for each family in each sample analog, and then fit the equations in (7) and (8) using these sample analog estimates. In the second, we simply calculate a new PCA index for each family in each sample analog and then estimate the 2SLS model. In the third, we calculate a new PCA index and a new resource share distribution for each sample analog, then plug in those variables to the 2SLS model. For each algorithm, the percentile intervals we construct are the middle 95% of the empirical distributions of $\hat{\beta}_1$ from equation (8). We run the first algorithm 500 times, and the second and third 200 times each.

We present the first-stage regression results in Table 3. The point estimates for the instrument are positive across measures, and range from 0.014 to 0.044. Power and matrilineal descent are positively related. We present the percentile confidence intervals for $\hat{\beta}_{M,h,t}$ directly below the point estimate. This is a strong instrument for both the PCA method, and the power measure attained from the Klein and Barham (2019) approach. In addition the F-statstics (presented at the bottom of Table 3) are large.

Although the instrument is strong for the PCA and Klein and Barham (2019) measures, the prevalence of matrilineal and matrilocal traditions is a weak instrument for the bargaining power measure constructed from the parents' resource share ratio. This outcome may be explained by the high degree of censoring in the demand data required to estimate the DLP method. This leads to a smaller number of families to analyze (821, or 11% of the total sample). In turn, this mechanically reduces precision since, in a given bootstrap analog, the number of eligible families may be very small given the higher potential for outliers in the empirical distribution function and large confidence intervals. Because the resource share estimate of bargaining power will not produce unbiased, causal marginal effects using the 2SLS approach, we do not run the second-stage analysis for this variable.

We report the 2SLS results for the Klein and Barham (2019) and PCA index power measures in Tables 4 and 5. In both tables, we report four different models in columns (1)-(4). In columns (1) and (2) of these tables, we report coefficients recovered by fitting equation (8) without instrumenting for power, both with and without controls. These coefficient estimates can be interpreted as summaries of the correlations between power and malaria contraction. In columns (3) and (4), we report the 2SLS results, which can be interpreted as the causal relationships between power and malaria. In column (3) we report the results for the 2SLS model with a logistic regression as the second stage. In column (4) we report the results of the 2SLS model with a Poisson regression as the second stage, where the outcome variable is the count of the number of family members who were ill with malaria in the last two weeks. For the logistic and Poisson 2SLS models, we reject the null hypothesis that an increase in women's power does not reduce the likelihood that family members contract malaria. We conclude that an increase in women's bargaining power reduces the likelihood that family members contract malaria.

Table 3: First-Stage Regression Results

	Dependent Variable:		
	DLP	KB	PCA
Instrument	0.014	0.044**	0.022***
	[-0.035, 0.050]	[0.008, 0.057]	[0.013, 0.033]
Controls	Yes	Yes	Yes
Region-Year Fixed Effects	Yes	Yes	Yes
Observations	660	2,824	2,824
R^2	0.765	0.822	0.936
Adjusted R^2	0.760	0.821	0.936
Residual Std. Error	0.176	0.124	0.110
F Statistic	140.358***	866.231***	2,754.382***
	(df = 15; 645)	(df = 15; 2809)	(df = 15; 2809)

Note: 95% Bootstrapped Confidence Intervals in Brackets. Controls include family size, per capita monthly total household expenditures, percent of neighbors with malaria in the last two weeks, number of children under the age of 5 in the family, number of rooms in the dwelling, dwelling material fixed effects, and a dummy variable for whether there is a health clinic or hospital in the community. *p<0.1; **p<0.05; ***p<0.01.

The logistic model coefficients are in log odds units. We can convert these back to probabilities to gain additional insight. The coefficient value of -4.219 in Table 4 tells us that a one standard deviation increase in gender equality would decrease the likelihood that a family member contracts malaria from 27% to 16%. This is roughly a 40% decrease in the likelihood that someone in the family contracts malaria. The magnitudes of the effect of an increase in women's bargaining power on malaria transmission may seem large. However, this effect is commensurate with

Table 4: An Increase in Women's Bargaining Power Decreases the Malaria Burden for the Family (KB Results)

	Dependent Variable: Malaria Contraction			
	Not IV	Not IV	IV	IV
	logistic	*logistic*	*logistic*	*Poisson*
	(1)	(2)	(3)	(4)
$\eta^{KB}_{f,h,t}$	-2.583^{***}	0.222		
	(0.143)	(0.340)		
Instrumented $\eta^{KB}_{f,h,t}$			-4.219^{**}	-4.202^{**}
			[-33.98, -0.12]	[-31.33, -1.63]
Controls	NO	YES	YES	YES
Region-Year Fixed Effects	NO	YES	YES	YES
Observations	2,793	2,793	2,790	2,790
Log Likelihood	−1,754.677	−1,635.380	−1,632.109	−2,142.635
Akaike Information Criterion	3,511.355	3,300.760	3,294.218	4,315.270

Note: 95% Bootstrapped Confidence Intervals in Brackets. Controls include family size, per capita monthly total household expenditures, percent of neighbors with malaria in the last two weeks, number of children under the age of 5 in the family, number of rooms in the dwelling, dwelling material fixed effects, and a dummy variable for whether there is a health clinic or hospital in the community. *p<0.1; **p<0.05; ***p<0.01.

Table 5: An Increase in Women's Bargaining Power Decreases the Malaria Burden for the Family (PCA Results)

	Dependent Variable: Malaria Contraction			
	Not IV	Not IV	IV	IV
	logistic	*logistic*	*logistic*	*Poisson*
	(1)	(2)	(3)	(4)
$\eta^{PCA}_{f,h,t}$	-1.962^{***}	-0.305		
	(0.097)	(0.385)		
Instrumented $\eta^{PCA}_{f,h,t}$			-9.335^{**}	-9.297^{**}
			[-19.230, -2.760]	[-16.393, -3.796]
Controls	NO	YES	YES	YES
Region-Year Fixed Effects	NO	YES	YES	YES
Observations	2,793	2,793	2,790	2,790
Log Likelihood	−1,710.054	−1,635.279	−1,632.109	−2,142.635
Akaike Information Criterion	3,422.107	3,300.558	3,294.218	4,315.270

Note: 95% Bootstrapped Confidence Intervals in Brackets. Controls include family size, per capita monthly total household expenditures, percent of neighbors with malaria in the last two weeks, number of children under the age of 5 in the family, number of rooms in the dwelling, dwelling material fixed effects, and a dummy variable for whether there is a health clinic or hospital in the community. *p<0.1; **p<0.05; ***p<0.01.

Table 6: An Increase in Women's Bargaining Power is Negatively Correlated With the Malaria Burden for the Family (DLP Model Results)

	Dependent Variable: Malaria Contraction	
	Not IV	NOT IV
	logistic	*logistic*
	(1)	(2)
$\eta^{RS}_{f,h,t}$	-1.549^{***}	-0.591^{*}
	(0.169)	(0.353)
Controls	NO	YES
Region-Year Fixed Effects	NO	YES
Observations	652	652
Log Likelihood	−403.526	−380.344
Akaike Information Criterion	809.052	790.687

Note: controls include family size, per capita monthly total household expenditures, percent of neighbors with malaria in the last two weeks, number of children under the age of 5 in the family, number of rooms in the dwelling, dwelling material fixed effects, and a dummy variable for whether there is a health clinic or hospital in the community. *p<0.1; **p<0.05; ***p<0.01.

the large magnitude of a one standard deviation increase in power. That is a massive move toward equality in the family. We can put the one standard deviation increase in bargaining power into more perspective by discussing the magnitude of a cash transfer targeted to mothers required to engender such a change. One example of such a program is Progresa, which increased women's income by 1,300%, their contribution to family income by 1,000%, and their bargaining power by 100% (See Angelucci [2008] for the original framing of Progresa's impact in this way, and Klein and Barham [2019] for the calculation of Program effects on power in that setting). This 100% increase is slightly larger than a standard deviation increase. Something similar in this context would also produce such an increase in women's bargaining power, and thus a 40% reduction in malaria transmission. We suggest that future researchers conduct a randomized controlled trial of such a sort, perhaps paired with a public health intervention or condition as well.

In Table 6 we report the regression coefficients for fitting equation (8) with non-instrumented resource share power estimates. These give the correlations between this measure of power and malaria contraction. These correlations suggest that an increase in this power measure may reduce the malaria burden, however, they are not causal estimates. We cannot conclude that an increase women's share of parents' surplus consumption would decrease malaria. We can simply conclude that the naive, and biased, estimate of the correlation between the two is negative and consistent with the results in Tables 4 and 5.

6 Potential Mechanisms

We take an initial look at two possible explanations for the negative relationship between women's decision-making power and malaria transmission rates: bed net use and private latrine use. It is possible that more equal parents are better able to enforce bed net use for children. They may also invest more in this preventative technology, purchasing more comfortable nets or more nets per capita. It is also possible that women with more power are able to allocate collective resources toward improving household hygiene and sanitation facilities. Total health benefits may accrue disproportionately to women but may also result in reduced exposure to carrier mosquitoes for all family members. We run 2SLS models to study these mechanisms, with the same first stages as reported in (7), and with logistic regressions for the second stage. We report the regression results in Table 7. The assumptions required for identification are that the prevalence of matrilocal and matrilineal marital traditions are uncorrelated with household-level latrine sharing or bed net use, respectively.

We find that an increase in bargaining power increases the likelihood that a family has a private bathroom. Women with less power are far more likely to share a

Table 7: Mechanisms

	Dependent variable:	
	Toilets	Nets
Instrumented $\hat{\eta}^{KB}$	13.620**	3.176
	[12.11, 82.97]	[-7.17, 22.51]
Normalized Family Expenditures	0.185	1.056***
	(0.178)	(0.216)
Family Size	0.175***	−0.084***
	(0.027)	(0.031)
Percent of Neighbors with Temp Malaria	−0.644**	1.116***
	(0.316)	(0.387)
Number of Kids 0-5 yo	−0.123**	0.376***
	(0.060)	(0.074)
Hospital Dummy	0.080	0.188
	(0.093)	(0.118)
Number of Rooms in Dwelling	0.464***	0.058
	(0.053)	(0.062)
Dwelling Material Fixed Effects	Yes	Yes
Region-Year Fixed Effects	Yes	Yes
Observations	2,609	2,789
Log Likelihood	−1,585.940	−1,163.899
Akaike Information Criterion	3,201.880	2,357.799

Note: 95% Bootstrapped Confidence Intervals in Brackets. Controls include family size, per capita monthly total household expenditures, percent of neighbors with malaria in the last two weeks, number of children under the age of 5 in the family, number of rooms in the dwelling, dwelling material fixed effects, and a dummy variable for whether there is a health clinic or hospital in the community. Unreported 2SLS models using the PCA estimates of power give qualitatively similar results. *p<0.1; **p<0.05; ***p<0.01.

bathroom with members of another family. Sharing a bathroom may increase exposure to mosquitoes that have bitten neighbors. Increased privacy may be a good in itself and may reduce malaria transmission. Further, having a private restroom may be linked to other positive health outcomes. For instance, people with private latrines are less likely to suffer from diarrhea (Heijnen et al, 2014). Stopnitzky (2017), and Alam and Monica (2018), among others, also document the link between increased privacy and gender equality in the family.

However, we find that gender equality is not linked to the likelihood that families use bed nets. Bed nets are very common in Malawi, largely because of the Malawi government's, and international organizations', efforts to disseminate preventative technologies in the last few decades. More than half of Malawi's families have at least one bed net for every two members (World Health Organization, 2018). Between 2009 and 2015, more than 20 million nets were disseminated in Malawi (Lindblade et al 2015). This dissemination effort likely did not target families based on their power dynamic. This would explain why this technology use is not a function of gender equality in the family in this context.

We suggest three more mechanisms may explain our results, and leave their analysis for future research. The most obvious possible mechanism is that more equal parents invest more in other preventative measures like indoor residual spraying, or health behaviors like regularly treatments during pregnancy. The second is that men and women with more equal decision-making power may be more likely to engage in safe sex practices. This would make more equal parents less likely to have HIV/AIDS, which weakens people's immune systems and increases their risk of infection. Roughly one in ten people in Malawi in 2004 were HIV positive, and so this may be a mechanism explaining our findings (estimates from the Malawi Demographic and Helath Survey of 2004, reported in Greenwood et al, 2019). The third is that mothers who contract malaria during pregnancy may be more likely to have children who contract malaria, and that mothers' contraction is negatively correlated with gender equality.

7 Conclusion

The Malawi government, with support from international organizations like the World Health Organization and the USAID-funded President's Malaria Initiative, is working to reduce the malaria burden in many ways. Over the last five years, donors spent more than $100 million to control and eliminate malaria in Malawi (World Health Organization, 2018). Funded projects include the dissemination of treated bed nets, indoor residual spraying, improved treatment for those diagnosed with Malaria (World Health Organization, 2018), text message campaigns to improve medical professionals' performance (Steinhardt et al, 2019), and, recently, a vaccination campaign (van den Berg et al, 2019). All of these tools are useful in reducing the malaria burden, and in tandem may be more effective than individual efforts. Nonetheless, the malaria burden remains high. Additional tools to reduce malaria transmission may be necessary to continue lowering malaria prevalence, and one day, eradicate the disease in Malawi.

We show that increasing gender equality reduces malaria transmission. We estimate that a standard deviation increase in women's decision-making power would reduce the likelihood that a family member contracts malaria by 45%. Some examples of programs that have increased women's bargaining power elsewhere are gender-targeted cash transfers (Duflo, 2003; and Tommasi, 2019), increased equality of asset division and rights in the case of divorce (Voena, 2015), and vocational training (Bandiera et al, 2018). We suggest that the government of Malawi and other donors working to eradicate malaria consider these policies as additional methods to combat the disease. Like the text message campaigns documented by Steinhardt et al (2019), these types of interventions are not based on public health or epidemiological research, but on social science. Combining methods with foundations in many disciplines may be key to reducing the malaria burden further.

We suggest pairing conventional public health policies with women's empowerment policies, piloting their coupling with regional randomized controlled trials, and scaling up in accordance with the experimental results. This work could be conducted in tandem with the Department of Gender Affairs in Malawi. In addition, we hope that future studies analyze the external validity of our results to other countries in the region. It is possible that increased gender equality could reduce the malaria burden elsewhere in sub-Saharan Africa, and around the world.

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Appendix A: Details on Klein and Barham (2019)

In this appendix, we provide the basic derivation for the estimator in (11). There are four steps. The first is to reframe the family's constrained optimization problem in (9) using the second welfare theorem. The second is to write down the individuals' problems to divorce or not, and to incorporate them into the family's constrained optimization problem as participation constraints. The third step is to solve the model and show that a linear functional relates partners' utility functions (which are random variables) to the optimal sharing rule. The fourth is to show that a weak conditional uniformity assumption on the pair of partners' utility functions imply (11), which can be estimated via (10).

Step 1: A Two-Step Collective Model

Recall that the family's problem is to allocate the total family budget, y, such that the allocation solves (9). Let parents make decisions on their children's behalf, such that any good a child consumes is a public good (since it increases children's welfare, and both parents care about their children's well-being). For simplicity, we suppress public goods in the optimization problem.[25] Such an allocation will be Pareto efficient. As such, by the second welfare theorem, the same allocation will be reached by a private economy subject to the optimal division of resources. That is, this second problem comprises two steps and is solved with backwards induction. In a slight abuse of notation, let the function A translate market prices into Lindahl prices. Denote the full set of prices as p, so that $p = (p_f, p_m)$. The first step is the individual optimization problem for both partners, and the second is the family's problem:

$$\underset{x_f}{max} \quad U_f(x_f) \text{ s.t. } \eta y = A(p_f)' x_f \tag{19}$$

$$\underset{x_f}{max} \quad U_m(x_m) \text{ s.t. } (1-\eta) y = A(p_m)' x_m \tag{20}$$

The solutions to these private optimization problems are the demand functions

[25]See Blundell, Chiappori, and Meghir (2005) for a decomposition with public goods. The same derivation obtains regardless of whether we use a more complex two-stage problem, or the simple one presented here. However, the motivation for the two-step problem is slightly different, since allocation problems with public goods do not necessarily need to be Pareto efficient. Blundell, Chiappori, and Meghir (2005) show that they are "conditionally efficient." The model in this paper is also "conditionally efficient" once we incorporate the individuals' participation constraints. In general, inefficiencies are common, and many families are inefficient. See Ramos (2016) for a compelling argument in favor of this assertion. While it is interesting that the same expected value for bargaining power obtains regardless of whether we explicitly model public goods, covering that topic is beyond the scope of this appendix.

$x^*_f(A(p_f), \eta y)$ and $x^*_m(A(p_m), (1-\eta)y)$, so that parents attain indirect utility from a given η equal to $V_f(A(p_f), \eta y)$ and $V_m(A(p_m), (1-\eta)y)$. Here, η is the degree to which partners' preferences are expressed in the aggregate allocation, a natural measure of bargaining power. The second step is to solve for the division of surplus, η, that maximizes the families social welfare function:

$$\underset{\eta\in[0,1]}{max} \quad \tilde{U}\big(V_f(p_f, \eta y), V_m(p_m, (1-\eta)y)\big). \tag{21}$$

The solution is the family's optimal division of resources between decision makers, η^*, and is a function of real (Lindahl) prices: $\eta^* = \eta^*(y/A(p))$. The solutions obtained by solving (19)-(21) using backwards induction are the same solutions to the problem in (9), after applying the simplifications for the exposition of the derivation. As such, we can formulate a family's problem as choosing the bargaining power between members that maximizes aggregate welfare.

Step 2: Relaxing the Assumption of Full Commitment to the Collective Allocation

Let decision makers also consider divorce. Since half of marriages in Malawi end in divorce within 20 years (Reniers, 2003), this is an important feature of the data generating process. The relative attractiveness of seeking a divorce will determine the individuals' bargaining positions — the value of η^* that solves (21). We model the value of partners outside options in two ways: their income flows while divorced, and a set of one-time utility shocks like stigma during divorce and the loss of access to the consumption technology, A.

Denote the amount of income an individual would have if he or she divorced as y^0_t for $t \in \{f, m\}$. Then, the indirect utility values that individuals would get in the case of divorce are $V_f(p_f, y^0_f)$ and $V_m(p_m, y^0_m)$, whereas the indirect utilities that they would get within the family are $V_f(A(p_f), \eta y)$ and $V_m(A(p_m), (1-\eta)y)$. As such, a partner chooses to stay married if the indirect utility that partner receives from marriage is larger than the indirect utility from divorce. The partners solve problems $max\{V_f(A(p_f), \eta y), V_f(p_f, y^0_f)\}$ and $max\{V_m(A(p_m), (1-\eta)y), V_m(p_m, y^m_0)\}$. These decisions depend on bargaining power in the family, the value of consuming at Lindahl prices instead of market prices, and incomes in the outside options.

To simplify these problems, note that there exists a pair of compensating variation values (γ_f, γ_m) that makes the decision makers indifferent between consuming at the Lindahl and market prices: $V_f(A(p), \eta y) = V_f(p, \eta y + \gamma_f)$ and $V_m(A(p), (1-\eta)y) = V_m(p, (1-\eta)y + \gamma_m)$. By substituting these into the individuals' decisions, their problems will be over functions that differ only in their second arguments. As such, the individuals' decisions to stay married can be written as $max\{\eta y + \gamma_f, y^f_0\}$

and $max\{\eta y + \gamma_m, y_0^m\}$. These problems are not only simpler, they are also measured in money, not in utils. These problems can be incorporated into the family's constrained optimization problem as participation constraints:

$$\max_{\eta \in [0,1]} \quad \tilde{U}\big(V_f(p_f, \eta y), V_m(p_m, (1-\eta)y)\big) \tag{22}$$
$$\text{s.t. } \eta y + \gamma_f \geq y_0^f \text{ and } (1-\eta)y + \gamma_m \geq y_0^m.$$

By the Kuhn-Tucker theorem, we know that this problem will have a unique solution that satisfies the following properties, suppressing notation:

$$\frac{\partial \tilde{U}}{\partial V_f}\frac{\partial V_f}{\partial \eta^*} = -\frac{\partial \tilde{U}}{\partial V_m}\frac{\partial V_m}{\partial \eta^*}$$
$$\eta^*(y/A(p)) \in \left[\frac{y_f^0 + \gamma_f}{y}, 1 - \frac{y_m^0 + \gamma_m}{y}\right].$$

Step 3: Functional Analysis of the Family's Constrained Optimization Problem When Parents' Utility Functions Are Random Variables

Partners' utility functions are random variables. The research does not know what they are before collecting data from a family (and even then cannot observe them) but might know something about the distribution of preferences in a population. For cultural reasons, for example, people in certain families may be more likely to have particular political or religious beliefs. They may be more likely to consume certain types of food, or be more likely to prefer certain forms of entertainment. Let the pair of partners' utility functions be elements from the infinite, compact set of all quasi-concave, increasing, twice differentiable functions, C. Picking one (of the infinite) functions to describe preferences for each partner would be a parameter approach to identification. We use a semi-parametric approach by assuming that (U_f, U_m) have a particular distribution on C.

if utility functions are random variables, then η is a random variable. Note that η is a function of real total income, so $\eta : \mathbb{R}_+ \rightarrow \left[\frac{y_f^0+\gamma_f}{y}, 1 - \frac{y_m^0+\gamma_m}{y}\right]$. Denote the set of all possible functions $\eta(y/A(p))$ as $\mathbb{H}$. There exists a functional, $\Gamma : C \times C \rightarrow \mathbb{H}$, that relates the realized utility functions to the parents' bargaining positions:

$$\Gamma(\tilde{U}(U_f, U_m)) = \left\{ \eta^*(y/A(p)) \quad \middle| \quad 0 = \frac{\partial \tilde{U}}{\partial U_f}\frac{\partial U_f}{\partial \eta^*} + \frac{\partial \tilde{U}}{\partial U_m}\frac{\partial U_m}{\partial \eta^*} \right\} \tag{23}$$

This functional is a linear differential operator on the social welfare function. As such, making assumptions about the joint distributions of utility functions on C directly implies a distribution of $\eta^*(y/A(p))$ on $\left[\frac{y_f^0+\gamma_f}{y}, 1 - \frac{y_m^0+\gamma_m}{y}\right]$. This in turn implies a specific functional form for the expected value of η^* for any particular family, on the family-specific subset of the unit interval.

Step 4: Making an Assumption on the Joint Distributions of Utility Functions, and Deriving an Estimator for η

We follow Klein and Barham (2019) in making a weak "conditional uniformity" assumption. If we assume that all utility functions (and all preference relations) are equally likely in a population, we would be asserting that no type of preference is more common than others. However, there are patterns that are often predictable in people's preferences, like enjoying certain types of food. Therefore, it seems too strong to assume that all preferences are equally likely. In addition, we might expect that some quasi-concave, increasing, differentiable functions do not describe anyone's preferences. To capture these likely states of the world, we can relax the assumption that all preferences are equally likely by making a conditional uniformity assumption.

Let there be a partition of C comprising an arbitrarily large number of sets. Each of these sets is a subset of C, each subset has an empty intersection with any other subset, and the union of all subsets in the partition is equal to C. This partition can be drawn in any way. Assume that each family's pair of utility functions is jointly drawn from the same subset. Then, saying that some types of preferences are more common than others in a population is analogous to saying that more families draw from particular subsets of C than others.

This imposes a weak "similarity between partners" condition, since their utility functions will be drawn from the same subset of C. This is a weak assumption since this subset can be arbitrarily large (it could be unaccountably infinite) or small (a singleton, in which case partners have identical preferences). In the case of an infinitely large subset, partners' preferences could be arbitrarily similar or dissimilar. Any subset could comprise any "type" of utility function, and exclude any other "type."

This is empirically tractable. Under this conditional uniformity assumption, the expected value of η is the central point of the family-specific bounds on possible power dynamics. It is given by

$$\eta^{KB}_{f,h,t} = \frac{1}{2} + \frac{1}{2}\frac{y^f_0 - y^m_0 + (\gamma_m - \gamma_f)}{y_{h,t}}. \tag{24}$$

The econometrician can bring this parametric expression of the expected value of bargaining power to data in the following way. First, note that the economist can predict y^f_0 and y^m_0 using one of several methods. We use a Heckman selection function. So

$$y^f_0 = F(X_f, \psi_f) \text{ and}$$

$$y_0^m = F(X_m, \psi_m).$$

Second, note that the parameter of interest, $\eta^{KB}_{f,h,t}$, is linear in income, predicted earnings in the outside options, and the difference $\gamma \equiv \gamma_m - \gamma_f$. We can rewrite (24) as:

$$y = \frac{F(X_f, \psi_f) - F(X_m, \psi_m) + \gamma}{2\eta^{KB}_{f,h,t} - 1} \tag{25}$$

We estimate the following fixed effects model using constrained least squares.

$$y = \beta_{0,h} + \beta_1 (F(X_{f,h,t}, \psi_{f,h,t}) - F(X_{m,h,t}, \psi_{m,h,t})) + \epsilon_{h,t} \text{ s.t.} \tag{26}$$

$$\beta_{0,h,t} = \frac{\gamma_{h,t}}{2\eta_{f,h,t} - 1}, \text{ and}$$

$$\beta_1 + \epsilon_{1,h,t} = \frac{1}{2\eta_{f,h,t} - 1}, \text{ and}$$

$$\epsilon_{h,t} = \epsilon_{1,h,t}(F(X_{f,h,t}, \psi_{f,h,t}) - F(X_{m,h,t}, \psi_{m,h,t})), \text{ and}$$

$$\eta \in [0, 1].$$

Estimating this model gives parameter estimates $\tilde{\beta}_{0,h}$ and $\tilde{\beta}_1$. Plugging back in gives functional forms for $\eta_{f,h,t}$ and $\gamma_{h,t}$ for each family in each period:

$$\hat{\eta}^{KB}_{f,h,t} = \frac{1}{2} + \frac{1}{2} \frac{F(X_{f,h,t}, \psi_{f,h,t}) - F(X_{m,h,t}, \psi_{m,h,t})}{y_{h,t} - \tilde{\beta}_{0,h}} \tag{27}$$

$$\hat{\gamma}_{h,t} = \tilde{\beta}_{0,h}(2\hat{\eta}^{KB}_{f,h,t} - 1).$$

We calculate the equations in (27) and report the results in Figures 1 and 2, respectively. As in the DLP approach, the nuisance parameters (intercepts and slope estimates calculated by fitting the model in equation (26)) are simply discarded after constructing the estimate of bargaining power. To incorporate the family-specific constraints, the econometrician can use penalized least squares in their fixed effects model, or, as we do, use the simulated method of moments, where the assumed, truncated distributions for each intercept are taken from an unconstrained OLS regression. See Klein and Barham (2019) for identification proofs and an even more detailed derivation.

Appendix B: Details on Recovering Resource Shares from DLP (2013).

In this appendix, we reproduce the derivation of the sharing rule from the model by DLP. This derivation is provided by DLP, as well as by Calvi (2017). The goal of this appendix is to orient interested readers so that the relationship between the point estimates of power and the data are clear. This section is brief; for more information see the online appendix of DLP, or the appendix by Calvi (2017).

The authors proceed from equation (9) and assume that each partners' preference relations are represented by price-independent general log (PIGLOG) utility functions. Let G be a nonzero, differentiable, homogeneous of degree one function of prices. Let $\tilde{p}$ be a vector of all prices besides those for the private assignable goods. Indirect utility functions for individual's of type $t \in \{f, m, c\}$ are:

$$V_t(p, y) = ln\left(ln\left(\frac{y}{G_t(p)}\right)\right) + p_t e^{-a' ln(\tilde{p})}. \tag{28}$$

Each family maximizes a Bergson-Samuelson social welfare function, which weights each member's indirect utility by Pareto weights. The households problem can be written as in (9), or in an extended format that explicitly models positive externalities of consuming using the family's production technology. In this extended format, the family's problem is to maximize the sum of positive externalities and the weighted members utility functions. This extended program can also be decomposed into two steps: the optimal distribution of resources across members, and the members' optimal allocation of their resource share. The first order conditions of this problem equate each partners marginal utility with respect to his or her resource share, and forces the resource shares to sum to one. This is the same as a subset of the Kuhn-Tucker conditions to the problem in (22). All of the marginal utilities are set equal to a Lagrangian multiplier, ν, which has the interpretation "relaxing the constraint that resource shares must sum to one increases each person's utility by ν." The demand function for good k of individual of type t can be derived by applying Roy's identity to the version of (28) that obtains from specifying the household's problem as a two-step constrained optimization problem:

$$x_t^k(\eta_t y, A(p)) = \eta_t y(\alpha_t^k + \beta_t^k ln(\eta_t y)) \tag{29}$$

Dividing both sides of (29) by y gives the budget share devoted to good x_t^k. If this is a private good, then this individuals' budget share is equal to the family budget share. The family's budget share for the system of private assignable goods, then, is given by (14).

One important extension is to condition the resource share estimates on other information about the family, and the setting they live in. These additional parameters should produce more accurate sharing rule estimates, if the added parameters influence the division of surplus within the family. To condition the sharing rule estimates on observable characteristics, the researcher can include them in the regressions in (3) as linear scalars on the intercept and slope estimates.[26]

Consider an example. If researchers wanted to include parents' relative ages, and their relative ages squared, in the resource share estimation, they could add $\beta_{age}\text{age} + \beta_{age^2}\text{age}^2$ in two places in each of the regression equations in (3). They would multiply the intercept and slope parameters by this expression. Then the seemingly unrelated regressions model fits the slopes, intercepts, and scaling parameters. The new system of equations to fit, then, would be

$$W_m(y) = (\beta_{I,age}\text{age} + \beta_{I,age^2}\text{age}^2) + \beta_{1,m}ln(y) \times (\beta_{S,age}\text{age} + \beta_{S,age^2}\text{age}^2) + \epsilon_m \quad (30)$$

$$W_f(y) = (\beta_{I,age}\text{age} + \beta_{I,age^2}\text{age}^2) + \beta_{1,f}ln(y) \times (\beta_{S,age}\text{age} + \beta_{S,age^2}\text{age}^2) + \epsilon_f$$

$$W_c(y) = (\beta_{I,age}\text{age} + \beta_{I,age^2}\text{age}^2) + \beta_{1,c}ln(y) \times (\beta_{S,age}\text{age} + \beta_{S,age^2}\text{age}^2) + \epsilon_c$$

$$\eta_m + \eta_f + \eta_c = 1.$$

With these additional parameters, each family's resource shares are explicitly modeled as functions of the scaling information. That is, families with decision makers who have the same relative ages will have the same scaled slope and intercept parameters. Without scaling, all families would have the same slope and intercept parameters. These scaling estimates are nuisance parameters, however. There is no immediate intuition afforded from the values of $\hat{\beta}_{I,age}$, $\hat{\beta}_{S,age}$, $\hat{\beta}_{I,age^2}$ or $\hat{\beta}_{S,age^2}$. They can be roughly interpreted as how parents' relative ages influence purchases of PAGs, but not how they influence the sharing rule. That information is conditional on the entire set of population parameters and the specific family's budgeting decisions.

Appendix C: Tables Reporting Nuisance Parameters

[26]See DLP, Calvi (2017), and Tommasi (2019) for examples of papers that include linear indices of underlying preference parameters in their sharing rule estimation.

Table 8: Women's Selection and Earnings Regression Results

	Estimate	Std. Error	T-Value	Pr(>|t|)
Selection Regression Results				
Intercept	-2.275***	0.364	-6.258	0.00
Male Female Ratio	-0.38	0.59	-0.643	0.52
Number Kids Under 5	0.072**	0.031	2.326	0.02
Head Dummy	0.755***	0.062	12.164	0.00
Plot Size	0.381***	0.032	11.914	0.00
Age	0.109***	0.01	11.012	0.00
Age Squared	-0.001***	0.00	-8.875	0.00
Rural Dummy	0.117	0.076	1.55	0.121
Same-Community-Rural Interaction	0.277***	0.042	6.524	0.00
Same Community	0.108	0.116	0.928	0.354
Chichewa Literacy	-0.083	0.054	-1.546	0.122
English Literacy	-0.049	0.048	-1.019	0.308
Highest Grade Completed	0.009	0.007	1.276	0.202
Number of Men	-0.237***	0.022	-10.733	0.00
Number of Women	0.014	0.029	0.492	0.623
Number of Girls	-0.057***	0.019	-3.042	0.002
Number of Boys	-0.019	0.019	-1.01	0.313
2013 Dummy	-0.106	0.403	-0.264	0.792
ER Interaction 1	0.547	0.778	0.703	0.482
ER Interaction 2	-0.085*	0.038	-2.217	0.027
Earnings Regression Results				
Intercept	4.825***	0.364	13.254	0.00
Head Dummy	0.439***	0.107	4.114	0.00
Plot Size	0.329***	0.036	9.176	0.00
Age	0.138***	0.015	9.271	0.00
Age Squared	-0.001***	0.00	-7.584	0.00
Entrepreneurship Dummy	0.604***	0.061	9.937	0.00
Rural Dummy	-0.354***	0.108	-3.289	0.001
Same-Community-Rural Interaction	0.101*	0.057	1.783	0.075
Same Community	-0.128	0.181	-0.705	0.481
Chichewa Literacy	-0.23***	0.067	-3.407	0.001
English Literacy	0.013	0.066	0.197	0.844
Number of Men	-0.149***	0.032	-4.6	0.00
Number of Women	0.098**	0.039	2.522	0.012
Number of Girls	-0.042*	0.024	-1.712	0.087
Number of Boys	-0.05**	0.024	-2.088	0.037
Highest Grade	0.118***	0.01	12.328	0.00
2013 Dummy	0.308***	0.048	6.429	0.00
Sigma	1.361***	0.017	77.804	0.00
Rho	0.116	0.077	1.516	0.13
District Fixed Effects	Yes			
Observations	6,658			
R^2	0.981			
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 9: Men's Selection and Earnings Regression Results

Variable	Estimate	Std. Error	T-Value	Pr(>|t|)
Selection Regression Results				
Intercept	-0.661	0.445	-1.486	0.137
Male Female Ratio	-1.022	0.728	-1.403	0.161
Number Kids Under 5	0.035	0.039	0.888	0.374
Head Dummy	1.432***	0.072	19.828	0.00
Plot Size	0.458***	0.059	7.82	0.00
Age	0.114***	0.011	10.042	0.00
Age Squared	-0.001***	0.00	-9.386	0.00
Rural Dummy	-0.117	0.094	-1.245	0.213
Same-Community-Rural Interaction	-0.053	0.049	-1.086	0.277
Same Community	-0.286**	0.125	-2.292	0.022
Chichewa Literacy	0.11	0.078	1.403	0.161
English Literacy	-0.092	0.06	-1.524	0.128
Highest Grade Completed	-0.027***	0.007	-3.782	0.00
Number of Men	-0.129***	0.026	-5.049	0.00
Number of Women	-0.065**	0.027	-2.405	0.016
Number of Girls	-0.059***	0.022	-2.621	0.009
Number of Boys	-0.046**	0.022	-2.075	0.038
2013 Dummy	0.336	0.474	0.709	0.478
ER Interaction 1	-0.517	0.93	-0.556	0.579
ER Interaction 2	0.052	0.047	1.111	0.267
Earnings Regression Results				
Intercept	6.563***	0.231	28.471	0.00
Head Dummy	1.043***	0.081	12.83	0.00
Plot Size	0.169***	0.02	8.462	0.00
Age	0.125***	0.01	11.892	0.00
Age Squared	-0.001***	0.00	-10.893	0.00
Entrepreneurship Dummy	0.473***	0.045	10.579	0.00
Rural Dummy	-0.322***	0.073	-4.435	0.00
Same-Community-Rural Interaction	-0.225***	0.039	-5.713	0.00
Same Community	-0.14	0.136	-1.035	0.301
Chichewa Literacy	-0.024	0.06	-0.405	0.686
English Literacy	-0.104**	0.046	-2.263	0.024
Number of Men	0.031	0.024	1.263	0.206
Number of Women	0.056**	0.025	2.216	0.027
Number of Girls	0.002	0.017	0.101	0.919
Number of Boys	-0.03*	0.017	-1.812	0.07
Highest Grade	0.086***	0.006	14.55	0.00
2013 Dummy	0.229***	0.034	6.743	0.00
Sigma	1.152***	0.012	98.68	0.00
Rho	-0.032	0.057	-0.553	0.58
District Fixed Effects	Yes			
Observations	7,014			
R^2	0.989			
Note:			*p<0.1; **p<0.05; ***p<0.01	

Table 10: Regression Results for Eligible Families with Mothers, Fathers, Sons, and Daughters, Used to Back Out Resource Shares Using the DLP Method

Dependent Variable	$\hat{\beta}_0$	$\hat{\beta}_1$
$W_{food}(y)$	6.068***	-0.371***
	(1.038)	(0.075)
$W_f(y)$	0.046***	-0.003***
	(0.015)	(0.001)
$W_m(y)$	0.032**	-0.002*
	(0.014)	(0.001)
$W_b(y)$	0.023***	-0.001**
	(0.009)	(0.001)
$W_g(y)$	0.043***	-0.003***
	(0.012)	(0.001)
N	397	
Note:	*p<0.1; **p<0.05; ***p<0.01	