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Contractibility in Intrahousehold Labor, Bargaining Power, and Technology Adoption

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Contractibility in Intrahousehold Labor, Bargaining Power, and Technology Adoption

By

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DISSERTATION

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To the Professor who introduced me to the world of economics,

Dr. David Dean

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Abstract

In my dissertation, I investigate the relationships between the non-contractibility in household labor, spousal bargaining power, and labor-intensive technological change. I extend the conjugal contract model introduced by Carter and Katz (1997) to understand (1) why non-contractibility in spousal labor matters and (2) how bargaining power may affect the efficiency loss due to non-contractibility in spousal labor. The model suggests that in households with greater bargaining power for the wife, the wife provides more labor on the farm, even if the husband controls the production. As a result, the household can take better advantage of a labor-intensive technological change that benefits the husband's sphere of control. I then discuss how to measure bargaining power and analyze the impact of a technological change based on spousal bargaining power. In addition, I propose a strategy to mitigate the non-adoption problem when assessing the effectiveness of agricultural technologies. I find that encouraging farmers to self-select into the sample yields more statistically powerful results than selecting from an experimental population. This sampling method is then applied to the randomized controlled trial study design to evaluate the impact of large-scale in-person agronomy training offered to smallholder coffee households in Uganda.

Contents

Acronyms

BPS Best Practice Survey. 10, 14

HRNS Hanns R. Neumann Stiftung. 7–10, 59

IPDM Integrated Pest Disease Management. 8, 14, 15

MAAIF Ministry of Agriculture, Animal Industries and Fisheries. 6, 8

MDES Minimum Detectable Effect Size. xii, 68, 76, 77

NAADS National Agricultural Advisory Services. 6

NGO Non-Governmental Organization. 71, 72

PPP Purchasing Power Parity. 6, 11

RCT Randomized Controlled Trial. 7, 64, 68, 78

TNS TechnoServe. 7–10, 59, 71–73

UCAT Uganda Coffee Agronomy Training. 7, 14, 23, 59, 60, 66, 72, 76, 77

UCDA Uganda Coffee Development Association. 8

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Chapter 1

Introduction: Intrahousehold Conflict over Resource Allocation and the Efficacy of Agricultural Interventions

Smallholders in many low-income countries, particularly in Sub-Saharan Africa, face stagnant agricultural productivity and cannot reach their full productivity potential. In response to this challenge, various development projects have set out to increase crop yields and sustain yield gains by promoting the adoption of improved inputs and effective farm management techniques, typically targeted at the male household head for major earning crops (World Bank (2008); Davis and Heemskerk (2012)). However, much to the disappointment of both donors and implementers, the adoption rate of these seemingly promising technologies remains low (Udry (2010); Blair et al. (2020)). The dissertation explores one particular angle to explain these failures: the potential existing conflicting interests over labor and income allocation within the household. I argue that for an intervention that demands intensive labor investment from the household, it is crucial to take into consideration the structure of the household, particularly who controls the income and who bears the cost of providing additional labor.

A distinctive feature of many agrarian settings is the gendered spheres of economic activities within the household. Although spouses jointly engage in agricultural activities, husbands are typically the primary decision-maker of the production of main crops and control the revenues while supplementing their efforts with spousal labor and hired labor (Kasente et al. (2000); Peterman, Behrman, and Quisumbing (2014)). Studies in the agricultural labor literature have moved away from assuming that hired and family labor are perfect substitutes (Benjamin (1992); Sadoulet, De Janvry, and Benjamin (1998); Taylor and Adelman (2003); Chowdhury (2016)). Yet, full contractibility within the household is often assumed, which implies that intrahousehold family labor is effortlessly and costlessly supervised and enforced. However, family members often engage in multiple income-earning activities and do not always work simultaneously next to each other. Non-contractibility in spousal labor may arise because the husband cannot easily observe, enforce, and compensate the wife's labor efforts accordingly (Dwyer and Bruce (1988)). The misalignment between control of non-contractible labor and residual claims thus may result in income and welfare losses for the household.

Furthermore, intrahousehold characteristics, including altruism and bargaining power, are crucial in quantifying efficiency loss and providing insights for development programs to avoid gender biases. Within the household, individuals make decisions based on not only their self-interest but also the interests of other members. Given that household members care about each other, altruism may incentivize the wife to work more and offset some efficiency loss. Even though a high level of the wife's altruism may explain why certain households do not experience losses, a policy should not simply encourage the wife's altruism at the cost of increasing gender disparity within the household. Alternatively, policies can actively promote women's bargaining power in household decision-making. Higher bargaining power for the wife allows her to negotiate for greater control over the earnings of her labor, which affects both resource allocation and the extent of the efficiency loss.

Given that households may have already suffered from efficiency loss prior to the introduction of any intervention, what are the consequences for programs such as extension programs that promote high returns to male-controlled crops that depend on non-contractible female labor? Due to the capital and credit constraints prevalent in many rural settings, most agronomy training programs focus on the abundance of cheap labor to promote yield-boosting practices. Particularly in settings where the husband benefits directly from the intervention while the wife bears the increasing labor burden, the skewed distribution of labor and income may lower the likelihood of households attending training and adopting these best agronomic practices. Therefore, the success of such programs hinges on the severity of the non-contractability in spousal labor.

In the dissertation, I explore the interactions between the non-contractibility in household labor, spousal bargaining power, and labor-intensive technological change. There is a relative paucity of research that explores technology adoption within an intrahousehold context (Doss (2013)). The dissertation complements this body of work by providing a theoretical framework based on the conjugal contract model introduced by Carter and Katz (1997) to explain how non-contractibility in labor can lead to inefficient household resource allocation. The conjugal contract model is particularly appealing in contexts where autonomy and interdependence co-exist in the household economy.

The rest of the dissertation is structured as follows. Chapter 2 introduces the setting, the intervention, the experimental design, and the conceptual issues related to resource allocation within the household. Then, built on the key stylized facts highlighted in chapter 2, chapter 3 presents an extension of the conjugal contract model to understand (1) why non-contractibility in spousal labor matters in this setting, and (2) how bargaining power may affect the efficiency loss due to non-contractibility in spousal labor. The model generates a testable hypothesis that households with greater bargaining power for the wife have higher yields and income before and after an introduction of a labor-intensive technological change that benefits the husband's sphere of control while relying on the wife's non-contractible labor. Transitioning from theory to empirics, chapter 4 discusses how to measure bargaining power and empirically estimate the impact of bargaining power on the take-up rate of labor-intensive technological change. Lastly, chapter 5 evaluates a filtering sampling methodology that can help interventions that require high labor input and thus a high cost of participation to increase the statistical power for the impact evaluation.

Chapter 2

Intrahousehold Conflict over Resource Allocation of Smallholder Coffee Households in Uganda

In this chapter, I provide key information that serves as the foundation for the setup of the theoretical framework in chapter 3. I first lay out the context of the study, the intervention, and the experimental design. Next, I discuss the profile of households, focusing on two particular facets of the households. First, I present the baseline adoption levels of improved farming techniques, which provides insights into why donors and implementers believe there is a need for extension programs. Second, I describe how spouses allocate resources within a household, particularly regarding coffee production. Later in the dissertation, I argue that the tension between who gets the money and who does the work may hinder a household's decision to adopt welfare-enhancing technologies.

2.1 Context

The study takes place in Uganda, a landlocked country in East Africa with an estimated population of 44 million, of which 63% live in rural areas (Uganda Bureau of Statistics (2022)). According to World Bank (2021), about 41% of the population lives below $1.90/day

2011 PPP poverty line, and 79% engage in agriculture.

Coffee is one of Uganda's most important commercial agricultural commodities and a major foreign exchange earner, accounting for 16% of total export revenue (Uganda Bureau of Statistics (2022)). The current production level places Uganda eighth in the world's total production of coffee and third in Robusta, which accounts for 80% of its coffee exported. Coffee is primarily cultivated by smallholder growers (estimated at 1.7 million) with an average plot size of less than one acre (Mugoya (2018)). Smallholder coffee-growing households typically use family labor and occasionally hire labor for harvesting. They also face significant challenges, including a lack of access to financial, marketing, and value-added services. About 23% of coffee-growing households belong to a group or cooperative, whereas a majority sell their coffee at the farm gate directly to middlemen at low values (Uganda Coffee Development Association (2020)).

Expanding coffee exports is a major goal of Uganda's government. By focusing on this high-value crop, almost all of which is sold to higher-income countries, Uganda hopes to boost farmers' incomes and increase the country's foreign exchange earnings and its tax base. According to a recent report commissioned by the Government of Uganda to inform its coffee strategy, two-thirds of coffee farmers in Uganda use traditional practices and achieve yields between 25-33% of the yield potential (Mugoya (2018)). However, with its limited budgeting and shortages of qualified staff, the government lacks the capacity to provide a viable and efficient agricultural extension system serving the diverse needs of farmers for various crops, including coffee (Ministry of Agriculture, Animal Industry, and Fisheries (2016)).

The government set up National Agricultural Advisory Services (NAADS) in 2001 as a private delivery of extension services with public financing. But after 14 years in operation, NAADS got phased out due to its lack of progress despite taking up almost 43% of the total agricultural spending in 2009/10 (Sebaggala and Matovu (2020)). In place of NAADS, the Ministry of Agriculture, Animal Industries and Fisheries (MAAIF) launched the National Agricultural Extension Strategy to reform the delivery of extension services which have increasingly prioritized input distribution over advisory and information services (Van Campenhout, Lecoutere, and Spielman (2021)). Coverage is reported to be as low as one extension worker per 1,800 farming households in 2019 (see Kato (2020)). This, in turn, has attracted major philanthropic investments to supplement the government's efforts in promoting coffee agronomy training with the end goal of improving yields and incomes of poor households.

2.2 Intervention

Benkiser Stiftung Zukunft[1] launched the Uganda Coffee Agronomy Training (UCAT) program with the goal of achieving at least a 50% increase in Robusta coffee yields across 60,000 farming households in Western Uganda. Under the project, two implementers, Hanns R. Neumann Stiftung (HRNS) and TechnoServe (TNS), provided in-person agronomy training to three two-year cohorts. An RCT is then utilized to evaluate the impact of agronomy training for the second cohort on the adoption rates of best agronomic practices, coffee yields and profits, and the well-being of participating coffee-growing households. The dissertation focuses on the second cohort. However, chapter 5 uses data from the first cohort to inform the design for the RCT evaluation.

The two implementers worked in different districts located in the Western districts of Uganda. The program included 22 training sessions held monthly for 11 months of the year. Topics of training depend on the coffee cycle in each region. Although HRNS and TNS independently carried out training, both implementers used a farmer field school approach to promote experiential, participatory, and farmer-centered learning. The training sessions took place on a coffee plot where the trainer demonstrated the practice and provided opportunities for a group of farmers to practice and ask questions.

HRNS recruited one volunteer from each village to be the farmer-trainer and provided them with a two-day quarterly training from agronomists and continuous support from the

[1] Benkiser Stiftung Zukunft later transferred the project to the Stiftung Uganda Coffee Agronomy Training, a foundation managed by the Dutch Coffee Company Jacobs Douwe Egberts.

HRNS staff. HRNS based the training material on a training manual published jointly by the UCDA and MAAIF. On the other hand, TNS recruited trainers locally and paid for their time. The trainers first received two weeks of training in coffee agronomy after hiring and a two-day refresher training every month before their training session with farmers. TNS developed its own materials but still covered the same topics as HRNS. Table 2.1 presents the definition of the nine agronomic practices that HRNS and TNS agreed on and included in their training curricula. For smallholders in this setting who do not have access to capital, tools, and machines, the criteria below suggest that farmers will have to devote significant labor to be considered "adopted" for methods such as weeding, rejuvenation, pruning, mulching, and erosion management.

Table 2.1: Definition of Coffee Agronomic Practices

Practice	Adopted if:
Weeding	1. Farmer has NOT exclusively dug under the tree canopy, AND 2. Farmer weeds twice or more per year, AND 3. There are few or no weeds under the canopy, AND 4. If there are few weeds, they are less than 30cm tall
IPDM	Farmer can name at least 3 out of 9 Integrated Pest Disease Management (IPDM)
Rejuvenation	1. Most trees have 4 main stems or fewer, AND 2. The oldest main stems on the majority of the plot are 8 years or younger
Pruning	Trees have been pruned using 3 of the 4 following methods listed - Centres opened - Unwanted suckers removed - Dead and broken branches removed - Branches touching the ground removed
Coffee Nutrition	1. At least one of the following is used: compost, manure, NPK, Foliar Feeds, Lime and DAP. If foliar feed is used only count if this is zinc/boron-based, 2. IF fertilizer is applied to the soil, the fertilizer: has been applied using a measure, and is not broadcast, AND 3. Nearly all leaves are dark green
Mulching	1. Farmer has applied mulch, AND 2. Mulch is more than 2cm thick, AND 3. Mulch has been applied to at least 25% of the coffee plot
Erosion Control	At least one erosion control method observed
Shade	There is 20% shade or more

Intercropping	Crops grown with coffee do NOT include maize, cassava, or root crops

2.3 Experimental Design

The two implementers, HRNS and TNS, worked in different districts: HRNS operated in Kagadi, Kibaale, and Kyenjojo, while TNS worked in Bushenyi, Mbarara, and Ntungamo. Each implementer surveyed their assigned districts and identified the name of villages with at least 20 coffee-growing households. Then, for each implementer region, 360 villages were selected such that the minimum distance between any two study villages was maximized but feasible for the implementer to operate. The final minimum distance imposed was 1.9 km for HRNS and 1.4 km for TNS.[2]

A representative sample includes many farmers who never attend training, which dilutes the impact of the training on the population and makes the treatment effects difficult to detect statistically, which will be discussed in further detail in chapter 5. Instead, farmers were selected into the sample following a one-session training on coffee harvest and post-harvest practices before the start of the actual training program.[3] The design increases the chance that our final sample includes farmers with a high propensity to participate in agronomy training. After the one-session training, we stratified 360 study villages into 90 geographically-defined clusters of 4 villages in each implementer region. Within each cluster, 2 villages were randomly assigned to receive in-person agronomy training.[4] We then randomly chose 12 farmers per treatment village and 18 farmers per control village from the set of farmers who attended the harvest training sessions for data collection and analysis. For cohort 2, the training ran from 2019 up to 2021.

[2]The difference is due to the size of each implementer's regions.

[3]Note that the attendance of the one-session training was taken at the household level.

[4]A subset of farmers in both control and treated villages were further assigned to a mobile extension treatment, which I do not discuss in the dissertation.

2.4 Data Sources

The baseline took place after the harvest training sessions but prior to the onset of agronomy training, in October 2018 for the HRNS region and April 2019 for the TNS region. The baseline covers 8,548 coffee-farming households on the following topics: demographics, coffee production, coffee agronomy practices, coffee agronomy knowledge and perception, income, assets, and household decision-making. For the dissertation, I focus on 6,390 households in a monogamous marriage at baseline, which represents 75% of the full sample. It is important to note that the enumerators encouraged but did not require both spouses to be present for the interview. Out of 6,390 households, 75% of the main respondents were men, and 32% had both spouses present.

Due to the time constraint between the end of harvest training and the beginning of the intervention, not all baseline modules were administered to the households in the sample. Randomization to survey version was conducted at the same time as sample selection, and separate survey teams were responsible for administering each survey type. A subset of 1,042 coffee farming households received detailed, largely observational data on agronomy practices, denoted as Best Practice Survey (BPS) households. An expanded version of the baseline survey that included questions about income sources specific to the female head of married households was administered to a subset of 2,063 households. Two years after the baseline, a randomly selected subset of 252 dual-headed households was administered a survey on gender roles in coffee production and income (gender survey). Husbands and wives of these 252 households were interviewed separately and simultaneously by different enumerators about their own and their spouse's time spent on coffee and about who decided how to spend coffee income.

I first describe household characteristics for the sample of 6,390 households, followed by the baseline adoption of the main recommended practices for the 1,042 BPS households. I then combine data from the full sample and the gender survey to provide insights into the intrahousehold resource allocation of coffee-farming households in these regions.

2.5 Profile of Households

In this section, I discuss the profile of households and some characteristics related to their coffee production. Table 2.2 presents the baseline demographic characteristics of the 6,390 monogamously married households. The average household size was seven members with four children. The mean age was 46 for the husband and 40 for the wife. About 39% of men and 34% of women have completed at least primary school. The fraction of coffee-farming households that lived below $1.90/day 2011 PPP poverty line is estimated at 24%, which is consistent with the rate of 26% reported by Uganda Bureau of Statistics (2022) for the Western region of Uganda.[5]

Table 2.2: Household Demographics

Variable	N	Mean	SD
Household size	6,390	6.77	2.61
Number of children	6,390	3.81	2.10
Husband's age	6,194	46.16	14.14
Wife's age	6,069	39.81	12.93
Husband completed primary school	6,292	0.39	-
Wife completed primary school	6,257	0.34	-

Table 2.3 provides a summary of (1) the main income sources of the household, (2) the main income sources of the wife, and (3) the share of each income source in the total household income. Most households earned income from farming and had a diversified portfolio of crops and activities, with 79% of all the households earning some income from coffee. The main income-generating crops were coffee at 29%, banana at 13%, and legumes at 9%. Among households with wives earning income from farming, 77% had their own plots, and legume was the most common income-generating source for the wife. More than half (56%) of the wives had some form of saving.

About 47% of the households reported that the wife did not earn any income. Given that we did not interview them separately at baseline, it could be that the husband neglected

[5] We use the Poverty Probability Index created by IPA for Uganda to estimate the poverty likelihoods.

to mention the wife's income sources, or the wife hid the income from her husband. Albeit interviewed two years later, the data of 252 spouses from the gender survey in which we interviewed spouses separately provides additional insights. Out of the 121 households reporting the wife without an income source in the baseline data, only 12 women reported that they did not have an independent income source in the gender survey.

Table 2.3: Income Sources

	Income Sources Indicator		Proportion of HH	
	Household (HH)	Wife	Income from source	
	N = 6,390	N = 2,063	N = 6,380	
Source	Mean	Mean	Mean	SD
Coffee	0.79	0.05	0.29	0.23
Banana	0.36	0.08	0.13	0.21
Legumes	0.32	0.26	0.09	0.17
Maize	0.19	0.09	0.07	0.17
Groundnut	0.07	0.08	0.02	0.08
Cassava	0.04	0.05	0.01	0.07
Potatoes	0.04	0.05	0.01	0.08
Fruits	0.02	0.00	0.01	0.05
Vegetables	0.02	0.01	0.01	0.05
Other cash crop	0.08	0.01	0.03	0.12
Other cereal	0.05	0.03	0.01	0.05
Livestock	0.27	0.05	0.06	0.13
Casual	0.11	0.03	0.04	0.13
Salary	0.07	0.03	0.03	0.1
Business	0.26	0.09	0.08	0.17
Has saving		0.56		
Has her own plot		0.77		

Table 2.4 summarizes households' coffee production. The median agricultural landholding was 3 acres, of which 1 acre was dedicated to coffee with about 200 trees per farm. Mean figures are skewed by a few large farms, at 5.4 acres of agricultural land, of which 1.4 acre was under coffee with 461 trees. A third of the households did not incur any expenses for coffee production in the past 12 months. 40% of households incurred some labor expenses, 28% incurred transportation costs, 26% purchased equipment, and 24% paid for pesticides. Very few households spent on coffee processing (14%), coffee inorganic fertilizers or manure

(12%), mulch (12%), seedlings (6%), or compost (2%).

Coffee yield and revenue are self-reported at baseline, and the standard variation for both quantities and prices is high.[6] The average coffee earnings were $157 USD, while the median farm earned much less at $54 USD at the average 2018 exchange rate. The mean self-reported yield per acre among those reporting any coffee sales was 142 kgs while the median yield per acre was 80 kgs.[7]

Table 2.4: Coffee Production

Variable	N	Mean	Median	SD
Land of coffee (acre)	5,747	1.36	1	1.75
Number of coffee trees	3,071	461	200	1311
Year of planting	5,933	2008	2012	10.71
Prop of productive trees	6,386	0.61	0.70	0.31
Yields (kg/acre)	4,302	142	80	173.43
Coffee earning (USD)	5,856	157	54	272.59

To put the value of coffee yields in perspective, table 2.5 presents how Mugoya (2018) categorizes Ugandan Robusta coffee farmers along with each category's associated average yield per acre. Based on his categorization, the average yield per acre of farmers in the sample at 142 kgs/acre is significantly lower than that of a traditional farmer (232 kgs/acre).[8]

Table 2.5: Categories of Ugandan Robusta Coffee Farmers based on Mugoya (2018)

Category	Definition	Ave. yields (kgs/acre)
Traditional	A farmer who carries out basic agronomic practices and exclusively uses family labor and does not use fertilizer nor any pest and disease management practices.	232
Improved	A farmer who significantly adopts best agronomic practices, applies fertilizers, proper canopy management, and pest and disease management practices.	505

[6]To limit the influence of extreme and likely incorrect values, we drop the top 5% of observations for amounts of coffee sold and prices and the top 1% of observations for amounts of coffee revenue.
[7]I report yields in the unit of green beans, also known as FAQ-equivalent.
[8]The mean yield per acre for a recommended farmer is about the same as that of an average Robusta coffee farmer in Vietnam (807 kgs/acre), a country with the highest yields globally (Tiemann et al. (2018)).

Table 2.5 continued from previous page

Category	Definition	Ave. yields (kgs/acre)
Recommended	A farmer who adopts most best agronomic practices and applies the recommended amount of fertilizers.	841

2.5.1 Best Agronomic Practice Adoption

One primary outcome of the study is the household's agronomic practice adoption rate.[9] A practice is considered adopted if a household passes each of the elements required for that practice as listed in table 2.1. The percentages of households implementing coffee nutrition recommendations, IPDM, and mulching were all below 15%.[10] The high pass rate on shade at 70% is driven by the fact that most farmers intercropped their coffee with bananas. Finally, while 41% of farmers "practiced" rejuvenation, an important caveat is that almost all of the farmers who passed this practice had young trees that had not yet reached the stage at which systematic rejuvenation is required.

To understand how each practice contributes to final yield, the UCAT project also reached out to 15 agronomists with at least four years of professional experience in coffee agronomy to assess the yield response to coffee practices. Each agronomist was asked to report the complexity of each recommended practice and the percentage increase in yield relative to the expected yield in the absence of each practice for a small-scale Robusta coffee farmer in the Western region of Uganda. Table 2.6 presents the median percentage increase of each practice on yield, the complexity of each practice, and the adoption rate at baseline. Adding the percentage increases for all the practices yields 252.5% (abstracting from the complementarity across practices), suggesting that a farmer who did not use any best practices and then adopted all the listed practices can potentially increase yield by 252.5%. Therefore, for

[9] The enumerators for the BPS sub-sample received one intensive week of training with coffee agronomists so that they could directly observe the coffee field and accurately assess the adoption level during the baseline data collection. Furthermore, if the household had more than one plot of coffee, the enumerator would ask to visit the plot where the household would first implement the new techniques to improve their coffee production.

[10] Despite the potential high returns for using fertilizer, many papers have shown that farmers in Sub-Saharan Africa choose not to adopt fertilizer due to the high costs relative to the returns (Kaizzi, Ssali, and Vlek (2004); Suri (2011)).

an average farmer in the sample who currently harvests 142 kg/acre, his predicted yield is 500 kg/acre if he adopts all the practices.

Table 2.6: Percentage Increase in Yield and Complexity Ranking

Practices	% Increase	Complexity	Prop. Adopted at BL
Intercropping	12.5	Low	0.75
Erosion Control	20	High	0.32
Shade	20	High	0.70
Mulching	25	Low	0.07
Weeding	30	Low	0.57
IPDM	30	High	0.08
Pruning	35	High	0.26
Rejuvenation	40	High	0.41
Coffee Nutrition	40	Low	0.14

2.5.2 Intrahousehold Resource Allocation

Since gender is not a focus of the project, the baseline gender variables were mostly asked to the male head of the household, concealing much of the gender dynamics within the household.[11] On the other hand, the gender survey interviewed spouses separately and simultaneously about household resource allocation. Therefore, I rely on the individual-level data collected from the gender survey to understand the intrahousehold resource allocation, particularly related to coffee production.

Data from the gender survey reveals that men are more likely than women to control coffee income. Table 2.7 shows responses by each spouse to the question of how coffee revenue was handled over the past year. In roughly 40% of the households, the husband kept all of the coffee revenue. Households in which the wife kept all the coffee income or both spouses kept a portion each represent less than 10% of the sample. There are some differences in husbands' and wives' responses. A higher proportion of the husbands (28%)

[11] Two studies in Tanzania demonstrate the importance of collecting individual-level data. Bardasi et al. (2011) find evidence supporting that the labor statistics (excluding agricultural labor) differ depending on the respondent type (self-reporting versus proxy informant). According to Anderson, Reynolds, and Gugerty (2017), when husbands and wives were interviewed separately on the same set of questions, there was some disagreement over the allocation of authority on household and farming decisions. Ambler et al. (2022) also came to the same finding in a study set in Nepal.

reported that spouses sat down to discuss how to use the coffee revenue compared to 19% of the wives. In contrast, 24% of wives reported that the household immediately used the coffee revenue to pay down debt compared to 10% of husbands.

Table 2.7: Proportion of Households Reported How Coffee Revenue Was Handled (N = 252)

Who handled coffee revenue?	Husband's report	Wife's report	Difference
Husband kept all	0.39	0.34	0.05
Wife kept all	0.10	0.09	0.01
Each kept some	0.08	0.07	0.01
Spouses discussed	0.28	0.19	0.09**
Paid debt	0.10	0.24	-0.14***
Other	0.04	0.06	0.02

The predominance of male control over coffee income may be partly due to men underestimating their wives' contribution to coffee production. In the gender survey, the spouse who was mostly responsible for coffee was asked to report the number of hours spent over the past year by the male and female head, children living in the household, and any hired laborers, on each of the three most time-consuming coffee activities: pruning, weeding, and harvesting. The other spouse was asked to report their own time spent on these activities. As shown in Table 2.8, for households in which the male head was the one mostly responsible for coffee, men reported that they spent more time on each task than their wives, but wives indicated that they spent significantly more time on weeding than that reported by their husbands and devoted more time to these three tasks overall. Additionally, a comparison between the husband's hours and the wife's self-reported hours suggests that there is no sharp gender division of labor.

Table 2.8: Total Hours Spent Working on Coffee (N = 236)

	Pruning	Weeding	Harvesting	Total
Husband	13	41	71	125
Wife (reported by the husband)	0.52	22	46	69
Wife (self-reported)	11	64	55	130
Children	0.39	19	52	71
Hired labor	1.2	21	26	48

Despite the instruction to interview the household member primarily responsible for coffee production, 29% of baseline survey respondents are female, far more than the 7% of women primarily responsible for coffee production according to the gender survey, suggesting that in many cases, the male head was not available to be interviewed at baseline. I use this variation in the gender of the respondent to analyze differences in men's and women's preferences regarding which crops to grow. All baseline respondents were asked which crop they would choose if they had the opportunity to expand the production of one crop.

Table 2.9 displays the proportion of respondents who selected each crop by respondent's gender. The last column presents the gender gap in this preference by crop. Households were selected into the sample based on their cultivation of coffee, and the baseline survey covered various aspects of coffee production. It is, therefore, not surprising that coffee ranks highest overall. However, significant differences in the preferred crop by gender are apparent. The positive differences, reflecting male's preferred crops compared to that of female, include coffee, maize, and banana, which account for over half of household cash income. Possibly due to men's primary control of revenue from coffee (and speculatively, other cash crops as well), the negative differences indicate higher female's preferences for food crops for expansion, with legumes, groundnut, and potatoes ranking highest, which together account for 12% of household cash income. Men preferred coffee by the widest margin at 14%, while women favored legumes by the highest margin at 15%.

Table 2.9: The Gender Gap in Preferred Crop for Expansion

Preferred crop for expansion	Overall	Male	Female	Difference
Coffee	0.387	0.427	0.290	0.137***
Maize	0.066	0.070	0.056	0.014***
Banana	0.164	0.172	0.146	0.025***
Cassava	0.023	0.021	0.026	-0.004
Legumes	0.165	0.120	0.271	-0.152***
Creepers	0.002	0.002	0.002	0.000
Groundnut	0.045	0.036	0.066	-0.030***
Potatoes/sweet potatoes	0.048	0.041	0.065	-0.023***
Other cash crops	0.038	0.045	0.024	0.021***
Fruits	0.019	0.023	0.009	0.013***
Vegetables	0.008	0.008	0.009	0.000
Other grains	0.009	0.006	0.015	-0.009***
Other crops	0.027	0.029	0.021	0.008***
Observations		5,999	2,549	

2.5.3 Conclusion

Overall, the data suggest that although most participating households rely on coffee income, they face low yields. Based on the agronomists' predictions, households can increase coffee outputs significantly by adopting the best agronomic practices, with many practices (weeding, pruning, mulching, and erosion control management) demanding more labor from the household. Women reported putting significant time into growing coffee but having less control over the resulting income than their husbands. Additionally, there seems to be a discrepancy in the reported wife's hours by the husband and the wife. Either the husbands seem to underestimate the hours that the wives put into coffee, or the wives overestimate the hours they devoted to coffee. The last table also shows that the wives prefer to expand food crops like legumes to coffee. Therefore, a potential misalignment of spousal incentives may reduce the efficiency of coffee production and dampen the effectiveness of programs that aim to expand production of this crop. In the next chapter, I take the stylized information suggested from the data and the context and incorporate it into a theoretical framework to explain whether, when, and how households experience income and welfare losses.

Chapter 3

A Model of Intrahousehold Resource Allocation with Non-contractibility in Spousal Labor

3.1 Introduction

The theoretical model sets out to explore the interactions between the non-contractibility in spousal labor, intra-household characteristics, and labor-intensive technological change while bringing in key features from the context of coffee-producing households in Uganda. A distinctive feature of coffee farming in Uganda is that husbands traditionally make most of the decisions on coffee production and keep a higher proportion of the profit than their share of labor, leaving wives with a significantly lower proportion of the proceeds. Additionally, since spouses do not always work simultaneously next to each other, and farm output is subjected to stochastic shocks, the husband cannot monitor the wife's labor costlessly. This potential misalignment of incentives can reduce the efficiency of coffee production and dampen the effectiveness of programs that aim to expand the production of this crop. However, the efficiency loss would vary depending on the type of household. While there are many interesting facets to explore, I focus on two particular dimensions of intrahousehold characteristics: the level of caring between spouses or altruism and the relative spousal bargaining power.

The literature on intrahousehold decision-making can be categorized broadly into unitary and non-unitary models.[1] In the unitary model, households pool all resources and behave as a single unit with a common set of preferences (Samuelson (1956); Becker (1973, 1974, 1981); Friedman and Becker (1993)). Since then, empirical evidence has increasingly rejected the unitary model, and as a result, economists have moved towards developing and using the non-unitary model. The class of non-unitary model, including collective and cooperative bargaining model and non-cooperative bargaining model, lets households bargain to determine household outcomes. However, while collective and cooperative bargaining model assumes household decisions to be Pareto-efficient (Manser and Brown (1980); McElroy and Horney (1981); Chiappori (1988); Lundberg and Pollak (1993); Browning and Chiappori (1998)), the non-cooperative bargaining model allows for asymmetric information, enforcement problems and inefficiency (Browning and Lechene (2001); Kanbur and Haddad (1994); Lundberg and Pollak (2003)). Within this space, the conjugal contract model, proposed by Carter and Katz (1997), allows researchers to study household resource allocation in settings with autonomy and interdependence in the household economy. Households can thus behave both cooperatively and non-cooperatively, depending on the decisions, which Sen (1985) has described as "cooperative conflicts".

The model follows the conjugal contract approach in which a household has "separate gender-specific spheres of economic activity and resource allocation linked by a conjugal contract." The individual autonomous control over income is crucial in the conjugal contract approach and sets it apart from the cooperative approach in which households pool resources and allocate them jointly. Based on the norms of coffee households in Uganda, I assume that the husband earns money from coffee production and an off-farm activity, whereas the wife's only earning source is her off-farm work. While each controls their own source of earning, the interdependence between spouses comes from the intrahousehold transfer of labor and

[1] Kulic and Dotti Sani (2020) offer the most recent literature review on the theory and empirics of intrahousehold resources allocation.

income. Therefore, the model is set up to have households behave non-cooperatively in mobilizing labor toward agricultural production in the man's sphere of control while bargaining cooperatively for the consumption allocation based on the relative spousal bargaining power.[2]

The model focuses on a set of households in which inefficient labor allocation can explain the current low coffee production level. Throughout the model, I make the following key assumptions: (i) the husband's off-farm wage is higher than that of the wife, (ii) there is no absolute advantage in skills for coffee production between spouses, and (iii) the size of the coffee farm is large enough that one person has to work full-time while the other person works part-time in order to maximize profits.[3] Under these assumptions, the household is better off allocating all the wife's time endowment on the coffee farm and then some of the husband's time to achieve the profit-maximization labor. Since coffee production is under the husband's sphere of control, the husband pays the wife at her wage rate for her time working on coffee and keeps the remaining profit. Once the household income is maximized, spouses can negotiate the consumption allocation depending on spousal altruism and bargaining power.

The underlying assumption for the husband to remunerate the wife at her off-farm wage rate is that he can observe and enforce the labor efforts of the wife. I refer to this scenario as contractible. Now, imagine a more realistic scenario - the spouses work on different fields or the same field at different times, or the husband works as casual labor or salaried worker and thus away from the coffee field most of the time. Furthermore, unexpected shocks commonly associated with agricultural production and the nature of a permanent crop like coffee make it harder to infer the potential output from inputs. The non-contractible labor scenario arises when the husband can no longer observe and enforce the wife's labor costlessly. In the paper, I do not examine the sources leading to non-contractibility but take it as given and

[2]In a qualitative study carried out in Kenya and Tanzania, Njuki et al. (2017) find that "women respondents indicated that a woman could threaten to withdraw labor from a specific crop or plot if not involved in decision making or management of income from a particular crop."

[3]For households with a small piece of land, the wife's labor is sufficient for the farm labor, leaving the husband to use all his labor off-farm. On the other hand, if households have big farms such that the marginal value of labor productivity exceeds their wage rates, spouses spend all their time endowments on the farm.

evaluate the impact of non-contractibility on labor allocation within the household.

Under the non-contractible labor scenario, the husband does not know the amount of labor the wife puts in. Nevertheless, he can precommit a monetary transfer - beyond his altruistic behavior - to elicit the wife's labor to his coffee production.[4] The transfer operates as an inducement to lower the shadow price of the wife's income and shifts her labor in favor of coffee. Unlike the contractible labor scenario, separability between labor and consumption allocations breaks down. First, the household determines the consumption allocation through a bargaining process. Then based on the agreed-upon transfer level, each spouse chooses the amount of labor on the coffee farm given their conjecture of the other person's labor. Therefore, the wife's bargaining power plays a crucial role in the consumption distribution as well as the intrahousehold negotiation for a higher transfer to compensate for her earning loss from not working off-farm.

The failure to mobilize the wife's labor to work full-time on the farm would result in an income loss for the household compared to the contractible scenario. Without any transfer from the husband, the wife may choose to work on the coffee farm because she cares about him. Similarly, the husband may provide some monetary transfer out of altruism even when she does not work on his coffee farm. However, if the wife has little cash income and a low level of consumption, she would prefer to allocate time to her own income-earning activities. Unless the transfer level is sufficient to elicit the wife to spend all her time on the coffee farm, the household will suffer an income loss.

Even with such income loss, households may continue with the existing conjugal contract due to the current low yields. But suppose that a labor-intensive technological change comes along and improves the marginal returns to labor on coffee. Then if households do not reorganize the division of their labor and the proceeds, the income loss potentially gets further exacerbated, and the household will lose out on the benefits of technological change. Therefore, ambitious programs which aim to improve the returns to a male-controlled crop while

[4] A few papers lend support to the transfer of labor and income within the household (Jones (1983); Fisher, Warner, and Masters (2000)).

neglecting intrahousehold dynamics, such as the UCAT project, may result in disappointing outcomes.

Throughout this chapter, I aim to shed light on the following three questions:

1. How does non-contractibility in the wife's labor affect crop production under the husband's sphere of control?

2. How does the efficiency loss associated with non-contractibility in the wife's labor vary by the level of altruism and bargaining power of spouses?

3. Given the existence of non-contractibility in labor, how does a labor-augmenting technological change affect household resource allocation?

Section 3.2 presents the setup of the model, including the labor market, the coffee production function, the budget constraint, and the preferences. The next two sections discuss the intrahousehold resources allocation, with section 3.3 on the contractible labor scenario and section 3.4 on the non-contractible labor scenario. In section 3.5, I analyze the efficiency loss caused by non-contractibility and evaluate how the loss varies with altruism and relative bargaining power. Finally, section 3.6 concludes with policy implications.

3.2 Setup

A household consists of two individuals, one male and one female ($i = m, f$), to which I refer from here onward as husband and wife.

3.2.1 Labor Market

Each spouse has a time endowment ($\bar{L}$), which they allocate between the coffee production (l_c) and an off-farm activity (l_o). Without leisure, each supplies labor inelastically. I assume an asymmetric labor market where husband and wife could supply labor off-farm but cannot hire labor on-farm.[5] Spouses can work off-farm as much as they want, at the wage rate of

[5] By ignoring hired labor, I assume that households are optimally in a regime where no hired labor is needed. Although a third of the households in the empirical study hired some labor, it is not a far-fetched assumption. On the other hand, the assumption to let husband and wife have an option of working off-farm is fairly strong given that 65% of the couples did not work off-farm. However, this assumption allows me to simplify the model and focus on the coffee labor allocation.

ω^f for the wife and ω^m for the husband. I further assume that the husband's outside wage is higher than the wife's outside wage, similar to the norm in rural Uganda.

I consider two scenarios for the household labor allocation on the coffee farm. First, in the contractible labor scenario, the husband can costlessly observe and enforce the wife's labor and compensate for her time at ω^f. In essence, the husband "hires" the wife to work on his coffee farm. Next, in the non-contractible labor scenario, the husband can no longer observe and enforce the wife's labor costlessly. Instead of paying the wife a wage, the husband relies on the transfer ϕ to incentivize her to work on the farm. Each individual then chooses their time on coffee based on the transfer level and their conjecture of the spouse's labor.

3.2.2 Coffee Production Function

Coffee production uses two inputs: (i) labor, l_c, and (ii) land, T, which I assume to be fixed in the short run and large enough that the optimal labor allocation occurs when one works full-time and the other part-time. I assume the coffee production to be constant returns to scale and concave in both arguments. Furthermore, I assume that labor and land are complementary in the production function, so an increase in land size raises the marginal productivity of labor on coffee.

Total labor on coffee is a linear function of the husband's and wife's labor, which I assume to be perfect substitutes in effective labor. An additional unit of the husband's (or wife's) labor on coffee does not increase the marginal contribution of the wife's (or husband's) labor on coffee to the effective coffee labor unit.

The output of the coffee production can then be expressed as:

$$q = Q\Big(l_c|T,\gamma\Big) = Q\Big(l_c^m + l_c^f|T,\gamma\Big) \tag{3.1}$$

The parameter γ captures the labor-intensive technology of coffee production. An increase in γ is associated with an increase in the marginal productivity of labor on coffee ($\frac{\partial^2 Q}{\partial l_c \partial \gamma} > 0$).

3.2.3 Budget Constraints

Whereas the husband's earned income comprises income from coffee production and an off-farm activity, the wife's only earned income source is from her off-farm work. Additionally, the husband can give his wife a monetary transfer ϕ. By excluding scenarios where the wife transfers income to the husband, I rule out cases where the husband can exploit the wife's income or the wife is over-altruistic and provides him a transfer even with her lower earned income. I assume they face the same price for their private goods, normalized to 1. Each spouse uses all the income towards one's private goods.

3.2.4 Preferences

Each individual cares about their own consumption and the well-being of their spouse. I assume that each person's welfare, W^i, is additive separable in the preference over their own consumption, $u(x^i)$, and caring for the other person, $u(x^{-i})$.[6] The parameter δ^i captures how much one cares about the partner, which I refer to as altruism. I assume that $\delta^i \in [0, 1]$, implying that each individual does not care more about the spouse than their own well-being. Whereas $\delta^i = 0$ corresponds to egoistic preference, $\delta^i = 1$ represents the maximum level of altruism towards the spouse. The preferences over own consumption versus the other person's consumption have the same functional form, which is continuously differentiable and strictly concave. The corresponding preferences for the husband and wife are:

$$W^m(x^m, x^f) = u(x^m) + \delta^m u(x^f) \tag{3.2}$$

$$W^f(x^m, x^f) = u(x^f) + \delta^f u(x^m) \tag{3.3}$$

I use the non-cooperation equilibrium within marriage rather than a divorce as a threat point similar to work by Lundberg and Pollak (1993), Kanbur and Haddad (1994), and Chen and Woolley (2001). The threat point in the model occurs when there is no labor and income transfer between spouses, but the structure of the preferences remains the same.

[6] Browning, Chiappori, and Weiss (2013) refer to this commonly-used preference as 'caring preference'.

While the wife spends all her time working on the off-farm activity, the husband allocates all of his time on the coffee farm and does not provide her with a transfer. In this case, each individual obtains their reservation utility. An example is when the wife leaves the household to stay with her parents nearby but still cares for her husband. Furthermore, each spouse's threat point is neither fixed nor exogenously given but defined as outcomes from scenarios in which spouses do not cooperate to work on coffee together. Hence, a change in wages or parameters related to coffee production affects both the optimal utility and the threat point of each spouse.

$$W_R^m = u\Big[p_c Q\Big(\bar{L}|T,\gamma\Big) + \delta^m u\Big[\omega^f \bar{L}\Big] \tag{3.4}$$

$$W_R^f = u\Big[\omega^f \bar{L}\Big] + \delta^f u\Big[p_c Q\Big(\bar{L}|T,\gamma\Big)\Big] \tag{3.5}$$

The gain from cooperation is the difference between following the conjugal contract to exchange labor and income, W^i, and reverting to the threat point, W_R^i. I present the household's objective function to maximize the joint gains following the Nash bargaining model:

$$\Big[W^f - W_R^f\Big]^{\alpha}\Big[W^m - W_R^m\Big]^{1-\alpha} \tag{3.6}$$

The parameter $\alpha \in [0,1]$ captures the relative weight of the wife's bargaining in the household's decision to allocate the transfer.[7] The wife's bargaining power increases as α increases. The extreme case where the husband has all the bargaining power corresponds to $\alpha = 0$, which I refer to as a dictatorial household.

3.3 Contractible Labor Scenario

Under the contractible labor scenario, the husband can observe the wife's labor on coffee and remunerates her at her wage rate. The household maximizes the following Nash bargaining

[7] Katz (1997) refers to α as the voice within the household.

objective function subject to the budget and reservation utility constraints:

$$\begin{aligned}
&\max_{\phi, l_c^m, l_c^f \geq 0} \Big[W^f - W_R^f\Big]^\alpha \Big[W^m - W_R^m\Big]^{1-\alpha} \\
&\quad \text{st} \;\; (i)\; x^m \leq p_c Q\Big(l_c^m + l_c^f | T, \gamma\Big) + \omega^m(\bar{L} - l_c^m) - \omega^f l_c^f - \phi \\
&\qquad (ii)\; x^f \leq \omega^f \bar{L} + \phi \\
&\qquad (iii)\; \phi \leq p_c Q\Big(l_c^m + l_c^f | T, \gamma\Big) + \omega^m(\bar{L} - l_c^m) - \omega^f l_c^f \\
&\qquad (iv)\; W^m(\phi) \geq W_R^m \\
&\qquad (v)\; W^f(\phi) \geq W_R^f
\end{aligned} \tag{3.7}$$

Since the production decision is independent of the consumption decision, I can decompose the household's optimization problem into two stages. In the first stage, the household maximizes its income by allocating labor on-farm and off-farm according to the corresponding wage rates and the marginal values of productivity of labor. Once labor allocation is set, household income is fixed and maximized. In the second stage, the household allocates consumption across spouses by choosing the transfer level to maximize the joint gain subject to the optimal household income obtained from the first stage.

3.3.1 Labor Allocation

Consider the household's total income:

$$Y^{C*} = \max_{0 \leq l_c^m, l_c^f \leq \bar{L}} p_c Q\Big(l_c^m + l_c^f | T, \gamma\Big) + \omega^m(\bar{L} - l_c^m) + \omega^f(\bar{L} - l_c^f) \tag{3.8}$$

The first-order necessary conditions are:

$$[l_c^m] \quad p_c \frac{\partial Q}{\partial l_c} = \omega^m \tag{3.9}$$

$$[l_c^f] \quad p_c \frac{\partial Q}{\partial l_c} > \omega^f \tag{3.10}$$

The land size to the time endowment ratio determines the household's labor regime.

Under the given assumption of land size, both spouses work on the farm. Since the wife's wage is lower than the husband's wage, the wife spends all her time on coffee, and the husband works on coffee until the marginal value of the productivity of labor falls below his wage rate. Furthermore, altruism does not play a role in labor allocation.

Recall that the conjugal contract approach assumes individual autonomous control over income. However, the separability feature under the contractible labor scenario yields the same solution as in the case where each spouse's income is maximized. Implicitly, each individual's earned income (before the transfer) can be expressed as follows:

$$Y^{m,C*} = p_c Q\Big(l_c^{m*} + l_c^{f*} | T, \gamma\Big) + \omega^m(\bar{L} - l_c^{m*}) - \omega^f l_c^{f*} \tag{3.11}$$

$$Y^{f,C*} = \omega^f \bar{L} \tag{3.12}$$

3.3.2 Transfer Allocation

The household decides how to distribute its income after allocating labor and optimizing the household's income. The objective is to maximize the joint gain product subject to the feasibility and the reservation utility constraints.

$$\begin{aligned}
&\max_{\phi \geq 0} \Big[W^f(\phi) - W_R^f\Big]^{\alpha} \Big[W^m(\phi) - W_R^m\Big]^{1-\alpha} \\
&\quad = \Big[u(x^f) + \delta^f u(x^m) - W_R^f\Big]^{\alpha} \Big[u(x^m) + \delta^m u(x^f) - W_R^m)\Big]^{1-\alpha} \\
&\text{st} \;\; (i)\; x^f \leq Y^{f,C*} + \phi \\
&\qquad (ii)\; x^m \leq Y^{m,C*} - \phi \\
&\qquad (iii)\; \phi \leq Y^{m,C*} \\
&\qquad (iv)\; W^f(\phi) \geq W_R^f \\
&\qquad (v)\; W^m(\phi) \geq W_R^m
\end{aligned} \tag{3.13}$$

It is worth noting that the last three constraints do not bind. Since the husband will always consume a positive amount of private goods, the transfer level has to be less than his earned income. The last two constraints ensure that the transfer does not make either spouse worse off compared to the reservation case. The wife's optimal utility will never be less than the reservation utility since she earns the same wage rate for both on-farm and off-farm labor. Lastly, since the opportunity cost of time is higher for the husband than the wife, the optimal solution for the husband's private good consumption is always higher than the reservation case.

I first look at the case with $\alpha = 0$, reflecting households in which the husband has all the bargaining power to determine the transfer, denoted as ϕ_C^{DH}. This case provides theoretical intuition and implications for many households in a patriarchal society. I then proceed to a more general case where $0 < \alpha < 1$, indicating that the woman has some negotiating leverage over the transfer.

Dictatorial Household ($\alpha = 0$)

The choice of the conjugal contract in a dictatorial household is similar to a principal-agent process, with the husband acting as the principal and choosing the value of the transfer to maximize his well-being while only being constrained by the wife's reservation utility. The optimization problem in 3.13 collapses to:

$$\max_{\phi \geq 0} W^m(\phi) = u(x^m) + \delta^m u(x^f) \text{ st } \begin{array}{l} (i)\ x^f \leq Y^{f,C*} + \phi \\ (ii)\ x^m \leq Y^{m,C*} - \phi \\ (iii)\ \phi \leq Y^{m,C*} \\ (iv)\ W^f(\phi) \geq W^f_R \end{array} \tag{3.14}$$

The first-order necessary condition is:

$$\delta^m \frac{\partial u}{\partial x^f} \leq \frac{\partial u}{\partial x^m} \tag{3.15}$$

The marginal cost of increasing one unit of transfer is the marginal utility he gives up from consuming an additional unit of his private consumption. On the other hand, the marginal benefit of an additional unit of transfer is his marginal utility from an additional unit of his wife's consumption. Unless the marginal benefit from the transfer falls below the marginal cost, the husband always provides a positive amount of transfer to his wife. As the husband cares more about the wife, i.e., an increase in δ^m, the marginal benefit increases leading to an increase in the transfer. The wife's altruism, however, does not enter into his decision to allocate the transfer.

Generalized Nash-Bargaining Household $(0 < \alpha < 1)$

The general case allows the wife to have some bargaining power over the consumption allocation. The optimal transfer from the optimization problem 3.13 reflects the household's internal trade-off of utilities between spouses, as shown in the first-order necessary condition:

$$\frac{W^f(\phi) - W_R^f}{W^m(\phi) - W_R^m} \leq -\frac{\alpha}{1-\alpha}\frac{\partial W^f(\phi)\partial\phi}{\partial W^m(\phi)\partial\phi} = -\frac{\alpha}{1-\alpha} \quad \frac{\frac{\partial u}{\partial x^f} - \delta^f \frac{\partial u}{\partial x^m}}{\delta^m \frac{\partial u}{\partial x^f} - \frac{\partial u}{\partial x^m}} \tag{3.16}$$

The first-order condition suggests that the division of gains from cooperation is proportional to the marginal rate of the utility transfer weighted by the relative bargaining power of the spouses. The marginal rate of the utility transfer captures how much the household needs to reduce the husband's utility when increasing the wife's utility by one unit to have the division of the gains stay constant. Altruism plays a crucial role in determining the optimal transfer, increasing with an increase in the husband's altruism and a decrease in the wife's altruism.

In a dictatorial household, the husband chooses the transfer level to maximize his welfare, so any transfer level above ϕ_C^{DH} will result in lower welfare for him. On the other hand, he will not accept a transfer where his welfare falls below his reservation utility. Denote ϕ_C^{max} as the minimum between (i) the transfer level at which the husband is at his reservation utility and (ii) the transfer level above which the wife's welfare starts to fall. Focusing on the relevant range of transfer between ϕ_C^{DH} and ϕ_C^{max}, I observe the following characteristic of the transfer. An increase in the wife's bargaining power shifts up the transfer level, leading to higher welfare for her. Therefore, households in which a wife has some bargaining power will have a higher transfer than a dictatorial household.

3.4 Non-Contractible Labor Scenario

Under the non-contractible labor scenario, because the husband cannot observe and enforce the wife's labor, he does not know the number of hours his wife puts in to pay her. The wife works on the husband's coffee farm if she cares about him. But every hour she works on the farm takes time away from her earning activity and reduces her private good consumption. As the transfer indirectly provides the wife with more income to afford her private good, the husband can approach the transfer as a tool to incentivize her to work on the farm beyond caring about her.

Unlike the contractible labor scenario, since the transfer affects how the spouses allocate their labor, the consumption and production decisions are no longer separable. Therefore, I approach the household optimization problem stage-wise and solve it through backward induction. First, since the spouses are autonomous in their labor allocation, each allocates labor based on the conjecture of the other person's labor and the agreed-upon transfer level. Their sub-optimization problems yield two best response functions, which I then solve to get the husband and wife's Cournot-Nash labor supply on a fixed transfer level. In the second stage, I solve for the household's optimal transfer level, keeping in mind that the labor supply is a function of the transfer.

3.4.1 Labor Allocation (at a given transfer level)

In this section, I explore the labor allocation of each spouse. Taking the transfer level and the anticipation of the other person's labor as given, each individual maximizes their welfare based on the budget constraints. I denote $\hat{l_c^f}$ as the wife's labor supply contributions anticipated by her husband, and $\hat{l_c^m}$ as the husband's labor supply anticipated by the wife. From their best response functions, I solve for the Cournot-Nash labor supply at a fixed transfer level.

Husband's sub-problem

$$\max_{0\le l_c^m \le \bar{L}} W^m = u(x^m) + \delta^m u(x^f) \quad \text{st } (i) \quad x^m \le p_c Q\Big(l_c^m + \hat{l}_c^f | T, \gamma\Big) + \omega^m(\bar{L} - l_c^m) - \phi$$
$$(ii) \quad x^f \le \omega^f(\bar{L} - \hat{l}_c^f) + \phi \tag{3.17}$$

The first-order necessary condition is:

$$[l_c^m] \quad p_c \frac{\partial Q(\hat{l}_c^f|\phi)}{\partial l_c} \ge \omega^m \tag{3.18}$$

The husband optimizes his utility by evaluating the marginal value of the productivity of his labor on coffee to his wage rate based on the anticipated labor from the wife. Since coffee production is in the husband's sphere of control, he has the incentive to allocate his labor to maximize the coffee profit. Recall that the land size is such that the husband always provides some, if not all, of his labor on the coffee farm. If the marginal value of the productivity of labor exceeds his wage rate, the husband works full-time on coffee.

If the husband anticipates the wife to put in some labor enough to drive down the marginal productivity of labor to his wage rate, he then shifts some of his time to the off-farm activity. In this case, the husband's best response function with respect to the wife's anticipated labor is downward-sloping with a slope of 1. This follows the intuition that the husband chooses his labor to maximize his coffee profit, knowing that the amount of labor the wife puts in affects his marginal value of productivity of labor on the coffee farm. Since the wife's labor perfectly substitutes the husband's labor, he reduces his labor by exactly one hour as the wife's anticipated labor increases by one hour.

Wife's sub-problem

$$\max_{0\le l_c^f \le \bar{L}} W^f = u(x^f) + \delta^f u(x^m) \quad \text{st } (i) \quad x^f \le \omega^f(\bar{L} - l_c^f) + \phi$$
$$(ii)\ x^m \le p_c Q\Big(\hat{l}_c^m + l_c^f | T, \gamma\Big) + \omega^m(\bar{L} - \hat{l}_c^m) - \phi \tag{3.19}$$

The first-order necessary condition is:

$$[l_c^f] \quad \delta^f \frac{\partial u}{\partial x^m}\left(p_c \frac{\partial Q(\hat{l}_c^m|\phi)}{\partial l_c}\right) \le \omega^f \frac{\partial u}{\partial x^f}; \text{ or } \quad l_c^f(\hat{l}_c^m|\phi) = \bar{L} \tag{3.20}$$

While the husband's labor on coffee only affects his own consumption, the wife's labor on coffee affects both of their consumption. The asymmetry arises due to the husband's control over the coffee revenue. When the wife increases her labor on coffee resulting in more coffee output, her husband can afford more private goods. The marginal benefit is her marginal value of utility derived from her husband consuming an additional unit of his private goods. At the same time, she has to reduce the time working on her income-generating activity, which allows her to purchase her private goods. The marginal cost is the marginal value of utility lost from consuming less of her private goods. Therefore, the wife's best response hinges on the consumption allocation.

If the wife puts in some hours on the farm, her best response function with respect to the husband's labor allocation has a negative slope with an absolute magnitude of less than 1. For example, if the wife anticipates that the husband puts in one more hour on the coffee farm, she will reduce her time there by less than a full hour.

Cournot-Nash equilibrium for coffee labor allocation

The solutions to the best response functions from the husband's and the wife's sub-optimization problems, inequalities 3.18 and 3.20, yield a unique Cournot-Nash equilibrium for labor allocation of each spouse for a given level of transfer.

Suppressing other parameters, the best response functions in essence can be expressed as:

$$\begin{aligned} l_c^m &= l_c^m(\hat{l}_c^f|\phi) \\ l_c^f &= l_c^f(\hat{l}_c^m|\phi) \end{aligned} \tag{3.21}$$

The Cournot-Nash labor equilibrium is then:

$$\begin{aligned} l_c^{m*}(\phi) &= l_c^m(l_c^f(\phi)|\phi) \\ l_c^{f*}(\phi) &= l_c^f(l_c^m(\phi)|\phi) \end{aligned} \tag{3.22}$$

First, note that the husband's altruism does not affect the labor allocation, but an increase in the wife's altruism raises the wife's labor. Second, as I have highlighted that the transfer under the non-contractible scenario plays an additional role in incentivizing the wife to work on the coffee farm, it is useful to look at the impact of the transfer on the Cournot-Nash labor allocation. The corner solution for the wife's labor can occur even with a positive transfer level and some altruism. The wife does not work on coffee when her private goods consumption is low, while the husband's private goods consumption is sufficiently high. In this case, she rather works off-farm to increase her private goods consumption. The other corner is when the wife already puts in all her time endowment on coffee, so any additional transfer will solely give her more disposable income but not affect her labor.

The following observations assume that both spouses put some (but not all) of their labor on the coffee farm. An increase in the transfer reduces the husband's labor allocation and increases the wife's labor on coffee. Furthermore, if the wife cares about the husband ($\delta^f \neq 0$), the effective wage rate, $1/\frac{\partial l_c^{f*}(\phi)}{\partial \phi}$, is higher than the wife's wage rate, ω^f.[8] This suggests that it is more costly for the husband to "hire" the wife under the non-contractible labor scenario.

3.4.2 Transfer Allocation

Under the non-contractible labor scenario, the household maximizes its joint gain product subject to the feasibility and the reservation utility constraints. However, labor allocation on the coffee farm depends on the transfer level. The household solves the following optimization

[8] The partial derivative, $\frac{\partial l_c^{f*}(\phi)}{\partial \phi}$, captures the number of hours the wife would put in if she receives an additional unit of transfer.[9] Therefore, $1/\frac{\partial l_c^{f*}(\phi)}{\partial \phi}$ is the amount the husband gives to the wife for her to work one additional hour on the farm under the non-contractible case, which I refer to as the wife's effective wage rate.

problem:

$$
\begin{aligned}
N = \max_{\phi \geq 0} & \Big[W^f(\phi) - W_R^f\Big]^{\alpha}\Big[W^m(\phi) - W_R^m\Big]^{1-\alpha} \\
= & \Big[u(x^f) + \delta^f u(x^m) - W_R^f\Big]^{\alpha}\Big[u(x^m) + \delta^m u(x^f) - W_R^m)\Big]^{1-\alpha} \\
\text{st} \;\; & (i)\; x^f \leq \omega^f\Big(\bar{L} - l_c^{f*}(\phi)\Big) + \phi \\
& (ii)\; x^m \leq p_c Q\Big(l_c^{m*}(\phi) + l_c^{f*}(\phi)|T,\gamma\Big) + \omega^m\Big(\bar{L} - l_c^{m*}(\phi)\Big) - \phi \\
& (iii)\; \phi \leq p_c Q\Big(l_c^{m*}(\phi) + l_c^{f*}(\phi)|T,\gamma\Big) + \omega^m\Big(\bar{L} - l_c^{m*}(\phi)\Big) \\
& (iv)\; W^f(\phi) \geq W_R^f \\
& (v)\; W^m(\phi) \geq W_R^m
\end{aligned}
\tag{3.23}
$$

I first consider the consumption allocation under a dictatorial household ($\alpha = 0$) and then move to a generalized Nash-bargaining household ($0 < \alpha < 1$).

Dictatorial Household ($\alpha = 0$)

In the extreme case where the husband has all the bargaining power, the optimization problem collapses to:

$$
\begin{aligned}
& \max_{\phi \geq 0} W^m(\phi) = u(x^m) + \delta^m u(x^f) \\
\text{st} \;\; & (i)\; x^f \leq \omega^f\Big(\bar{L} - l_c^{f*}(\phi)\Big) + \phi \\
& (ii)\; x^m \leq p_c Q\Big(l_c^{m*}(\phi) + l_c^{f*}(\phi)|T,\gamma\Big) + \omega^m\Big(\bar{L} - l_c^{m*}(\phi)\Big) - \phi \\
& (iii)\; \phi \leq p_c Q\Big(l_c^{m*}(\phi) + l_c^{f*}(\phi)|T,\gamma\Big) + \omega^m\Big(\bar{L} - l_c^{m*}(\phi)\Big) \\
& (iv)\; W^f(\phi) \geq W_R^f
\end{aligned}
\tag{3.24}
$$

The first-order necessary condition is:

$$
\underbrace{\delta^m \frac{\partial u}{\partial x^f} - \frac{\partial u}{\partial x^m}}_{\text{Direct effect}} + \underbrace{\frac{\partial l_c^{f*}}{\partial \phi}\Big[\frac{\partial u}{\partial x^m}\Big(p_c \frac{\partial Q}{\partial l_c^*}\Big) - \delta^m \frac{\partial u}{\partial x^f}\omega^f\Big]}_{\text{Wife's labor incentive effect}} + \underbrace{\frac{\partial l_c^{m*}}{\partial \phi}\Big[\frac{\partial u}{\partial x^m}\Big(p_c \frac{\partial Q}{\partial l_c^*} - \omega^m\Big)\Big]}_{\text{Profit effect}} \leq 0 \tag{3.25}
$$

I deconstruct the left-hand side of equation 3.25 into three effects. The first term, *the direct effect*, captures altruism or the utility trade-off between the husband's and the wife's consumption holding labor allocation constant. Similar to the contractible labor scenario, the husband's altruism increases the transfer, while the wife's altruism does not affect the transfer. The second term, *the wife's labor incentive effect*, shows how the transfer affects the wife's labor on coffee. An increase in the transfer increases the wife's coffee labor and thus his coffee revenue and private good consumption. At the same time, the wife has to reduce her time off-farm and can afford less of her private good consumption. Since the husband cares about his wife, a reduction in her consumption lowers his utility. The last term, *the profit effect*, shows the effect of the transfer on the husband's labor.

The husband adjusts his labor accordingly to his wife's labor to keep the same profit, so the profit effect term drops out:[10]

$$\delta^m \frac{\partial u}{\partial x^f} - \frac{\partial u}{\partial x^m} + \frac{\partial l_c^{f*}}{\partial \phi}\left[\frac{\partial u}{\partial x^m}\left(p_c \frac{\partial Q}{\partial l_c^*}\right) - \delta^m \frac{\partial u}{\partial x^f}\omega^f\right] \leq 0 \tag{3.26}$$

Suppose that the wife puts in some labor in response to the transfer, then the first-order condition for an interior solution holds with equality. On the other hand, if the transfer does not affect the wife's labor, only the direct effect remains to allocate the disposable income between spouses based on the husband's altruism. Although the inequality 3.25 collapses to the condition under the contractible labor scenario, if the wife does not work on the farm, the household income will be less than that under the contractible labor scenario.

Generalized Nash-Bargaining Household $(0 < \alpha < 1)$

A generalized Nash-bargaining household model allows the wife to have some bargaining

[10] If the husband allocates all his time on coffee and the wife's labor contribution is not enough to drive down the marginal value of productivity of labor to his wage rate, the transfer does not affect his labor. Therefore, the profit effect also drops out.

power, so here I derive the first-order necessary condition from problem 3.23:

$$
\begin{aligned}
\frac{W^f(\phi)-W_R^f}{W^m(\phi)-W_R^m} &\leq -\frac{\alpha}{1-\alpha} \quad \frac{\partial W^f(\phi)\partial\phi}{\partial W^m(\phi)\partial\phi} \\
&= -\frac{\alpha}{1-\alpha} \quad \frac{\frac{\partial u}{\partial x^f} - \delta^f\frac{\partial u}{\partial x^m} + \frac{\partial l_c^{f*}}{\partial\phi}\left[\delta^f\frac{\partial u}{\partial x^m}\left(p_c\frac{\partial Q}{\partial l_c^*}\right) - \frac{\partial u}{\partial x^f}\omega^f\right] + \frac{\partial l_c^{m*}}{\partial\phi}\left[\delta^f\frac{\partial u}{\partial x^m}\left(p_c\frac{\partial Q}{\partial l_c^*} - \omega^m\right)\right]}{\delta^m\frac{\partial u}{\partial x^f} - \frac{\partial u}{\partial x^m} + \frac{\partial l_c^{f*}}{\partial\phi}\left[\frac{\partial u}{\partial x^m}\left(p_c\frac{\partial Q}{\partial l_c^*}\right) - \delta^m\frac{\partial u}{\partial x^f}\omega^f\right] + \frac{\partial l_c^{m*}}{\partial\phi}\left[\frac{\partial u}{\partial x^m}\left(p_c\frac{\partial Q}{\partial l_c^*} - \omega^m\right)\right]} \\
&= -\frac{\alpha}{1-\alpha} \quad \frac{\frac{\partial u}{\partial x^f} - \delta^f\frac{\partial u}{\partial x^m} + \frac{\partial l_c^{f*}}{\partial\phi}\left[\delta^f\frac{\partial u}{\partial x^m}\left(p_c\frac{\partial Q}{\partial l_c^*}\right) - \frac{\partial u}{\partial x^f}\omega^f\right]}{\delta^m\frac{\partial u}{\partial x^f} - \frac{\partial u}{\partial x^m} + \frac{\partial l_c^{f*}}{\partial\phi}\left[\frac{\partial u}{\partial x^m}\left(p_c\frac{\partial Q}{\partial l_c^*}\right) - \delta^m\frac{\partial u}{\partial x^f}\omega^f\right]} \quad \text{(due to the husband's labor response)}
\end{aligned}
\tag{3.27}
$$

The household allocates the transfer such that the division of gains from cooperation is proportional to the marginal rate of the utility transfer weighted by the relative bargaining power. However, unlike the contractible labor scenario, the marginal rate of the utility transfer reflects the dual role of the transfer - altruism and incentivizing the wife to work on the coffee farm. Define ϕ_{NC}^{max} as the minimum between (i) the transfer level at which the husband is at his reservation utility and (ii) the transfer level above which the wife's welfare starts to fall. The range of interest is between the transfer level to maximize the husband's welfare in the dictatorial case, ϕ_{NC}^{DH}, and ϕ_{NC}^{max}. This range of transfer guarantees that $\frac{\partial W^m}{\partial\phi} < 0$ and $\frac{\partial W^f}{\partial\phi} > 0$. Therefore, the transfer solution under the generalized Nash-bargaining household will be higher than that under the dictatorial household. In general, an increase in the wife's bargaining power raises the transfer level.

3.5 Efficiency Loss due to Non-contractibility in Labor

Given the layout of the contractible and non-contractible labor scenarios, I proceed to evaluate the efficiency loss due to non-contractibility through labor allocation, coffee production, and welfare of the household, as well as the distribution of welfare.

3.5.1 Labor Allocation

I first assess the difference in the labor supply of the husband and the wife under the two labor scenarios. Regardless of the labor scenario, the husband acts as a profit maximizer. While the husband splits his time between coffee and the off-farm activity under the contractible labor scenario, the husband spends some if not all of his time on coffee depending on the wife's labor under the non-contractible labor scenario:

$$\begin{aligned} \text{Contractible:} \quad & p_c \frac{\partial Q(l_c^m, l_c^f)}{\partial l_c} = \omega^m \\ \text{Non-Contractible:} \quad & p_c \frac{\partial Q(l_c^{m*}(\phi), l_c^{m*}(\phi)}{\partial l_c}) \geq \omega^m \end{aligned}$$

Instead of working full-time on coffee like in the contractible labor scenario, the wife decides on her labor based on the consumption allocation under the non-contractible labor scenario :

$$\begin{aligned} \text{Contractible:} \quad & p_c \frac{\partial Q(l_c^m, l_c^f)}{\partial l_c} > \omega^f \\ \text{Non-Contractible:} \quad & p_c \frac{\partial Q(l_c^{m*}(\phi), l_c^{f*}(\phi)}{\partial l_c}) \leq \omega^f \frac{\frac{\partial u}{\partial x^f}}{\delta^f \frac{\partial u}{\partial x^m}} \text{ or } p_c \frac{\partial Q(l_c^{m*}(\phi), l_c^{f*}(\phi)}{\partial l_c}) > \omega^f \frac{\frac{\partial u}{\partial x^f}}{\delta^f \frac{\partial u}{\partial x^m}} \end{aligned}$$

The household suffers income loss due to the non-contractibility in labor if the wife does not work full-time on coffee. Even in the case that the wife puts in some time, and the husband works full-time on coffee such that the total labor does not change, the additional husband's hours on the coffee farm (beyond the amount he would put in under the contractible case) comes at the expense of his higher return off-farm job. Therefore, as long as the wife uses up all of her time on coffee, the overall household incomes under contractible and non-contractible scenarios are the same. Consider two cases:

- Case 1: If the optimal transfer is such that the wife works part-time or does not work on the coffee farm while the husband adjusts and works full-time on coffee. This scenario implies the following:

$$\begin{aligned} & \omega^m < p_c \frac{\partial Q}{\partial l_c^*} \leq \frac{1}{\delta^f} \frac{\partial u / \partial x^f}{\partial u / \partial x^m} \omega^f \\ \rightarrow \quad & \delta^f \frac{\partial u / \partial x^m}{\partial u / \partial x^f} < \frac{\omega^f}{\omega^m} \end{aligned} \tag{3.28}$$

- Case 2: If the optimal transfer is such that the wife works full-time on the coffee farm, then the husband works part-time on coffee. This scenario implies the following:

$$\begin{aligned} \omega^m = p_c \frac{\partial Q}{\partial l_c^*} &> \frac{1}{\delta^f} \frac{\partial u / \partial x^f}{\partial u / \partial x^m} \omega^f \\ \rightarrow \quad \frac{\omega^f}{\omega^m} &< \delta^f \frac{\partial u / \partial x^m}{\partial u / \partial x^f} \end{aligned} \tag{3.29}$$

The key difference between the two cases is where the wage ratio, $\frac{\omega^f}{\omega^m}$, lies in regard to the marginal rate of substitution of utility between spousal private goods, $\delta^f \frac{\partial u/\partial x^m}{\partial u/\partial x^f}$. Consider the case in which the transfer is quite low, resulting in a high x^m and a low x^f, and thus a small value for the marginal rate of utility between spousal private goods. Furthermore, if the wife does not care much about the husband (a low δ^f), she would rather work off-farm partially or entirely. Under this scenario, the amount of labor provided by the wife under the non-contractible labor scenario is lower than that under the contractible labor scenario, resulting in a lower income and lower total welfare for the household.

3.5.2 Transfer Allocation

Recall the necessary first-order condition for an interior optimal transfer:

$$\frac{W^f(\phi) - W_R^f}{W^m(\phi) - W_R^m} = -\frac{\alpha}{1-\alpha} \quad \frac{\frac{\partial u}{\partial x^f} - \delta^f \frac{\partial u}{\partial x^m} + \frac{\partial l_c^{f*}}{\partial \phi} \left[\frac{\partial u}{\partial x^m} \left(p_c \frac{\partial Q}{\partial l_c^*} \right) - \frac{1}{\delta^f} \frac{\partial u}{\partial x^f} \omega^f \right]}{\delta^m \frac{\partial u}{\partial x^f} - \frac{\partial u}{\partial x^m} + \frac{\partial l_c^{f*}}{\partial \phi} \left[\frac{\partial u}{\partial x^m} \left(p_c \frac{\partial Q}{\partial l_c^*} \right) - \delta^m \frac{\partial u}{\partial x^f} \omega^f \right]} \tag{3.30}$$

We have previously established that an increase in the wife's bargaining power, α, increases the transfer. In the extreme case of a dictatorial household with $\alpha = 0$, the wife has no bargaining power, so the husband chooses the transfer to maximize his welfare. Now, consider a more general scenario in which the wife has some bargaining power. If the transfer does not affect the wife's labor allocation, the wife's bargaining power allows her to negotiate for a larger share of the household income. The first-order condition collapses to the condition under the contractible scenario, albeit with a lower household income. As α increases further, the wife has more transfer which boosts her consumption level and shifts some of her labor to coffee. The optimal transfer, which leads to the husband working full-time on coffee and the wife working part-time, requires that $\delta^f \frac{\partial u/\partial x^m}{\partial u/\partial x^f} < \frac{\omega^f}{\omega^m}$. If the wife's bargaining power is high enough to increase the transfer further and satisfy the condition, $\frac{\omega^f}{\omega^m} < \delta^f \frac{\partial u/\partial x^m}{\partial u/\partial x^f}$, the wife puts all of her time on coffee.

A sufficiently large transfer can elicit the wife to spend all her time on coffee, thus eliminating income loss. A large transfer can happen under two conditions. First, households with higher bargaining power for the wife can bargain and allocate a higher share of the income towards the wife. Second, although the husband's altruism does not enter directly into the wife's decision on labor allocation, transfer increases with the husband's altruism. Alternatively, even at a low transfer, the wife may devote all her time to coffee if she cares a lot about the husband, preventing the household from incurring any income loss. Even if labor allocation under the contractible and non-contractible scenarios are the same, the welfare distributions are different. From the husband's perspective, the wife's labor is more expensive under the non-contractible scenario. With more disposable income to afford her private goods, the wife's welfare under the non-contractible scenario is higher than her welfare under the contractible labor scenario, while the opposite applies to the husband's welfare.

3.6 Policy Implications

The theoretical framework explains how misalignment between non-contractible labor and residual claims on the income derived from such labor can lead to households missing out on income and welfare gains even before an intervention program comes along. Given the assumption of the land size, there is no income loss if the wife provides all of her time on coffee. What would it take for the wife to work on coffee, a husband's controlled source of income, at the expense of her monetary earnings? I find that a high level of spousal altruism and the wife's bargaining power may reduce or completely remove the potential income loss due to the non-contractibility in labor. The higher the wife's altruism is, the more she is willing to work on the husband's coffee farm. In addition, households in which the wife has more bargaining power or the husband cares a lot for his wife can come to an agreement on a higher transfer which then elicits more labor from the wife.

The model provides implications for outcomes of interventions that promote a labor-intensive technological change for a male-controlled crop. Increased productivity may not benefit all household members equally since changes in agricultural production may affect the reallocation of labor between spouses and their exit options. For example, an agronomy training program aims to expose coffee farmers to the best agronomic practices to increase coffee yields. The technological change affects the spouses' welfare and threat points by raising the marginal productivity of labor on coffee. As the husband's income increases, he can afford more of his private good, which drives down the marginal utility for his consumption good. But note that the wife's labor response depends on the wife's altruism and the transfer level (which is indirectly linked to the wife's bargaining power and the husband's altruism). If the spouses do not care much for each other, and/or a low wife's bargaining power prevents the wife from claiming a higher share of the household income, the wife may not be willing to work full-time on coffee. The failure to elicit the wife's labor with the appropriate transfer amount would dampen the benefits of a labor-intensive technological change.

Furthermore, the model provides evidence that interventions like the agronomy training program may achieve better results if they incorporate promoting spousal altruism and women's bargaining power into the training agenda. Although there has been more recent work documenting and measuring altruistic behaviors between spouses (Iversen et al. (2006); Akresh, Chen, and Moore (2016)), few studies have intervened to promote altruistic behaviors toward spouses (Gloster, Rinner, and Meyer (2020)). Additionally, a policy that promotes altruism may come at the cost of higher gender inequality within the household. On the other hand, women's bargaining power has increasingly become a central focus in many research and policy programs (Doss (2013)). In the next chapter, I build on the intuitions from the theoretical framework and focus empirically on this specific dimension, the relative spousal bargaining power. The model opens up an interesting and policy-relevant testable hypothesis: What are the impacts of spousal bargaining power on technological adoption and household agricultural production? I leverage data from a randomized evaluation of an extension program offered to smallholder coffee growers in Uganda to propose a setup to study the heterogeneous impact of training on labor allocation, adoption, and yields based on spousal levels of bargaining power.

Even though the theoretical framework is based on stylized facts about coffee households in Uganda, the framework is relevant for households in many agrarian settings. Moreover, the implications derived from the model are consistent with the findings of many empirical studies. For example, Jones (1983) finds that married women devote less time to their husband's fields at the expense of household income in North Cameroon. In more recent work, Meemken, Veettil, and Qaim (2017) find that the wives of coffee-producing households in Uganda seem to prefer fewer responsibilities to improve coffee quality. Another work in a similar context by Lecoutere and Wuyts (2021) examines the impact of giving an intensive coaching package to promote household cooperation in Western Uganda. They find that, while the net household income reported by women increases, the change does not raise the household income but rather that the wife is better informed about the coffee sales of the household. Increasing household cooperation thus may not be sufficient to shift the income distribution, as suggested in the model.

Appendix

The appendix provides the properties of the solution(s) of the theoretical framework shown in chapter 3. Section 3.A shows the propositions and proofs from the contractible labor scenario, followed by section 3.B shows the propositions and proofs from the non-contractible labor scenario.

3.A Contractible Labor Scenario

3.A.1 Labor Allocation

$$Y^{C*} = \max_{0 \le l_c^m, l_c^f \le \bar{L}} p_c Q\Big(l_c^m + l_c^f | T, \gamma\Big) + \omega^m(\bar{L} - l_c^m) + \omega^f(\bar{L} - l_c^f) \tag{3.31}$$

The first-order necessary conditions are:

$$[l_c^m] \quad p_c \frac{\partial Q}{\partial l_c} = \omega^m \tag{3.32}$$

$$[l_c^f] \quad p_c \frac{\partial Q}{\partial l_c} > \omega^f \tag{3.33}$$

Proposition 1. *Under the contractible labor scenario, an increase in one's own altruism or the spouse's altruism does not affect either spouse's labor.*

Proof: The altruism parameters, δ^m and δ^f, do not affect the spouse's labor allocation on coffee, so an individual does not change their labor with an increase in either their own altruism towards the spouse or the spouse's altruism towards them.

Proposition 2. *Under the contractible labor scenario, the labor-intensive technological change raises the husband's labor.*

Proof:

I conduct the comparative statics for the following equation:

$$G = \frac{\partial Q}{\partial l_c} - \frac{\omega^m}{p_c} = 0 \tag{3.34}$$

Comparative static with respect to the technology parameter:

$$\frac{\partial l_c^m}{\partial \gamma} = -\frac{G_\gamma}{G_{l_c^m}} = -\frac{\frac{\partial^2 Q}{\partial l_c \partial \gamma}}{\frac{\partial^2 Q}{\partial l_c^2}} > 0 \tag{3.35}$$

The sign of this expression depends on the cross-partial derivative $\frac{\partial^2 Q}{\partial l_c \partial \gamma}$, which implies the nature of the technology on labor. For a labor-augmented technology such that an increase in γ leads to a rise in the marginal productivity of labor on coffee, the sign of the cross-partial is positive, and the husband shifts more labor to coffee. Note that with technological change, the first-order condition for l_c^f continues to hold, so the wife still remains working full-time on coffee.

3.A.2 Transfer Allocation

$$\begin{aligned}
&\max_{\phi \geq 0} \Big[W^f(\phi) - W_R^f\Big]^\alpha \Big[W^m(\phi) - W_R^m\Big]^{1-\alpha} \\
&= \Big[u(x^f) + \delta^f u(x^m) - W_R^f\Big]^\alpha \Big[u(x^m) + \delta^m u(x^f) - W_R^m)\Big]^{1-\alpha} \\
&\text{st } \; (i)\; x^f \leq Y^{f,C*} + \phi \\
&\quad (ii)\; x^m \leq Y^{m,C*} - \phi \\
&\quad (iii)\; \phi \leq Y^{m,C*} \\
&\quad (iv)\; W^f(\phi) \geq W_R^f \\
&\quad (v)\; W^m(\phi) \geq W_R^m
\end{aligned} \tag{3.36}$$

Dictatorial Household

For a dictatorial household ($\alpha = 0$), the first-order necessary condition for an interior solution to the transfer is:

$$\delta^m \frac{\partial u}{\partial x^f} = \frac{\partial u}{\partial x^m} \tag{3.37}$$

I conduct the comparative statics for the following equation:

$$H = \delta^m \frac{\partial u}{\partial x^f} - \frac{\partial u}{\partial x^m} \tag{3.38}$$

Proposition 3. *Under the contractible labor scenario for a dictatorial household, the transfer increases with an increase in the husband's altruism but does not change with an increase in the wife's altruism.*

Proof:

i. Comparative static with respect to the husband's altruism:

$$\frac{\partial \phi}{\partial \delta^m} = -\frac{H_{\delta^m}}{H_\phi} = -\frac{\frac{\partial u}{\partial x^f}}{\delta^m \frac{\partial^2 u}{\partial x^{f2}} + \frac{\partial^2 u}{\partial x^{m2}}} > 0 \tag{3.39}$$

ii. The wife's altruism, δ^f, does not affect the transfer decision.

Proposition 4. *Under the contractible labor scenario for a dictatorial household, the transfer in the contractible labor scenario increases with the labor-intensive technological change.*

Proof: Comparative static with respect to the technology parameter:

$$\frac{\partial \phi}{\partial \gamma} = -\frac{H_\gamma}{H_\phi} = \frac{p_c \frac{\partial Q}{\partial \gamma} \frac{\partial^2 u}{\partial x^{m2}}}{\delta^m \frac{\partial^2 u}{\partial x^{f2}} + \frac{\partial^2 u}{\partial x^{m2}}} > 0 \tag{3.40}$$

Generalized Nash-Bargaining Household

In the generalized Nash-bargaining case, the first-order necessary condition for an interior transfer is:

$$\frac{W^f(\phi) - W^f_R}{W^m(\phi) - W^m_R} = -\frac{\alpha}{1-\alpha} \frac{\partial W^f(\phi)\partial \phi}{\partial W^m(\phi)\partial \phi} = -\frac{\alpha}{1-\alpha} \frac{\frac{\partial u}{\partial x^f} - \delta^f \frac{\partial u}{\partial x^m}}{\delta^m \frac{\partial u}{\partial x^f} - \frac{\partial u}{\partial x^m}} \tag{3.41}$$

I define $G^m = W^m(\phi) - W^m_R$, $G^f = W^f(\phi) - W^f_R$, $I = \frac{G^f}{G^m} + \frac{\alpha}{1-\alpha} \frac{\partial W^f/\partial \phi}{\partial W^m/\partial \phi}$.

Proposition 5. *Under the contractible labor scenario for a generalized Nash-bargaining household, an increase in the husband's altruism or a decrease in the wife's altruism increases the transfer in the contractible labor scenario.*

Proof:

i. Comparative static with respect to the husband's altruism:

$$\frac{\partial\phi}{\partial\delta^m} = -\frac{I_{\delta^m}}{I_\phi} = \frac{\frac{G^f\left(u(x^f)-u(x_R^f)\right)}{(G^m)^2}}{\frac{G^m\frac{\partial W^f}{\partial\phi}-G^f\frac{\partial W^m}{\partial\phi}}{(G^m)^2}+\frac{\alpha}{1-\alpha}\frac{\frac{\partial W^m}{\partial\phi}\frac{\partial^2W^f}{\partial\phi^2}-\frac{\partial W^f}{\partial\phi}\frac{\partial^2W^m}{\partial\phi^2}}{\left(\frac{\partial W^m}{\partial\phi}\right)^2}} > 0 \tag{3.42}$$

ii. Comparative static with respect to the wife's altruism:

$$\frac{\partial\phi}{\partial\delta^f} = -\frac{I_{\delta^f}}{I_\phi} = -\frac{\frac{G^m\left(u(x^m)-u(x_R^m)\right)}{(G^m)^2}-\frac{\alpha}{1-\alpha}\frac{\frac{\partial W^m}{\partial\phi}\frac{\partial u}{\partial x^m}}{\left(\frac{\partial W^m}{\partial\phi}\right)^2}}{\frac{G^m\frac{\partial W^f}{\partial\phi}-G^f\frac{\partial W^m}{\partial\phi}}{(G^m)^2}+\frac{\alpha}{1-\alpha}\frac{\frac{\partial W^m}{\partial\phi}\frac{\partial^2W^f}{\partial\phi^2}-\frac{\partial W^f}{\partial\phi}\frac{\partial^2W^m}{\partial\phi^2}}{\left(\frac{\partial W^m}{\partial\phi}\right)^2}} < 0 \tag{3.43}$$

Proposition 6. *Under the contractible labor scenario for a generalized Nash-bargaining household, the labor-intensive technological change increases the transfer unless the wife has already gained sufficiently from cooperation and the spousal gain effect dominates the reallocation effect of the transfer.*

Proof:

$$\frac{\partial\phi}{\partial\gamma} = -\frac{I_\gamma}{I_\phi} = -\frac{\frac{\frac{\partial G^m}{\partial\gamma}\left(\delta^fG^m-G^f\right)}{(G^m)^2}+\frac{\alpha}{1-\alpha}\frac{\frac{\partial W^m}{\partial\phi}\frac{\partial^2W^f}{\partial\phi\partial\gamma}-\frac{\partial W^f}{\partial\phi}\frac{\partial^2W^m}{\partial\phi\partial\gamma}}{\left(\frac{\partial W^m}{\partial\phi}\right)^2}}{\frac{G^m\frac{\partial W^f}{\partial\phi}-G^f\frac{\partial W^m}{\partial\phi}}{(G^m)^2}+\frac{\alpha}{1-\alpha}\frac{\frac{\partial W^m}{\partial\phi}\frac{\partial^2W^f}{\partial\phi^2}-\frac{\partial W^f}{\partial\phi}\frac{\partial^2W^m}{\partial\phi^2}}{\left(\frac{\partial W^m}{\partial\phi}\right)^2}} \tag{3.44}$$

The sign of the effect is not clearly predictable because while the denominator is positive, the sign of the numerator is undetermined and depends on the following two terms. The first term in the numerator generates the effect of a change in γ on the spousal gains from cooperation, holding constant the transfer level. Its sign depends on the sign of $\delta^fG^m - G^f$. The second term is negative and captures the effect of γ on the allocation of the transfer while holding constant the share of the cooperative gains. The transfer decreases with an increase in γ only when the wife has already gained a lot from cooperation ($\delta^f G^m < G^f$) and the spousal gain effect dominates the reallocation effect of the transfer (the first term is greater than the second term). Otherwise, the transfer increases with technological change.

Proposition 7. *Under the contractible labor scenario, an increase in the wife's bargaining power raises the transfer level.*

Proof:

$$\frac{\partial \phi}{\partial \alpha} = -\frac{I_\alpha}{I_\phi} = -\frac{\frac{1}{(1-\alpha)^2}\frac{\partial W^f \partial \phi}{\partial W^m \partial \phi}}{\frac{G^m \frac{\partial W^f}{\partial \phi} - G^f \frac{\partial W^m}{\partial \phi}}{(G^m)^2} + \frac{\alpha}{1-\alpha}\frac{\frac{\partial W^m}{\partial \phi}\frac{\partial^2 W^f}{\partial \phi^2} - \frac{\partial W^f}{\partial \phi}\frac{\partial^2 W^m}{\partial \phi^2}}{\left(\frac{\partial W^m}{\partial \phi}\right)^2}} > 0 \tag{3.45}$$

Within the range between ϕ_C^{DH} and ϕ_C^{max}, $\frac{\partial W^m}{\partial \phi} < 0$ and $\frac{\partial W^f}{\partial \phi} > 0$. For the husband, any transfer level above ϕ_C^{DH} will result in lower welfare for him. The condition $\frac{\partial W^f}{\partial \phi} > 0$ holds when $\frac{\partial u}{\partial x^f} > \delta^f \frac{\partial u}{\partial x^m}$, which happens when we have small x^f and high x^m.

3.B Non-Contractible Labor Scenario

3.B.1 Labor Allocation

Husband's sub-problem

$$\begin{aligned} \max_{0 \le l_c^m \le \bar{L}} W^m = u(x^m) + \delta^m u(x^f) \quad \text{st } (i) \quad & x^m \le p_c Q\left(l_c^m + \hat{l}_c^f | T, \gamma\right) + \omega^m(\bar{L} - l_c^m) - \phi \\ (ii) \quad & x^f \le \omega^f(\bar{L} - \hat{l}_c^f) + \phi \end{aligned} \tag{3.46}$$

The first-order necessary condition is:

$$[l_c^m] \quad p_c \frac{\partial Q(\hat{l}_c^f | \phi)}{\partial l_c} \ge \omega^m \tag{3.47}$$

Proposition 8. *Suppose the marginal value of the productivity of labor equates to the husband's wage. Under the non-contractible labor scenario and at a given level of transfer, the husband's labor on coffee decreases by exactly the same additional amount increase in his anticipation of the wife's labor on coffee.*

Proof: The husband continues to work full-time on coffee unless he anticipates her labor to drive down the marginal value of the productivity of labor to his wage rate. For an interior solution to the husband's labor (at a given level of transfer and his expectation of the wife's labor), I conduct the comparative statics for the following equation:

$$J = \frac{\partial Q(\hat{l}_c^f|\phi)}{\partial l_c} - \frac{\omega^m}{p_c} = 0 \tag{3.48}$$

Comparative static with respect to his anticipation of the wife's labor:

$$\frac{\partial l_c^m}{\partial \hat{l}_c^f} = -\frac{J_{\hat{l}_c^f}}{J_{l_c^m}} = -\frac{\frac{\partial^2 Q}{\partial l_c^2}}{\frac{\partial^2 Q}{\partial l_c^2}} = -1 \tag{3.49}$$

Wife's sub-problem

$$\max_{0 \le l_c^f \le \bar{L}} W^f = u(x^f) + \delta^f u(x^m) \quad \text{st } (i) \quad x^f \le \omega^f(\bar{L} - l_c^f) + \phi$$
$$(ii)\; x^m \le p_c Q\left(\hat{l}_c^m + l_c^f|T,\gamma\right) + \omega^m(\bar{L} - \hat{l}_c^m) - \phi \tag{3.50}$$

The first-order necessary condition is:

$$[l_c^f] \quad \delta^f \frac{\partial u}{\partial x^m}\left(p_c \frac{\partial Q(\hat{l}_c^m|\phi)}{\partial l_c}\right) \le \omega^f \frac{\partial u}{\partial x^f}; \text{ or } \quad l_c^f(\hat{l}_c^m|\phi) = \bar{L} \tag{3.51}$$

Proposition 9. *Suppose the wife puts in some labor on the coffee farm. Under the non-contractible labor scenario and at a given level of transfer, the wife reduces her labor on coffee by less than the additional amount increase in her anticipation of the husband's labor on coffee.*

Proof: Rewriting the first-order condition for an interior solution of the wife's labor:

$$K = \delta^f \frac{\partial u}{\partial x^m}\left(p_c \frac{\partial Q(\hat{l}_c^m|\phi)}{\partial l_c}\right) - \omega^f \frac{\partial u}{\partial x^f} = 0 \tag{3.52}$$

Comparative static with respect to the husband's anticipated labor:

$$\frac{\partial l_c^f}{\partial \hat{l_c^m}} = -\frac{K_{\hat{l_c^m}}}{K_{l_c^f}} = -\frac{\delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}-\omega^m\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right]}{\delta^f p_c\left[p_c\frac{\partial^2 u}{\partial x^{m2}}\left(\frac{\partial Q}{\partial l_c}\right)^2+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right]+(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}}} \in (-1,0) \tag{3.53}$$

This holds because $p_c\frac{\partial Q(\hat{l}_c^m|\phi)}{\partial l_c} \geq \omega^m$ which corresponds to the optimal condition for the husband's labor allocation. Note that when the wife does not work on coffee unless the household commits to a transfer that can elicit her labor, she does not respond to the anticipation of the husband's labor.

Nash equilibrium for coffee labor allocations

The Nash equilibrium allocation of labor, $(l_c^m(\phi),\, l_c^f(\phi))$, has to satisfy the two first-order conditions:

$$\begin{gathered} p_c\frac{\partial Q(l_c^{m*}(\phi), l_c^{m*}(\phi)}{\partial l_c}) \geq \omega^m \\ p_c\frac{\partial Q(l_c^{m*}(\phi), l_c^{f*}(\phi)}{\partial l_c}) \leq \omega^f\frac{\frac{\partial u}{\partial x^f}}{\delta^f\frac{\partial u}{\partial x^m}} \text{ or } p_c\frac{\partial Q(l_c^{m*}(\phi), l_c^{f*}(\phi)}{\partial l_c}) > \omega^f\frac{\frac{\partial u}{\partial x^f}}{\delta^f\frac{\partial u}{\partial x^m}} \end{gathered} \tag{3.54}$$

For the comparative statics of this section, I assume that the Nash equilibrium allocation of labor, $(l_c^m(\phi),\, l_c^f(\phi))$, is interior and thus has to satisfy the two best response functions:

$$\begin{aligned} \text{Husband: } N_1 &= p_c\frac{\partial Q}{\partial l_c} - \omega^m = 0 \\ \text{Wife: } N_2 &= \delta^f\frac{\partial u}{\partial x^m}\left(p_c\frac{\partial Q}{\partial l_c}\right) - \omega^f\frac{\partial u}{\partial x^f} = 0 \end{aligned}$$

Proposition 10: *Under the non-contractible labor scenario, there exists one and only one unique Nash equilibrium allocation of labor, $(l_c^m(\phi),\, l_c^f(\phi))$ at a fixed level of transfer.*

Proof: There are two parts to this proof: first, there exists at least one Nash equilibrium solution; second, the Nash equilibrium is unique.

1. The set of strategies for each spouse is finite, making their interaction of labor choice decision a finite game. Nash's Theorem (1951) implies that there exists at least one

Nash equilibrium for coffee labor allocation at any given level of transfer.

2. I prove the uniqueness of the Nash Equilibrium by contradiction. For a given choice of wife's labor at $\bar{l_c^f}$ and a transfer value $\bar{\phi}$, the husband's labor $\bar{l_c^m}$ is unique, that is $\bar{l_c^m} = l_c^m(\bar{l_c^f}(\bar{\phi}))$. Suppose that there is another allocation of husband's labor $l_c^{m'}$ such that $l_c^{m'} = l_c^m(\bar{l_c^f}(\bar{\phi}))$. This means that $l_c^{m'}$ solves the utility maximization of the husband. However, since u is strictly concave in l_c^m, there is only one value of labor l_c^m that maximizes u. Therefore, both $\bar{l_c^m}$ and $l_c^{m'}$ cannot be values of the husband's labor. This leads to a contradiction.

   Similarly, for a given choice of husband's labor $\bar{l_c^m}$ and a transfer value $\bar{\phi}$, the wife's labor $\bar{l_c^f}$ is unique, that is $\bar{l_c^f} = l_c^f(\bar{l_c^m}(\bar{\phi}))$. Suppose that there is another allocation of wife's labor $l_c^{f'}$ such that $l_c^{f'} = l_c^f(\bar{l_c^m}(\bar{\phi}))$. This means that $l_c^{f'}$ solves the utility maximization of the wife. However, since u is strictly concave in l_c^f, there is only one value of labor l_c^f that maximizes u. Therefore, both $\bar{l_c^f}$ and $l_c^{f'}$ cannot be values of the wife's labor. This leads to a contradiction.

Proposition 11. *Under the non-contractible labor scenario and at a fixed level of transfer: i. an increase in the husband's altruism does not affect either spouse's labor; and ii. an increase in the wife's altruism increases the wife's labor and decreases the husband's labor.*

Proof: The altruism parameter δ^m does not enter into the best response functions, so both spouses do not change their labor with an increase in the husband's altruism towards the wife. I will thus show the proof of the effect of the wife's altruism on each spouse's labor.

$$\frac{\mathrm{d}l_c^m}{\mathrm{d}\delta^f} = -\frac{\det\begin{pmatrix}\frac{\partial N_1}{\partial l_c^f} & \frac{\partial N_1}{\partial \delta^f}\\ \frac{\partial N_2}{\partial l_c^f} & \frac{\partial N_2}{\partial \delta^f}\end{pmatrix}}{\det\begin{pmatrix}\frac{\partial N_1}{\partial l_c^f} & \frac{\partial N_1}{\partial l_c^m}\\ \frac{\partial N_2}{\partial l_c^f} & \frac{\partial N_2}{\partial l_c^m}\end{pmatrix}}$$

$$= -\frac{\det\begin{pmatrix} p_c\frac{\partial^2 Q}{\partial l_c^2} & 0\\ \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right]+(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}} & p_c\frac{\partial u}{\partial x^m}\frac{\partial Q}{\partial l_c}\end{pmatrix}}{\det\begin{pmatrix} p_c\frac{\partial^2 Q}{\partial l_c^2} & p_c\frac{\partial^2 Q}{\partial l_c^2}\\ \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right]+(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}} & \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}-\omega^m\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right]\end{pmatrix}} \tag{3.55}$$

$$= \frac{p_c\frac{\partial u}{\partial x^m}\frac{\partial Q}{\partial l_c}\frac{\partial^2 Q}{\partial l_c^2}}{\frac{\partial^2 Q}{\partial l_c^2}\left[(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}}+\delta^f p_c\omega^m\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\right]} < 0$$

$$\frac{\mathrm{d}l_c^f}{\mathrm{d}\delta^f} = -\frac{\det\begin{pmatrix}\frac{\partial N_1}{\partial l_c^m} & \frac{\partial N_1}{\partial \delta^f}\\ \frac{\partial N_2}{\partial l_c^m} & \frac{\partial N_2}{\partial \delta^f}\end{pmatrix}}{\det\begin{pmatrix}\frac{\partial N_1}{\partial l_c^m} & \frac{\partial N_1}{\partial l_c^f}\\ \frac{\partial N_2}{\partial l_c^m} & \frac{\partial N_2}{\partial l_c^f}\end{pmatrix}} \tag{3.56}$$

$$= -\frac{\det\begin{pmatrix} p_c\frac{\partial^2 Q}{\partial l_c^2} & 0\\ \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}-\omega^m\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right] & p_c\frac{\partial u}{\partial x^m}\frac{\partial Q}{\partial l_c}\end{pmatrix}}{\det\begin{pmatrix} p_c\frac{\partial^2 Q}{\partial l_c^2} & p_c\frac{\partial^2 Q}{\partial l_c^2}\\ \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}-\omega^m\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right] & \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right]+(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}}\end{pmatrix}} \tag{3.57}$$

$$= -\frac{p_c\frac{\partial u}{\partial x^m}\frac{\partial Q}{\partial l_c}\frac{\partial^2 Q}{\partial l_c^2}}{\frac{\partial^2 Q}{\partial l_c^2}\left[(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}}+\delta^f p_c\omega^m\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\right]} > 0 \tag{3.58}$$

Note that the wife's best-response function suggests that when the wife does not work on coffee, an increase in her altruism may be sufficient enough to incentivize the wife to care more about the husband and start putting more of her labor on coffee.

Proposition 12. *Under the non-contractible labor scenario and at a fixed level of transfer, the labor-intensive technological change raises the labor of the husband and reduces the labor of the wife.*

Proof:

$$\frac{\mathrm{d}l_c^m}{\mathrm{d}\gamma} = -\frac{\det\begin{pmatrix}\frac{\partial N_1}{\partial l_c^f} & \frac{\partial N_1}{\partial \gamma}\\ \frac{\partial N_2}{\partial l_c^f} & \frac{\partial N_2}{\partial \gamma}\end{pmatrix}}{\det\begin{pmatrix}\frac{\partial N_1}{\partial l_c^f} & \frac{\partial N_1}{\partial l_c^m}\\ \frac{\partial N_2}{\partial l_c^f} & \frac{\partial N_2}{\partial l_c^m}\end{pmatrix}} \tag{3.59}$$

$$= -\frac{\det\begin{pmatrix} p_c\frac{\partial^2 Q}{\partial l_c^2} & p_c\frac{\partial^2 Q}{\partial l_c \partial\gamma}\\ \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right]+(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}} & \delta^f p_c\left[\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c\partial\gamma}+p_c\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\frac{\partial Q}{\partial \gamma}\right]\end{pmatrix}}{\det\begin{pmatrix} p_c\frac{\partial^2 Q}{\partial l_c^2} & p_c\frac{\partial^2 Q}{\partial l_c^2}\\ \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right]+(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}} & \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}-\omega^m\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right]\end{pmatrix}} \tag{3.60}$$

$$= \frac{\delta^f p_c^2\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left[\frac{\partial^2 Q}{\partial l_c^2}\frac{\partial Q}{\partial\gamma}-\frac{\partial^2 Q}{\partial l_c\partial\gamma}\frac{\partial Q}{\partial l_c}\right]-(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}}\frac{\partial^2 Q}{\partial l_c\partial\gamma}}{\frac{\partial^2 Q}{\partial l_c^2}\left[(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}}+\delta^f p_c\omega^m\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\right]} > 0 \tag{3.61}$$

$$\frac{\mathrm{d}l_c^f}{\mathrm{d}\gamma} = -\frac{\det\begin{pmatrix}\frac{\partial N_1}{\partial l_c^m} & \frac{\partial N_1}{\partial \gamma}\\ \frac{\partial N_2}{\partial l_c^m} & \frac{\partial N_2}{\partial \gamma}\end{pmatrix}}{\det\begin{pmatrix}\frac{\partial N_1}{\partial l_c^m} & \frac{\partial N_1}{\partial l_c^f}\\ \frac{\partial N_2}{\partial l_c^m} & \frac{\partial N_2}{\partial l_c^f}\end{pmatrix}} \tag{3.62}$$

$$= -\frac{\det\begin{pmatrix} p_c\frac{\partial^2 Q}{\partial l_c^2} & p_c\frac{\partial^2 Q}{\partial l_c \partial\gamma}\\ \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}-\omega^m\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right] & \delta^f p_c\left[\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c\partial\gamma}+p_c\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\frac{\partial Q}{\partial \gamma}\right]\end{pmatrix}}{\det\begin{pmatrix} p_c\frac{\partial^2 Q}{\partial l_c^2} & p_c\frac{\partial^2 Q}{\partial l_c^2}\\ \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}-\omega^m\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right] & \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right]+(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}}\end{pmatrix}} \tag{3.63}$$

$$= -\frac{\delta^f (p_c)^2\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\frac{\partial^2 Q}{\partial l_c^2}\frac{\partial Q}{\partial\gamma}}{\frac{\partial^2 Q}{\partial l_c^2}\left[(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}}+\delta^f p_c\omega^m\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\right]} < 0 \tag{3.64}$$

Proposition 13: *Under the non-contractible labor scenario, an increase in the transfer reduces the husband's labor allocation and increases the wife's labor on coffee.*

Proof:

$$\frac{\mathrm{d}l_c^m}{\mathrm{d}\phi} = -\frac{\det\begin{pmatrix}\frac{\partial N_1}{\partial l_c^f} & \frac{\partial N_1}{\partial \phi}\\ \frac{\partial N_2}{\partial l_c^f} & \frac{\partial N_2}{\partial \phi}\end{pmatrix}}{\det\begin{pmatrix}\frac{\partial N_1}{\partial l_c^f} & \frac{\partial N_1}{\partial l_c^m}\\ \frac{\partial N_2}{\partial l_c^f} & \frac{\partial N_2}{\partial l_c^m}\end{pmatrix}} \tag{3.65}$$

$$= -\frac{\det\begin{pmatrix} p_c\frac{\partial^2 Q}{\partial l_c^2} & 0 \\ \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right]+(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}} & -\delta^f p_c\frac{\partial Q}{\partial l_c}\frac{\partial^2 u}{\partial x^{m2}}-\omega^f\frac{\partial^2 u}{\partial x^{f2}} \end{pmatrix}}{\det\begin{pmatrix} p_c\frac{\partial^2 Q}{\partial l_c^2} & p_c\frac{\partial^2 Q}{\partial l_c^2} \\ \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right]+(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}} & \delta^f p_c\left[\frac{\partial^2 u}{\partial x^{m2}}\frac{\partial Q}{\partial l_c}\left(p_c\frac{\partial Q}{\partial l_c}-\omega^m\right)+\frac{\partial u}{\partial x^m}\frac{\partial^2 Q}{\partial l_c^2}\right] \end{pmatrix}} \tag{3.66}$$

$$= -\frac{\delta^f\frac{\partial^2 u}{\partial x^{m2}}\left(p_c\frac{\partial Q}{\partial l_c}\right)+\omega^f\frac{\partial^2 u}{\partial x^{f2}}}{\delta^f\frac{\partial^2 u}{\partial x^{m2}}\left(p_c\frac{\partial Q}{\partial l_c}\right)^2+(\omega^f)^2\frac{\partial^2 u}{\partial x^{f2}}} < 0 \tag{3.67}$$

$$\frac{\mathrm{d}l_c^f}{\mathrm{d}\phi} = -\frac{\mathrm{d}l_c^m}{\mathrm{d}\phi} \in (0,1) \tag{3.68}$$

Proposition 14: *If the wife cares about the husband $\delta^f \neq 0$, the effective wage rate, $1/\frac{\partial l_c^f}{\partial\phi}$, is higher than the wife's shadow wage, ω^f.*

Proof: Assuming $\delta^f \neq 0$. Comparing the effective wage and her outside wage yields:

$$\frac{1}{\frac{\partial l_c^f}{\partial\phi}} - \omega^f = \frac{\delta^f\frac{\partial^2 u}{\partial x^{m2}}\left(p_c\frac{\partial Q}{\partial l_c}\right)\left(p_c\frac{\partial Q}{\partial l_c}-\omega^f\right)}{\delta^f\frac{\partial^2 u}{\partial x^{m2}}\left(p_c\frac{\partial Q}{\partial l_c}\right)+\omega^f\frac{\partial^2 u}{\partial x^{f2}}} > 0 \tag{3.69}$$

3.B.2 Transfer Allocation

$$\begin{aligned} N = \max_{\phi\geq 0} & \left[W^f(\phi)-W_R^f\right]^{\alpha}\left[W^m(\phi)-W_R^m\right]^{1-\alpha} \\ = & \left[u(x^f)+\delta^f u(x^m)-W_R^f\right]^{\alpha}\left[u(x^m)+\delta^m u(x^f)-W_R^m\right]^{1-\alpha} \\ \text{st} \;\; & (i)\; x^f \leq \omega^f\left(\bar{L}-l_c^{f*}(\phi)\right)+\phi \\ & (ii)\; x^m \leq p_c Q\left(l_c^{m*}(\phi)+l_c^{f*}(\phi)|T,\gamma\right)+\omega^m\left(\bar{L}-l_c^{m*}(\phi)\right)-\phi \\ & (iii)\; \phi \leq p_c Q\left(l_c^{m*}(\phi)+l_c^{f*}(\phi)|T,\gamma\right)+\omega^m\left(\bar{L}-l_c^{m*}(\phi)\right) \\ & (iv)\; W^f(\phi)\geq W_R^f \\ & (v)\; W^m(\phi)\geq W_R^m \end{aligned} \tag{3.70}$$

Dictatorial Household

$$
\begin{aligned}
&\max_{\phi \geq 0} W^m(\phi) = u(x^m) + \delta^m u(x^f) \\
&\text{st} \;\; (i)\; x^f \leq \omega^f \Big(\bar{L} - l_c^{f*}(\phi)\Big) + \phi \\
&\quad\;\; (ii)\; x^m \leq p_c Q\Big(l_c^{m*}(\phi) + l_c^{f*}(\phi) | T, \gamma\Big) + \omega^m \Big(\bar{L} - l_c^{m*}(\phi)\Big) - \phi \\
&\quad\;\; (iii)\; \phi \leq p_c Q\Big(l_c^{m*}(\phi) + l_c^{f*}(\phi) | T, \gamma\Big) + \omega^m \Big(\bar{L} - l_c^{m*}(\phi)\Big) \\
&\quad\;\; (iv)\; W^f(\phi) \geq W_R^f
\end{aligned}
\tag{3.71}
$$

The first-order necessary condition is for an interior transfer:

$$
\underbrace{\delta^m \frac{\partial u}{\partial x^f} - \frac{\partial u}{\partial x^m}}_{\text{Direct effect}} + \underbrace{\frac{\partial l_c^{f*}}{\partial \phi} \left[\frac{\partial u}{\partial x^m} \left(p_c \frac{\partial Q}{\partial l_c^*} \right) - \delta^m \frac{\partial u}{\partial x^f} \omega^f \right]}_{\text{Wife's labor incentive effect}} = 0 \tag{3.72}
$$

I conduct the comparative statics for the following equation:

$$
M = \delta^m \frac{\partial u}{\partial x^f} - \frac{\partial u}{\partial x^m} + \frac{\partial l_c^{f*}}{\partial \phi} \left[p_c \frac{\partial Q}{\partial l_c^*} \frac{\partial u}{\partial x^m} - \delta^m \omega^f \frac{\partial u}{\partial x^f} \right] \tag{3.73}
$$

Proposition 15. *Under the non-contractible labor scenario for a dictatorial household, the transfer increases with an increase in the husband's altruism but does not change with an increase in the wife's altruism.*

Proof:

i. Comparative static with respect to the husband's altruism:

$$
\frac{\partial \phi}{\partial \delta^m} = -\frac{M_{\delta^m}}{M_\phi} = -\frac{\frac{\partial u}{\partial x^f} \left[1 - \omega^f \frac{\partial l_c^{f*}}{\partial \phi} \right]}{\frac{\partial^2 W^m}{\partial \phi^2}} > 0 \tag{3.74}
$$

$$
\text{(I show in Proposition 14 that} 1 > \omega^f \frac{\partial}{\partial l_c^{f*}} \text{ as long as } \delta^f \neq 0)
$$

(I show in Proposition 14 that $1 > \omega^f \frac{\partial}{\partial l_c^{f*}}$ as long as $\delta^f \neq 0$).

ii. The wife's altruism, δ^f, does not affect the transfer decision.

Proposition 16. *Under the non-contractible labor scenario for a dictatorial household, the impact of the labor-intensive technological change on the transfer is ambiguous.*

Proof: Comparative static with respect to technology:

$$\frac{\partial \phi}{\partial \gamma} = -\frac{M_\gamma}{M_\phi} = -\frac{-p_c \frac{\partial^2 u}{\partial x^{m2}} \frac{\partial Q}{\partial \gamma} + \frac{\partial l_c^{f*}}{\partial \phi}\left[p_c \frac{\partial u}{\partial x^m} \frac{\partial^2 Q}{\partial l_c \partial \gamma} + p_c^2 \frac{\partial^2 u}{\partial x^{m2}} \frac{\partial Q}{\partial l_c} \frac{\partial Q}{\partial \gamma}\right]}{\frac{\partial^2 W^m}{\partial \phi^2}} \tag{3.75}$$

The sign of $\frac{\partial \phi}{\partial \gamma}$ depends on the sign of the numerator. The two terms in the bracket have an opposite sign - while the first term is positive, indicating the effect of technological change on the coffee labor holding the coffee output constant, the second term is negative, reflecting the effect of technological change on the coffee output holding the coffee labor constant. If the first effect dominates the second effect, the technological change increases the transfer. Alternatively, if the first term in the numerator dominates the remaining terms, the transfer also gets shifted up.

Generalized Nash-Bargaining Household

In the generalized Nash-bargaining case, the first-order necessary condition for an interior solution is:

$$\frac{W^f(\phi) - W_R^f}{W^m(\phi) - W_R^m} = -\frac{\alpha}{1-\alpha} \quad \frac{\frac{\partial u}{\partial x^f} - \delta^f \frac{\partial u}{\partial x^m} + \frac{\partial l_c^{f*}}{\partial \phi}\left[\delta^f \frac{\partial u}{\partial x^m}\left(p_c \frac{\partial Q}{\partial l_c^*}\right) - \frac{\partial u}{\partial x^f}\omega^f\right]}{\delta^m \frac{\partial u}{\partial x^f} - \frac{\partial u}{\partial x^m} + \frac{\partial l_c^{f*}}{\partial \phi}\left[\frac{\partial u}{\partial x^m}\left(p_c \frac{\partial Q}{\partial l_c^*}\right) - \delta^m \frac{\partial u}{\partial x^f}\omega^f\right]} \tag{3.76}$$

Define $N = \frac{G^f}{G^m} + \frac{\alpha}{1-\alpha} \quad \frac{\frac{\partial u}{\partial x^f} - \delta^f \frac{\partial u}{\partial x^m} + \frac{\partial l_c^{f*}}{\partial \phi}\left[\delta^f \frac{\partial u}{\partial x^m}\left(p_c \frac{\partial Q}{\partial l_c^*}\right) - \frac{\partial u}{\partial x^f}\omega^f\right]}{\delta^m \frac{\partial u}{\partial x^f} - \frac{\partial u}{\partial x^m} + \frac{\partial l_c^{f*}}{\partial \phi}\left[\frac{\partial u}{\partial x^m}\left(p_c \frac{\partial Q}{\partial l_c^*}\right) - \delta^m \frac{\partial u}{\partial x^f}\omega^f\right]}$

Proposition 17. *Under the non-contractible labor scenario for a generalized Nash-bargaining household, an increase in either the husband's altruism or the wife's altruism has an ambiguous effect on the transfer.*

Proof:

i. Comparative static with respect to the husband's altruism:

$$\frac{\partial\phi}{\partial\delta^m} = -\frac{N_{\delta^m}}{N_\phi} = -\frac{-\frac{G^f\left(u(x^f)-u(x_R^f)\right)}{(G^m)^2} + \frac{\alpha}{1-\alpha}\frac{-\frac{\partial W^f}{\partial\phi}\frac{\partial^2 W^m}{\partial\phi^2}\frac{\partial u}{\partial x^f}\left(1-\frac{\partial l_c^{f*}}{\partial\phi}\omega^f\right)}{\left(\frac{\partial W^m}{\partial\phi}\right)^2}}{\frac{G^m\frac{\partial W^f}{\partial\phi}-G^f\frac{\partial W^m}{\partial\phi}}{(G^m)^2} + \frac{\alpha}{1-\alpha}\frac{\frac{\partial W^m}{\partial\phi}\frac{\partial^2 W^f}{\partial\phi^2}-\frac{\partial W^f}{\partial\phi}\frac{\partial^2 W^m}{\partial\phi^2}}{\left(\frac{\partial W^m}{\partial\phi}\right)^2}} \tag{3.77}$$

The ambiguity comes from the numerator. The first term is negative, indicating the effect of the husband's altruism on the cooperative gain holding the transfer constant. The second term is positive, representing the effect of the husband's altruism on the transfer holding the cooperative gain constant. If the cooperative gain effect dominates the transfer effect, an increase in the husband's altruism increases the transfer and vice-versa.

ii. Comparative static with respect to the wife's altruism:

$$\frac{\partial\phi}{\partial\delta^f} = -\frac{N_{\delta^f}}{N_\phi} = -\frac{\frac{G^m\left(u(x^m)-u(x_R^m)\right)}{(G^m)^2} + \frac{\alpha}{1-\alpha}\frac{\frac{\partial W^m}{\partial\phi}\frac{\partial^2 W^f}{\partial\phi^2}\frac{\partial u}{\partial x^m}\left(p_c\frac{\partial Q}{\partial l_c}\frac{\partial l_c^{f*}}{\partial\phi}-1\right)}{\left(\frac{\partial W^m}{\partial\phi}\right)^2}}{\frac{G^m\frac{\partial W^f}{\partial\phi}-G^f\frac{\partial W^m}{\partial\phi}}{(G^m)^2} + \frac{\alpha}{1-\alpha}\frac{\frac{\partial W^m}{\partial\phi}\frac{\partial^2 W^f}{\partial\phi^2}-\frac{\partial W^f}{\partial\phi}\frac{\partial^2 W^m}{\partial\phi^2}}{\left(\frac{\partial W^m}{\partial\phi}\right)^2}} \tag{3.78}$$

The ambiguity comes from the numerator. The first term is positive, indicating the effect of the wife's altruism on the cooperative gain holding the transfer constant. The second term is negative, representing the effect of the wife's altruism on the transfer, holding the cooperative gain constant. If the cooperative gain effect dominates the transfer effect, an increase in the wife's altruism reduces the transfer and vice-versa.

Proposition 18. *Under the non-contractible labor scenario for a generalized Nash-bargaining household, the labor-intensive technological change has an ambiguous impact on the transfer.*

Proof: Comparative static with respect to technology:

$$\frac{\partial\phi}{\partial\gamma} = -\frac{N_\gamma}{N_\phi} = -\frac{\frac{\frac{\partial G^m}{\partial\gamma}\left(\delta^f G^m-G^f\right)}{(G^m)^2} + \frac{\alpha}{1-\alpha}\frac{\frac{\partial W^m}{\partial\phi}\frac{\partial^2 W^f}{\partial\phi\partial\gamma}-\frac{\partial W^f}{\partial\phi}\frac{\partial^2 W^m}{\partial\phi\partial\gamma}}{\left(\frac{\partial W^m}{\partial\phi}\right)^2}}{\frac{G^m\frac{\partial W^f}{\partial\phi}-G^f\frac{\partial W^m}{\partial\phi}}{(G^m)^2} + \frac{\alpha}{1-\alpha}\frac{\frac{\partial W^m}{\partial\phi}\frac{\partial^2 W^f}{\partial\phi^2}-\frac{\partial W^f}{\partial\phi}\frac{\partial^2 W^m}{\partial\phi^2}}{\left(\frac{\partial W^m}{\partial\phi}\right)^2}} \tag{3.79}$$

The sign of the effect is ambiguous and depends on multiple factors. The first term in the numerator generates the effect of a change in γ on the spousal gains from cooperation, holding constant the transfer level. Its sign depends on the sign of $\delta^f G^m - G^f$. The second term captures the effect of γ on the allocation of the transfer while holding constant the share of the cooperative gains. The sign is ambiguous and depends on the wife's labor response regarding the technological change.

Proposition 19. *Under the non-contractible labor scenario, an increase in the wife's bargaining power raises the transfer level.*

Proof: Comparative static with respect to the bargaining power:

$$\frac{\partial \phi}{\partial \alpha} = -\frac{N_\alpha}{N_\phi} = -\frac{\frac{1}{(1-\alpha)^2}\frac{\frac{\partial W^f}{\partial \phi}}{\frac{\partial W^m}{\partial \phi}}}{\frac{G^m \frac{\partial W^f}{\partial \phi} - G^f \frac{\partial W^m}{\partial \phi}}{(G^m)^2} + \frac{\alpha}{1-\alpha}\frac{\frac{\partial W^m}{\partial \phi}\frac{\partial^2 W^f}{\partial \phi^2} - \frac{\partial W^f}{\partial \phi}\frac{\partial^2 W^m}{\partial \phi^2}}{\left(\frac{\partial W^m}{\partial \phi}\right)^2}} > 0 \tag{3.80}$$

Chapter 4

Empirical Approach on Measuring Bargaining Power and Its Effect on Technology Adoption

This chapter builds on the theoretical framework presented in chapter 3 to empirically investigate the link between spousal bargaining power and technology adoption. The theory predicts that households in which the women have more bargaining power can take better advantage of programs designed to increase returns to a male's crop while relying on female's non-contractible labor. In the model, the parameter α captures women's bargaining power, specifically, the relative weight of the wife's gains from cooperation in the negotiation process for more favorable income distribution. The natural first question is how to measure α empirically. The chapter begins with a review of the literature on the empirical measures of spousal bargaining power and a discussion of how bargaining power is measured in the study (section 4.1).

Section 4.2 gives a brief overview of the literature on the intersection between spousal bargaining power and technology adoption, followed by a discussion of how the study fits within this literature. Then, in section 4.3, I present the setup of how to leverage the experiment from the UCAT program introduced in section 2.3 to study whether the impact of agronomic training varies across households with different levels of spousal bargaining power. Note that the main data collection for the HRNS is ongoing, and the project has not collected data from the TNS region at the time of the dissertation. At this stage, I present the econometric model of how I would go about implementing the impact heterogeneity analysis but not the results. Finally, section 4.4 concludes.

4.1 Measuring Bargaining Power

Women's bargaining power is determined by various factors, from individual characteristics to law, institutional practices, and cultural norms. Since bargaining power is not observable to researchers, the literature has relied on gender-linked variables to proxy for bargaining power and considered interchangeably or closely connected to concepts of women's voice, agency, and empowerment (Doss (2013); Klugman et al. (2014); Gammage, Kabeer, and van der Meulen Rodgers (2015)).[1]

Several papers use spousal education level to indicate the wife's bargaining power (Thomas (1994); Yusof (2015); Ngenzebuke, De Rock, and Verwimp (2018); Moeeni (2021)), asserting that higher women's education or more comparable spousal educational attainment allows them to have more control over household finances and decision-making. Other research links a large spousal age gap or marriage at a young age to less decision-making power (Field and Ambrus (2008); Jensen and Thornton (2010); Carmichael (2012); Sunder (2019)). Alternatively, many studies have focused directly on women's decision-making power within the household to proxy for their bargaining power (Patel et al. (2007); Reggio (2011); Mehraban et al. (2022); Waid et al. (2022)). One notable index is the Women's Empowerment in Agriculture Index (WEAI), which provides a direct measure of women's empowerment and inclusion in the agricultural sector (Alkire et al. (2013); Malapit et al. (2019)).

A large body of work captures women's bargaining power with women's independent

[1] For a comprehensive review of the literature on intrahousehold bargaining and resource allocation, see Doss (2013).

sources of earned income (Blumberg (1988); Qian (2008); Luke and Munshi (2011)) and unearned income such as transfers targeted at women (Thomas (1990); Schultz (1990); Doss (1996); Behrman and Hoddinott (2005); Bobonis (2009)). They argue that women who have control over their income have a greater influence on how their money is spent. Other work has associated women's bargaining power with women's access to and ownership of land (Allendorf (2007); Doss et al. (2014); Menon, Van Der Meulen Rodgers, and Nguyen (2014); Kumar and Quisumbing (2015)) and various assets (Quisumbing and Maluccio (2003); Doss (2006); Doss et al. (2014); Johnson et al. (2016)), which offer women economic securities and strengthen their position within the households.

Lastly, the practice of bride price is prevalent, especially in rural Uganda, and carries implications for the spousal dynamics. Bride price is considered as a payment from the groom or the groom's family to the bride's family at the time of marriage in exchange for the bride's labor and reproductive capabilities (Anderson (2007)).[2] Since the practice of bride price varies by setting, I focus on the studies set in Uganda.[3] A few papers about bride price in Uganda concur that the negative impacts of bride price outweigh the positive impacts (Kaye et al. (2005); Hague, Thiara, and Turner (2011)). They claim that bride price legitimates the marriage and represents the recognition and respect for the bride and her family. Nevertheless, the transactional nature of bride price seems to validate the husband's authority over the wife while exacerbating the household's existing gender inequalities. They further argue that a higher bride price is associated with increased male power and domestic violence incidents. In a study set in Ghana, Horne, Dodoo, and Dodoo (2013) also point out that when a husband has paid the full bride price, he gains complete control over the woman's reproductive rights, and the wife's disobedience may result in social disapproval.

As the UCAT program did not primarily focus on gender issues, the survey only in-

[2]Interestingly, Anderson (2007) suggests that bride price is commonly practiced in societies in which women have a prominent role in agriculture, and the amount does not vary by familial wealth.

[3]Lowes and Nunn (2018) find no evidence to support the detrimental effects of bride price on the well-being of married women in the Democratic Republic of the Congo. However, in a different study conducted in Ghana, Horne, Dodoo, and Dodoo (2013) provide evidence that bride price reduces women's reproductive autonomy.

terviewed the main respondent (typically male) and included limited questions on gender dynamics, particularly at the baseline. Mindful of these constraints, I approach measuring bargaining power in several ways. A decision-making index gathered at the baseline is one potential proxy for bargaining power. The respondents were asked about who had more influence over four spheres of household decision-making: food purchases, children's clothes, children's healthcare, and children's education. The involvement of women in these four decision-making spheres has been associated with higher women's empowerment and bargaining power (Quisumbing and Maluccio (2003); Doss (2006); Patel et al. (2007); Pratley (2016)). I create a categorical variable that takes a value of 1 if the respondent stated that the wife was solely responsible for making decisions regarding different aspects of the household and 0 otherwise. Then, I create an index using the wife's decision-making power from the four spheres weighted by the inverse of the covariance matrix to adjust for highly correlated outcomes (Anderson (2008)). The overall wife's decision-making power index has two limitations. First, the variable was only collected for a small sub-sample. Second, the answers to these questions are potentially different depending on who in the household is the respondent.[4]

Due to the limitations of the decision-making index, we set out to collect additional variables to proxy for bargaining power at the endline. These variables satisfy two conditions: (i) they are time-invariant variables and thus not affected by the treatment, and (ii) the information is not sensitive to the gender of the respondent, so there is less potential for discordance in the responses even when only one spouse is interviewed, or spouses were not interviewed separately. The proxies related to spousal demographic characteristics are the wife's age at marriage, the wife's educational level, the spousal age gap, and the spousal educational gap.

In addition, we collect data on the bride price at the time of marriage. Bride price is

[4] Recent research has increasingly underlined the need for collecting gender data at the individual level to accurately describe what happens within the household (Anderson, Reynolds, and Gugerty (2017); Doss and Quisumbing (2020); Ambler et al. (2022)).

typically common knowledge since the families of both the groom and the bride meet to discuss and settle the amount (Lowes and Nunn (2018)), so the gender of the respondent is not a major concern here.[5] At the endline, the respondent will be asked: "At the time of the marriage, did the husband or the husband's family give anything to the wife's family?" Bride price can take the form of cash, land, or livestock. Furthermore, we will inquire whether the total bride price has been paid and, if not, whether the respondent thinks that the remaining bride price may be paid in the future. Because there is a possibility of sample selection bias for respondents willing to disclose information about bride price, I will include an indicator variable of households that refuse to answer questions about bride price.

Based on the literature, I hypothesize that the decision-making index and the wife's age at marriage are positively associated with women's bargaining power. In contrast, the remaining three proxies, the spousal age gap, the spousal educational gap, and bride price, are negatively associated with women's bargaining power. Lastly, I will construct a bargaining power index using the principal component analysis to allow each proxy to be weighted differently.

4.2 Technology Adoption and Bargaining Power

Although there is rich and active literature on technology adoption in agriculture and the effect of intrahousehold decision-making on agricultural production decisions, the intersection of these two strands of literature is relatively sparse. In a review on intrahousehold bargaining and resource allocation in developing countries, Doss (2013) emphasizes the need for more work in this exact intersection, which has emerged into two distinct approaches.

In the first approach, intrahousehold bargaining power is viewed as an outcome that might be impacted by various technologies. Seminal work by Von Braun and Webb (1989) demonstrates that new labor-saving technology in rice farming in the Gambia transformed production arrangements within the household. Once a common women's crop largely grown

[5] Lowes and Nunn (2018) conduct interviews with husbands and wives separately regarding bride price and learn that husbands tend to know the information better than wives. However, if the wife knows the amount, the values reported by both spouses tend to be highly correlated.

on an individual farm, rice became more of a communal crop under the control of the male head after the introduction of the technology. They argued that the new technology undermines women's bargaining power by taking away the opportunity for them to grow rice as a private cash crop. In a different study, Quisumbing and Kumar (2011) show that technology impacts gender asset inequality, and dissemination through women's groups reduces gender asset inequality more than individual targeting. According to these studies, the nature of technology may play a role in changing the existing dynamics between spouses. Albeit interesting and relevant, this is not the approach I use to analyze the impact heterogeneity.

Instead, I follow the second approach, which studies how a given level of intrahousehold bargaining power affects technology adoption. Fisher, Warner, and Masters (2000), for example, explore the determinants of a household's decision to adopt a labor-intensive technology in Senegal. They show that households with older women have a lower likelihood of adoption, whereas adding another wife increases the likelihood of adoption, implying a positive relationship between the wife's bargaining power and technology adoption. Additionally, when the husband adopted a new technology to increase milk production, women were compensated for increased labor and loss of income. However, it is important to note the potential selection bias of the study, households who adopted the technology may have very different characteristics than non-adopted households.

While agricultural development programs, particularly extension services, have typically targeted men, some have shifted to focus on women and their potential role in improving children's nutritional status. Technological change for women's food crops may translate into better nutrition and well-being for women and children than technological change for men's cash crops. An example of this is Gilligan et al. (2020), in which they study the impact of bargaining power on the adoption of a new variety of crops. The program aims to encourage women to adopt orange sweet potatoes, known for their high level of vitamin A. Using ownership and control of land and other assets as a proxy for bargaining power, they find that plots controlled by women are more likely to have the new variety of sweet potatoes.

In a paper set in the same context as mine, Lecoutere and Wuyts (2021) study the impact of giving an intensive coaching package to increase household cooperation in coffee households in Western Uganda. Interestingly, the paper can be viewed as an empirical test for one of the hypotheses stated in Chapter 3, namely, does promoting cooperation or relative women's bargaining power improve adoption and household welfare? Their findings suggest that the net household income reported by women (but not the actual household income) increases since the wife is better informed about the coffee sales of the household. Nevertheless, they conclude that intensive coaching increases the adoption intensity of best agronomic practices more than a one-time couple seminar, indicating that shifting gender norms is complicated and requires time and effort from both households and implementing partners.

My paper is set apart from all the above studies due to the unique design of the study. I leverage the RCT evaluation design for a large-scale in-person agronomy training program to address a policy-relevant question that, to the best of my knowledge, has not been rigorously evaluated in the literature. How do different baseline levels of spousal bargaining power affect the effectiveness of a training program targeting a male-dominant crop? To answer this question, I propose an empirical strategy in the next section.

4.3 Empirical Strategy

The theory presented in Chapter 3 predicts that the difference in the outcome variables between treated and control households is larger among households in which the wife has a higher level of bargaining power. Following the pre-analysis plan of the project, I consider the following outcomes:

1. The adoption rate of best agronomic practices: A yield-based index will be constructed using a linear combination of binary practice indicators (as presented in table 2.5) weighted by the median expected effect of each practice on yield (as shown in table 2.6).

2. The inverse hyperbolic sine of coffee yield per tree: To account for the trade-off between yield and the size of the cherry, the yield outcome will be determined as the mean number of green cherries per tree multiplied by the mean weight of ripe cherries collected at the peak of harvest for each farm. This outcome is measured by three separate teams. The data collection for the first two teams takes place before the harvesting season. The first team is responsible for identifying three trees along the longest diagonal transect of the coffee plot. To avoid shirking, the second team then harvests and records the amount of green cherries from the trees marked by the first team. Then, at the height of the harvest, the third team randomly collects at least 10 trees along a vertical transect of the same coffee plot to weigh the ripe cherry.

3. The inverse hyperbolic sine of gross coffee profit over the past 12 months, defined as total coffee revenue minus the cost of inputs, hired labor, and marketing expenses.

I use the following specification to calculate the impact of training based on women's bargaining power (BP):

$$Y_{i,v} = \beta_0 + \beta_1 * Training_v + \beta_2 * BP_i + \beta_3 * Training_v * BP_i + \beta_4 * X_i + \gamma_c + e_{i,v} \tag{4.1}$$

The subscripts denote household i residing in village v within cluster c. $Training_v$ is the village-level assignment to the training, X_i captures a vector of baseline variables at the household level (including household asset ownership, total land managed, land under coffee, number of coffee plots and type of survey), and γ_c is a cluster-level (randomization stratum) fixed effect. Section 4.1 discusses variables that I plan to proxy for bargaining power. Specifically, I will run the above regression for each of the following variables as an indicator for women's bargaining power: (i) baseline decision-making index, (ii) spousal age gap, (iii) spousal educational gap, (iv) an indicator of whether the husband paid a bride price to the wife's family, and (v) a bargaining power index using the principal component analysis method. Throughout the analysis, I will use robust standard errors to allow for heteroskedasticity and cluster the standard errors at the village level to allow for correlations across households within a village. Additionally, the p-values will be corrected for multiple hypothesis tests using the Romano-Wolf step-down procedure.

4.4 Future Work

By providing insights into the relationship between women's bargaining power and household outcomes after the intervention, the results from the impact heterogeneity analysis can inform how policies can incorporate gender dimensions into their program design. However, suppose the findings indeed indicate that bargaining power significantly impacts the adoption level of the best agronomic practices. In that case, there are several key things to keep in mind. First, it is unclear what interventions would increase the wife's bargaining power in a specific context. Second, Jayachandran (2015) argues that interventions should consider addressing the gender attitudes of not only women but also the men in the household. Lastly, it is important to emphasize that raising women's bargaining power is not a magic solution to economic development, in that it can improve certain outcomes but not all (Duflo (2012)). Overall, the dissertation highlights the need for initiatives such as UCAT to understand the contexts within which the technology is promoted and analyze who within the household is likely to benefit or bear the burden of adopting such technological change.

On the other hand, if women's bargaining power does not affect the efficacy of the extension services, it may be due to how the bargaining power is measured. Future studies can explore the optimal way to collect gender-sensitive data considering both the cost of data collection and the potential discordance in spousal responses. Furthermore, despite not being a focus of this paper, an important angle is how technology adoption affects intrahousehold bargaining power and gender inequality. Even though gender norms do not change quickly, the dynamics between spouses constantly change with external and internal factors. In future work, I plan to examine how the training program affects the income controlled by women, which may be impacted due to the shift of household resources to coffee production.

Chapter 5

Self-selection versus Population-based Sampling for Evaluation of an Agronomy Training Program in Uganda[1]

5.1 Introduction

Many programs promoting an increase in labor investment potentially face a serious issue of low take-up rates. This chapter focuses on a general concern of how to identify an appropriate sample when it comes to evaluating the impact of agronomy training. To our knowledge, the experimental literature published on this topic has mostly used population-based sampling, wherein study participants are recruited from the population targeted by or eligible for training. A risk of this approach is that the pool of farmers to whom training is offered may include a sizable portion with little interest in training. Such farmers may either fail to attend training sessions, or if obtaining training is sufficiently convenient, they may attend training, but may not be motivated to make use of the information provided. The presence of such farmers in a study sample dilutes treatment effects and threatens the researchers'

[1]This chapter is joint work with Vivian Hoffmann from the International Food Policy Research Institute and Tomoko Harigaya from Precision Agriculture for Development.

ability to detect effects on practices, yield, and other outcomes with statistical precision. When the research objective is to evaluate the impact of access to training on farmers who are trained, identifying farmers likely to complete training ex ante is critical to improving statistical power.

In this chapter, we assess the effectiveness of screening farmers for their interest in a coffee agronomy training program based on their participation in a pre-training program designed to appeal to the same potential participants but not affect the outcomes targeted by the agronomy training program. We conducted an experiment in 22 coffee-growing villages in Uganda. Pre-training sessions were held in all study villages, and agronomy training was offered in half of these, based on random assignment. We compare the treatment effect on agronomy training attendance rates between the population-based sample of eligible farmers and the subset of farmers screened through attendance of one or more pre-training sessions.

We find that 52% of farmers self-selected through pre-training attended agronomy training, compared to 22% of the farmers identified through a census of eligible households. We estimate that by increasing the proportion of sampled farmers who attend training, the Minimum Detectable Effect Size (MDES) on coffee yield impact of a large-scale RCT is reduced from 38% to 15.83%. Attendance of multiple pre-training sessions is a stronger predictor of subsequent training attendance than attendance of a single pre-training session but sharply reduces the number of farmers selected into the sample. In contrast, the order of the pre-training session attended has no influence on subsequent training attendance.

This study makes a methodological contribution to the literature evaluating the impacts of agronomy training. Early evaluations of the impact of extension services on agricultural productivity or poverty reduction typically relied on non-experimental variation in access to training (see reviews in Waddington et al. (2014)). To the extent that it was not possible to fully observe and control for differences or differential trends in outcomes between areas where programs were offered versus not, or farmers who took up training versus those who did not, these studies were subject to selection biases.

An emerging body of literature uses random assignment to evaluate the impacts of agricultural extension and training. This literature largely uses a population-based sampling approach (BenYishay and Mobarak (2019); Arouna et al. (2021)), sometimes combined with inclusion criteria that reflect program eligibility or researchers' priors about who is likely to enroll (Carter, Tjernström, and Toledo (2019); Blair et al. (2020)). The advantages of population-based sampling include representativeness and comprehensiveness. Impacts estimated on all land-owning, or maize-farming households, for example, can be extrapolated to populations that share these characteristics. Furthermore, any spillover effects on farmers meeting the sample inclusion criteria but who do not attend training are captured under this approach.

Population-based sampling, however, may suffer from diluted effect sizes due to the inclusion of farmers who are not interested in trying new technology.[2] This often leads to the low take-up of the training intervention, which reduces the expected effect size in intent-to-treat analysis and implies the need for a larger sample to ensure adequate statistical power. If extensive baseline data on individuals in the study sample were available, researchers might attempt to predict program take-up and conduct the analysis with a sub-sample of farmers with a high propensity to participate in the program. In practice, however, predicting program take-up based on observable characteristics can be difficult, and a loss of statistical power from reducing the sample size may outweigh a small gain in power (Crépon et al. (2015)).

While some studies overcome this challenge by working with an implementing organization to target specific individual farmers for training (Arouna et al. (2021)), this approach has two limitations. First, one-on-one training is relatively costly compared to group-based training in terms of both staff time and transport. Group-based training has become increasingly common over the past decade based on its reach to a greater share of the target

[2]We note that the impact of training among farmers who have little prior interest in the training is ambiguous. In the context of a business training program for microcredit clients, Karlan and Valdivia (2011) find that the mandatory training was most effective in increasing business knowledge and changing practices among those who expressed the least interest in the program at baseline.

population (FAO (2019)). Second, the average impact estimate of such interventions may have limited policy relevance because the beneficiaries of one-on-one extension services are often highly selected when such programs operate at scale (Bandiera et al. (2020)).

More commonly, studies evaluating the impact of agricultural training programs draw a study sample using inclusion criteria that reflect program eligibility. For example, Blair et al. (2020), based on training implementers' perceptions of those most likely to participate in training, restrict their sample to include households actively engaged in farming, who manage a modest amount of agricultural land, have lived in the community for several years, and who include members of working age. Carter, Tjernström, and Toledo (2019) use the eligibility criteria for a rural agriculture and business development program to construct the study sample frame and compare the early treatment group against the late treatment group. These approaches can generate relatively large differences in the program exposure between treatment and control groups when the determinants of participation are well understood, or if a program is popular among eligible households, as was the case for those evaluated by both Blair and Carter and coauthors.

Table 5.1: Sampling Strategy and Observed Exposure to the Agricultural Extension Intervention from Selected Studies

Authors	Type	Sampling strategy	Selection criteria	Take-up
BenYishay and Mobarak (2019)	Individual extension, agents deliver extension to target communities under status-quo	Population-based sampling	–	9%
Arouna et al. (2020)	Individual extension, agents deliver advice via smartphone video to treated households	Population-based sampling	–	>98%
Blair et al. (2020)	Group agronomy training	Population-based sampling + eligibility criteria	Implementer identified farmers "most likely to benefit"	59% (vs. 10% in control)
Carter et al. (2019)	Group agronomy and business training with input subsidies	Population-based sampling + eligibility criteria	Eligible households for a rural business development program	64%

Self-selection into study samples offers an alternative approach to population-based sampling combined with inclusion criteria in cases where these conditions are not met. Self-selection has been widely used in randomized evaluations of business and skills training programs (for example, Fairlie, Karlan, and Zinman (2015); Campos et al. (2017)), as well as other interventions, including credit access (for example, Attanasio, Kugler, and Meghir (2011); Banerjee, Karlan, and Zinman (2015)). Under this approach, study participants are selected from those who express interest in or apply for a program. The primary advantage of evaluating program impacts among those most likely to participate is greater statistical power relative to population-based sampling. In the context of agricultural training interventions, it may be possible to detect impacts on not only immediate outcomes, such as knowledge and adoption of targeted practices but also follow-on outcomes, such as yield and farm income.

Despite the technical advantage of using self-selection via applications and expression of interest when evaluating a group training program, this approach is not always feasible. In the case of the training program we describe, the implementing partner was concerned that soliciting farmers' interest in training, and then only offering that training to a subset of those interested, would damage relations with the communities they served.[3] Further, expressions of interest may be subject to courtesy bias and thus serve as a poor predictor of follow-through.

During formative work for this study, another Non-Governmental Organization (NGO) offering coffee agronomy training in Uganda indicated that farmers might sign up for training or attend initial sessions based on short-lived curiosity or an expectation of material benefits, such as fertilizer or seedlings, only to stop attending if these expectations are not met. For these reasons, we developed a self-selection mechanism based on farmers' interest in training, as revealed by participation in a training program on farm business management. The business training program spanned three sessions to test the relative selection efficacy

[3] Within-village randomization of treatment status was ruled out for the same reason. This approach was used in a previous evaluation of TNS's coffee agronomy training program in Uganda, for which only preliminary results are available (Duflo and Suri (2010)).

of sustained attendance, or attendance in sessions beyond the first one or two held.

The next section describes the study design. We then present results comparing training attendance among the self-selected sample relative to a sample that was screened based on program eligibility criteria, and among those who participated in the first session versus later pre-training sessions, as well as on training spillovers to nearby comparison villages. The last section concludes.

5.2 Study Design

The present study was conducted to inform the design of the large-scale randomized evaluation of the UCAT program. We drew the sample for this study from the first cohort, while the sample of the UCAT evaluation consists of farmers recruited for the second cohort. Districts were selected for training based on widespread cultivation of Robusta coffee combined with low previous investment in coffee agronomy training by either government or NGOs.

Through a census of coffee-growing villages,TNS identified 55 villages within Matete subcounty where coffee was grown by a sufficient number of farmers to form a training group. From this list, we selected the 22 villages that were maximally distant from any of these other 55 villages. The thirty-three additional villages in the sub-county received agronomy training but were not part of the study. Among the 22 study villages, the distance to the nearest village in the sampling frame varied between 1.2 and 2.5 KM.

Approximately four months prior to the start of TNS's agronomy training program in April of 2018, farmers in each of the 22 study villages were informed that three sessions on farm business practices would be offered over a six-week period. No mention was made at this time of the agronomy training that would later be offered in half of these villages. Farm business training took place from April to May of 2018 and consisted of three separate sessions, the first on financial planning, the second on record keeping, and the third on savings. The first session of agronomy training in half of the study villages began two months after the end of farm business training in all study villages.

Half of the 22 villages were randomly assigned to receive TNS's standard Farm College program, while the remaining villages were assigned to a comparison group, in which only no additional training would be offered. Thus, farmers in all 22 villages were offered farm business training. After the pre-training, farmers from the 11 treated villages were additionally offered 22 agronomy training sessions over the course of 24 months, beginning in August 2018. Farmers in the 11 comparison villages received no further training from TNS. Figure 5.1 illustrates the study design.

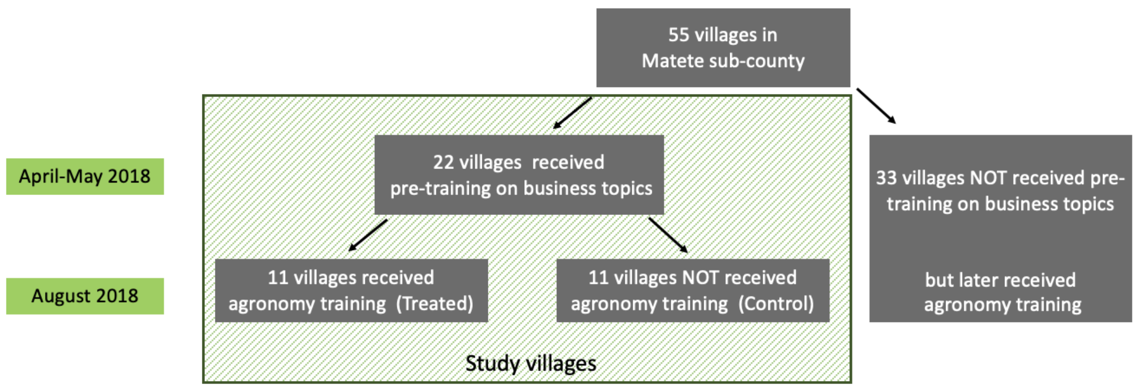

Figure 5.1: Study Design

We have two data sources: the census of coffee-growing households and the attendance records. Prior to the start of any training, in March of 2018, enumerators from a private data collection firm conducted a census of coffee-growing households in all study villages. This generated a total sample of 1,725 coffee-growing households across the 22 study villages, 924 of which were in the 11 villages randomly assigned to receive agronomy training. Then, farmers' attendance at both business and agronomy training was recorded by TNS staff. As a roll call of all farmers on the census list would have implied a lengthy and tedious process, farmers' names were recorded the first time they attended a session. The same farmers' attendance of subsequent sessions was then recorded against this list. We use data from the first three months of agronomy training (August to October 2018).

5.3 Empirical Approach and Results

We first test for potential differences in farmers' interest in training across experimental groups. We match farmer names on the census lists of each village to those on the pre-training attendance list for that village using a fuzzy matching computer algorithm and compare the attendance rates. We address the small number of clusters (22 villages) using the wild cluster bootstrap procedure suggested by Cameron, Gelbach, and Miller (2008) to obtain p-values for the differences in the proportion of farmers in villages assigned to agronomy training versus those assigned to the control condition. As shown in Table 5.2, farmers in these two groups attended pre-training at similar rates. The proportion of farmers attending the first, second, and third pre-training sessions was fairly constant, between 25% and 30% of those identified through the census, respectively. In both treatment and control villages, attendance appears to be slightly declining over time. While 46% of farmers in treatment villages and 45% of those in control villages attended at least one business skills training, only 12% and 10%, respectively, attended all three.

Table 5.2: Attendance of Business Skills Sessions by Farmers in Training and Control Villages

	AgT	Control	Difference	p-value
1st session	0.30	0.28	0.02	0.856
2nd session	0.29	0.25	0.04	0.504
3rd session	0.26	0.25	0.01	0.710
Any business skills session	0.46	0.45	0.01	0.852
$\geq$ 2 business skills sessions	0.27	0.23	0.04	0.464
3 business skills sessions	0.12	0.10	0.02	0.586
Observations	924	801		

We apply the same algorithm to match names between the pre-training and agronomy training attendance lists for farmers in treatment villages. Since agronomy training was not offered in villages assigned to the control group, the names of farmers residing in these villages â taken from either the census or pre-training attendance list) are matched to agronomy training attendance lists in the three nearest villages where training was offered.

Based on these matches, we estimate the agronomy training attendance rates by the experimental arm for different sampling frames (i.e., population-based sample vs. self-selected samples) and compare the attendance rate between treatment and control villages for each sampling frame. This difference is the 'first stage' impact of the randomized agronomy training program on farmers' take-up of training, based on which we can estimate the impact of training on outcomes of interest such as farm practices, yield, and profits. As for the comparison of business training attendance shown in Table 5.2, p-values for differences in agronomy training across treatment groups are obtained using the wild cluster bootstrap approach.

As shown in Table 5.3, 22% of coffee farmers in treatment villages identified through the village census were matched to agronomy training attendance records. Among the farmers who attended the first business skills session, the proportion who subsequently attended agronomy training, at 52%, is over twice as high as the proportion of those listed in the census who attended. Attendance of the second and the third business skills sessions does not appreciably increase the likelihood of attending agronomy training. On the other hand, attendance of a greater number of business skills sessions increases the probability of attending agronomy training, to 58% of those who attended at least two pre-training sessions, and 66% of those who attended all three. However, this comes at a steep cost in terms of sample size. On average, across the 11 agronomy training villages, only 10 farmers per village attended all three business skills training sessions, with just 6.6 of these per village subsequently attending agronomy training. Sampling instead from the 25 farmers per village on average who attended the first business training yields a mean of 13 agronomy training attendees.

Table 5.3: Agronomy Training Attendance by Business Skills Training Attendance

	AgT		Control			
	Matched	N	Matched	N	Difference	p-value
Population-based: Census	0.22	924	0.02	801	0.20	0.000
Self-selected sample:						
1st business skills session	0.52	274	0.04	228	0.48	0.000

Table 5.3 continued from previous page

	AgT		Control			
2nd session	0.51	267	0.06	203	0.45	0.000
3rd session	0.52	244	0.08	198	0.44	0.000
Any business skills session	0.45	429	0.05	361	0.40	0.000
$\geq$ 2 business skills sessions	0.58	246	0.07	184	0.51	0.000
3 business skills sessions	0.66	110	0.08	84	0.58	0.000

Importantly, a higher percentage of farmers in control villages who were screened through attendance of business training attended agronomy training in nearby treatment villages. The relationship between attendance of additional business training sessions and agronomy training attendance follows a similar pattern for farmers in treatment villages. However, the increase in training spillovers is minor compared to the increase in participation among treatment village farmers. The difference in agronomy training attendance rates between treatment and control farmers is about 2.5 times greater among those who attended the first business training session compared to population-based sampling.

5.4 Implications for Statistical Power in Impact Evaluations

In Table 5.4, we present MDES for the UCAT evaluation on coffee yields using both population-based (census) and self-selected sampling approaches, using attendance of the first business training session as the screening criterion for the latter. Estimates of the control mean (0.069) and standard deviation (0.89) of log coffee yield are based on physical yield data collected in the study region (Hoffmann et al. (2019)). Endline data for UCAT will be collected using the same method. The intra-cluster correlation of log yield (0.12) is estimated using baseline self-reported yield data from the UCAT evaluation sample, which gives a higher, and likely more reliable estimate due to the greater number of villages than the small-scale yield measurement study. Using the sample size of the UCAT evaluation (12 farmers in each of 360 control and 360 treatment villages) and setting the significance level of a one-sided test to 10% and power to 0.8, we calculate the MDES on coffee yield in villages where training is offered of 7.6% overall.

Assuming that the entire effect is driven by farmers who attend coffee agronomy training, we divide the MDES by the difference in agronomy training attendance rates between treatment and control villages reported in Table 5.3 to obtain the implied required impact among trained farmers. For the population-based sample identified through the census, this difference is 0.2, implying that the yields of trained farmers would need to increase by an average of at least $7.6\%/0.2 = 38\%$ for the effect to be detectable. For the sample of farmers selected based on participation in the first business skills training, the difference is 0.48. Under this sample selection approach, the minimum detectable impact on trained farmers is a far more attainable yield increase of $7.6\%/0.48 = 15.83\%$.

Table 5.4: Villages per Treatment Arm, MDES, and Survey Cost by Sampling Strategy

Sampling Strategy	Villages per treatment arm	MDES (% of harvest)	Cost
population-based sampling (UCAT sample size)	360	38.0%	1
self-selected sample	360	15.8%	1.03
population-based sampling	16,151	15.8%	39.4

Note: The last column captures the cost (multiples) relative to population-based sampling. All scenarios assume baseline and endline surveys of 12 farmers/village.

The first two rows of Table 5.4 hold the number of villages constant at 360 per arm, and show MDES and selection plus pre-training cost, relative to population-based sampling, for the two sampling approaches. The cost of population-based sampling assumes that lists of coffee farmers are available to use as sampling frames. We note that this is not always the case (indeed no such lists were available in UCAT villages and collecting names of farmers would have entailed a cost). Nevertheless, even assuming lists are available, the cost of self-selection through pre-training entails a modest 3%, compared to the reduction in MDESof 58%. In the third row, we present the number of villages (over 16,000) and associated costs required under population-based sampling to attain the same MDES as in the case of self-selection with 360 villages per arm.

5.5 Conclusion

Due in part to the low take-up of agronomic training programs, studies evaluating their impact are typically only able to detect impacts on intermediate outcomes such as knowledge about and adoption of targeted practices. The ultimate outcomes of interest targeted by these programs, typically yields and household income, are subject to a host of exogenous stochastic influences, and are thus more difficult to detect statistically. The sampling approach tested in this paper can be used to identify farmers interested in agronomy training, thus increasing the statistical power to detect impacts, and helping to overcome a critical evidence gap on the impact of group-based agronomic training, and of agronomic training on yields. This is the exact approach we took to design the RCT evaluation for the second cohort presented in chapter 2.

Evaluating impacts on a self-selected sample, however, has limitations. The populations on which impacts are assessed are those interested in the program studied. This group may be difficult to define outside the study itself, complicating the extrapolation of population-level impacts. If statistics are available on the pool from which participants self-select (in our case, coffee farmers), a lower bound of total program impact can be defined for this larger group as the estimated effect on the study sample, multiplied by the proportion of this group who self-selected into the sampling frame. Note that only a lower bound of impact on the larger group can be estimated because those who do not initially express an interest in the program may also benefit from it. Such benefits may be direct (if other farmers later decide to join) or indirect (if other farmers, who do not join, learn new practices from those who are trained).

In the study setting, screening farmers based on attendance of a single pre-intervention training session selected a sample for which the difference in the intervention training attendance rate between treatment and control groups (i.e., the first stage treatment effect) was just as high as attendance of multiple pre-intervention sessions. Requiring attendance of multiple pre-intervention sessions also substantially reduces the eligible population of farmers:

compared to 274 farmers in the study who attended the first session, only 110 attended all three. A final advantage of selecting the sample from attendees of a single pre-intervention session is the lower cost of holding just one such session.

While offering a separate program does entail some cost, our results show that it has the potential to greatly improve the power to detect program effects. In the study setting, the cost of increasing power through a larger sample size with population-based sampling exceeds that of self-selection through pre-training by a large margin.

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