The indirect effects of clean cookstoves: Foraging time, gender, and agricultural production in Rwanda

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We acknowledge and respect the Lək̓ʷəŋən, (Songhees and Xʷsepsəm/Esquimalt) Peoples on whose territory the university stands, and the Lək̓ʷəŋən and W̱SÁNEĆ Peoples whose historical relationships with the land continue to this day.

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Abstract

Well-designed improved cookstove interventions reduce the foraging time requirement for energy provision. What are the indirect effects of this time savings, particularly for the women and children who traditionally collect fuelwood for their households? In this paper, I study the impacts of the Tubeho Neza clean technology program in Rwanda, which to date has delivered 1.5 million improved cookstoves to rural Rwandan households. I use the Integrated Household Living Conditions Survey (EICV, 2011, 2013-14, 2016-17) and proprietary stove delivery data from DelAgua for my analysis. I examine several outcomes, including minutes spent foraging, missing school in the previous week, and the production of crops traditionally cultivated by women. Given the limited geographic information in the EICV, I measure individual treatment intensity based on the cumulative stove receipt at the district level post-treatment. Drawing on recent advances in the econometrics literature, I estimate a difference-in-differences two-way fixed effects regression specification for two separate treatment groups based on their year of initial treatment (2014 or 2016). I also use an event study with binary treatment classification to examine evidence of parallel pre-trends and as a post-treatment robustness check. Across outcome variables, I fail to reject the null hypothesis of zero treatment effect, but these null findings are likely due to the coarse treatment definition.

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1 Introduction

Improved or "clean" cookstoves are a cooking technology that reduce household emissions and biofuel use relative to the prevailing cooking technology of use. Interventions that seek to replace traditional, less efficient stoves with improved cookstoves are not new, as economists and development planners have been delivering these technologies to developing countries for nearly 50 years (Inayatullah, 2012). Past literature shows that ICS technology decreases foraging time for households (Krishnapriya et al., 2021), can limit degradation in surrounding forests and woodlands (Barnes et al., 1993, Gebreegziabher et al., 2017), and reduces household air pollution, resulting in respiratory health benefits (Kirby et al., 2019, Gordon et al., 2014). A less thoroughly examined result of introducing clean cookstoves is the indirect effect of increased free time for women and children assigned to the household chore of gathering wood. The resulting time use changes may influence educational outcomes, productive activities, and household expenditures. However, evidence on the indirect time use effects is limited and mixed.

In this paper, I examine the impacts of the Tubeho Neza Improved Cookstove program on time use related outcomes for women and children in Rwanda. The Tubeho Neza program, a project delivered by UK based social enterprise DelAgua, has provided free improved bio-fuel cookstoves to households in Rwanda at scale since 2014. During the period of Tubeho Neza delivery my study focuses on (2014-2016), DelAgua targeted the poorest Rwandan families, primarily in rural and agricultural communities. Considerable empirical work has been done on the Tubeho Neza program, mainly focusing on the health and forest cover impacts due to improved cookstove use (Barstow, 2010, Barstow et al., 2016, Barstow, 2019). The time use aspect and the specific benefits afforded to women and children in the program due to changes in their time budgets have not been comprehensively investigated.

I use three cross-sections of the Integrated Household and Living Conditions Survey (EICV), a nationally representative dataset collected by the National Institute of Statistics Rwanda (NISR). Using household data from 2011, 2013, 2014, 2016, and 2017, as well as DelAgua's proprietary stove data,[1] I classify stove uptake based on stove receipt at the district level. This is a very coarse measurement of stove receipt, but since the accessible EICV data only identifies the household's district, I cannot use a more precise measure, such as receipt at the village level.

I define a difference-in-differences two-way fixed effects (DID TWFE) estimation model with a continuous stove receipt explanatory variable. Given recent insights on DID TWFE with heterogeneous treatment timing, I separately examine two treatment cohorts: districts first treated in 2014, and districts first treated in 2016. I use event studies with binary treatment assignment to examine evidence related to the parallel trends assumption and as a robustness check for post-treatment outcomes.

The outcome variables I focus on relate to children and women's time use: for women ages 15-64, and for school-age boys and girls ages 7-14, I examine changes in time spent foraging. For the same boys and girls, I also examine recent attendance. At the household level, I examine changes in the production of subsistence crops typically understood to be cultivated by women.

[1]DelAgua holds a Memorandom of Understanding with University of Victoria to facilitate data sharing with faculty currently working with them. The MOU does not allow Masters students to directly access DelAgua's proprietary data. To conduct my research, I developed all cleaning and analysis code using artificial data, and my supervisor, Dr. Colette Salemi, ran my code using the true DelAgua data. Data access is part of a Social Sciences and Humanities Research Council (SSHRC) funded project called "Firewood and Deforestation: A Study of the Clean Cookstove Sector and the Effect of Clean Cookstoves on Forests."

Across outcome variables, I largely fail to reject the null hypothesis of no treatment effect. However, it seems likely that the very coarse definition of treatment is resulting in inflated standard errors and potentially biased coefficient estimates.

The remainder of my paper is as follows: Section 2 reviews the existing literature on improved cookstoves and organizes theory linking cookstoves to foraging, time use, and other outcomes. Section 4 introduces the DelAgua stove and EICV data, describing limiting factors and the process of combining the two sources. Section 5 lays out my DID methodology and my event study approach. I report results in Section 6. My concluding remarks are in Section 7.

2 Literature Review/Theoretical Framework

2.1 Chores and harvesting

Women and girls are disproportionately responsible for household chores worldwide, and in Sub-Saharan Africa this is especially true (Biran et al., 2004, Graham et al., 2016, Koolwal and Van De Walle, 2009). The time burden of domestic chores prevents women from participating in income-generating market activities that could otherwise promote growth or financial independence (Koolwal and Van De Walle, 2009). In terms of specific chores, women and girls are more likely to be responsible for collecting water (Graham et al., 2016, Koolwal and Van De Walle, 2009, Agesa and Agesa, 2019) and collecting firewood (Friman, 2024, Bapfakurera et al., 2024) than their male counterparts. Small scale studies in Rwanda have indicated predominant involvement of women and children in firewood collection. Households may spend 5-8 hours in collection sessions over 9 kilometers away from their homes, and nearly half of the households in the respondent districts gather firewood twice a week (Bapfakurera et al., 2024). 57% of Rwandan energy consumption is directly accounted for via firewood, and 23% via (fuelwood derivative) charcoal (Ndegwa et al., 2011). The market for firewood is sizable in Rwanda, and in 2007 total revenue from firewood (and charcoal as a subsector) was estimated at 122 million USD, or 5% of the country's GDP (Ndegwa et al., 2011).

The evidence linking women and children's time use and educational outcomes in developing countries is mixed. A strong negative relationship between domestic chores and school attendance for girls has been observed in Egypt (Assaad and Levison, 2010), and a negative relationship was found between school attendance and time spent on chores when there are large time burdens of resource gathering chores on children (Levison et al., 2018, Dinku et al., 2019). In Kenya, the incidence of missing school due to fetching water is higher for girls than boys (Agesa and Agesa, 2019). Additionally, past research has also demonstrated a negative relationship specifically between resource-gathering chores (gathering wood and collecting water) and advancement to upper primary school (Nankhuni and Findeis, 2004). However, studies in Kenya, Tanzania, Ethiopia, Ghana, and Malawi were unable to demonstrate a negative relationship between school attendance and time spent doing household chores (Levison et al., 2018, Gebru and Bezu, 2014, Nankhuni, 2004, Nankhuni and Findeis, 2004, Ndiritu and Nyangena, 2011, Alirigia, 2019).

2.2 Gender and agriculture

Women play a crucial role in rural economies defined by small-scale agricultural production. Most Rwandans are employed in agriculture, with 67.6% of Rwandans receiving income from agriculture in 2013/14 (Republic of Rwanda Gender Monitoring Office, 2017). Agriculture is a more important source of income for women relative to manufacturing and services (Doss and Team, 2011). Women are more likely to receive income from agriculture than men (79.1% vs 54.4%) and more likely to be self-employed in agriculture (66.4% vs 54.4%); however, men are still primarily responsible for selling agricultural goods (Republic of Rwanda Gender Monitoring Office, 2017). This is true for both large and small scale crops. Different crops are often associated with different genders, while men primarily responsible for cash crops, women are generally responsible for the crops consumed by the household (Duflo and Udry, 2004, Doss, 2001, Okonya et al., 2019, Nakazi et al., 2017). The gendered division of crop harvest remains true in Rwanda post-genocide, with male labour depleted and subsistence crops heavily dependent on cultivation by women (Okonya et al., 2019). Subsistence farming is conducive to a large family size: while men and boys are responsible for clearing brush, women and girls are responsible for household crops and field work (Boserup, 1985).

The cash crops in Rwanda include coffee, paddy rice, tomato, avocado, and beer banana, while the lower value (non-cash or subsistence) crops include cassava, maize, non-beer banana, sweet potato, and beans (Benimana et al., 2024, Okonya et al., 2019). Benimana et al., 2024 find that 80% of agricultural households in Rwanda sell crops, but average sales are only 33% of production. This suggests a large quantity of crops consumed by households, saved for the next season, or put to other uses. Although gendered labour provisions may be clear in terms of specific crop management, oftentimes there is no clear line from crop production to decision making about the crops in question (i.e., men are more likely across the board to make decisions about crops they did not produce), making the determination of female labour participation levels difficult to precisely measure (Okonya et al., 2019, Floro and Komatsu, 2011). As a result, census data often under-reports women's contributions to household agricultural production, due in part to gendered attitudes around income generation (Doss and Team, 2011, Jiggins, 1989). Regardless, estimates of female contributions are as high as 80% of agricultural labour and 60% of food consumed by households (Jiggins, 1989).

2.3 Cookstoves, health, and air quality

Air pollution is the primary environmental cause of death worldwide, affecting nearly half of Earth's population (Gordon et al., 2014, Phillip et al., 2023). Household air pollution (HAP) is a major contributor to adverse health effects in homes that use traditional stoves due to inefficient combustion of biomass fuel, expelling fine particulate matter and toxic gases into dwellings (Phillip et al., 2023). HAP and ambient air pollution contribute to millions of deaths around the world annually via lung disease, cancer, increased cardiovascular risk, and respiratory infection (Gordon et al., 2014). Black carbon emissions from traditional (inefficient) stoves disproportionately affect women and children as the primary stove users, accounting for 60% of HAP-related deaths (Kyayesimira and Muheirwe, 2021, Gordon et al., 2014). Respiratory illnesses (usually acute lower respiratory infections such as pneumonia or bronchitis) are one of the leading causes of morbidity in children under 5 (Gordon et al., 2014). Furthermore, air pollution has adverse consequences on the learning and cognitive function of children worldwide (Grineski et al., 2020), as well as academic achievement (Balakrishnan and Tsaneva, 2021).

The health component of Tubeho Neza was a primary motivator in the inception of the project (as is the case for most improved cookstove interventions). Improved cookstoves burn fuel more efficiently, and when not used concurrently with traditional stoves, can significantly decrease ambient smoke and gas (Gordon et al., 2014). The presence of DelAgua's Tubeho Neza program in the Western Provinces of Rwanda has had notable effects on the respiratory health of participants. Kirby et al., 2019 found a 25% decrease in acute respiratory infection (ARI) reported among children under 5, but no significant impact was detected on household air particulate concentration. The discrepancy is likely due to concurrent stove use (often referred to as "stove stacking") and the limitations of self-reported data. Rosa, 2014 found a 48% median reduction in 24 hour particulate matter concentrations in the main cooking area of treated households. A 2021 analysis by the WiFOR institute valuated the socioeconomic benefits of Tubeho Neza's cookstove and water filter program at around $9.1 million USD in total, or around $11.75 USD per person (Alexandraki et al., 2021). The results come from an analysis of the health benefits of the program, as well as the immediate benefits from paid and unpaid work due to decreased illness related absenteeism and medical costs avoided.

Clean cookstoves play a multifaceted role in time use. Clean cookstoves studies have shown decreased foraging times in several developing countries, with an average decrease of 34 minutes per day (Krishnapriya et al., 2021). The introduction of clean cookstoves impacts cooking, a time-intensive chore primarily delegated to women (Dinkelman and Ngai, 2022). Afridi et al., 2023 observed decreased cooking times of 11-36 minutes per day in households using clean stoves, however this was in conjunction with clean fuel (liquid petroleum gas) instead of the solid fuel used in the

EcoZoom Dura stove. The proven health benefits of increased access to clean stoves have also demonstrated positive contributions to school attendance, participation, and math and reading skills (Ninan, 2024).

3 Context

3.1 Rwanda

Rwanda, an equatorial African nation bordered by Tanzania, Uganda, Burundi, and the Democratic Republic of the Congo, sits in the Great Rift Valley of East Africa. It is a geographically small (26,338 ha^2) mountainous country colloquially called the "Land of a Thousand Hills." Rwanda supports a population of 13.2 million residents (2022), of whom 51.2% are women. Rwanda is a relatively young country, with 65% of residents under the age of 30. Poverty levels have been steadily decreasing in Rwanda since 2004, (58.9% to 38.2%); however there is evidence that COVID has counteracted this trend, resulting in a recent increase in the share of impoverished Rwandans (up to 41.9% in 2021). This could be due to a variety of factors including climate change, political instability, and inflation. Regardless, life expectancy has increased significantly over the past two decades from 51.2 to 69.6. Rwanda's GDP has nearly tripled over the past decade, from RWF (Rwandan Franc) 4,133 billion in 2011 to RWF 13,716 billion in 2022, with per capita GDP rising from USD $674 to USD $1004. Rwanda is classified by the UN as both a Least Developed Country (LDC) and a Landlocked Developing Country (LLDC). As a landlocked country, Rwanda relies heavily on its neighbors for access to trade routes. Though usually relatively peaceful, recent conflict within the Democratic Republic of the Congo as well as Burundi has affected stability within the region.

The development of human capital and the advancement of gender equality is a stated priority of the Rwandan government. Rwanda was ranked 39th worldwide and 2nd in Africa in the 2024 Gender Gap index, and the country boasts the highest representation of women in parliament in the world (63.8%). Rwanda also ranks high globally in girls enrollment in primary and secondary education. Still, large gaps persist in economic participation and opportunities for women in the country. The Global Gender Gap Index ranks Rwanda at 109th for women's estimated earned income, 113th for female representation in legislators, senior officials, and managers, and 98th for professional and technical workers. Women's labour force participation rate in Rwanda is high relative to other East African countries (54.76%). However, domestic care and agricultural work in the informal sector make labour notoriously difficult to measure. Subsequently, 89.14% of women in Rwanda work in the informal sector, as do 86.78% of men. The vast majority of this informal work is agricultural.

According to the 2020/2021 Agricultural Household Survey conducted by the National Institute of Statistics Rwanda, there are 2.3 million agricultural households in the country (80.1% of total households). 86.3% of those agricultural households rely on agriculture as their primary livelihood. The other 13.7% practice crop and livestock production as a supplemental income generating activity. 78.1% of households in this study produced crops (as opposed to cultivating livestock). For all agricultural households, 71.8% of household heads are men. In agricultural households that are headed by women, 65% are widows. 87.6% of agricultural households own land for cultivation and 49.5% of households rent land. For some landowners, rented land is used as a complement to household's owned cultivation land. 97.8% of agricultural households in this survey used the land to produce crops (National Institute of Statistics of Rwanda, 2020).

3.2 DelAgua and Tubeho Neza

DelAgua, a UK based social enterprise, distributes affordable efficient cookstoves to rural and impoverished communities in Rwanda. DelAgua delivered its first stove as part of its ”Tubeho Neza” (”Live Well” in Kinyarwanda) program in 2012, as part of a small-scale pilot. Since then, DelAgua has distributed more than 1.5 million stoves in Rwanda. DelAgua works in collaboration with the Ministry of Health of the Republic of Rwanda (MOH) with the stated goal of providing 2.3 million cookstoves to rural households in need.

The EcoZoom Dura high efficiency wood cookstoves (Figure 1) provided by DelAgua represent a departure from the traditional cooking/heating mechanism used in Rwanda, which is typically an open or ”three stone” fire. The three-stone stove requires large quantities of foraged wood or other biomass to produce enough heat to cook and heat households. In contrast, DelAgua's clean stove, the ”Live Well” stove, is a portable, compact, stainless steel chamber that uses small pieces of foraged wood (twigs, branches, etc.) to maximize thermal efficiency, reducing both biomass used and carbon emitted. The typical ICS can improve the percentage of energy transferred from less than 20% (Three Stone fire) to more than 80% (Gordon et al., 2014).

Figure 1: The EcoZoom Dura Stove

Notes: Image obtained from DelAgua Health Rwanda Limited, 2020

In addition to providing cookstoves, DelAgua also invests in household and community education to encourage use. Each stove recipient also receives certification, an educational poster, and access to a smartphone app that scans the unique bar codes on the stoves to accurately track usage data. On staff are Community Health Workers (CHWs) who visit each household to provide training and assistance with the new stoves. The CHWs continuously follow up with the households for six months after the recipient receives the stove, in part to encourage continued use.

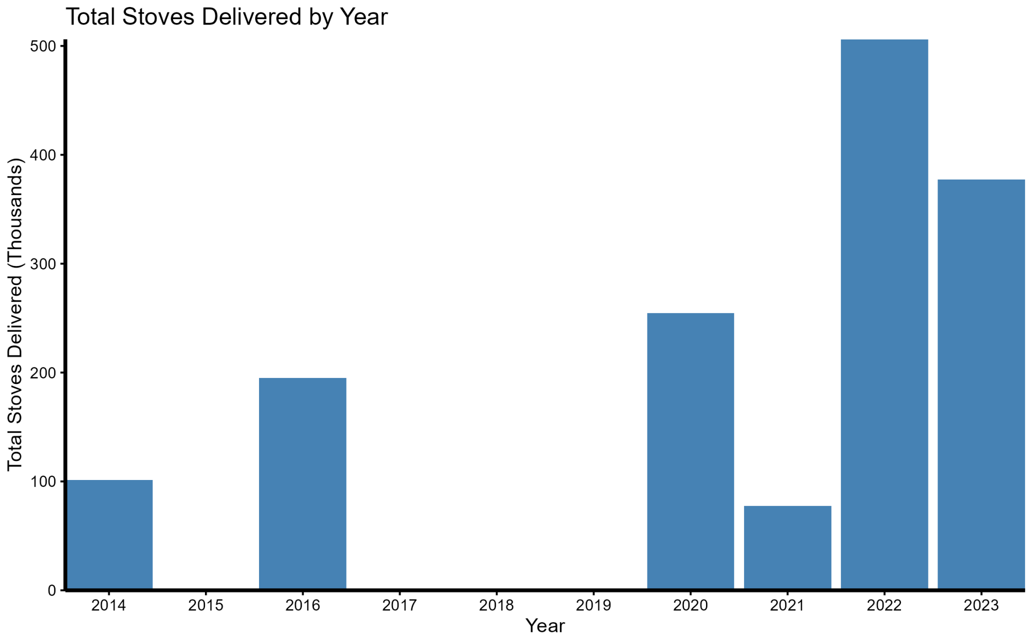
During the time period on which I focus (stoves delivered in 2014 and 2016), Tubeho Neza was financed through carbon credits verified in the United Nations Clean Development Mechanism (CDM). Under the CDM, countries with emission reduction commitments under the Kyoto Protocol can offset some of their emissions by purchasing certified emission reduction (CER) credits (United Nations Framework Convention on Climate Change, n.d.), or “carbon credits”. Credits are supplied by entities like DelAgua, who certify the program specific emissions reductions with the CDM and, upon program completion, sell their credits. The reduction of wood burning emissions due to Tubeho Neza stoves qualifies the project for CER credits, which currently fund the project through the carbon finance market. The stoves have upfront costs of $35-40 USD, and the use of carbon credits offsets these costs, enabling free distribution by DelAgua’s community health partners.

3.3 Program Implementation

The pilot phase of Tubeho Neza began in October 2012 with the distribution of stoves and water filters to approximately 2,000 households in 15 villages in the Western Province of Rwanda (Barstow, 2019). Selection was designed to be representative of typical rural Rwandan villages (Barstow, 2010). The pilot program included all “Ubedehe”[2] categories in the Western Province; however, under the direction of the Rwandan MOH, future waves of distribution included only Ubedehe 1 & 2 (Barstow, 2010). In the initial stage, high and sustained adoption of the EcoZoom Dura stove as the primary cookstove of households was measured in both a primary verification survey (92.8%, 6 weeks to 6 months after distribution) and a secondary verification survey (89.3%, 10 months to 14 months after distribution) (Barstow, 2010, Barstow, 2019, Rosa, 2014). To circumvent bias in self-reported data, Fankhauser et al., 2019

[2]“Ubedehe” is a program by the Rwandan government that categorizes households into 5 different subsections based on economic standing and general welfare. Ubedehe 1 & 2 are the most impoverished classifications.

Figure 2: Number of stoves (in thousands) delivered by year

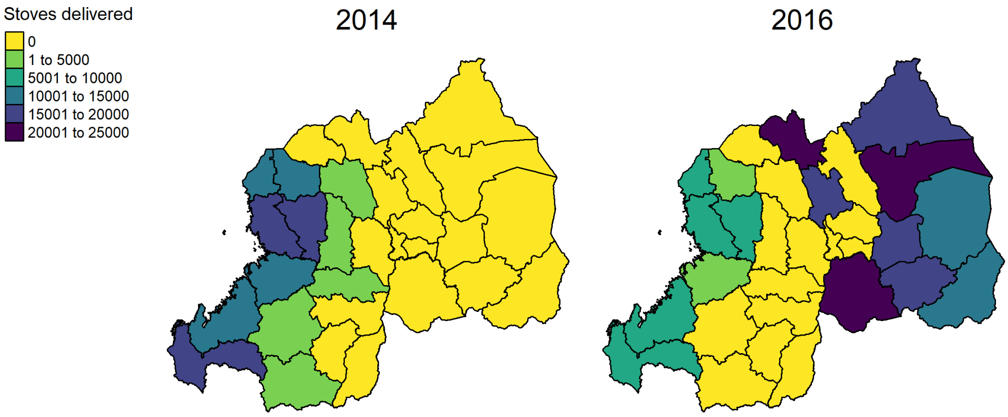


Notes: Author's calculations based on DelAgua proprietary data. Pre-2014 counts are not available in data shared for this project.

used sensor-based measurement for Rwandan households with EcoZoom stoves and reported 73.2% sustained adoption rates (Thomas et al., 2016). Several studies were conducted following this initial distribution wave and used in implementing the second stage, including a randomized control trial on health impacts (Rosa, 2014).

After piloting, DelAgua scaled up delivery and provided more than 100,000 stoves to households in the Western Province of Rwanda between September and December of 2014 (Barstow, 2019). This wave also included water filter distribution. The counts per year are shown in Figure 2. In 2016 nearly 200,000 more cookstoves were distributed, primarily in the Eastern Province of Rwanda (Barstow, 2019). For the Tubeho Neza program specifically, 93.1% of households that primarily used firewood for fuel reported a decrease in time spent collecting wood. 74.1% of the reported

Figure 3: Number of stoves delivered by district and year



Notes: Author's calculations based on DelAgua proprietary data. Maps report delivery in 2014 and 2016 only.

activities with respect to the extra time was associated with income generation or agriculture. In 2019 it was estimated that there was a total monetary benefit of $66.67 million USD based on fuelwood/time savings and environmental benefits (Barstow, 2019).

The largest stove roll-out periods were in the years 2020 - 2023. Ideally I would be able to use this data in conjunction with the EICV, but the planned 2020 EICV6 was postponed indefinitely due to COVID and there has not been a subsequent EICV since then, making any further analysis with these specific data sets impossible at this moment in time.

Figure 3 details the geographical distribution of stoves over the years included in this study. The 2014 roll out was exclusively in the Western Province of Rwanda, followed in 2016 by a heavy push into the Eastern and Northern Provinces. There was continued distribution in the Western Province after the first 2014 wave.

4 Data and Descriptive Statistics

4.1 Integrated Household and Living Conditions Survey (EICV)

My study uses household data from the Integrated Household Living Conditions Survey (Enquête Intégrale sur les Conditions de Vie des Ménages, or EICV), collected by the National Institute of Statistics of Rwanda (NISR). The EICV is a repeated cross-sectional survey that samples approximately 2,000 households in each of Rwanda's 30 districts. There are a total of 198,793 individuals recorded across the three surveys (EICV3, 4, and 5) used in this study. EICV3 ran from January 2011 to December 2011. Data collection for EICV4 was carried out between October 2013 and October 2014. And data collection for EICV5 ran from October 2016 to October 2017.

NISR used a two-stage sampling methodology for each EICV wave. In the first stage the probability proportional to size method was used to draw nationally representative primary sampling units (PSUs). In the second stage, households were drawn from each selected rural and each selected urban PSU and surveyed.

The EICVs provide information on factors like education, employment, health, housing conditions, consumption, household expenditures, agricultural activity, and monetary transfers in and out of households (of Statistics of Rwanda, 2011). Data is collected for both individuals (education, health, income, etc.) and for households (crop production, housing conditions, etc.).

My initial data inspection revealed that the province of Kigali City, Rwanda's capitol, contributed to many of the outliers in the variables of interest. Table 1 demonstrates the disparities between Kigali City provincial averages and the rest of the country. Kigali City is demographically a complete departure from the rest of

Rwanda. It is richer, more urban, less agricultural, and households rely more on varied fuel sources for food production. Kigali City was at no point treated, as DelAgua does not operate there. To reduce noise caused by outliers and to ensure that my study uses comparable treatment and non-treatment areas, I decided to omit it from my dataset.

Table 1: Kigali City Inclusion/Exclusion Statistics (Individuals)

	Full Sample	Kigali City	Non-Kigali
N	196,586	18,489	178,097
Percent Rural	%84.27	%19.25	%91.02
Percent Poor	%41.13	%14.57	%43.89
Average Minutes Foraging	72.80	19.60	78.32
Std. Dev.	(172.66)	(95.43)	(177.87)

The descriptive data supports what we know about Rwanda demographically. Excluding Kigali City, the population is over 90% rural, and 44% ”Poor” or ”Extremely Poor.” Women are household heads for approximately one fifth of the households surveyed, and the majority of household heads surveyed have some level of education. Average school expenditures for the full sample are around $4.66 USD, but with a large standard deviation (around $35 USD) The foraging statistics also support an important prerequisite for this study - women and children are the primary foragers in households.

4.2 DelAgua stove delivery data

Cookstove data received from DelAgua included Tubeho Neza stoves received in each village from 2014 - 2023. Over this interval, DelAgua delivered 1.5 million stoves with

Table 2: Full Sample Summary Statistics

Variable	**Mean/Value**	**Std. Dev.**
General Household Characteristics		
Percent Female	52.52	–
Percent Rural	91.02	–
Percent Poor	43.89	–
Percent Female Head of Household	21.05	–
Percent Head of Household Who Has Been to School	74.67	–
Continuous Household Variables		
Age (Years)	22.93	18.86
Household Size	5.55	2.15
Minutes Foraging	78.32	177.87

Source: RWF = Rwandan Franc. N = 178097. Kigali City excluded.

Table 3: Summary Statistics by Group (Adult Men, Adult Women, Girls, Boys)

Statistic	**Men**	**Women**	**Girls**	**Boys**
N	44,359	51,156	20,418	19,912
Percent Attended School	25.91	22.82	98.02	97.25
Avg. Minutes Foraging	48.03	106.14	147.15	134.42
	(127.70)	(185.72)	(247.78)	(243.47)
Avg. Age (Years)	31.66	32.63	10.41	10.39
	(13.22)	(13.30)	(2.30)	(2.29)
Avg. Household Size	5.46	5.37	6.18	6.20
	(2.24)	(2.18)	(1.97)	(1.95)

Table 4: Subsistence Crop Statistics (Surveys 1, 2, & 3)

Variable	**Mean**	**Std. Dev.**
Total Small Scale Crop Value (RWF)	82,459.33	98,789.29
Banana Consumed (kg, 7 days)	2.54	6.71
Banana Harvested (kg, 12 months)	128.94	410.31
Avg. Consumption / Harvest (Banana)	2.17	6.74
Sweet Potato Consumed (kg, 7 days)	7.1	11.91
Sweet Potato Harvested (kg, 12 months)	344.74	584.36
Avg. Consumption / Harvest (Sweet Potato)	2.2	–
Beans Consumed (kg, 7 days)	0.88	5.45
Beans Harvested (kg, 12 months)	27.53	44.17
Avg. Consumption / Harvest (Beans)	2.07	–
Cassava Consumed (kg, 7 days)	2.18	4.48
Cassava Harvested (kg, 12 months)	152.59	306.29
Avg. Consumption / Harvest (Cassava)	1.54	–

Note: N = 43,190 for all variables. Consumption / Harvest is calculated as consumption of crop in last seven days / (Harvest in last twelve months /52), susceptable to seasonality. Kigali City Exluded.

higher roll-out in later years. The increase in stove delivery over time may be due to the increase in the trading value of carbon credits. The stove data is DelAgua's proprietary administrative data, and usership access is dictated by a Memorandum of Understanding between The University of Victoria and DelAgua. Raw data includes the exact date and location of delivery for every stove. For this project, I aggregate stove received in the 2014-2016 period per district, as well as the cumulative stove receipt to date.

Table 5: Summary Statistics by Treatment Group

	All Districts	Treated 2014	Treated 2016
N	30	12	8
Population 2011	8,809,616	3,458,225	2,666,079
Stoves Received as of 2017	296,427	140,136	156,291

Note: Population data from WorldPop. N = all districts including Kigali City.

4.3 Data processing

Foraging related variables include whether the respondent had foraged wood in the last 7 days, subsequent minutes spent foraging or collecting fuel over the past 7 days (see data limitations), and variables related to income generated from fuelwood sales. When narrowing the focus of this study it became clear that the wood sales variables were of limited interest. While selling firewood may be connected to stoves (lower demand) the connection to women's time use is more tenuous. They were excluded from my analysis.

The educational variables I chose to focus on were whether the respondent had ever been to school, whether the student had attended school in the last 12 months, and whether or not the respondent had missed school in the 7 days before being interviewed. The variable ”beentoschool” was consistently reported across all surveys, which made it appealing to use in this study. That being said, Rwanda's government is incredibly steadfast in its pursuit of educational goals, so the vast majority of respondents have experienced at least *some* schooling (as seen in Table 5).

The EICV included two agricultural sections for all three surveys; ”Large Scale” and ”Small Scale”. There was no quantifiable difference between the two, the survey verbiage being “Over the last 12 months, have you engaged in any larger scale agricultural production (Starting with cereals, legumes, Tubers then cash crops)?” for large scale and “Over the last 12 months, have you engaged in any piecemeal agricultural production (Tubers, fruits, vegetables and other crops produced on a small scale)?”. With an emphasis on small scale production being “bit-by-bit”, it was the agricultural dataset of interest to look at subsistence harvest, instead of the clearly cash crop focused “Large Scale” section. There was also a subsistence farming section, however questions asked were about consumption by households (”Has your household consumed any ... from your own production over the course of the last 12 months?” and ”How much ”....” did you consume since my last visit?”). The small scale farming section included consumption data as well as kilograms harvested and total value of harvest, which made it useful on multiple fronts for the variables I was interested in.

Small scale agriculture variables include whether respondents owned their own farm, the combined surface area of all agricultural plots owned by a household, and information indexed by crop. For each crop I had kilograms consumed and kilograms harvested per household over the past twelve months. In addition, I had the value of each individual crop harvested by a household if they *were* sold, not necessitating sale, and an aggregate measure for each household's total harvest of selected crops.

When it came to choosing specific crops for this study, I selected typical non-cash crops in Rwanda that are generally understood to be "gendered" (Duflo and Udry, 2004). My objective was to focus on crops that are particularly important to rural Rwandans. As seen in Table 5, the crops I chose are harvested by large percentages of households across most or all of the country. A notable exception is Maize, which I did not include in this study. Maize was split in the surveys to include both "Fresh Maize" and "Maize" (dry maize). The vast majority of maize production was dry, but EICV 3 did not include dry maize, unfortunately resulting in its exclusion from the chosen crop variables.[3]

[3] A complete list of variables with definitions can be found in the Appendix.

Table 6: Percentage of Households Producing Staple Crops by Crop Type and Province

Crop Name	South	West	North	East	Rwanda
Cereals	65.8	70.7	81.0	88.3	76.0
Maize	54.7	69.1	66.0	82.1	67.7
Paddy rice	6.8	1.1	0.1	3.9	3.2
Sorghum	23.3	3.7	30.4	26.9	20.9
Wheat	4.0	4.7	7.3	0.3	3.6
Tubers and Roots	83.7	75.4	74.7	57.0	72.1
Irish potato	11.6	17.3	25.8	11.8	15.5
Sweet potato	55.7	41.1	58.3	29.1	44.7
Taro	21.8	14.0	7.8	8.4	13.2
Yams	0.8	1.1	0.1	0.6	0.7
Cassava	64.4	42.0	21.5	45.6	45.7
Legumes and Pulses	95.3	85.8	90.2	89.5	90.3
Beans	94.0	83.0	89.9	87.5	88.6
Bush bean	67.2	25.0	17.1	83.4	53.0
Climbing bean	43.2	68.6	80.7	7.7	45.1
Pea	10.6	4.3	5.8	2.7	5.8
Soybean	24.5	11.5	2.9	7.6	12.3
Groundnut	6.5	1.0	1.4	14.0	6.3
Bananas	42.7	30.2	43.4	45.6	40.2
Cooking banana	23.0	18.1	31.0	41.3	28.2
Dessert banana	24.7	15.0	25.1	23.0	21.7
Banana beer	30.3	20.6	27.4	20.4	24.2
Vegetables	16.7	15.5	16.4	7.5	14.0
Other crops	3.6	4.4	4.3	1.5	3.3
No. of crop-producing HHs	623	522	429	613	2.188

Source: NISR, AHS 2020.

4.4 Limitations of data

The EICV collects data on 5 administrative levels (province, district, sector, cell and village). However, due to privacy concerns, NISR's publicly available EICV data restricts geographic identifiers, providing only district and province. This is likely the biggest source of measurement error in the study, as villages that never received stoves were still marked as "treated" at the district level.

Much of the EICV data was labeled and organized differently depending on the survey year. Unavailable data was entered as "NA", or "Missing", or as numerical representations of missing ("9", "999", etc.). I had to carefully screen each variable to determine whether it was a legitimate entry for certain variables. There seemed to be no discernible pattern to the frequency or usage of these placeholders, and occasionally there were inconsistencies that were severe enough that they resulted in the variables' exclusion.

Another major challenge was inconsistency in variable structure, which took several forms. A primary effect I wanted to measure was time spent foraging. Unfortunately, the way this variable was defined shifted between surveys. In EICV3 and EICV4, respondents reported "hours spent foraging for wood over the last 7 days", while in EICV5, the question changed to include "minutes spent foraging, purchasing, or gathering fuel". This change may be partially due to shifting legislation around live fuelwood harvesting. I adjusted by filtering the data to include only those who reported "firewood" or "charcoal" as their primary fuel, which restricted the data to the subset of interest, but the definition change still fundamentally altered the meaning of the variable. As this is a foundational result for this paper I still included it in the study, but imperfect nature of the variable should be acknowledged.

Missing variables across surveys also complicated the selection of outcome variables. For example, EICV4 & EICV5 included a variable "Minutes missed of school in the last 7 days," which was not available in EICV3. EICV5 included a "Type of stove" variable, detailing what brand of cookstove was in use in each household (including an option for the EcoZoom Dura stove). Unfortunately, the variable was absent in EICV3 & 4. The constantly evolving EICV structure proved to be an obstacle that significantly complicated the research process.

Crop data was another challenge. In EICV4 & EICV5, respondents reported crop production and consumption in kilograms harvested or consumed. However, EICV3 used multiple units of measurement, including kilograms, buckets, tons, Fanta bottles, milk bottles, and spatial references like "this room." To standardize these, I used the "kg per unit" conversion variable provided in the dataset. These estimations are subsequently approximations and likely imprecise. In all three surveys, respondents were able to choose the time unit to define their harvest, i.e. "In the last (Day, Month, Quarter, Year), I've harvested ... kilograms of (crop)." While I could include these as representative of some portion of consistent annual production, the seasonality of crop production made that option unsound. I restricted my analysis to annual production quantities only.

Many of the variables in my analysis are highly vulnerable to seasonality. Foraging time, school absences, and crop yields are particularly sensitive. Ideally, I would control for this by including interview month in my regressions. However, EICVs 4 & 5 included interview month while EICV3 had no interview timing information at all. The sole reason I was able to assign a year to EICV3 is because it was conducted in its entirety in 2011. The lack of seasonality controls, especially in agricultural results, was an issue that persisted throughout the study.

In addition to the construction, availability, and variability of definition in the EICV data, it should be acknowledged that social desirability bias likely played a role in some of the data reported by households. The increased stigmatization of live firewood harvesting due to growing concerns about deforestation (Times, 2025b, Times, 2025a) may have influenced respondents to under-report foraging times. Conversely, respondents may have reported more because the question in EICV5 now contained more activities (purchasing), adding an aspect of time use that was not accounted for previously. What the data showed differed for each district, but demonstrated the same general trend. Figure 4[4] shows the gradual decrease in reported minutes foraging over the course of the 3 included EICVs. Therefore, I am inclined to expect the general pressure on respondents would be to under-report. Additionally, social desirability bias may result in respondents eager to over-report school attendance and crop yields.

5 Method

5.1 Empirical framework

This paper estimates the effect of cumulative improved cookstoves per 1,000 people on multiple outcome variables using a two-way fixed effects (TWFE) difference-in-differences (DID) model. This approach accounts for time-invariant unit-specific heterogeneity and common shocks across time by including unit (district) and time (year) fixed effects. The baseline specification for individual respondents is given by:

[4]See appendix.

$$Y_{idt} = \alpha + \beta Stoves + \gamma \mathbf{X}_{it} + \delta_t + \lambda_d + \epsilon_{idt} \tag{1}$$

where Y_{idt} represents individual level outcomes, including educational expenditures, school attendance, and foraging activity and income for individual i at time t in district d. The vector $\mathbf{X}_{idt}$ controls for age, marital status, wealth quintile, household size, household head sex and education, and rurality. Categorical variables such as marital status and wealth enter the regression as sets of binary indicators. The terms δ and λ note time and unit fixed effects respectively, capturing time specific and unobservable district level heterogeneity. Standard errors are clustered at a district level.

Because small-scale agricultural data was not available at the individual level, I estimate impacts on agricultural outcomes using a household level regression. In this case, the outcome variable Y_{hdt} includes kilograms of each crop harvested and consumed, market value of all crops harvested, total value of small-scale crops, and total agricultural surface area. The control variables remain largely the same and include household characteristics such as household head demographics, household size, rural/urban residence, and household wealth quintile. Standard errors are clustered at a district level.

The treatment variable "Stoves" is defined as the cumulative number of stoves per 1,000 people in a given district, calculated using population data from WorldPop 100m resolution data. WorldPop is a spatial dataset that reports predicted population counts for small areas of the planet's surface by year. The predictions are based on settlement cover patterns and census data to create gridded population estimates. Due to the difficulty of finding yearly district level population data, WorldPop offered a reasonably accurate estimate to use (Bai et al., 2018). I have reason to suspect that these datasets are measured with error. Using settlement cover as a proxy for population often misses or understates the true population, especially in high-density and low-income areas (Thomson et al., 2022). With the exclusion of Kigali City, my data is overwhelmingly rural, possibly mitigating the issue. The other method to get population estimates would be to predict my own growth paths using census data; however, reliably predicting district-level annual population changes is a demographic application beyond the scope of this study.

5.2 Addressing Concerns with TWFE DID

Recent econometric literature has raised concerns about two-way fixed effects estimators in staggered DID settings, particularly with regard to biased weighting of treatment effects and the potential for negative weights (Goodman-Bacon, 2021). These issues arise primarily when treatment timing varies across units and the pool of never-treated observations is not particularly large. In such a case, groups that were already treated inadvertently serve as the counterfactual for groups that were later treated and groups that were later treated. Economists have adopted new DID estimators that avoid this resulting bias (for example Callaway and Sant'Anna, 2021). But most of these new tools require balanced panel data: my data is imbalanced and repeated cross-sectional.

In this study, I mitigate bias concerns within a TWFE DID framework by defining two treatment groups: those living in districts first treated in 2014 and those in districts first treated in 2016. In the regression for the 2014 (2016) treatment group, I remove all districts that first received stoves in 2016 (2014). This ensures that the already treated units cannot act as controls. Given my data structure, I retain a decent sample of households "never treated" 2014-2017. This is largely due to the fact that the vast majority of stoves were distributed in years beyond my study period (2020 and after), so I have a large portion of districts that act as untreated in the years I observe EICV data (30%). This definition of treatment groups is also important due to difference in treatments, namely the inclusion of water filters in the 2014 distribution wave.

In my primary estimator for the average treatment effect, I assume constant treatment effects over time within group. This assumption, if valid, preserves the consistency of TWFE DiD estimates. Because we observe the 2014 treatment group more than one year post-treatment, and to relax the assumption of homogeneous treatment effects within group, I conduct event studies that modify Equation 1 and estimate the average treatment effect for each treatment group and within each available relative time period.[5]. I specify these event studies using a binary treatment assignment, and the outcomes can be understood as a robustness check on my main results (under a different treatment definition), as well as a means of examining any signs of outcomes varying by relative time post-treatment.

My event studies also provide pre-trend analyses that help me examine the plausibility of the parallel trends assumption holding for my main specifications. I consider an event study as offering good evidence of the parallel trends assumption holding if coefficient estimates in negative relative time years (pre-treatment) are close to zero and statistically null. When these estimates are null, but measured with large

[5]For the 2014 treatment group, 2013 serves as the placebo "pre" year, and for the 2016 treatment group, 2014 is the placebo "pre" year

standard errors, I consider this evidence as weaker, but suggestive.[6].

6 Results and Discussion

The results as a whole are not immediately impressive, but do offer some possible insight into possible routes to pursue in further research. The vast majority of my results are statistically insignificant with large standard errors. The conclusions drawn attempt to make sense of the observed patterns and extrapolate potential implications (with caution).

6.1 Individual Results

The results do not clearly identify an effect of cookstoves on time spent foraging. While none of the results for minutes foraging are significant, the primarily negative signs are somewhat compelling. Taking into consideration the magnitude, seconds off of weekly minutes spent foraging is not a large effect, however the mostly consistent negative effects could signal a pattern. With lower level administrative data there may be clearer information as to the actual magnitude of these effects. This is especially true for the 2014 roll-out, as fewer stoves went to fewer villages, which in my estimation led to many untreated villages being problematically designated as ”treated” on a district level.

The event studies for minutes spent foraging do not violate the parallel trends assumption, but some of the point estimates (women in the 2014 treatment group, boys in the 2016 treatment group) are far from zero, and the standard errors are

[6]All event studies can be found in the appendix

large. While I cannot conclusively say the the distribution of cookstoves decreases foraging time, I find these results (cautiously) encouraging.

Table 7: OLS results for minutes foraging by treatment group, gender, and age

	2014 Treatment Group			2016 Treatment Group		
	Boys	Girls	Women	Boys	Girls	Women
Variables						
Cum. stoves per 1,000	0.1152	-0.6076	-0.2376	-0.3204	-0.0223	-0.1372
	(0.3003)	(0.4205)	(0.1808)	(0.2949)	(0.3516)	(0.2209)
Fixed-effects						
DISTRICT	Yes	Yes	Yes	Yes	Yes	Yes
YEAR	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics						
Observations	4,688	4,874	34,384	3,806	3,891	27,736
R^2	0.08238	0.09356	0.06325	0.06765	0.10607	0.06185

Notes: Clustered (DISTRICT) standard errors in parentheses. Signif. Codes: ***: 0.01, **: 0.05, *: 0.1. Each cell in table reports the coefficient estimate of a separate regression. Estimation for boys and girls restricted to children of school attending age (7-14). Women are age 15-64. Treatment groups indicate the sub-sample used in the regression: Columns 1-3 are based on a sample of those first treated in 2014 and the never-treated 2014-2017, and the sample Columns 4-6 consists of those first treated in 2016 and the never-treated 2014-2017

Our missed school results show very little, and are essentially negligible. I believe this is due to the use of a sub-par variable, which as discussed earlier was the only usable option. Rwanda has gone to great lengths to make primary education accessible to the general population. To infer that the distribution of stoves increases attendance due to the Tubeho Nexa program specifically would be helped with finer data.

The event study for school attendance again does not violate the parallel trends assumption. However, large standard errors are persistent and point estimates are occasionally far from zero.

Table 8: OLS results for missing school in previous week by treatment group and gender

	2014 Treatment Group		2016 Treatment Group	
	Boys	Girls	Boys	Girls
Variables				
Cum. stoves per 1,000	0.0006	-0.0002	0.0006	0.0006
	(0.0012)	(0.0011)	(0.0014)	(0.0017)
Fixed-effects				
DISTRICT	Yes	Yes	Yes	Yes
YEAR	Yes	Yes	Yes	Yes
Fit statistics				
Observations	4,356	4,660	3,473	3,678
R^2	0.06548	0.07851	0.07581	0.07554

Notes: Clustered (DISTRICT) standard errors in parentheses. Signif. Codes: ***: 0.01, **: 0.05, *: 0.1. Each cell in table reports the coefficient estimate of a separate regression. Estimation for boys and girls restricted to children of school attending age (7-14). Treatment groups indicate the sub-sample used in the regression: Columns 1-2 are based on a sample of those first treated in 2014 and the never-treated 2014-2017, and Columns 3-4 consist of those first treated in 2016 and the never-treated 2014-2017.

6.2 Household/Agriculture Results

The results from household level agricultural regressions are similar to the education and time-use results. There are few significant results, most likely a result of the coarse treatment definition. Agricultural results are also further removed from the initial assumption - that stoves may have an impact on time spent foraging. To extrapolate that the increase in free time could affect subsistence farming is a fair assumption to make based on previous research, but to nail down how exactly that effect works in harvest, consumption, etc. is a more difficult exercise.

Table 9: OLS results for surface area & small scale harvest total value by treatment group

	Surface Area		Small Scale Total Value	
	2014	2016	2014	2016
Cumulative Stoves	-0.102	-0.307*	167.513	229.320
	(0.095)	(0.135)	(182.918)	(222.313)
Observations	25,828	21,410	20,371	16,313
R-squared	0.037	0.072	0.037	0.072
FE: DISTRICT	Yes	Yes	Yes	Yes
FE: YEAR	Yes	Yes	Yes	Yes

Note: Clustered (DISTRICT) standard errors in parentheses. Signif. Codes: ***: 0.01, **: 0.05, *: 0.1. Each cell in table reports the coefficient estimate of a separate regression. 2014 columns are based on a sample of those first treated in 2014 and the never-treated 2014-2017, and the sample 2016 columns consists of those first treated in 2016 and the never-treated 2014-2017.

The results for small scale harvest total value are insignificant but positive, which I believe is a promising signal of possible increased small scale production. The negative results for surface area are harder to parse. In the survey, the language is plots that have been "owned," "cultivated," or "exploited" by any household member. The implication that stove recipients are ceding or selling cultivated plots is logically harder to contend with. My incoming assumption was that with increased free time women would cultivate more, possibly necessitating more plots for households. A feasible explanation is the offloading of plots that are used for fuel wood harvest, as many plots include trees or shrubbery. If the primary use for a plot is wood harvest, less fuel wood demand may cause those plots to become obsolete. Additionally, largely because the definition of the surface area variable was so vague, this estimate could include the effect on larger eucalyptus plots designed specifically for fuel wood production. There could also be some sort of intensification process taking place, where farmers produce more with less land.

The event studies for small scale total value and surface area sum do not violate the parallel trends assumption. The surface area event study is actually perhaps the most compelling evidence in favor of parallel trends holding. The small scale harvest study does however include large standard errors.

Table 10: OLS results for crops harvested (KG)

	Banana		Sweet Potato		Beans		Cassava	
Treated:	2014	2016	2014	2016	2014	2016	2014	2016
Cumulative Stoves	0.147	-1.827	0.621	1.434	-0.159*	0.090	1.647*	1.014
	(0.152)	(1.431)	(0.719)	(1.506)	(0.073)	(0.151)	(0.752)	(1.421)
Observations	20,371	16,313	20,371	16,313	20,371	16,313	20,371	16,313
R-squared	0.073	0.142	0.226	0.169	0.078	0.076	0.141	0.164
FE: DISTRICT	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FE: YEAR	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Clustered (DISTRICT) standard errors in parentheses. Signif. Codes: ***: 0.01, **: 0.05, *: 0.1. Each cell in table reports the coefficient estimate of a separate regression. 2014 columns are based on a sample of those first treated in 2014 and the never-treated 2014-2017, and the sample 2016 columns consists of those first treated in 2016 and the never-treated 2014-2017.

The harvest/value results are consistent with each other, which lends confidence in the data. Interestingly, there are both negative and positive effects (though most are insignificant). The 2014 cassava harvest result being both positive and (mildly) significant is encouraging. This could be a result of increased free time, and while 2kg is not a massive increase, it is not inconsequential. On the other hand, the negative result for bean harvest is so small that I believe the result is inconclusive. I am also hesitant to consider bean results as reliable due to the issues I had with the variable during data processing. The rest of the crop results aren't especially compelling.

The crop harvest event studies do not violate the parallel trends assumption but include large standard errors and point estimates considerable distances away from zero.

Table 11: OLS results for reported crop value (RWF)

	Banana		Sweet Potato		Beans		Cassava	
	2014	2016	2014	2016	2014	2016	2014	2016
Cumulative Stoves	18.280	-52.039	13.360	120.014	-39.693*	27.173	176.982+	96.248
	(24.140)	(84.772)	(90.097)	(91.964)	(18.551)	(33.304)	(88.903)	(183.092)
Fit statistics								
Observations	20,371	16,313	20,371	16,313	20,371	16,313	20,371	16,313
R-squared	0.088	0.154	0.179	0.125	0.098	0.102	0.130	0.147
Fixed Effects								
FE: DISTRICT	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FE: YEAR	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Clustered (DISTRICT) standard errors in parentheses. Signif. Codes: ***: 0.01, **: 0.05, *: 0.1. Each cell in table reports the coefficient estimate of a separate regression. 2014 columns are based on a sample of those first treated in 2014 and the never-treated 2014-2017, and the sample 2016 columns consists of those first treated in 2016 and the never-treated 2014-2017.

7 Summary and Concluding Remarks

Although this study did not find significant effects from improved cookstove distribution in Rwandan communities, there are several important points to be made about the value it holds. First, the study findings provide motivation for additional work using more precise administrative information, in order to reduce measurement error in treatment assignment. If sub-district (cell, village) information had been accessible for my work, it may have provided a clearer picture of what relationships exist between cookstoves and recipient behavior. Second, this paper and my work on the data can provide valuable insight for DelAgua or future researchers into research possibilities with the EICV data that currently exists.

An issue for extension work is the lack of EICV data for the years during/post the most intensive stove roll-outs. Because the 2020 EICV was postponed due to COVID, there is a major gap in available data. The almost decade long interlude between EICV5 and EICV6 may prove prohibitive for work on the higher intensity stove distribution periods. If anything, this is even more reason for NISR to make lower level administrative level data for the EICVs we do have available for use.

Although the EICV data is often limiting, there are quite a few untapped opportunities that I believe could be meaningful extensions of this work that are possible within the surveys. The EICV surveys contain large amounts of data looking at everyday expenditures of Rwandans, including medical supplies, clothing and food. Additionally there is data on income, income assistance, and transfers. There is consistent data for specific education variables regarding cognition and academic ability that could prove interesting to compare with stove data and expand on growing literature about the effects of household air pollution on school performance. While data cleaning and organization inside of the EICVs is relatively time-intensive, a deep dive into some of the other sections of these surveys may prove beneficial to our understanding of the impacts of DelAgua stoves beyond what I attempted to observe in this paper.

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8 Appendix

Figure 4: Aggregate Minutes Foraging by Sex, District, and Survey

8.1 Event Studies

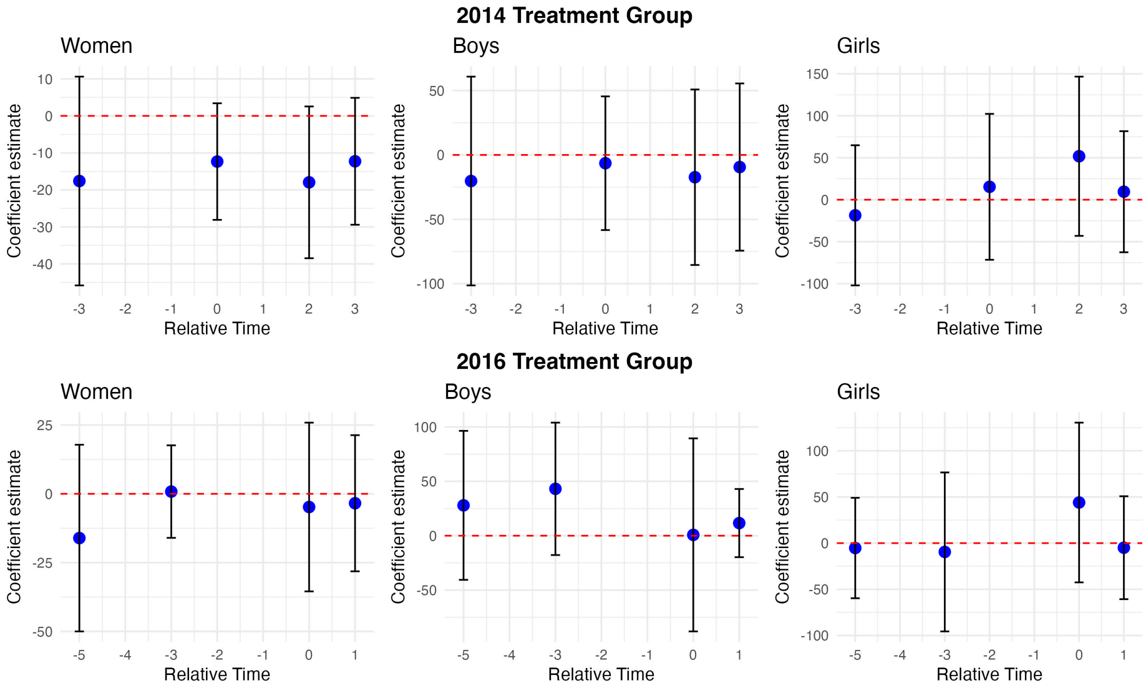

Figure 5: Event Study: Minutes Foraging

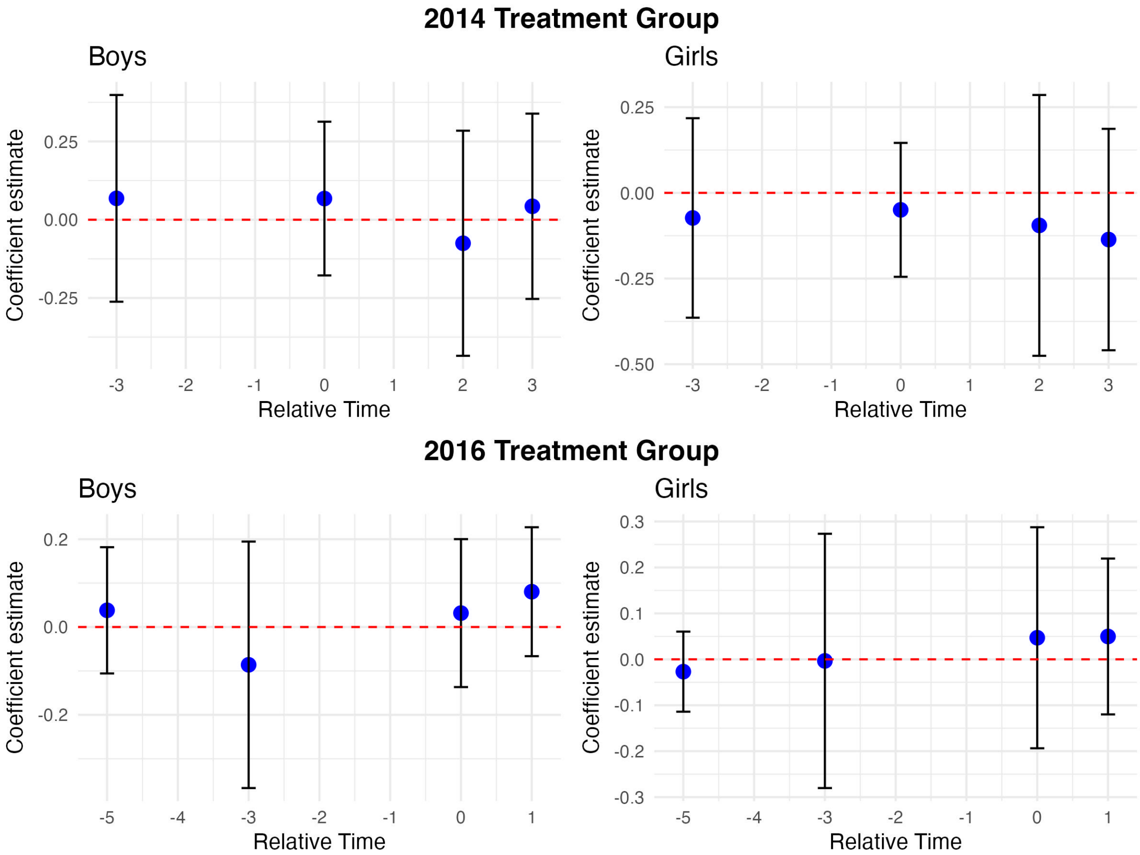

Figure 6: Event Study: Missed School

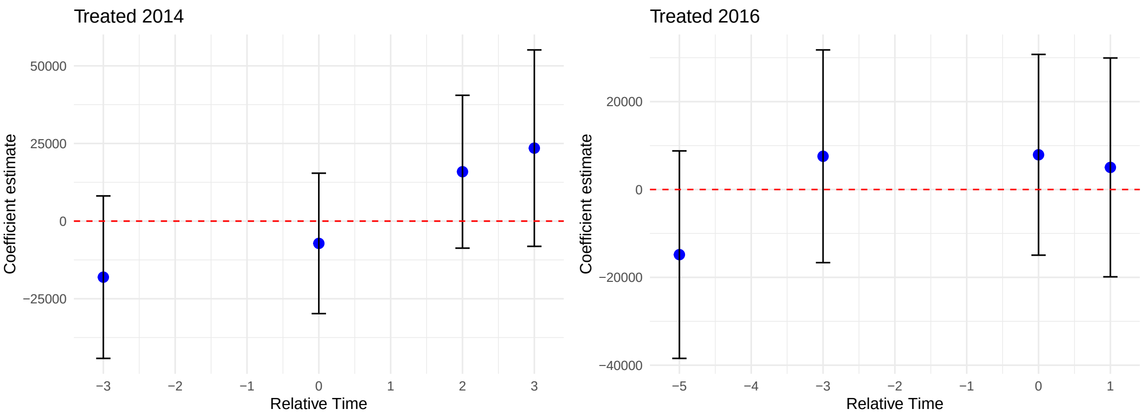

Figure 7: Event Study: Small Scale Total Value

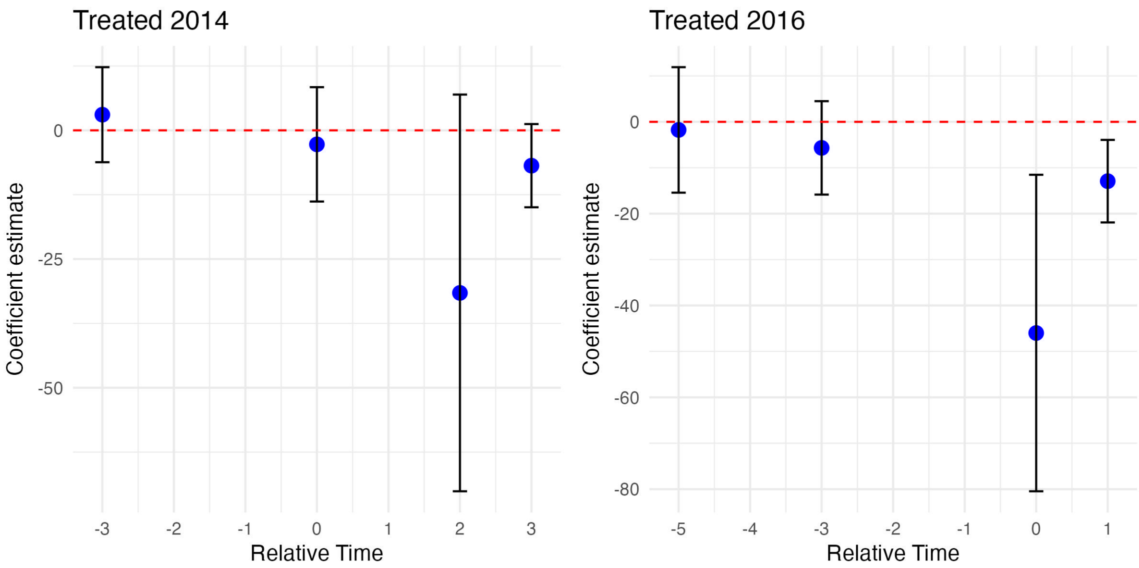

Figure 8: Event Study: Surface Area Sum

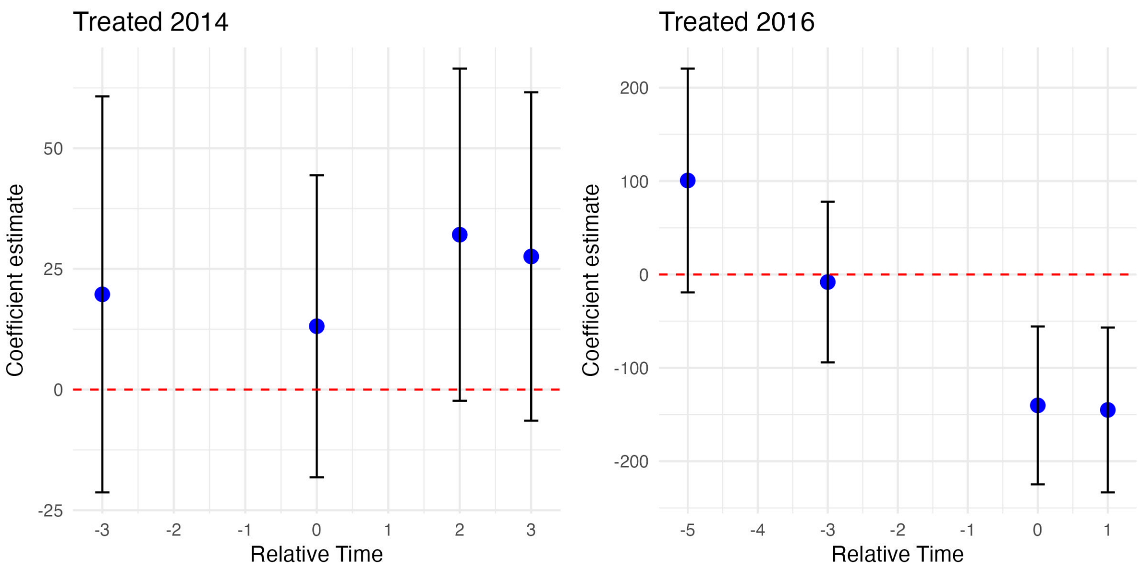

Figure 9: Event Study: Banana Harvest

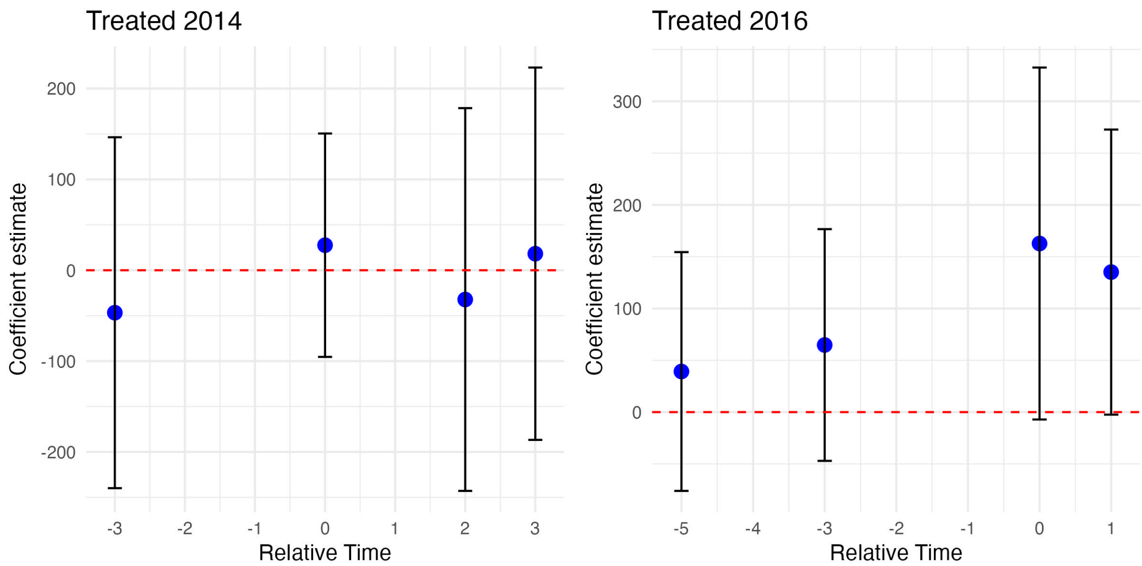

Figure 10: Event Study: Sweet Potato Harvest

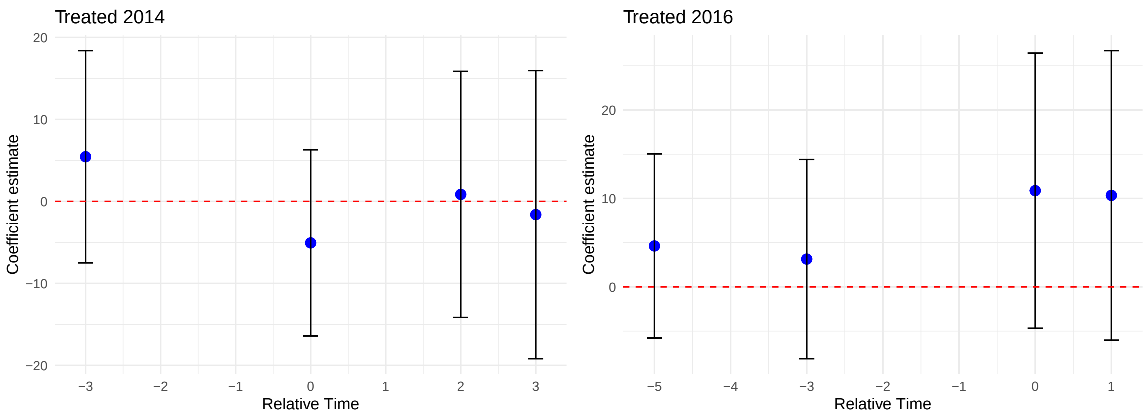

Figure 11: Event Study: Bean Harvest

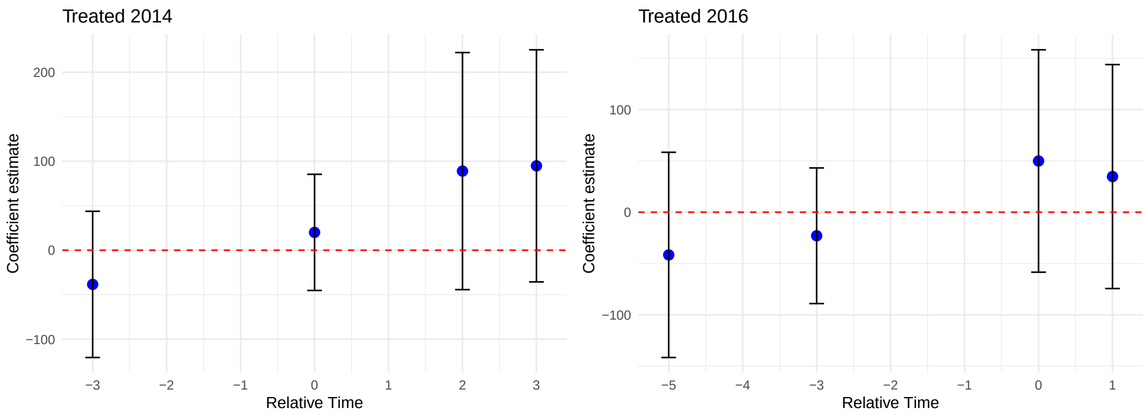

Figure 12: Event Study: Cassava Harvest

Variable	Definition and Construction
sstotalvalue	Total value of the 4 included small-scale crops in the survey (summed for each household), if all of each crop harvested over the previous 12 months had been sold (RWF).
kgcassavaharvested	Kilograms of cassava harvested by the household over the previous 12 months.
kgcassavaconsumed	Kilograms of cassava consumed by each household over the previous week.
cassavavalue	Total value of all cassava harvested by each household over the previous 12 months, if sold (RWF).
kgbeansharvested	Kilograms of beans harvested by the household over the previous 12 months.
kgbeansconsumed	Kilograms of beans consumed by each household over the previous week.
beanvalue	Total value of all beans harvested by each household over the previous 12 months, if sold (RWF).
kgsweetpotatoharvested	Kilograms of sweet potato harvested by the household over the previous 12 months.
kgsweetpotatoconsumed	Kilograms of sweet potato consumed by each household over the previous week.
sweetpotatovalue	Total value of all sweet potato harvested by each household (RWF).
kgbananaharvested	Kilograms of banana harvested by the household over the previous 12 months.
kgbananaconsumed	Kilograms of banana consumed by each household over the previous week.
bananavalue	Total value of all banana harvested by each household (RWF).
surfaceareasum	Summed surface area of first 25 plots of land per household.
minutesforaging	Minutes spent foraging for firewood over the past 7 days, changed in EICV 5 to ”minutes spent foraging, purchasing, or gathering fuel.”
stovetotal	Total stoves in each district at that point in time.
beentoschool	Has the respondent been to school, collected at an individual level (Y/N).
totalschexpend	Total school expenditures for each individual (summed for households).
missedsch7daysyn	Has the respondent missed school in the last 7 days, collected at an individual level (Y/N).
foragewood7days	Has the respondent gone foraging for firewood in the last 7 days, collected at an individual level (Y/N).
ownfarm	Does the respondent own their own farm?
incomereceievedfirewood	Has the respondent gone foraging for firewood in the last 7 days, collected at an individual level (Y/N).
amountsold4wksfirewood	Amount of firewood sold by the household in the last 4 weeks (RWF).
amountsold12mosfirewood	Amount of firewood sold by the household in the last 12 months (RWF).

Table 12: Variable Information (RWF: Rwandan Franc)