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Abstract

Achieving gender equality and women empowerment is an important part of development policy priority which is boldly highlighted in the Millenium Development Goals. It is also indicated that modern agriculture technologies and improved practices are crucial factors for increasing livelihood in rural economies. However, the measurements of women's empowerment are complex and multidimensional by their nature and have not been brought to the agenda in the context of specific impact evaluation of an intervention, especially in the agricultural sector. Thus, the study aims to evaluate the impact pathways of jointly adoption of fertilizers and extension services on women's empowerment in rural Ethiopia. The study is based on panel data obtained from the Ethiopian Socioeconomic Survey, waves 1-3. For estimation of the impact pathways of chemical fertilizers per plot with extension services (CFEXT), the study has employed fixed effect, correlated random effect and propensity score matching techniques. The so called 'Abbreviated Women's Empowerment in Agriculture Index, A-WEAI' and its two components, empowerment in five domain and gender parity index were also applied to measure the extent of women's empowerment. The results show that CFEXT significantly influences women's empowerment and its two components. The impact pathway analysis shows that adoption significantly influences women's empowerment through the income, food consumption expenditures and non-food expenditure pathways, and non-food expenditure being the most powerful channel. The study suggests that there is a need to further expand the application of fertilizers with appropriate extension service, which also equally benefit female farmers in a rural community.

Keywords: Modern Agricultural Technology, Women Economic Empowerment, Ethiopia

1. Introduction

1.1 Background of the Study

In gender studies, empowerment is set to represent a wide range of concepts and to describe multiple ranges of outcomes. Specific to the agricultural sector, it generally stands for one's ability for decision making on agriculture related activities as well as one's access to the material and resource ownership that are needed for the decision required (Alkire et al., 2013).

Increasing concerns reveal that women's empowerment is progressively being considered as one of the main components of poverty reduction strategies. Recently different governments and non-government agencies are increasingly focusing on empowering women as a means of promoting growth, reducing poverty and inequity, promoting better governance and reducing gender gap (King and Mason, 2001; World Bank, 2012). The inclusion of Women's empowerment in the third Millennium Development Goals (MDG) of promoting gender equality and empowering women and in the Sustainable Development Goals (SDGs): one of the 17 SDG#5, in 'achieving gender equality and empowering all women and girls' has significantly attracted the attention of many researchers and policy makers (Alkire et al., 2013; United Nations, 2015).

Women's role in agriculture is significantly high and they are among the key actors in food systems (Njuki et al., 2022). Women produce over 50 % of the world's food (FAO, 2011a) and they cover about 43 % of the global labor force in agricultural sector (Doss, 2014). As a major policy priority, supporting and empowering women leads to an increase in agricultural production (Abokyi et al., 2023; FAO, 2011a; Njuki et al., 2022).

Several evidences also reveal that women invest as much as 10 times more of their earnings than men do on their family development including in child health, education, and nutrition (Duflo, 2012; Skoufias 2005; Quisumbing 2003; Quisumbing and Hallman 2003; Quisumbing and Maluccio, 2000, 2003;). Thus, one may argue that women's empowerment can directly impact productivity in the agricultural sector and the levels of household food security (Harper et al., 2013; Njuki et al., 2022; Sraboni et al., 2014).

Increasing food production for local consumption and/or local markets through women's empowerment in the agriculture sector is one of the right ways of reducing vulnerability to poverty and food insecurity (Baiphethi and Jacobs, 2009) since women play greater roles in achieving all pillars of food security: food availability, access, utilization, and stability in their households (Bob, 2002; Galie, 2013). The literature also documents that women's empowerment is one of the main tools for reducing poverty in developing regions (Nadim and Nurlukman, 2017). Empowering women and enhancing women's status can play a great role in the achievement of several social development agenda (Gupta and Yesudian, 2006). It is also argued that empowering women and achieving gender equality in food systems may leads to greater food security and better nutritional attainments (Njuki et al., 2022). Upgrading the role of women in agriculture could boost agricultural outputs, reduce food insecurity and narrow gender inequality gaps (Giroud and Huaman, 2019).

Though women play significant role in the agricultural sector, still there exists a considerable gender inequality. Women who live in poor households and those who are more vulnerable to food-insecurity are more likely to get involved in the agriculture sector particularly as wage laborers, for the reason that women's earnings are important for families' subsistence living (Quisumbing 2003; Jaleta et al., 2023; Murray et al., 2016; Sraboni et al., 2014).

Women in the rural area act as producers of food, income earners and caretakers of their household. Several evidences indicate that investments in women's empowerment related projects contribute to improve broader development outcomes including health, education, poverty reduction, reducing vulnerability to food insecurity and economic growth (Mayoux, 2006; Quisumbing and Maluccio, 2000; Quisumbing 2003). In this regard, evidences indicate that empowering women in agriculture sector can have sustainable ways of feeding themselves and leads to greater income improvement from surplus produced, which again make them less vulnerable to both poverty and food insecurity.

Evidences also reveal that the concept of women's empowerment is relatively new, and its complex and multidimensional nature makes its measurement more difficult (Alkire et al., 2013; Bryan and Garner, 2020; Oxfam, 2016). Even though women's empowerment is a multidimensional concept, the highest focus is given to economic empowerment (Bayissa et al., 2018; Narayan, 2005). Even in certain circumstances, the nature, form (characteristics), and extent of gender gap and means of empowering women vary across countries, communities, and regions. Empowerment, is a complex social construct comprised of different dimensions (Kabeer 2001). Kabeer explains that empowerment represents the ability to exercise choice, voice, and influence. This concept has traditionally been investigated through proxy indirect measures such as employment and education, however, there have been increased efforts to directly measure empowerment through decision-making and control indicators (Malhotra and Schuler 2005).

In the past few decades, there exists a growing interest in the agricultural sector as an engine of growth and development, and parallelly a greater recognition is being given to the important roles of women in agricultural sector (Alkire et al., 2013; FAO, 2011a). Women in the rural society are often responsible for managing complex household activities and pursue multiple livelihood strategies. These bulk of activities include producing agricultural crops, tending animals, preparing food, working for wages in agricultural or other rural enterprises, collecting fuel and water, engaging in trade and marketing, caring for family members and maintaining their homes.

However, the productivity of women smallholders is constrained by lack of access to labor-saving technologies and deficient farm related practices (Murray et al., 2016). At the same times, women's work burden is also a constraint in responding to varieties of farm or non-farm related shocks, forcing them to prefer agricultural practices and technologies that reduce their labor burden (Khatri-Chhetri et al., 2020; Murray et al., 2016). Evidences also reveal that, compared to men, women farmers are less connected to experts, and farmer groups that facilitate access to improved agricultural technologies and practices (Jaleta et al., 2023; Otieno et al., 2021). It was also noted that in Ethiopian there are quite limited studies on the subject under study with coverage and methodology limitation. No study so far has assessed the impact pathways from agricultural technologies to women's empowerment in the country. In general, existing literature on the subject in Ethiopia is quite limited.

Given the above facts and multidimensional nature of women's empowerment, there exists a gap in understanding and measuring of empowerment; and at the same times the possible pathways improved agricultural technologies puts on empowerment in general.

1.2 Statement of the Problem

Since recently the status and contribution of women in agriculture is receiving attention in literature even though a research gap exists regarding the specific impact of agriculture related technologies/ improved practices on empowering women and the possible impact pathways. Large body of empirical literature has documented that adopting agricultural technologies improves social welfare. At the same times, a growing body of research aims to understanding the potential association between women's empowerment and dietary diversity and child nutrition (see Kassie et al., 2020; Bonis-Profumo et al., 2021; Gupta et al., 2019a, b; Malapit and Quisumbing, 2015; Heckert e al., 2019).

Few recent studies have also tried to explore impacts of different agriculture-related technologies on women's empowerments. These include the works of Altenbuchner et al. (2017) who tried to examine the effects of organic farming on the empowerment of women in India; and a study by Ragasa et al. (2020) which assesses the effect of interactive radio programming on women's empowerment and agricultural development in Malawi. However, none of these studies have shown the impact pathways from the stated agriculture technology to women's empowerment.

Given the sparse evidence available on this topic, research identifying the specific impact pathways through which improved agriculture technologies/practices[4] affect women's empowerment is not well documented. The single notable exception in the literature is the study by Bryan and Garner (2022) that tried to understand the pathways from small-scale irrigation to women's empowerment in Northern Ghana, however, it employed qualitative data analysis which failed to reveal the causal relationship.

Recently, a study by Quisumbing et al. (2022) have tried to investigate impacts of joint United Nations (UN) owned programs on women's empowerment. The study has compared the empowerment impacts of the UN Joint Program for Rural Women's Economic Empowerment in four countries namely, Ethiopia, Niger, Nepal, and Kyrgyzstan). Yet, none of them have assessed the impact pathways from those programs to women's empowerment.

A more closer look at the studies conducted in Ethiopian context also reveal as there is a coverage and methodologies gap in measuring impacts of agricultural technologies on women. Apart from quite limited studies in the country (for instance Belete and Melak, 2020 that evaluated the impact of small-scale irrigation technology on women empowerment in Ethiopia), the existing studies even fail to show the impact pathways from the stated agriculture technology to women's empowerment. Further, a study by Hillesland et al. (2022) has investigated the effectiveness of a joint UN program aimed at empowering rural women through women-run, rural savings and credit cooperatives in Ethiopia, but the study didn't assess the impact pathways from those programs to women's empowerment. In

[4] Improved (modern) agriculture technologies and improved practices are interchangeably used in the document simply to imply the application or use of innovative agricultural packages.

general, existing literature on the subject in Ethiopia is not sufficient to draw strong inferences on the subject matter.

Thus, it is possible to claim that there are gaps in literature which explores the possible impact pathways through which improved agriculture practices affect women's empowerment, and which dimensions of women's empowerment in agriculture drive the process of empowerment due to the adoption of improved agricultural technologies. In addition to these facts, in the case of Ethiopia no previous study has identified how the Five Domains of Empowerment (5DE) and Gender Parity Index (GPI) vary cross the different regions of the country. The study also tries to assess the specific impact of the stated agriculture related technologies on men's and women's empowerment status and how it affects gender differently. Evidences show that technology choice in agriculture is a good way for examining the structure of choice as a precondition for empowerment (Thiele et al., 2021), and the gender of the farmer household's or community-level gender affect the choice of a technology to be adopted (Ragasa 2012). In addition to this, agricultural interventions in general have gendered impacts and new technologies frequently change the gendered division of labor as well as the distribution of resources within the household (Meinzen-Dick et al., 2011).

Thus, to fill these research gaps, there is a clear need to conduct study that focuses on the adoption-empowerment linkages and the possible impact pathways. This new methodology hopefully helps researchers to promote further development of impact evaluation settings for studying women's empowerment in the agriculture sector.

1.3 Objectives of the Study

1.3.1 General Objectives

The main objective of the study is to identify the impact pathways of improved agricultural technology (Chemical Fertilizers per plot with Extension Services, hereafter CFEXT) adoption on women's empowerment in rural Ethiopia.

1.3.2 Specific Objectives

Specifically, the study tries to address issues such as:

- Identifying the dimensions and indicators of women's empowerment that are most affected by the adoption of the technology under study.

- To investigate the variation in the Five Domains of Empowerment and Gender Parity Index cross the different regions of the country.
- Identify the extent of impacts of the agriculture technology on the dimensions of women's empowerment.
- To explore the gender-differentiated impacts of CFEXT adoption in the country.

1.4 Scope of the Study

This analysis is based on panel data obtained from the Ethiopia Socioeconomic Survey (ESS)-Waves 1-3. Conceptually, the study is delimited to the relationship between agricultural technologies and women's empowerment while geospatially it covers only rural parts of the country. The sample is restricted to rural households to ensure that women's Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) indicators among urban households that are not engaged in agricultural production and not to misinterpret as low empowerment achievements.

1.5 Significance of the Study

It is a mere fact that, this is the first application of an A-WEAI tool in Ethiopian case, serving as a benchmark to examine the relationship between improved agricultural technologies and women's empowerment. As the concept of women's empowerment is a relatively new to the agriculture sector, it highlights some potential areas that need important policy interventions to enable farm households to exploit the full benefits of improved agricultural technologies.

2. Literature Review

2.1 A Brief Overview of the Women's Empowerment

The issue of women's empowerment is still an on-going and growing agenda. As Kabeer (2017) states "there are two broad ways in which is possible to conceptualize women's empowerment. It is possible to evaluate changes in women's lives from their own perspectives and priorities. Or it is also possible to use externally determined criteria based on a theoretical understanding of how patriarchal relations operate in particular contexts (Kabeer, 2017, p.2)".

The very notion and concept of empowerment is related to issues like agency, autonomy, self-direction, self-determination, liberation, participation, mobilization and self-confidence (Narayan, 2005; Ibrahim and Alkire, 2007). There exist large growing documentation and literature on the concepts and measurements of empowerment (see Kabeer 1999; Kabeer 2001; Narayan 2005; Alsop et al., 2006; Alsop and Heinsohn 2005); and most of these recent studies attempt to develop multiple indicators as empowerment is a multidimensional issue and complex process by its very nature that can be conceived and interpreted differently by different people (see for example Malhotra et al., 2002; Mosedale, 2005).

There are many different definitions of empowerment, but majority of the literature emphasize on agency and gaining the ability to make meaningful choices (Kabeer 2001). Many of the definitions are draw on the concept of an agent, an issue popularized by Sen (1989). Kabeer's study of "resources, agency, and achievements framework also provide a practical intuition for measuring empowerment, which involves three interrelated dimensions; namely resources (pre-conditions), agency (process) and achievements (outcomes)" (Kabeer 1999, p.437) and in this regard Kabeer conceived empowerment as a process that enables individuals/groups to exercise range of available choice.

Reflecting the multiple experiences and views of empowerment, there are numerous definitions of empowerment in the literature (see Ibrahim and Alkire 2007, p.380-82 for a different review of related works on empowerment). In the study of empowerment literature three definitions that are commonly cited are found in Kabeer (2001), Alsop et al. (2006) and Narayan (2002).

Kabeer (2001) defines empowerment as "the process by which people expand their ability to make strategic life choices, particularly in contexts in which this ability had been denied to them". Alsop et al. (2006, p.10) describes empowerment as "a groups or individual's capacity to make effective choices, that is, to make choices and then to transform those choices into desired actions and outcomes." Two specific components are contained in the definition, the one that is related to Sen's concept of agency (the ability to act on behalf of what people value and have reason to value it or make purposeful choices) and the part related to the institutional environment, which offers people the ability to exert agency fruitfully or in which actors operate that influence their ability to transform agency into action (Alkire 2008; Ibrahim and Alkire 2007). The second component focus on the opportunity structure that provides people what might be considered preconditions for effective achievements of agency. However, these are not mutually exclusive; such that the shift is one of focus, not the only factor. It is true that the process of women empowerment is incomplete unless it attends to people's abilities to act, the institutional structure, and the various non-institutional changes that are instrumental to increased agency.

Narayan (2002) defines empowerment as "the expansion of assets and capabilities of poor people to participate in, negotiate with, influence, control, and hold accountable institutions that affect their lives (Narayan, 2002, p.14)". Here this definition focuses on four main elements of empowerment: access to information, inclusion and participation, accountability and local organizational capacity. A focus on individual choice can limit the definition of empowerment, especially in cultural contexts where community and mutuality are valued. In their definition, both Kabeer and Alsop also include agency and capacity - the ability to act on one's choices. In comparison, Narayan's definition is broader than what is presented by Alsop such that it includes the interaction between people and institutions.

When dealing with the concept of women's empowerment, it will be essential to differentiate two aspects. First, empowerment as a field of operation, its dimensions, its interlinkages, as well as its inter-sectional nature with other fields of power relations, such as those of race/ethnicity and class (as empowerment is a multidimensional phenomenon). Second, women's empowerment is a process in which the following elements will be considered: awareness/ consciousness, choice/alternatives, resources, voice, agency and participation. The second dimension of women's empowerment is connected to enhancing women's capability to make choices over the areas in their lives that matter to them, both the 'strategic life choices' that Kabeer (1999; 2001) discusses and to choices related to daily life.

2.2 Theoretical Review

Evidences indicate that 'how technology adoption influences social well-being depends on varieties of factors, such as nature of the technology (for instance., labor-saving vs. labor-increasing), existing gender norms and values (for instance., gender division of labor), and the relative bargaining position of household members (Diiro et al., 2021). Some technologies (for example push pull technology), as described in the above study, is expected to increase labor for harvesting, as they involve harvesting many crops per season.

The process of adoption and diffusion of new innovative strategies and technologies in agriculture at the farm level is generally explained through various sets of theories. In this regards, Rogers (2003) explains that the first theories consider the characteristics (comparative advantage and trialability) of innovations in explaining the adoption and diffusion process. The pertinent factors in these theories explain that the adoption and diffusion process are learning and initial investment cost, and extra inputs are required to adopt innovations (Senyolo et al., 2018). Second, researchers use theories like the theory of planned behavior (Ajzen, 1985) to link the intentions and behavior of individuals to the adoption of innovations (Ajzen, 2002).

The expected utility of adopting an innovation is the third theories that takes into account also for different resource constraints (Dorfman, 1996). According to Hess et al. (2018) these adoption and diffusion theories do not consider the cognitive traits of farmers that may obstruct the adoption process. Comparative to the above-discussed theories, it is possible to assume women farmers as utility maximizers and active decision-makers where they face outcomes that are uncertain in the agriculture activities (Rahm and Huffman, 1984).

Actually, it is evidenced that enormous portion of the literature demonstrates that both utility maximization theory and theory of planned behavior are the two main types of models' utmost regularly used to analyze farmers' preference to adopt different technologies and improved practices (Rosário et al., 2022). More specifically, the utility maximization theory assumes that farmers make rational choices to maximize their wellbeing based on resource constraints (Edwards-Jones, 2006; Tey and Brindal, 2012). Apart from that, it is an economic theory relying on the logic that farmers can an agricultural technology targeting the expected utility maximization motive by comparing based on two conditions: expected utility from adopting the innovation and from not adopting it. The decision to adopt an innovation only occurs if the net expected utility exceeds zero (Feder et al., 1985; Jara-Rojas et al., 2012).

Thus, our model will base on this expected utility theory which better describes the behavior of women farmers. Women farmers need innovative behavior and decision-making power to adapt to changing circumstances, including climate change (Shahbaz et al., 2022) where decision-making is one of the most important components of a farm manager's responsibilities.

2.3 Empirical Review

Existing evidences reveal that very little is known about the association between women's empowerment and impacts of improved agricultural technology adoption in rural society. Even some authors argue that existing results show that impact of diverse agricultural technologies on women's empowerment are mixed and vary according to conditions and circumstances.

The existing empirical studies on gender in agriculture consistently show that women lack considerable access to and control over resources (Fletschner and Kenney, 2014) while at the same times women's ownership of varieties of agricultural inputs and technologies such as improved crop varieties, training, information on diverse agricultural practices, and marketing services is limited as compared to male in the same households. It is also evidenced that women have an unmanageable workload, they lack access to credit or have no decision-making powers over credit and are poorly represented in agricultural and non-agricultural groups and organizations (Alkire et al., 2013; Akter et al., 2016b). Women's limited access to resources constrains the scale of their production, frequently restricting them to subsistence food crops (World Bank, FAO, and IFAD 2009; Alex 2013). As a result, the adoption of agricultural technology by women is particularly important as it can generate large gains in alleviating poverty (Alex 2013).

In exploring the impacts of push-pull technology (which is considered as labor saving agricultural practice) on intra-household resource allocations, Diiro et al. (2021) has found that women in push-pull technology adopting households had 63% probability of participating in off-farm activities compared to the counterfactual scenario of non-adopting households. At the same times, the study indicates that the probability of women's empowerment is higher among adopter women, about 33% compared to the non-adopters which is only 31%. The CFEXT is also able to increase adoption women's consumption expenditure by about 7.5%; and reduced agricultural labor workload as it is a labor -saving technology. Other previous studies like Theis et al. (2018) support the results where time allocation could shift among different family members when technologies are adopted.

In their study, Bryan and Mekonnen (2023) assess whether small-scale irrigation provide a pathway to women's empowerment in Ghana have shown that about 4.2% of men and 3.9 % of women own a pump, while the study indicates that expanding access to small-scale irrigation technologies alone is not likely to increase women's empowerment.

Recently, a study by Hillesland et al. (2022) has indicated that the joint UN owned programs, called UN JP RWEE, implemented in Ethiopia has strengthened women's associations and cooperatives to offer financial products and credit to women. Beneficiaries who maintained access to credit were able to increase the number of asset categories women owned, but beneficiaries who lost access to credit had fewer types of credit sources over which they made decisions and also increased their work hours. Using a meta-analysis of Oxfam's women's empowerment projects impacts, Lombardini and McCollum (2018) have shown that the impact of development projects on women's empowerment is estimated to have a positive influence and increases by about a factor of 0.32 values.

Quisumbing et al. (2021) in their study "designing for empowerment impact in agricultural development projects: experimental evidence from the agriculture, nutrition, and gender linkages (ANGeL)" project in Bangladesh, have revealed that for women's empowerment outcomes, there are significant positive impacts from all treatment arms relative to the control group. The women's empowerment score increases by 0.04 to 0.07, and the prevalence of empowered women increases by 8% to 13%. Similarly, Quisumbing et al. (2022) in a study entitled "can agricultural development projects empower women?" conducted for rural women's economic empowerment in four countries: Ethiopia, Niger, Nepal, and Kyrgyzstan, have indicated that majority of those projects did not have a significant impact on the aggregate empowerment indicators. Of the 32 treatment arms across the 11 projects considered, there are 9 and 12 cases of significant positive impacts on whether the woman is empowered and the women's empowerment score, respectively, and 2 cases of negative impacts for both measures.

A study conducted in Northern Ghana by Yilma et al. (2015) that evaluated the impact of irrigation technology adoption on empowering women have found that adoption of irrigation technology has positively contributed to the overall poverty alleviation and empowerment of women. A study by Njuki et al. (2014) "a qualitative assessment of gender and irrigation technology in Kenya and Tanzania" have found that women can benefit from adoption of a technology even if they do not have recognized ownership in their household. According to Doss (2012) "improved technology or new input that can save or free up women's time and improve working method in the agriculture sector allow women to increase income, enable them to invest in new business ventures, increased agricultural production and reduce drudgery".

Paris and Chi (2005) have conducted a study in Vietnam that investigated the impact of row seeder technology on women labor, and the results revealed that the impact varies based on the women's initial living status. For those women farmers who are poor and landless, row seeding led to a substantial income loss. The study also revealed that following the introduction of row seeders technology, about 57% of women who worked as hired laborers have lost their gap-filling and 27% lost hand-weeding jobs. On the other hands, though the landless and poor women were worse off as a result of the introduction of row seeders, better-off women benefited from the reduction in their labor use. About 81% have decreased their labor input in gap-filling and hand-weeding. Women who were better-off due to the introduction of the technology had more time to be spent on activities such as taking care of their children and to attend to household chores. They also spent the time they saved in more remunerative income-generating activities such as animal raising, vegetable planting and small trade with an average earning of 4,581,000 Vietnamese Dong per year.

Huyer (2016) has conducted research targeting to explore possible ways of closing the gender gap in agriculture, and the findings evidenced that agricultural technologies could empower women under certain conditions. This includes preconditions such as accurate implementation of a framework of mutually reinforcing resources, women's control of assets, equitable decision-making between women and men, and strengthened women's capacity.

Recently, studies have evaluated the association between WEAI measures and improved dietary diversity. In particular, studies mostly in developing regions such as South Asian and Sub-Saharan African countries have found significant associations of women's empowerment with the diets of women (Malapit and Quisumbing 2015; Gupta et al. 2019a; Gupta et al. 2019b; Larson et al. 2019), and both of women and children (Malapit et al. 2013; Malapit et al. 2015b; Yimer and Tadesse 2015; Sraboni and Quisumbing 2018; Gali`e et al. 2019).

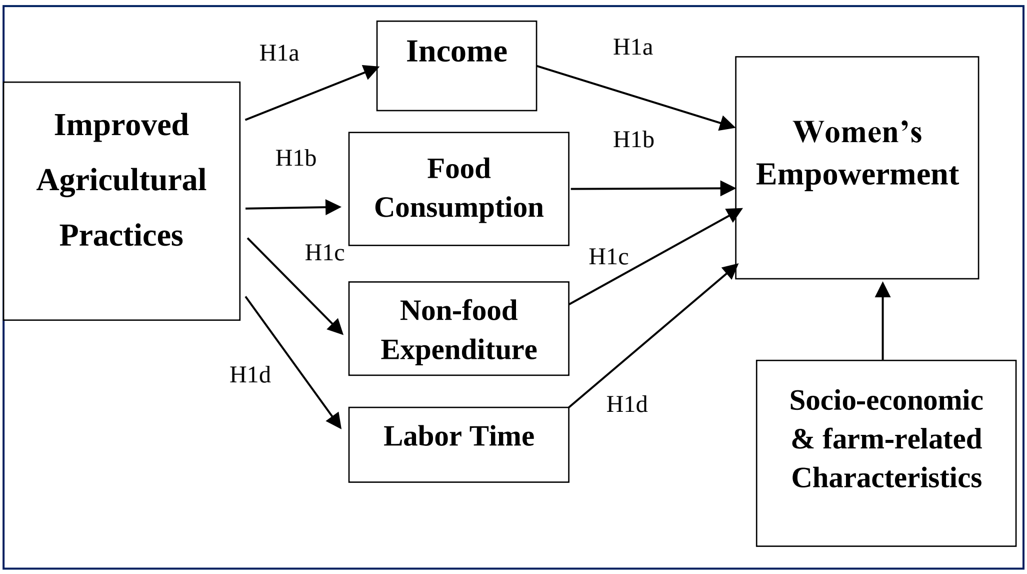
2.4 Conceptual Framework and Hypotheses

Once an agricultural technology is introduced or adopted, there are several potential pathways through which it can influence women's empowerment including 1) an income pathway 2) consumption pathway 3) non-food expenditure pathway and 4) and labor time saving pathway. Figure 1 proposes a framework for understanding links between agricultural technology adoption and women's empowerment. This framework presents a testable Hypothesis (H) related to the study's research questions.

The hypotheses relate to the influences of technology adoption on women's empowerment and its components, which is operated through four important pathways: income, consumption, non-food expenditure and labor time demand. Studies have shown that adoption of improved agricultural technologies and practices can increase household income (see Agbenyo et al., 2022; Kassie et al., 2018; Khonje et al., 2015; Wordofa et al., 2021). Increased income from adoption of those improved practices can increase women's access to means of life due to the income achieved and increase here empowerment (pathway H1a). The current study hypothesizes a positive association.

Other group of studies have also revealed that adoption of agricultural technologies/improved practices can increase the average per capita consumption expenditure of adopter households (for instance, Adomi et al., 2023; Ahmed, 2022; Asfaw et al., 2012a; Shiferaw et al., 2014) which in turn gives additional opportunity to increase the quantity and quality of food, gives here more power to decision making (pathway H1b). Recent study by Habtewold (2021) has investigated the impacts of adoption of row planting(spacing) with recommended amounts of fertilizer on multidimensional welfare indicator and the result showed that apart from increasing food consumption, adoption also increases availabilities of non-food household consumption expenditure, and this provides women additional increment in decision making (pathway H1c). Similarly, in both cases a positive association is hypothesized.

Figure 1. Conceptual Framework of Linking Agricultural Technology Adoption and Women's Empowerment



Evidences also reveal that if women adopt modern agricultural technologies and improved practices, they can save (reduce labor time) or free up women's time, leading women to reallocate their labor time to engage in other income-generating activities and improve working methods (Doss, 2012; FAO, 2011a; Njuki et al., 2014; Paris and Chi, 2005) (pathway H1d). The study hypothesizes a negative association between agriculture technology adoption and labor time demand. In the current study, however, due to data limitation for labor time demand it is not possible to explicitly model the labor time pathways, which captures the total amount of labor demanded by a typical household.

3. Methodology

3.1 Agricultural Technology Adoption Decisions and Impact Evaluation

In empirical researches, one of the major challenges that researchers face in assessing and estimating the impact of technology adoption on households' welfare outcome variables is the nature of non-experimental data. Experimental data can provide information on the counterfactual situation to solve the problem of causal inference which is a fundamental problem in non-experimental studies (Heckman et al., 1997). Others also state that the basic challenge of impact evaluation is causal inference (see for example Becker, 2009) and this author also shows that it is uncommon to observe for the same unit i in the treatment values Wi=1 and Wi=0 and similarly the outcome values Yi(1) and Yi(0). The researches of Amare et al. (2012) and Asfaw et al. (2012b) also discussed that adoption of technology is not randomly distributed between the treated and control groups, but rather households make their own adoption choices and thus, they may be systematically different. Due to the above facts, these studies argue that the presence of possible self-selection is common due to observed and unobserved household characteristics; and this makes an assessment of the real welfare impact of technology adoption using observational data more difficult than the experimental type.

Rahm and Huffman (1984) explain that in the context of technology adoption, farmer households face outcomes that are uncertain. In such a setting, farmer households are assumed to take adoption decisions based on the motives of utility maximization, as stated on the theoretical literature section of this document. In our case, the farm households are free to use CFEXT or not to do so. Based on the available options, households decide to adopt a technology if it will lead to an increase in utility levels (Jara-Rojas et al., 2012).

Following this utility maximizing motives of the farm households, the difference between the utility from adoption (U_{iA}) and non-adoption (U_{iN}) of the technology is given as W* such that the utility maximizing farm household i will choose to adopt the technology if the gain from adoption is greater than the utility of not adopting the technology given by $(W^* = U_{iA} - U_{iN} > 0)$ (Jara-Rojas et al., 2012). However, the common challenge here is that the two utilities are unobservable, so they need to be expressed as a function of observable components in the latent variable model as follows:

$$W_{it}^* = \beta X_{it} + \varepsilon_{it} \;, \quad with \;\; W_i = \begin{cases} 1 & if \; W_i^* > 0 \\ 0 & otherwise \end{cases} \qquad \textbf{(1)}$$

where W is a binary variable that indicates use of technology; W=1 if the technology is adopted and W = 0 otherwise. β is a vector of the parameters to be estimated, X is a vector that represents household and farm-related characteristics, t is time (year dummies), and ε is the random error term.

To attain both the main and specific objectives and to address possible bias, the study will use several strategies and estimation approaches that are relevant to the topic under investigation. As stated above, the estimated effects of the choice of technology adoption could suffer from self-selection bias. To remove this possible selection bias resulting from both observable and unobserved time-invariant heterogeneity, a panel data models with household Fixed Effects (FE) will be employed. Separate regressions for the A-WEAI and its components as well as for all the proposed impact pathway indicators is estimated.

The first empirical modeling approaches this study adopts is the FE method which allows us to estimate treatment effects considering differing adoption times. The result of this estimation method enables us to attain the major objective of the study. The FE model is used to eliminate the effects of observable and unobserved household heterogeneity that are fixed over time, as a source of bias in estimates of the technologies' impacts. But commonly, the fixed-effect approach only incorporates the potential influence of time-invariant unobservable (it does not control time-variant heterogeneity). Some, recent studies also argue that fixed-effects approach could still produce biased estimates for the treatment variables' coefficients (Arslan et al., 2017; Bezu et al., 2014; Manda et al., 2016). To address these limitations of the FE approach, the analysis is complemented by employing Correlated Random Effects (CREs) approach to further address selection bias and unobserved heterogeneity issues, and the non-parametric regression method, PSM method to assess the robustness of the results.

Second, the CREs also known as a Mundlak-Chamberlain (MC) device is also implemented which allows for correlation between the unobserved individual omitted variable and the variable of interest (agriculture technology), provided that unobserved effect is time invariant. To implement the CREs device, the means of all time-varying covariates must be included as additional explanatory variables for the household and thus controls for bias that may arise from time-invariant unobserved heterogeneity (Cameron and Trivedi, 2005). This estimation technique in combination with other methods can answer the first and last specific objectives of the study.

Third, the PSM technique compares the outcomes between households with similar probabilities of being treated given a set of household characteristics, X. This is a two-step procedure where a probability model is estimated first for adoption to calculate the probability (or propensity scores) of adoption for each observation and second each adopter and non-adopter with similar propensity score values are matched to estimate the average treatment effect on the treated (ATT). Several matching algorithms are employed, especially stratification matching method is used to attain the second specific objective which deals with evaluating the regional differences in the 5DE and GPI.

3.2 Measuring Women's Empowerment

Assessing the possible association between women's empowerment and social welfare is not an easy task (Bryan and Garner, 2020). The initial challenge starts with measuring empowerment as a variable of interest. Available evidence also reveals that the linkages between women's empowerment and social welfare is more difficult to quantify and apply in empirical studies. Several studies show that the existence of variety of definitions of empowerment makes the measurement of women's empowerment more difficult.

Among those definitions as to Alkire et al. (2013) empowerment in agriculture is generally defined as one's ability to take decisions on matters related to agricultural activities as well as one's access to material and social resources needed to carry out those decisions. In this context, ownership (control over resources) and decision making on those resources measure the levels of women's empowerment in the agricultural sector.

The women's empowerment in agriculture index (WEAI) is a new index used for monitoring gender gaps in agricultural production and development projects and it is one of the widely employed measure of women's empowerment in recent studies. The index consists of 5DE t including women's decision-making role in agricultural production, control over income and production resources, leadership opportunities, and time availability (Alkire et al., 2013). The USAID, IFPRI, and the

Oxford Poverty and Human Development Initiative (OPHI) have jointly developed the original version of the index. It was designed as tool for the monitoring and evaluation purpose of the US government's Feed the Future initiative to directly capture the status and level of women's empowerment and inclusion levels in the agriculture sector.

WEAI uses survey level data from a self-identified primary sample of male and female adult decision makers, whose age is 18 and over in the same household which makes it easy to aggregate the index at the program level. It has two sub-indices: the 5DE and the GPI that measures women's empowerment. Since its launch in February 2012, WEAI has been implemented in 19 Feed the Future focus countries (Malapit et al.,2017).

The first component of WEAI, 5DE, is constructed from individual-level empowerment scores which reflect each person's achievements in the five domains as measured by 10 indicators that show the involvement of unit i in the agriculture sector, with its corresponding weight.[5] On the other hands, the GPI, which reflects a woman's achievements in the five domains relative to the primary male in the same household captures the relative empowerment of a woman in each household. Households are classified as having gender parity if either the woman is empowered (her empowerment score is 80% or higher) or her score is greater than or equal to the male decision maker in her household. All these indices have values ranging from 0 to 1, with higher values reflecting greater empowerment. The overall WEAI is a weighted average of 5DE and GPI, with weights 0.9 and 0.1 respectively. IFPRI has released an abbreviated WEAI (A-WEAI) with six, instead of 10, indicators in the same domains (Malapit et al., 2017). A-WEAI retains the five domains and it takes about 30 % less time to administer than the original WEAI. It also includes new autonomy vignettes, a simplified 24-hour recall time module that collects only primary activities. So, our study employs A-WEAI rather than the earlies version, WEAI.

3.3 Model Specification

The FE model is given by:

$$y_{it} = \alpha_0 + \beta' X_{it} + \theta W_{it} + \varphi T_t + \mu_{it} + \varepsilon_{it} \quad \textbf{(2)}$$

[5] See Alkire et al. (2013) for the details of Domain, Indicator, Definition of Indicator and Weights for WEAI.

Where y_{it} is the outcome variable (5DE, empowerment gap (EG) and the pathway indicators in our case) for household i in the adoption category at time t, X_{it} is a vector of farm, household, and socio-economic characteristics, W_{it} is the treatment indicator factor which equals 1 if the household is an adopter and 0 otherwise; and θ is the impact of interest in our case, or a factor that captures the average treatment effects, T_t is a vector of year dummies to take account of time specific effects. μ_{it} is a household-specific unobservable FE and $\varepsilon_{it}$is an i.i.d random error term.

Again, the CRE model is estimated using the following estimating equation:

$$y_{it} = \alpha_0 + \beta' X_{it} + \theta W_{it} + \varphi T_t + \tau' \overline{X_{it}} + \varepsilon_{it} \qquad \textbf{(3)}$$

Where $\overline{X_{it}}$ is the household-level mean of the time-varying covariates.

The third method is PSM which compares the outcomes of a treated observation with the outcomes of comparable non-treated observations. It is defined as the conditional probability of receiving a treatment given pre-treatment characteristics as:

$$P(X) \equiv Pr\{W_i = 1|X\} = E\{W_i|X\} \qquad \textbf{(4)}$$

Where W_i = {0, 1} is the indicator of exposure to treatment and X is the multidimensional vector of pre-treatment characteristics.

Rosenbaum and Rubin (1983) show that if the exposure to treatment is random within cells defined by X, it is also random within cells defined by the values of the variable $P(X)$ .Let Y_{1t} be the value of the welfare outcome variable when household i is subject to treatment ($W = 1$) and Y_{0t} be the same variable when the household does not adopt the technology ($W = 0$); then , given a population of units denoted by i, if the propensity score P(Xi) is known the ATT can be estimated as:

$$ATT = E\{Y_{1t} - Y_{0t}|W = 1\} = E(Y_{1t}|W = 1) - E(Y_{0t}|W = 1)$$
$$= E(Y_{1t}|W = 1, P(X) - E(Y_{0t}|W = 1, P(X)\big) \qquad \textbf{(5)}$$

3.4 Data and a description of the Variables

This analysis is based on panel data obtained from the ESS-Waves 1-3. The data survey originally targeted the rural areas, small and medium towns of the country, however, in the current study households from both small and medium towns are excluded because of non-applicability of agricultural technology adoption. The survey data has good qualities like it covers different household members including males and females in the same household which our study primarily demands the existence of both primary adult male and female in each household. The sample is restricted to rural households to ensure that women's A-WEAI indicators among urban households that are not engaged in agricultural production are not misinterpreted as low empowerment achievements.

Households are included that had dual-adult households (primary adult male and female pairs in the same household). To ensure this pairing, households without a primary adult male and female pair are excluded from the sample. In several cases, the primary and secondary male and female are husband and wife; however, men and women can be classified as the primary male and female decision makers regardless of their relationship to each other.

4. Results and Discussion

4.1 Results of the Descriptive Analyses

As indicated earlier, agricultural technology in our current study refers to adoption of CFEXT, recommended amount of fertilizers per plot with extension services. Thus, adopters are farm households who use CFEXT, while non-adopters are those who do not use CFEXT during those study periods.

Table 1 below reports the descriptive statistics for CFEXT adoption, and the result of the summary statistics such as tests of statistical significance on equality of means for continuous variables and equality of proportions for binary variables for adopters and non-adopters, indicates that there are observable differences between the two subsamples on some key indicators.

The primary objective of this study is to evaluate the possible impact pathways from adoption of CFEXT to women's empowerment. However, first the study has computed the disempowerment index across the five domains (M0) prior to the analysis of the impact pathways. This approach has several advantages: first, the level of disempowerment of women subsample can be analyzed at different levels which enables us to identify which dimensions of women's empowerment drive the process of empowerment. Second, the computation of M0 also enables us to identify the critical indicators of the most disempowered women so that some primary focus area could be easily identified for improving women's empowerment. Thus, here the computation of a M0 is done as the first step and then 5DE is computed as (1- M0).

A comparison of the two household groups, adopters and non-adopter subsamples, shows significant differences on almost all outcome variables. The study has found significant differences in 5DE and all its components except the production indicator. They are also distinguishable in terms of EG. The summary statistics shows that adopters women on average had higher adequacy scores (about 51.3% in the six indicators), as compared to non-adopters (about 47.5%). This implies that women in the adopter's category are significantly more empowered in 5DE and enjoyed better gender parity (as their EG score is lower) as compared to women in the non-adopter group. A detail discussion is presented in the following sections with the aid of different graphs and figures.

Looking at the other characteristics and control variables, it is observed that adopter households have more house rooms, use more crop rotation system of farming, use improved water sources and own modern toilet, while the non-adopters have better access to electricity service as a source of light. The two groups are also distinguishable in terms of the religion they follow and marital status.

Table 1: Descriptive statistics of variables

Variables	Description	Full Sample[6]	Total Women	Adopter Women	Non-adopter Women
Outcome variables:					
5DE***	Empowerment score in the five domains	0.500	0.480	0.513	0.475
EG*	Relative empowerment gap between female and male scores in 5DE	0.557	0.561	0.548	0.563
M_0 components					
Production	=1 if inadequate in input in production decisions	0.561	0.376	0.382	0.375
Assets**	=1 if inadequate in asset ownership	0.628	0.718	0.685	0.724
Credit**	=1 if inadequate in access to and decisions on credit	0.779	0.765	0.724	0.771
Income**	=1 if inadequate in control over use of income	0.764	0.947	0.929	0.950
Leadership***	=1 if inadequate in group membership	0.426	0.347	0.451	0.330
Time***	=1 if inadequate in workload	0.369	0.382	0.164	0.418
Treatment					
Adoption Dummy	HH adopted chemical fertilizers jointly with extension services (1 = adopter)				
Year	Survey year (three round panel data, 2011, 2013, and 2015)				
Explanatory Variables:					
Religion dummy					
Catholic_ dummy*	HHs major religion is Catholic (1=yes)	0.009	0.007	0.001	0.008
Protestant_dummy***	HHs major religion is Protestant (1=yes)	0.219	0.216	0.117	0.232
Muslim_dummy***	HHs major religion is Muslim(1=yes)	0.345	0.351	0.225	0.372

[6] This includes both men and women in each category

Variables	Description	Full Sample[6]	Total Women	Adopter Women	Non-adopter Women
Tradition_dummy*	HHs major religion is Traditional (1=yes)	0.009	0.011	0.003	0.012
Pagan_dummy**	HHs major religion is Pagan(1=yes)	0.007	0.007	0.019	0.005
Wakefeta_dummy	HHs major religion is Wakefeta (1=yes)	0.006	0.005	0.004	0.005
Marital_stat_dummy					
Married_dummy	Marital status of the individual: is married (1=yes)	0.953	0.946	0.949	0.946
Divorced_dummy***	Marital status of individual: is divorced (1=yes)	0.001	0.002	0.008	0.001
Crop_rotation***	The individual uses the crop rotation method(1=yes)	.673	0.747	0.899	0.722
House_rooms***	Numbers of rooms in the house (rooms)	1.794	1.796	1.957	1.766
Family_size_AE	HH size in adult equivalent (AE)	4.661	5.743	5.739	5.744
Mean_Family_size	HH-level mean of family size	5.793	4.601	4.669	4.595
Mother's Educ	Mother's education status (1 = literate)	.061	0.099	0.085	0.114
Age	Age of the individual (years)	40.804	39.911	40.186	39.866
Mean_Age	Mean age of the household	37.251	37.750	38.205	37.295
Kitchen_type	Type of kitchen in the house (1=traditional kitchen)	0.671	0.275	0.276	0.275
Light_source*	Source of light in the house (1=electricity)	0.535	0.520	0.500	0.541
Cooking_fuel	Type of cooking fuel (1=electricity or solar energy)	0.011	0.011	0.010	0.011
Water_source***	Type of drinking water source (1=piped or protected water source)	0.572	0.596	0.621	0.570
Toilet_type***	Toilet type in the HHs (1=modern toilet)	0.454	0.483	0.512	0.453

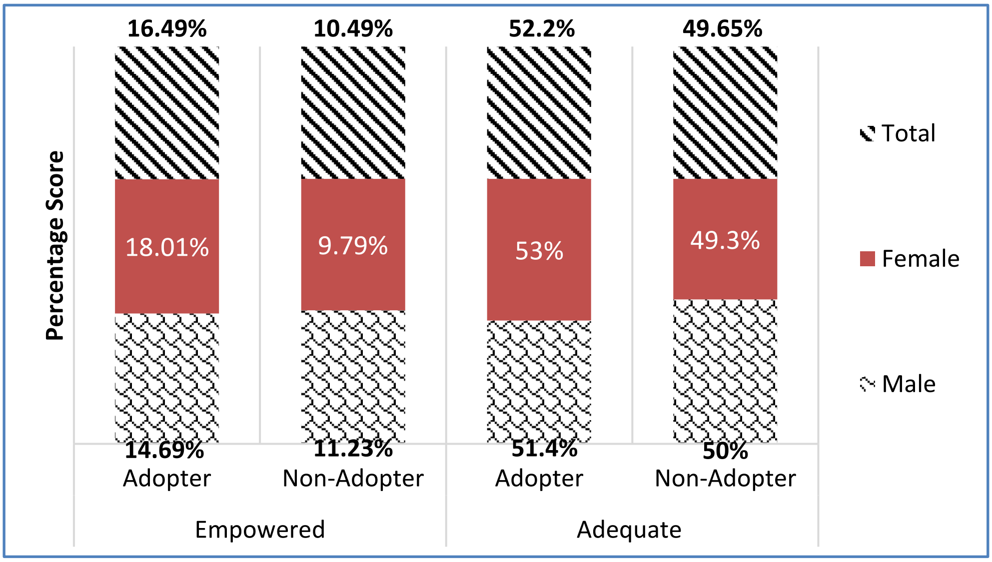
Note: Mean differences of Adopter and non-adopter women are significant at the 1 percent (***), 5 percent (**), and 10 percent (*) probability levels, respectively.

Source: Authors' calculations

Coming back to the empowerment records, it is found that women's empowerment is almost similar to that of men's in general, with a moderate and slight differences across some indicators. Substantial difference is observed between gender in the adopter's category (where adopter women are more empowered, about 18% while about 14.7 % of adopter men were empowered).

Concerning empowerment by adoption status, farmers who adopted CFEXT are more empowered as compared to the non-adopter households. The result shows that about 16.5% of the adopters are empowered as compared to 10.5% of non-adopter households. In Figure 2, it is possible to see that the adopters achieved higher adequacy scores (about 52% in the six indicators), as compared to non-adopters (about 50%). This result shows that there are significant differences in 5DE scores between the two technologies of adoption groups.

Figure 2: Empowerment and Adequacy achievements in the 5DE by Adoption status and sex



Another comparison is given in Figures 3 and 4 below which show the inadequacy scores and the contribution of each domain and indicator across different subsamples. The results of decomposed M0 and its components show that the domains that contribute the most to women's disempowerment are control overuse of income (34.2%) and lack of control over resources (25.9%) for the women subsample as reported in Figure 3.

When it comes to the contribution of each indicator to women's disempowerment, women were the most disempowered in control over use of income indicator (34.2%) followed by decision making and control over assets (16.5%). On the other hand, indicator-wise, women are less disempowered in access to and decisions on credit utilizations (9.4%) followed by membership in the community (12.5%), refer to Figure 4.

Figure 3: Contribution of each domain to Mo (%), for women subsample only

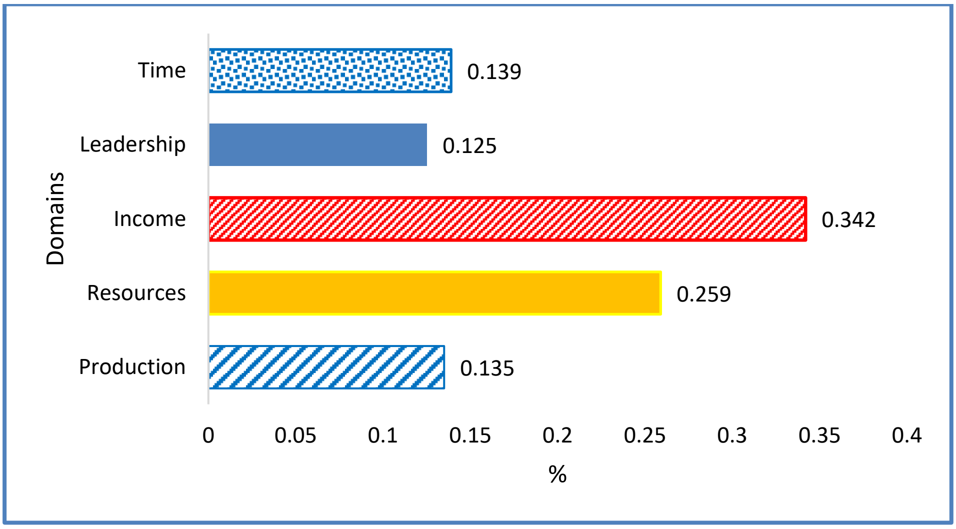
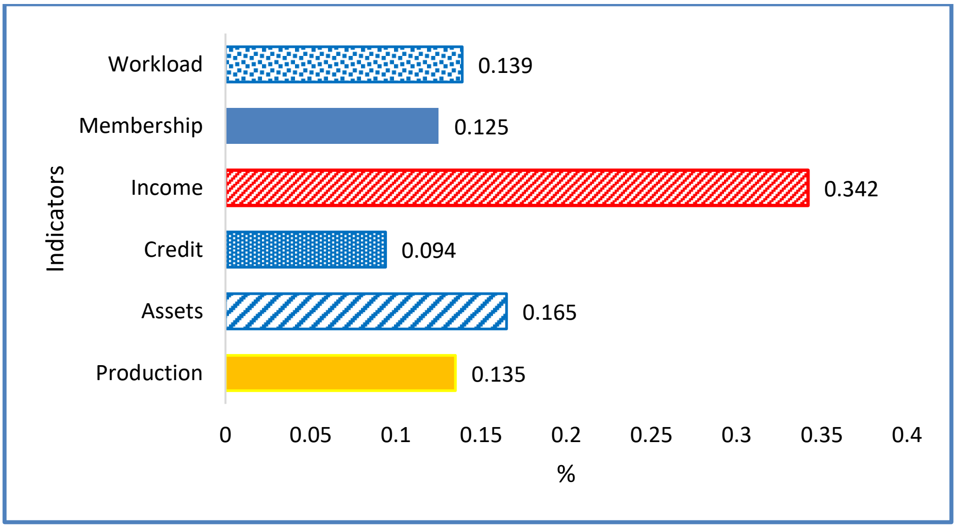


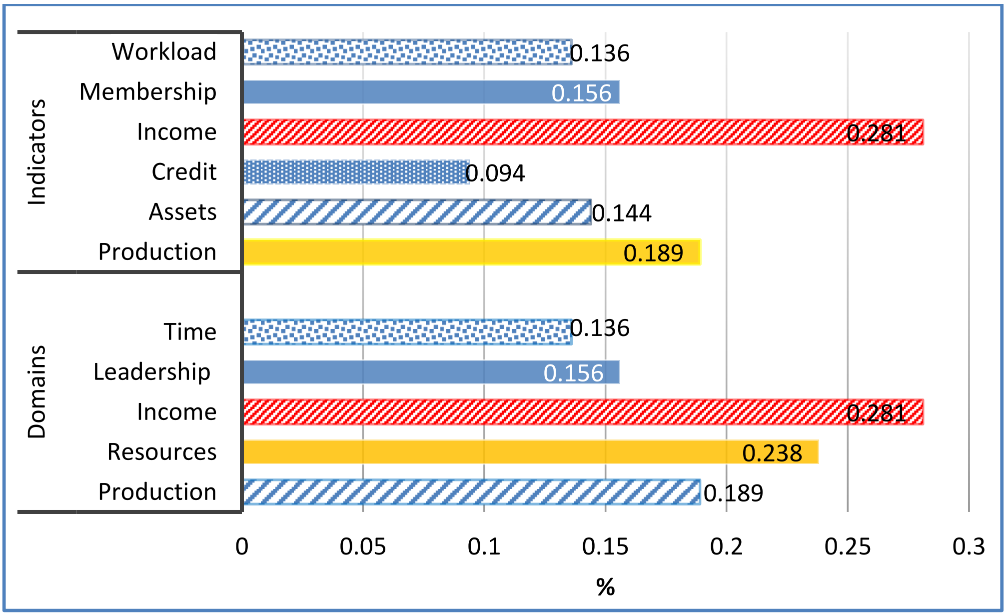
Figure 4: Contribution of each indicator to Mo (%), for women subsample only



The results of the whole sample are also presented on Figure 5. The disaggregated disempowerment scores reveal that the domains that contribute the most to women's disempowerment for the whole sample, almost similar to the women subsample, are control overuse of income (28.1%) and lack of control over resources was 23.8%.

Again, looking at the contribution of each indicator to women's disempowerment in the case of the whole sample, it was observed that women are the most disempowered in control over use of income indicator (28.1 %) followed by decision making in productive inputs (18.9 %). It was also reported in Figure 5 that domain-wise women are less disempowered in time use dimension (13.6%) followed by women participation in leadership position in the society (15.6%). Similarly, using indicators of the disempowerment scores as a point of comparison, women were less disempowered in access to and decisions on credit (9.4%) followed by workload indicator (13.6%). Thus, it is possible now to argue that the who households in general and women in particular are highly disempowered due to lack of control over some key welfare domains like income, assets in the households and production inputs in the agriculture sector, while households' availability of time and participation in the community on different social practice and their role in leadership activities contribute less to women's disempowerment.

Figure 5: Contribution of each domain and indicator to Mo (%), for the whole sample



4.2 Econometric Results

After the above preliminary descriptive analysis, empirical results of both FE and CRE models are presented in Tables 2 and 3 below for both total and women subsample. Table 2 presents the results for the whole sample, and findings of both estimation methods show that CFEXT adoption has significant effects on the 5DE component. The reported results show that the CFEXT highly increases women's empowerment in the five domains. FE results shows that due to the adoption of the technology women's empowerment scores in the five domains increases by about 4.16 percentage points and the result is highly significant. This level of impact implies that adoption leads to a 4.16 % increase in 5DE scores when the CFEXT is adopted.

As stated in the methodology section, in order to implement the CRE estimation method, which is thought to complement the standard FE approach, the means of major time-varying covariates (i.e., household age and family size) were constructed and included in the model. This practice can effectively control for bias that may arise from time-invariant unobserved heterogeneity (Cameron and Trivedi, 2005).

Concerning the CRE model results, the finding also show that adoption leads to a 4.7% increase in empowerment for women who used the specified technology as measured by the 5DE score. This means that if the technology is adopted, the overall average gains in the women's empowerment scores in the five domains increases by about 4.7 percentage points irrespective of gender of the household head.

When more control variables are included in both models and for both the entire sample and women subsamples, the results are almost similar in direction of influence and magnitude. When the whole sample is considered, it is noted that factors like observation period, mother's education level, access to electricity, household head's age, number of rooms of houses owned by the family and access to improved water sources positively influenced women's empowerment scores while other variables including family size and crop rotation practices negatively and significantly affected women's empowerment. However, the mean values of time-varying covariates, namely mean values household age and family size don't have significant influence on women's empowerment scores.

Table 2: Empirical Results of CFEXT Adoption for Whole Sample: Outcome variable is 5DE

Variable	Whole Sample: Models			
	FE		CRE	
	Coefficient	Std. Err.	Coefficient	Std. Err.
CFEXT	0.0416***	0.006	0.047***	0.005
Year dummy				
2013_Dummy	0.249***	0.004	0.246***	0.004
2015_Dummy	0.352***	0.005	0.351***	0.005
Crop_rotation	-0.025***	0.005	-0.019***	0.004)
Mother's Educ	0.029**	0.012	0.029***	0.007
Father's Educ	-0.007	0.008	0.004	0.005
Light_source	0.007	0.006	0.014***	0.004
Cooking_fuel	0.031	0.024	-0.019	0.016)
Oven_type	-0.020	0.016	-0.009	0.011
Water_source	0.002	0.005	0.006*	0.003
Toilet_type	-0.013***	0.004	-0.002	0.003
Religion dummy				
Catholic_ dummy			-0.001	0.017
Protestant_dummy			-0.012***	0.005
Muslim_dummy			-0.017***	0.004
Tradition_dummy			-0.074***	0.0163
Pagan_dummy			-0.037**	0.019
Wakefeta_dummy			-0.013	0.023
Marital_stat_dummy				
Married_dummy			-0.017	0.017
Divorced _dummy			0.103**	0.043
House_rooms	0.005	0.003	0.010***	0.002
Family_size_AE	-0.012*	0.007	0.002	0.002)
Age	0.003**	0.001	0.003***	0.001
Age^2	-2.66e-05**	1.23e-05	-2.96e-05***	7.01e-06
Mean_Age			-0.000	0.000
Mean_ Family_size			0.002	0.002
Constant	0.245***	0.030	0.242***	0.021
Observation	8,965		8,914	
No. of Groups	3,382		3,382	
R2(overall)		0.617		0.514

Notes: ***, ** and * are significant at 1%, 5% and 10% levels, respectively.
Source: Authors' computation

Table 3: Empirical Results of CFEXT Adoption for Women Sub-sample: Outcome variable is 5DE

Variable	Women: Models			
	FE		CRE	
	Coefficient	**Std. Err.**	**Coefficient**	**Std. Err.**
CFEXT	0.046***	0.007	0.056***	0.006
Year dummy				
2013_Dummy	0.251***	0.004	0.250***	0.004
2015_Dummy	0.251***	0.004	0.250***	0.004
Crop_rotation	0.005	0.010	-0.003	0.005
Mother's Educ	0.004**	0.001	0.000**	0.000
Kitchen_type	-0.029***	0.006	-0.021***	0.005
Light_source	-0.001	0.001	-0.003**	0.000
Cooking_fuel	0.003	0.002	-0.000	0.001
Oven_type	0.009**	0.004	0.002	0.003
Water_source	0.001	0.002	-0.000	0.001
Toilet_type	0.000	0.002	-0.000	0.001
Religion dummy				
Catholic_ dummy			-0.015	0.030
Protestant_dummy			-0.006	0.007
Muslim_dummy			0.008	0.006
Tradition_dummy			-0.068**	0.021
Pagan_dummy			0.009	0.024
Wakefeta_dummy			-0.056*	0.032
Marital_stat_dummy				
Married_dummy			-0.009	0.020
Divorced _dummy			0.104**	0.045
House_rooms	0.006	0.004	0.006*	0.004
Family_size_AE	-0.005**	0.002	-0.005**	0.003
Age	-0.001	0.000	0.000	0.000
Mean_Age			0.002**	0.000
Mean_ Family_size			0.010**	0.003
Constant	0.358***	0.035	0.307***	0.033
Observation	4,857		4,793	
No. of Groups	1,687		1,687	
R2(overall)	0.407		0.437	

Notes: ***, ** and * are significant at 1%, 5% and 10% levels, respectively.

Source: Authors' computation

Similarly for the women sample, the influences of some core variables are almost the same except few mostly women attached variable such as kitchen type and oven ownership which negatively and significantly influenced women's empowerment scores. This is true that the types kitchen and oven women own and cook food with it determines the time required to other activities. Poor and time-consuming kitchen arrangement and traditional oven types can limit women's performance on other activities and influence their work efficiency. Even food preparation finds itself in a gendered role, as women spend more time cooking in the kitchen while men don't do in most cases (Pollan, 2014). That is why variables like kitchen and oven types are most important time related factors to influence women's empowerment.

Next, the impacts of CFEXT adoption is estimated using PSM approach with different matching algorithms, and results are reported in Table 4 where a separate model is run for the pooled sample and women subsamples. The first part of the table presents the impacts on 5DE scores while the middle and bottom parts of the table provide the influence of the technology on EG[7] for the whole women and women without parity with the primary men in the household, respectively.

The PSM results are reported using three matching methods - nearest neighborhood matching (NNM), kernel matching (KM) and radius matching (RM). As compared to the FE and CRE estimation outputs, almost similar results were obtained using PSM across all estimation options for the case of 5DE. The overall average increment in women's empowerment scores measured by the 5DE due to adoption of CFEXT ranges from 3.7 to 4.2 percentage points for the entire sample and 5.7 to 8.7 percentage points for all women subsample. This implies that both male and female headed households benefit from the technology, though it seems that women are more beneficiary than men do.

As suggested by the descriptive statistics, the empowerment scores of adopter women in the 5DE is higher than non-adopter ones. This shows that the women's empowerment in the 5DE for farmers who adopted CFEXT is significantly higher than that the non-adopters by more than 5 percentage points on average. The other estimation of PSM gives the impact of CFEXT adopted on the EG or gender disparities, and results are reported in Table 4. When all women are considered, the ATT term is negative in all the matching methods and statistically significant. The overall decline in gender disparity as suggested by the results ranges between 0.7 to 1.2 percentage points. This result tells us that empowerment gap of adopter women with their counterparts in the household (primary male) declines due to the

[7] Relative empowerment gap between female and male scores in 5DE

technology, CFEXT adoption leads to a reduction in gender disparities between men and women in the same household.

Considering the impact of the technology on women who lack parity with the primary males in their households, still results show that adoption is negatively associated with a statistically significant change in EG, however, findings are statistically significant only for NNM with five neighbors and Kernel-based matching, while it is not the case for both NNM with a single neighbor and radius matching. Apart from this, results are not as strong as it was for the whole women (EG declines in the range between 0.5 to 0.6 in the case of women without parity). This has some important policy implication such that interventions that target to reduce gender disparity through agriculture related technologies need to focus on those women who have higher EG and who are characterized by lack of gender parity with the primary male in their households.

Table 4: Impact of technology adoption on 5DE and EG

Matching Type	Outcome mean and ATT					
	Whole Sample			Only Women		
	Adopters	Non-adopters	ATT	Adopters	Non-adopters	ATT
NNMa	0.523	0.481	0.042(5.45) ***	0.512	0.455	0.057(5.93) ***
NNMb	0.523	0.485	0.037(3.83) ***	0.512	0.425	0.087(6.73) ***
RM	0.523	0.485	0.037(3.83) ***	0.512	0.425	0.087(6.73) ***
KMa	0.523	0.481	0.041(5.87) ***	0.512	0.455	0.057(6.48) ***
KMb	0.523	0.480	0.042(5.98) ***	0.512	0.455	0.057(6.51) ***
Empowerment Gap (EG) for all women						
NNMa				0.218	0.229	-0.012(3.43)***
NNMb				0.218	0.226	-0.008(1.87)*
RM				0.218	0.226	-0.008(1.87)*
KMa				0.218	0.225	-0.007(2.52)**
KMb				0.218	0.225	-0.007(2.53)**
EG for women without parity with the primary mem						
NNMa				0.217	0.224	-0.006(1.84)*
NNMb				0.217	0.223	-0.005(1.14)
RM				0.217	0.223	-0.005(1.14)
KMa				0.217	0.225	-0.007(2.40)**
KMb				0.217	0.224	-0.007(2.29)**

Notes: ***, ** and * are significant at 1%, 5% and 10% levels, respectively. Absolute values of t-statistics in parenthesis.

Source: Authors' computation

NNMa= NNM based on five neighbors and common support
NNMb= NNM based on a single neighbor and common support
KMa= Kernel-based matching with a band width of 0.06 and common support
KMb= Kernel-based matching with a band width of 0.03 and common support

The findings of all estimation methods, FE, CRE and PSM highlight that CFEXT has the potential to improve women's empowerment in general. In line with our findings, several empirical evidence suggest that empowering women improves nutrition for mothers, their children, and other household members (Heckert et al., 2019; Smith and Haddad 2000). Some studies have found that women's income has greater impact on child nutrition and food security than men's (United Nations Children's Fund 2011; Smith et al. 2003), and among agriculture interventions that have improved nutrition, women's active involvement has been a constant component (Ruel and Alderman 2013).

4.2.1 Impact Pathways from CFEXT to Women's Empowerment

From the above deep analysis, it is noted that adoption of CFEXT has powerful and substantial influence on women's empowerment. The next task is evaluating the pathways from CFEXT to women's empowerment through the proposed channels (pathways). Understanding the pathways also helps to identify key intervention that can be measured along the way to monitor whether changes on women's empowerment are progressing in the right route or not.

In our model, it must be the case that for CFEXT to influence women's empowerment outcomes (5DE and EG), through the income, food consumption expenditures and non-food expenditure pathways, there should be two conditions that need to be fulfilled. First, CFEXT needs to improve all those pathway indicators (income, food consumption expenditures and non-food expenditure), and second, all these pathway indicators should improve women's empowerment by increasing 5DE and reducing gender disparity (EG).

For the first pathway(H1a), CFEXT is expected to influence household income, such that adoption must lead to higher agricultural income, and second, a strong relationship between household income and women's empowerment indicators are also expected. The results presented on Table 5 for both estimation methods, FE and CRE, generally meet our expectations that CFEXT adoption impacts women's empowerment through the proposed pathways.

Pathway 1 (H1a) highlights that adoption of CFEXT leads to an increase in income of the sample households, though results are not statistically significant. For the first pathway, CFEXT is expected to influence household income, such that adoption must improve adopters' income. Thus, the results from pathway 1 show that CFEXT adoption improved household income, and increasing household income, in turn, led to higher women's empowerment in the 5DE, suggesting that CFEXT positively influences women's empowerment through the income pathway, but the insignificant result should be interpreted carefully such that the influence of CFEXT on income is weaker.

As Kabeer (2017) argues women who receive an independent income are likely support several family related activities. Similarly, the World Bank (2012) states that an increase in income can increase women's self-esteem and increase their welfares such as food security status and so on.

In the second pathway 2 (H1b), FEXT is proposed to positively impact food consumption expenditure and, in turn the latter to lead a higher achievement in women's empowerment in the 5DE. It is revealed that CFEXT adoption led to higher food consumption expenditure as both estimation methods show and the increased food consumption expenditure has led to improvement in women's empowerment in the 5DE signifying that CFEXT influences women's empowerment significantly through food consumption expenditure pathway. The overall increment in food consumption expenditure due to adoption ranges between 3.8 and 6.1 percentage points and the corresponding average gain in women's empowerment from food consumption expenditure ranges between 0.4 and 0.8 percent in the two estimation methods.

Turning to the impact of CFEXT adoption on women's empowerment through non-food expenditure (pathway H1c), results show that adoption led to a positive and significant increase in non-food expenditure and following such change the increased non-food expenditure resulted in improvement to women's empowerment measured by 5DE component. CFEXT adoption is expected positively and significantly to influence households' non-food expenditure, and the results also confirm that there exists strong relationship between households' non-food expenditure and women's empowerment indicators. These results indicate that CFEXT adoption increases non-food expenditure by 4.6-5.3 percentage points, and following this women's empowerment is increased in the range 0.8 to 1.6 percent with a statistically significant value.

It is noted that this channel is the most powerful pathway that influence women's empowerment, and this also confirms the multidimensionality of women empowerment. It should however be noted that several agricultural activities typically are interrelated in a way that one factor may influence more than one indicator and may be linked through different pathway. Pathway 3 (H1c) highlights the special role that increment in non-food expenditure has on aspects such as education, health, nutrition and children safeguarding. In real practice, the linkage between factors like non-food expenditure and women's empowerment seems much more complicated, however it is not possible to hope to achieve empowerment without paying attention to households' spending on varies aspects including on education, health and nutrition and how women control and make decision on such recourses.

In summary, evidence is found in favor of the hypothesis that CFEXT adoption increases women's empowerment through the hypothesized channels. Our current study as well expects this effect to operate through labor time (allocation) and other possible pathways, in which we could not tested due to data limitation and suggest the way for further research.

Moving forward to the impact pathways to domains of 5DE, the results generally meet our expectations that CFEXT adoption influence women's empowerment components. In the case of income pathway, except for production and time domains, the result is quite surprising that the influence on the remaining components (resource and leadership) is found to be negative. This implies that though CFEXT adoption increases households' agricultural income, this increased income level is not directly translated into increased women's empowerment in resource and leadership components.

The production domain which is measured in decisions input, a sole or joint decision making in activities like land farming and livestock raising, can determine how a woman is empowered in those decision making. As the result indicates due an increase in income of the household, the women's empowerment score increases by about 2.2 percent through production component as indicated in the CRE model. However, the relationship between income and time is not statistically significant.

Concerning the food consumption and non-food expenditures pathways, an increase in both of these channeling factors is associated with an improvement in the women's empowerment score, with few exceptions. As it was the case for the aggregate 5DE analysis, each domain of women's empowerment is strongly influenced through the on-food expenditure pathway. Especially domains like production, resources and leadership are positively and significantly influenced by CFEXT adoption through the non-food expenditure pathway. Interestingly, these results appear to support the aggregate 5DE analysis discussed above and the heterogeneous impacts presented under section 4.4 of this document.

Table 5: Impacts Pathways from CFEXT to Women's Empowerment

Pathways (Channel of influence)	Outcome indicator	Estimation Method			
		FE		CRE	
		Coefficient	Std. Err	Coefficient	Std. Err
CFEXT ------>	Income	0.031	0.024	0.002	0.022
	Food Consumption	0.061 **	0.027	0.038 *	0.023
	Non-food expenditure	0.046 ***	0.003	0.053 *	0.029
	Total expenditure	0.033 ***	0.006	0.017 ***	0.002
Impact pathways to 5DE					
Income ---------->	5DE	0.006	0.005	0.013 ***	0.003
Food Consumption ---->		0.004 *	0.000	0.008 **	0.003
Non-food expenditure -->		0.008 *	0.004	0.016 **	0.003
Total expenditure ----->		0.004	0.005	0.015 ***	0.004
Impact pathways to the 5DE components					
Income --->	Production	0.021	0.017	0.022 *	0.012
--->	Resources	-0.025	0.086	-0.076 ***	0.012
--->	Leadership	-0.028 **	0.011	-0.031 ***	0.007
--->	Time	0.022	0.019	0.006	0.013
Food Consumption --->	Production	-0.008	0.015	0.003	0.011
--->	Resources	0.013	0.016	-0.051 ***	0.011
--->	Income	0.005	0.007	0.002	0.006
--->	Leadership	-0.010	0.009	-0.022 **	0.007
--->	Time	0.020	0.017	0.009	0.012
Non-food expenditure --->	Production	0.077 ***	0.012	0.041 ***	0.008
--->	Resources	0.035 **	0.013	0.084 ***	0.009
--->	Income	0.002	0.006	0.005	0.004
--->	Leadership	0.005 ***	0.008	0.022 ***	0.005
--->	Time	0.014	0.001	-0.004	0.009
Impact pathways to EG					
Income ---->	EG	0.006	0.004	-0.000	0.002
Food Consumption ---->		0.006 *	0.003	0.001	0.002
Non-food expenditure -->		-0.001	0.003	-0.003 **	0.001

Notes: ***, ** and * are significant at 1%, 5% and 10% levels, respectively.
Source: Authors' computation

In rural community, apart from owning and deciding on production inputs and resources, their participation has a key role in determining women's efficiency in their activities. A similar statistically significant result is found for women's group membership. Women's participation in agricultural decisions and participation in community groups is positively and significantly influenced by CFEXT through the non-food expenditure.

In case of EG, non-food expenditure is the most powerful pathway to influence gender disparity. The result show that gender disparity can decrease from 0.1 to 0.3 percentage points in households whose non-food expenditure is increased.

In short, though the relationship between agricultural technology adoption and improved practices has more complex picture and several agricultural activities are highly interrelated, the results in our analysis through different approaches shows that different components of women's empowerment have the hypothesized relationship with CFEXT having few exceptions(in some cases CFEXT may not affect all women's empowerment dimensions, however this doesn't affect the entire hypothesized channel of relationship significantly).

4.3 Heterogeneous Impacts

4.3.1 Differential Household-Level Impacts of CFEXT Adoption

Table 6 gives the estimated impact of CFEXT adoption on each sex separately. It shows that adoption affects empowerment positively and significantly for both sexes. In the case of women, the empowerment score in 5DE increased from 5.7 to 8.7 percentage points while the rise in 5DE for men households was in the range of 1.5 to 1.9 percent. This implies that the overall average gain in empowerment in the 5DE is more than 5 percentage points for the women subsample and more than 1.5 percentage points for the men ones.

The result indicates that both adopter men and women are almost equally benefiting from the technology, though there is observable difference between non-adopter men and women subsamples. The empowerment score in 5DE for non-adopted men is about 50 percent while the value is lower for the non-adopter women (only about 45 percent). Thus, women in the non-adopter households had a lower empowerment score in 5DE than non-adopter men, which implies that though they do not adopt the technology, non-adopter men are more empowered than non-adopter women households. In other words, disempowerment in the five domains is more severe in the non-adopter women category. This finding is in support of the real condition of most developing countries, especially in the agriculture sector, where men usually enjoy more empowerment than women. Thus, interventions need to emphasize more on women and girls whose disempowerment score severely higher.

Table 6: Impact of technology adoption on 5DE by Sex

Matching Type	Outcome mean and ATT					
	Women			Men		
	Adopters	Non-adopters	ATT	Adopters	Non-adopters	ATT
NNMa	0.512	0.455	0.057(5.93) ***	0.514	0.497	0.019(1.73) *
NNMb	0.512	0.425	0.087(6.73) ***	0.514	0.496	0.018(1.38)
RM	0.512	0.425	0.087(6.73) ***	0.514	0.496	0.018(1.38)
KMa	0.512	0.455	0.057(6.48) ***	0.515	0.500	0.015(1.52) *
KMb	0.512	0.455	0.057(6.51) ***	0.515	0.499	0.017(1.59) *

Notes: *** and * are significant at 1% and 10% levels, respectively. Absolute values of t-statistics in parenthesis.
Source: Authors' computation

Results were also further disaggregated based on major crop growing regions in the country and the results are presented in Table 7 below. Disaggregating women's empowerment by its components can help us identify key areas of empowerment which can be used for prioritizing interventions. Thus, the disaggregation of results in such way is one of the possible approaches to identify regional variations on the achievements of empowerment and its components, and enables us to suggest some possible policy option.

From the results of Table 7, it is noted that though CFEXT adoption improves women's empowerment score measured by 5DE and EG, it cannot rise women's empowerment in terms of all 5DE components across all those regions. The impacts on 5DE are higher in regions like Amhara, Oromia and South Nations Nationalities and Peoples (SNNP). In Amhara region CFEXT adoption increases women's empowerment by about 15 percentage points while in case of Oromia the impact was about 12 percent. These findings are in line with the real situation in the country such that new and improved agricultural technologies are widely used in these two regions and the two regions are dominant in all economic indicators including in terms of location for most arable land and productive resources.

The EG is also reduced in all the regions considered, and this supports the earlier results in sign that all are negatively related to adoption. However, CFEXT adoption is not associated with a statistically significant change in EG across all those regions. Except for Oromia and SNNP, results are not statistically significant. For Oromia and SNNP, EG declines for adopter women compared to non-adopter households by about 1.8 and 0.9 percentage points, respectively.

Table 7: Decomposition of CFEXT impacts on 5DE and its components, and EG by Regions, for women subsample

Region	ATT of CFEXT Adoption						
	5DE	**Production**	**Resources**	**Income**	**Leadership**	**Time**	**EG**
Tigray	0.039 (1.87)*	-0.108 (1.96)*	0.163 (2.99)***	-0.035 (2.49)**	0.197 (3.77)***	-0.274 (5.52)***	-0.023 (0.37)
Amhara	0.150 (10.16)***	0.072 (2.06)**	0.091 (2.44)**	0.070 (3.31)***	0.230 (7.61)***	0.308 (13.68)***	-0.006 (0.98)
Oromia	0.122 (5.62)***	0.154 (3.09)***	0.146 (2.59)**	0.007 (0.27)	-0.026 (0.46)	0.343 (9.78)***	-0.018 (2.11)**
SNNP	0.113 (7.85)***	0.172 (4.34)***	0.047 (1.37)	0.023 (1.29)	0.501 (15.38)***	-0.109 (2.90)**	-0.009 (1.69)*

Notes: ***, ** and * are significant at 1%, 5% and 10% levels, respectively. Absolute values of t-statistics in parenthesis.
Source: Authors' computation

The domain-wise influence of CFEXT reveals that it is not associated with a statistically significant change on component such as in decisions on production, income and time in case Tigray region. Similarly, factors like leadership in Oromia and time in SNNP are negatively associated to CFEXT adoption. Even if available literature has come to the conclusion that modern agricultural technologies improve welfare, it should also be noted that they may also worsen social welfare. In our case adoption led to a decline in 5DE components in some regions though the aggregate impact is positive.

The domains that contributed the most to women's empowerment are decision on production inputs, control over resource and leadership, though the impacts on production in the case of Tigray region is negative. The estimated impact ranged from 7-17, 9.1-16.3 and 19.7-50.1 percentage point rise in the empowerment score measured by 5DE in production, resource and leadership components, respectively. Thus, it is possible to argue that the first domain that contributed the most to women's empowerment is women's leadership activities in the community. The second domain that contributed the most to women's empowerment is resource control and use. On average, adoption led to a significant percentage point increase in the total empowerment score through ownership of assets and access to and decisions on credit use.

Table 8 shows the deferential impacts of CFEXT adoption based on different ranging values of empowerment scores and observation periods. This differential or distributional analysis can further help us to explore the heterogeneous impacts of CFEXT adoption on different segments of women based on their achievements in empowerment at different time period. This is because CFEXT adoption has differential impacts on different segments of the women (highly empowered, moderate or highly disempowered, etc.) across time. The entire women were divided into quartiles based on their achievements on 5DE, values of EG and observation period, and the PSM stratification method was employed to identify the heterogeneity of the impacts among those women segments.

Table 8: Differential impacts of CFEXT adoption based on values of empowerment scores and observation year

Outcome Variable		Category	ATT of CFEXT Adoption
5DE	Quartiles (based on values of 5DE)	Lowest	-0.003(0.43)
		Lowest middle	-0.002(0.54)
		Upper middle	0.004(1.7) *
		Highest	0.024(3.38) ***
	Observation Year	2013	0.011(11.40) ***
		2015	0.011(11.40) ***
EG	Quartiles (based on values of EG)	Lowest	-0.038(5.97) ***
		Lowest middle	-0.011(3.09) ***
		Upper middle	0.006(2.56) **
		Highest	-0.004(0.63) *
	Observation Year	2013	-0.113(11.01) ***
		2015	-0.113(11.01) ***

Notes: ***, ** and * are significant at 1%, 5% and 10% levels, respectively. Absolute values of t-statistics in parenthesis. Source: Authors' calculations

The analysis on the influence of CFEXT on 5DE, in general, it supports results obtained for the aggregate samples. Among the other categories, 3rd and 4th quartiles are strongly and positively impacted by CFEXT, while the first two categories are negatively associated with adoption. This implies that adoption of CFEXT strongly influences women with higher empowerment score in terms of 5DE while it is weaker in affecting women whose achievement is lower.

With respect to deferential impacts on EG, results are still in support of the aggregate analysis in general. Except for the 3rd quartile, CFEXT adoption is negatively associated with gender disparity across all women categories. On the other hands, the disaggregation by observation period indicates that there is improvement in women's empowerment with time based on results of both 5DE and EG.

To conclude, this further disaggregation of results by different categories provides us some additional dimension to evaluate the impacts of CFEXT adoption, and results show that though the impacts of improve agricultural technologies and improved practices is as documented in the vast literature, it is also reasonable to have a record of results against these general conclusions. Due to different nature and context, in our current study the impacts were against our expectation some segments of the sample are considered, and this is the power of differential analysis.

5. Conclusions and Policy Implications

Evaluating whether an intervention benefit or empower women is one way to identify which impact pathways need to be emphasized, and consequently what indicators to be used in assessing the progress in women's empowerment. This study attempted to explore the impact pathways of improved agricultural technology adoption on women's empowerment in rural Ethiopia.

As initial assessment of the impact pathways of CFEXT, as the technology of focus, on women's empowerment, this study is different from others in many ways. First, it sheds light on the multiple pathways that agriculture technologies have on women and girls' empowerment in the rural household context. It has been proposed several plausible agriculture technologies pathways and rigorously tested them out using the nature of the panel data. Second, it disaggregates the hypothesized impact into different segments of the sample households, i.e., by empowerment indicators. Finally, the data used in the study is a nationally representative and effective to reflect women's empowerment status in the country.

Coming to the major findings, preliminary descriptive analysis shows that adopters and non-adopter subsamples are significantly different on key outcome variables. Both these groups are distinguishable in terms of 5DE and EG, signifying that the CFEXT favors the adopter groups which implies that is has a potential to improve adopter women's empowerment. Women in the adopter group were significantly more empowered in 5DE and enjoyed more gender parity as compared to women in the non-adopter group.

In the empirical section, the estimation results from all methods (EF, CRE and PSM) reveal that the technology of focus in the study have the expected significant, and positive impact on the 5DE and negative influence on gender disparity (EG), and results are also consistent across estimation methods. For instance, the result of CRE model evidences that adoption leads to a 4.7% increase in 5DE score whereas a PSM results show that 5DE increment ranges from 3.7 to 4.2% for the entire sample and 5.7 to 8.7% women subsample. On the other hands, Though the impact on EG is in line with our prior expectation, the magnitude of influence due to the CFEXT is relatively small as compared to 5DE.

Moving to the core and novel contribution of this study, the impact pathway analysis, though it is noted in the study that agricultural activities are typically interrelated and complex while women's empowerment has a multidimensional nature, results from this study suggest that the relationship between CFEXT and women's empowerment is strong and meet our expectation. It shows that CFEXT significantly influences women's empowerment through the income, food consumption expenditures and non-food expenditure pathways.

However, the influence of CFEXT through non-food expenditure is found to be more powerful which signifies that women's empowerment is multidimensional concept. CFEXT adoption positive and significantly increase in non-food expenditure and due to the increment in non-food expenditure women's empowerment indicators were positively influence in general. This result suggest that non-food expenditure is the core channel through which women's empowerment is most affect by the CFEXT adoption. Apart from this, results were further disaggregated by sex, major region and ranging values of empowerment indicator, and the findings are in support of the aggregate analysis.

Finally, it was noted that the findings of this study have important suggestions for designing of policies and programs targeted at expanding improved agricultural technologies to improve general social welfare. So, the findings from our study have three important policy implications. First, the reported results suggest that women's empowerment is strongly influenced by CFEXT, there is a need to further expand the application of fertilizers with appropriate extension service that also equality benefit female farmers in the rural community. Second, though all the hypothesized pathways influence empowerment, indicators such as income were found to have less contribution as compared to non-food spending implying that nonincome factors should also be the focus of intervention in the agriculture sector. Empowering women is one of the best channels to influence children's nutrition and family wellbeing, income increment is not the sufficient condition for social welfare. Last, the differential impact analysis reveals that there is regional difference women's empowerment achievement which calls different intervention across those regions in the country. Further it is suggested that more researchers to explore other dimension and pathways to women's empowerment including the one that our study could not include, such as labor use paths.

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