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Impact of Energy Access on Food Security and Child Nutrition

Panel Data Evidence from Rural Ethiopia

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Abstract

In this paper, we investigate the impact of electricity on household food consumption and the nutritional status of children under the age of five, with attention to female-headed households, and discuss possible channels of causation. Using three rounds of the World Bank's Living Standard Measurement Survey and a Difference in Difference approach, we found that access to electricity increased households' calorie consumption by 153 Kcal per day in 2013 and by 187 Kcal in 2016. Further, children in households with access to electricity are less stunted than children in households without access to electricity. The findings imply that the channel of causation may be related to the greater convenience of electricity as a cooking fuel compared to firewood or other biomass. In terms of policy, expansion of electricity, in addition to providing lighting and other end use services, has an impact in improving households' calorie intake and reducing children's stunted growth.

Keywords: electricity, energy, nutrition, wasting, stunting

JEL Codes: D10, D12, Q40

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In this paper, we investigate the impact of electricity on household food consumption and the nutritional status of children under the age of five, with attention to female-headed households, and discuss possible channels of causation. Using three rounds of the World Bank's Living Standard Measurement Survey and a Difference in Difference approach, we found that access to electricity increased households' calorie consumption by 153 Kcal per day in 2013 and by 187 Kcal in 2016. Further, children in households with access to electricity are less stunted than children in households without access to electricity. The findings imply that the channel of causation may be related to the greater convenience of electricity as a cooking fuel compared to firewood or other biomass. In terms of policy, expansion of electricity, in addition to providing lighting and other end use services, has an impact in improving households' calorie intake and reducing children's stunted growth.

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1. Background

A recent global assessment of food insecurity and malnutrition estimates that between 720 and 811 million people in the world faced hunger in 2020 – as many as 161 million more than in 2019. Nearly 2.37 billion people did not have access to adequate food in 2020 – an increase of 320 million people in just one year (FA0, 2021). Reducing food and nutrition insecurity also remains Africa's central challenge. Regardless of overall progress, Africa remains the region with the highest prevalence of hunger. More than one-third of the world's undernourished are found in Africa (282 million). Compared with 2019, about 46 million more people in Africa were affected by hunger in 2020 (FA0, 2021). As in most African countries, food insecurity and malnutrition is still a persistent problem in Ethiopia. Recent estimates indicate that 16.2 percent (18.2 million) of the population were undernourished in 2018-20 (FA0, 2021), showing food shortages as an ongoing problem in the country. Child malnutrition continues to be one of the most serious problems facing Ethiopia. In 2020, 35.3%, and 7.2% of children under the age of five had stunted growth and were wasted, respectively (FA0, 2021).

Limited access to energy and unaffordable energy influence households' dietary choices and cooking practices (Sola *et al.*, 2016). Lack of energy for cooking can influence the type, the quantity and the quality of the foods consumed and their ability to be digested, and could be a cause of malnutrition (Sola *et al.*, 2016). Energy insecurity can result in reduced cooking times, skipping meals and a switch to foods that need less fuel for cooking. Sola *et al*. (2016) further argued that lack of access to energy may force household members to spend less time in productive and income generating activities, including agriculture and food production. Chikaire *et al*. (2011) also reported that energy scarcity causes precious cash resources to be spent on purchasing fuel, thereby reducing households' ability to purchase food or accumulate productive resources.

Among energy sources, access to electricity is among the fundamental constraints to ensuring sustainable development, food security, and global poverty reduction (Lee and Chang, 2008; Kebede *et al.*, 2010). Electricity access, as part of a portfolio of clean and renewable energy sources, plays a crucial role in achievement of the Sustainable Development Goals such as SDG 2 (food security and zero hunger), SDG 3 (good health and wellbeing), SDG 5 (gender equality), and SDG 13 (climate action). However, 600 million people in sub-Saharan Africa have no access to electricity, despite ambitious electrification plans implemented in the last decades (International Energy Agency, 2019).

Ethiopia's National Electrification Plan stipulates 100% electrification by 2025, with 65% through the grid and 35% off the grid. Despite progress over the past decades, 68% of the rural population (about 75 million people) had no access to electricity in 2018 (International Energy Agency, 2020). The vast majority of rural households in Ethiopia use fuel wood and agricultural residue as their main energy sources. Heavy dependence on solid biomass has multi-dimensional negative effects on health, food security, and nutritional status (Guta, 2014; Mekonnen *et al.*, 2017; Apanovich, 2018).

There has been little or no research on the effect of access to electricity on food security and children's nutritional status among Ethiopian rural households, although there is related literature in other developing countries (Wang, 2003; Van de Poel *et al.*, 2009; Klauw and Wang, 2011; Diallo *et al.*, 2012; Grogan and Sadanand, 2013; Barron and Torero, 2015; Cavatorta *et al.*, 2015; Akpandjar and Kitchens, 2017; Fujii *et al.*, 2018; Candelise *et al.*, 2021). Much of this literature observes that female-headed households are disproportionately vulnerable to food insecurity (Quisumbing *et al.*, 2001; Babatunde *et al.*, 2008; Mallick and Rafi, 2010). One explanation is that female-headed families have lower incomes and fewer assets than their male counterparts (Buvinic´ and Rao Gupta, 1997). However, the differential effect of access to electricity is less understood. Thus, it is important to examine whether access to electricity and household food security differ across the gender of household heads.

Not enough is known about the channels through which access to electricity affects household food security and children's nutritional status. Electricity has the potential to improve the nutritional status of households and children through a variety of routes, such as increased income, reduced fertility, the spread of information through technology such as TV, and improved health care (Fujii *et al.*, 2018). Perhaps, income improvement may not be the main driver. For example, using a panel of 54 developing countries over the period 2000–2014, Candelise et al. (2021) showed that electricity access exerts immediate impacts on food availability and utilization, with only one-fifth of the impacts coming from income-mediated effects.

This study uses panel data evidence to investigate the impact of access to electricity on household food security and the nutritional status of children under the age of five. We address the existing knowledge gaps by providing new evidence in at least three ways. First, our analysis of panel data will contribute to the impact evaluation of Ethiopia's rural electrification efforts through a new lens of electricity as an input to household food security and child nutrition. Second, we go a step further by establishing whether the impacts are gender neutral. Third, we discuss possible channels through which electricity has these effects. This will help public officials and policy makers by generating objective evidence about how household's food security and child nutrition can be improved through enhancing access to electricity. To the best of our knowledge, there is no study that provides empirical evidence about such relationships in the Ethiopian context.

2. Literature review

The existing empirical studies on Ethiopia mainly focus on fuel choice and scarcity in the context of traditional biomass use (Mekonnen and Köhlin, 2008; Mekonnen and Köhlin, 2009; Beyene *et al.*, 2012; Guta, 2012; Guta, 2014; Mekonnen *et al.*, 2017). Mekonnen and Köhlin (2008) is one of the few studies that has investigated the association between access to modern energy and household welfare in Ethiopia, finding the expected positive correlation. There is a large literature documenting positive correlations between electricity and household income and expenditure in other developing countries (Grogan and Sadanand, 2013; Akpandjar and Kitchens, 2017; van de Walle *et al.*, 2017). However, Lenz *et al*. (2017) find weak impacts of rural electrification on classical poverty indicators for Rwanda.

With respect to food security, Sola *et al*. (2016) reviewed 19 studies on the effect of a lack of access to all types of energy on food security in sub-Saharan African countries. Most of these studies suggested that lack of access to energy can affect food security, but very few of them provided empirical data to support this argument. For example, the review noted that FAO (2013) reported that lack of access to sufficient and appropriate cooking fuel may force people to change their eating and cooking habits by reducing the number of meals, switching to foods that require less cooking time, undercooking their food and bartering part of the food ration for fuel. However, FAO (2013) provides no empirical evidence or literature citations to support these statements. Overall, their review concludes that, due to the limited number of studies with detailed data, it was not possible to perform a comparative analysis that could support or refute a hypothesis that lack of access to energy can impact food security.

In Ethiopia, empirical evidence on the impact of access to electricity on household food security and the nutritional status of children is largely missing. Hence, we aim to fill this gap by providing objective evidence from rural Ethiopia.

3. Data description and Summary Statistics Methodology

3.1. The study setting

Ethiopia is the second-largest country in sub-Saharan Africa. The majority of the population (about 80 per cent) resides in rural areas. The country is divided into eight regional states and two administrative regions. As a result of Ethiopia's topography and geographic location, four traditional agro-ecological zones can be recognized based on elevation. These are desert (locally called *Bereha*), below 500 m above sea level (a.s.l.); low land (*Kolla*), 500–1500 m a.s.l.; middle (*Weynadega*),1500–2500 m a.s.l.; and highland (*Degua*), 2500–3500 m a.s.l.

Agriculture constitutes the basis of livelihood for the Ethiopian population. The sector constitutes about 40 per cent of the country's gross domestic product. An overwhelming proportion of the population depends on subsistence rain-fed farming for survival. The country's agriculture largely depends on seasonal rainfall, which is characterized by a high coefficient of variation. As a result, the sector is highly exposed to changes in climate variability (Conway and Schipper, 2011). Over the past decades, the country has been overwhelmed by climate variability and associated droughts that resulted in profound effects on the country's food production (Bewket and Conway, 2007; Araya and Stroosnijder, 2011; Conway and Schipper, 2011). Recurrent droughts form the major threat to rural livelihoods and food security in the country. Almost every year, the country experiences localized drought disasters that cause crop failure.

3.2. Data

The data used in the ensuing analysis are from the Ethiopian Socio-economic Survey (ESS), a panel household survey collected by the Central Statistical Agency (CSA) with the support of the Living Standards Measurement Surveys – Integrated Surveys in Agriculture (LSMS-ISA) project of the World Bank in all regions of Ethiopia. The survey was implemented in 2012, with two additional rounds of data collection in 2014 and 2016. The dataset comprises rural households from ten different regions of the country. The survey covers both rural and urban households, but this study covers only rural households. Because almost all urban households have access to electricity, it was difficult to create a control group.

The survey covers a wide range of topics, including household information on basic demographics; education; health (including anthropometric measurement for children); labor and time use; food consumption patterns and expenditure; household nonfarm income; food security and shocks; livestock holdings, land holdings, households' access to (and use of) different forms of energy, and use of energy efficient cooking technologies, among other variables (ESS, 2013). In this paper, we focus on rural households. We excluded households in urban areas and those that had missing data for relevant variables.

3.3. The food and nutrition security outcome indicator

Several indicators in the nutritional sciences literature can be used to measure nutrition-based impact (Babatunde and Qaim, 2010; Nguyen and Winters, 2011). We will use dietary diversity as a measure of a household's food and nutrition security. Dietary diversity is defined as the number of different foods or food groups consumed over a given reference period (Ruel, 2002). It can be measured at the household or individual level. At the household level, dietary diversity is generally considered as a measure of access to food (Kant *et al.*, 1993). At the individual level, dietary diversity reflects dietary quality, mainly the micronutrient adequacy of the diet. Accordingly, dietary diversity indicators are associated with dietary quality, energy (calorie) intake, and food security.

Different methods are available to measure dietary diversity. In the nutritional literature, the food variety score and the dietary diversity scores are the two indicators most commonly used (Kant *et al.*, 1993; Swindale and Bilinsky, 2006; FAO, 2011). The food variety score simply counts the number of consumed food items and food groups recorded (Kant, 1996). While count measures are simple to construct and interpret, they fail to account for differences in the nutrition content across food items or groups (Nguyen and Winters, 2011). Furthermore, owing to cultural differences in dietary habits, the food variety score is less suitable for comparisons across countries or regions (Sibhatu *et al.*, 2015). Variety should therefore be measured not only by the number of food items consumed but also by their distribution. There are other commonly used indices that allow capturing differences in the nutrition content of the food items consumed, such as the dietary diversity score (HDDS), the diet quality index (Kant *et al.*, 1993; Patterson *et al.*, 1994), and the per adult equivalent nutrient intake.

In this paper, we use dietary per adult equivalent nutrient intake of calories, protein and iron separately, and construct the dietary diversity[1] score, which is one of the most direct indicators related to food and nutrition security (Hoddinott and Skoufias, 2004; Gilligan and Hoddinott, 2007), using the Simpson index (SI) of food diversity. The SI measures household access to a variety of foods. It is mathematically defined as a function of a household's consumption share of each food items:

$$SI = 1 - \sum_{i=1}^{n} w_i^2 ,$$

where w_i is the calorie share of the i^{th} food item. The Simpson index varies from 0 to 1, such that the higher the index, the more diversified the diet. The dietary diversity score is derived based on seven food groups that include 26 food items. Total consumption was determined by summing

[1] Dietary diversity refers to nutrient adequacy, defined as a diet that meets the minimum requirements for energy and has all essential nutrients. The rationale for using dietary diversity as an indicator for dietary quality stems primarily from a concern related to nutrient deficiency and the recognition of the importance of increasing food and food group variety to ensure nutrient adequacy.

consumption levels collected for 26 food items, in seven food groups, during seven days. The physical quantity of food consumed by a household was converted into calories, protein and iron intake, adjusted for household age and sex composition, using the national food composition table compiled by the Ethiopian Health and Nutrition Research Institute (EHNRI, 2000).

We also used anthropometric measures to assess children's nutritional status. The most commonly used anthropometric measures are height-for-age and weight-for-height. For these measures to be useful, they have to be compared to corresponding measures for a well-nourished and healthy reference population of children. In order to standardize the measures of child under-nutrition, they are typically transformed into z-scores using the WHO growth standards (WHO, 2006) referred to as height-for-age z-scores (HAZ) and weight-for-height z-scores (WHZ). Children with height-for-age z-scores (HAZ) less than –2 from the median of the reference population are regarded as stunted or chronically malnourished, while those with HAZ less than –3 are considered severely stunted (CSA, 2014; Bastagli *et al.*, 2016). Similarly, children with weight-for-height z-scores (WHZ) less than –2 are regarded as wasted or acutely malnourished. Wasting, in contrast to stunting, reflects acute malnutrition and may be the result of more recent insufficient food intake (Bastagli *et al*., 2016). Hence, in this study, we will compute child stunting and wasting using the three waves of data.

3.4. Definition of Covariates

Definitions of variables are shown in Table 1.

Table 1: Variables used in the specification of the outcome regression model

Variables	Type	Measurement
Treatment variable	Dummy	1 if household is connected to grid electricity, zero otherwise.
Outcomes		
Calorie intake	Continuous	
Protein intake	Continuous	
Iron intake	Continuous	
Household dietary diversity score	Continuous	
Height-for-age z-scores (HAZ) – Stunting	Continuous	
Weight-for-height z-scores (WHZ) – Wasting	Continuous	
Other explanatory variables		
Sex of household head	Dummy	1 if head is male, 0 otherwise
Age of household head	Continuous	Age of the household head in years
Land holding size	Continuous	Hectares
Livestock ownership in TLU	Continuous	Tropical Livestock Units

Food expenditure	Continuous	Ethiopian Birr
Non-food expenditure	Continuous	Ethiopia Birr
Dependent family members	Continuous	Number of children under 15 years age
Agricultural labor worked per week	Continuous	Number of days worked
Non-agricultural labor worked per week	Continuous	Number of days worked

The explanatory variable of interest is access to electricity, defined as household-level connection to electricity. Not all households in grid-connected communities are actually connected.

The off-grid electric sources currently available in rural Ethiopia, such as solar, are mainly designed for lighting and/or radio. By contrast, cooking requires high-powered electric energy. We do not have survey data on households' ownership and use of modern cooking facilities. However, we observed in our field work that most grid-connected households are using electricity to power clean, modern cooking devices. There, we believe that grid connection is a reasonable proxy for a household's use of electric-powered rather than biomass cooking equipment.

Hence, access to electricity is measured as a binary variable indicating whether the household is actually connected to grid electricity.

Empirical studies indicate that the gender of the household head influences household dietary diversity. For instance, Quisumbing *et al*. (1998) argued that, since women are primarily involved in food preparation and have power to allocate household family budgets, food selection within a household is expected to be influenced by women's knowledge regarding the nutritional benefits of different foods. Accordingly, female-headed households are expected to have a higher likelihood of attaining better dietary diversity than their male counterparts (Rogers, 1996; Taruvinga *et al.*, 2013). In contrast, Tankari and Badiane (2015) found that, when the household is headed by a man, food diversity improves relative to households headed by a woman. However, this result could be confounding the effect of differences in access to income-generating opportunities for men relative to women.

Education refers to the educational level of the head of the household and is measured as the highest level of education attained. Education is presumed to increase the farmer's knowledge, improving the use of information relevant to farm productivity, which in turn plays a role in improving household dietary diversity. Taruvinga *et al*. (2013) find that more educated households are more likely to attain a high dietary diversity. Gronau and Hamermesh (2008) report a positive correlation between education and diet diversity.

The head's age might affect a household's dietary diversity through asset accumulation or diversifying his/her production activity. Empirical studies indicate that age of head and household size have a significant influence on food diversity and have a nonlinear relationship (Thiele and Weiss, 2003; Tankari and Badiane, 2015).

We also included other measures that could influence household dietary diversity. Land and livestock holding are the main wealth indicators in rural Ethiopia. We use the amount of land cultivated by a household to control for farm size, which may explain much of the underlying difference in household wealth and food security status. Farm size is also expected to influence household dietary diversity (Oyarzun *et al.*, 2013). Furthermore, in order to control the wealth effect on household nutrition, we included the number of livestock owned by a household, aggregated in terms of tropical livestock units (TLU).

Food-related expenditures are expected to directly influence the quantity and quality of household diets, while non-food expenditures may indirectly influence the amount of resources available for diversifying diets (Jones *et al.*, 2014). Thorne-Lyman *et al*. (2009) found significant positive correlations between dietary diversity score and per capita food and non-food expenditure. Accordingly, household expenditures for food and non-food, reported over a period of seven days, are considered to control for household-level use of productive resources.

4. Empirical Strategy

We employed a combination of empirical strategies to examine how access to electricity has impacted household food security and nutritional status of children under the age of five. A household's food security and child nutrition status are expressed as:

$$Y_{ikjt} = \alpha + \theta E_{ijt} + \lambda C_{jt} + \beta X_{ikjt} + \eta_{ij} + \varpi_{ikj} + \nu_j + \varepsilon_{ikjt}$$

1

where Y_{ikjt} is the household's food security and child nutrition status for household *i* and child *k* living in community j at time *t*. E_{ijt} is a binary variable, which denotes a household's status of connection to electricity at time t, C_{jt} is a vector of observable community characteristics, X_{ikjt} represents a vector of observed household-level and child-level characteristics, and h_{ij}, ϖ_{ikj} and u_j are unobserved time-invariant household-level, child-level, and community-level characteristics, respectively. ε_{ikjt} is unobserved time-varying household and community characteristics and is assumed to be normally distributed with mean zero and variance s_e^2.

As discussed in the data section, the LSMS data has three waves. Using these waves, we applied a Difference in Difference (DID) approach to estimate the short-run and long-run impact of access to electricity on households' food security and child nutrition. We used the 2011 and 2016 panel data to estimate the 'long-run' effect of access to electricity and 2011 and 2013 to estimate the short-run effect. The DID approach has the advantage of differencing out the existing differences between households with and without connection to grid electricity.

The DID method works best when households are randomly assigned (treated) to get connected to electricity, or at least when the observable characteristics can be used to control for getting treated. However, households were not randomly selected to get connected to grid electricity. Households may self-select and get connected to electricity provided that there is electricity in their community. Placement of electricity at the community level is not also randomly determined. The decision to provide electricity for a certain community depends on observable and unobservable characteristics. For example, access to electricity at the community level may be determined based on some feasibility study, implying that villages (communities) that have access to electricity are different from those that do not have access. In addition, those households in the control group (not connected to electricity) may not be similar to treated households and may not satisfy the basic condition of DID. Thus, to obtain a control group that is not systematically different from the treatment group, we used the propensity score matching method (PSM) to select them. In what follows, we present how we applied these two methods to get the estimates.

Using the 2011 survey data (baseline data), we applied the nearest neighborhood propensity matching method with 0.05 calipers to select control households that are similar to the treated households based on their propensity score. PSM uses a logistic regression (the dependent variable is equal to 1 for those that are connected to electricity and 0 otherwise) in which the independent variables consist of 2011 characteristics that may affect the propensity to get connected to electricity. We used households' socio-economic characteristics such as occupation, education level, gender, age, marital status, household size, prices of alternative fuels, and community-level fixed effects to match treated and control households.

After matching treated and control households based on 2011 socio-economic characteristics of households, we used the 2011 and 2016 survey data and applied the Difference in Difference approach. Because the time gap between 2011 and 2013 is relatively short, we applied the DID using the 2011 and 2013 survey data to estimate the 'short-run' effect. Thus, using these survey data, we used the following DID model to estimate our parameters of interest.

$$Y_{ijt} = a + f(E_{ijt}\ X\ year) + qE_{ijt} + d year + bX_{ijt} + h_{ij} + u_j + e_{ijt} \qquad 2$$

where year is a dummy variable taking a value of one if the year is 2016 (long run) or 2013 (short run) and zero for 2011. All other variables are as explained above.

5. Descriptive Statistics

5.1.1. Basic summary statistics for household with and without connection to electricity

The Ethiopian socio-economic survey consists of about 3,206 farm households on average during the years 2011/12, 2014, and 2016. About 15 percent of the households surveyed are connected to grid electricity, while 21 percent are connected to grid and/or off-grid electricity. This section looks at some descriptive statistics on food consumption, nutritional outcomes and some variables of interest. Using LSMS data, we look at household level of food consumption, calorie, protein and iron intake, and energy access, using headship characteristics.

The data indicates that, on average, 75 per cent of household heads in the three surveys are male-headed and the remaining 25 per cent are female-headed. The most common age range of household heads is between 31 and 40 years (18.7% for female heads and 26.9% for male). The mean age for household heads is 46.7, while the mean age for male heads of households is lower (45.5 years) compared to female counterparts (50.4 years). With regard to educational status, 86.5% of female heads of households and 62.6% of their male counterparts do not have any formal education. Forty-five per cent of households surveyed had a household size of four to six.

Livestock and land holding are very important assets and play a significant role in the rural Ethiopian economy, with important implications for household food security. Based on these key indicators, the data from the Ethiopian socio-economic survey indicate that 58% of households reported owning land used for agricultural activities, while 67.1 % of heads of households had land holding size of less than 1 hectare. The mean livestock holding measured in tropical livestock units (TLU) is 3, 3.3, and 3.4 for the first, second and third round surveys, indicating an increase in livestock holding. In waves 1, 2, and 3 respectively, 48%, 44%, and 43% of households had livestock of 2 TLU or less.

As a measure of food and nutrition security, calorie and protein consumption per adult equivalent per day was calculated. The physical quantities of food items consumed during a month in 2011/12, 2013/14 and 2015/16 were converted into food calories and protein by adopting the national composition table compiled by the Ethiopian Health and Nutrition Research Institute (EHNRI, 2000).

Table 2 presents sample statistics of the outcome variables (per adult equivalent calorie and protein consumption) and dietary diversity measured as a simple count of food groups consumed by a household across the three waves. The descriptive result reveals that average per capita calorie consumption was about 2,128 kcal, which is 1% higher than the national average daily per capita calorie requirement needed to maintain a healthy life (2,100 kcal) set by the Ethiopian government. About 52% of the households consume fewer calories than the recommended daily physiological requirement. We also noted changes in calorie consumption between the three waves. Although about 53% of households consumed more than the recommended average daily per capita calorie requirement in 2011/12, this declined to 44% in 2013/14 and 45% in 2015/16. This is mainly attributable to the worst drought in decades in 2015/16, which was a year marked by a strong El Niño, with localized droughts occurring in the preceding years.

Average protein consumption per day per person is about 69 grams, which is higher than the national average dietary protein consumption (57 gm per person per day). Table 3 further reveals that protein consumption per day declined from 70.4 gram per person per day in 2011/12 to 57.1 gram in 2015/16, although it is still above the national average. The average Simpson index value is about 0.39. These values shows that households exhibit a high level of dietary diversity, and that it was relatively higher in 2016 than in 2011 or 2014. On the other hand, when dietary diversity is measured by a simple count of food groups that households consumed over the last seven days, the mean dietary diversity for all households is 5 across the three waves. This indicates that on average every household consumed almost 5 different food groups in the 7-day period preceding the survey. By this measure, households in the survey exhibit medium dietary diversity on average. We also noted a change in the number of food groups consumed by households between wave 1 and wave 3. The mean dietary diversity increased from 4.6 in 2011/12 to 5.8 in 2015/16, indicating a transition from average or medium dietary diversity to the edge of high dietary diversity between the periods, based on the Food and Agriculture Organization's classification of food consumption (FAO, 2007).

Table 2: Household dietary intake and food diversity across years

	Year			Total
	2011/12	2013/14	2015/16	
Calorie intake per adult equivalent, Kcal per day	2230.3	2060.6	2095.4	2128.5
	(887.2)	(843.1)	(857.9)	(865.8)
Protein intake per adult equivalent, gm per day	70.4	70.2	67.1	69.2
	(42.4)	(87.6)	(67.0)	(68.1)
Iron intake per adult equivalent, mg per day	27.3	25.4	23.6	25.4
	(18.3)	(18.9)	(17.9)	(18.4)
Simpson index (based on calorie share)	0.38	0.38	0.42	0.39
	(0.19)	(0.19)	(0.19)	(19)
Number of food groups	4.6	4.6	5.8	5
	(1.2)	(1.3)	(1.3)	(1.39)

Table 3 reflects descriptive statistics of the sample households who have access to electricity (grid or off-grid electricity) across the survey rounds. The descriptive result indicates that on average about 15 percent of the sampled households use grid electricity, while only 6 percent use off-grid electricity. The temporal data indicates that the number of households who use grid and off-grid electricity increased over the period.

Table 3: Access to electricity across years

Variables	2011	2013	2016
Households' connection to grid electricity	11.4%	15.6%	18.1%
Households' connection to grid and off grid electricity	11.5%	18.6%	33.3%

5.1.2. Summary statistics for children under age of 5 years

In this section, we will briefly discuss the summary statistics for nutrition outcomes for children under the age of five years. We generated z-score values for height-for age, weight-for-height, and weight-for-age using the WHO (2006) child growth standard measurement. The three indices show the standard deviation from the median height or weight of WHO's well-nourished reference group (Debela *et al.*, 2014). In the 2011/12, 2014 and 2016b survey rounds, anthropometric data were obtained for all children living in the household who were aged from 6 months to 5 years. Of the 3268, 3093 and 3267 rural households covered in this study by the LSMS survey in waves 1, 2 and 3, we obtained anthropometric data for 1,236, 1,155 and 1,238 children living in the household who were aged from 6 months to 59 months.

Based on the anthropometric data, we determined height-for-age z-scores (HAZ), weight-for-height z-scores (WHZ) and weight-for-age z-scores (WAZ). A child is considered as stunted, wasted or underweight if the measurement for the child is greater than two standard deviations below the median for the reference population (Bastagli *et al.*, 2016). Thus, children with height-for-age z-scores (HAZ) less than –2 from the median of the reference population are regarded as stunted or chronically malnourished, while those with HAZ less than –3 are considered as severely stunted. Stunting considers height by age and reflects failure to get sufficient nutrition over a long period of time (CSA, 2014; Bastagli *et al.*, 2016). Thus, height-for-age represents long-term effects of malnutrition and is not sensitive to short-term changes in dietary intake (CSA, 2014). Similarly, children with weight-for-height z-scores (WHZ) less than –2 were regarded as wasted or acutely malnourished. Wasting, by contrast, reflects acute malnutrition and may be the result of a more recent insufficient food intake (Bastagli *et al.*, 2016). Weight-for-age is an overall indicator of a children's nutritional status. Children with weight-for-age below minus two standard deviations (−2 SD) are classified as underweight.

In a 2019 nationwide Ethiopian Demographic and Household Survey (DHS), 37 per cent of children under the age of 5 years were found to be stunted, while 7 percent were wasted and 21 percent underweight (EPHI and ICF, 2021). Similarly, we found that about 45.9 percent of children under the age of five were stunted, and 11.6 percent were wasted, indicating the existence of chronic malnutrition in the country. This figure is slightly higher than the national average reported by the 2019 Demographic and Household Survey, showing 37 stunted and 7 per cent wasted (EPHI and ICF, 2021). Looking at the temporal pattern, the mean height-for-age z-score slightly worsened between 2011/12 and 2014, although the percent of children who were stunted declined from 49.7 per cent in 2014 to 42.2 per cent in 2016 (Table 4).

Furthermore, the summary result reveals that, on average, 11.6 per cent of children under the age of five are wasted. The mean value for weight-for-height and the proportion of children wasted between 2011/12 and 2016 worsened, indicating that the prevalence of wasting or acute malnutrition worsened among children under the age of five years. However, our result showed a lower prevalence of wasting, 11.6 per cent, compared to the finding of 15.5 percent in 2012 in Berhane et al. (2016) .

Table 4: Mean values of height-for-age, stunting, weight-for-height, and wasting, by survey round

	Height-for-age		Weight-for-height		Weight-for-age	
	Mean score	Per cent stunted	Mean score	Per cent wasted	Mean score	Per cent underweight
2011/12	-1.80	47.2	-0.126	7.4	-1.04	23.6
2013/14	-1.72	49.7	-0404	10.2	-1.30	29.1
2016	-1.50	42.2	-0.322	14.6	-1.19	27.2
Full Sample	-1.64	45.9	-0.315	11.6	-1.21	27.2

Table 5 presents the mean values for key children's nutrition outcome indicators, comparing children from households that are connected to grid electricity to children from households that are not connected, by survey round. Long-term nutritional status, HAZ, improved in both groups between 2011/12 and 2016, declining from -1.85 in 2011/12 to –1.50 in 2016. On the contrary, WHZ declined from -0.13 in 2011/12 to -0.32 in 2016, and the short-term nutritional status (WAZ) also declined over the period. Table 6 further indicates that, in general, long-term under-nutrition (HAZ) in households that are not connected to electricity is slightly worse than among children living in households that are connected to electricity. The children living in households that are connected to electricity exhibited higher WHZ than children in households without access to electricity.

Looking at the proportion of children who are stunted within households that have and do not have access to electricity, we found that children in households that do not have access to electricity (grid or off-grid) are slightly more likely to be stunted (32.3%) than children in households with access to electricity (10 %) in 2016. However, the prevalence of wasting is higher among households that are connected to electricity than among children in households that are not connected to electricity (Table 5). The results further show that the prevalence of underweight is slightly higher for children in households without connection than in households with connection to electricity across the survey rounds.

Table 5: Summary of child nutrition outcome indicators by access to electricity and across years

Outcome variable	Year	Full sample	Not connected	Connected	t-test
Height-for-age (HAZ)	2011/2	-1.80	-1.91	-1.51	-2.756
	Stunting		-3.26	-2.85	1.14
	2014	-1.72	-1.74	-1.66	0.733
	Stunting		-3.01	-3.19	0.394
	2016	-1.50	-1.54	-1.37	-0.013
	Stunting		-3.33	-3.28	
Weight-for-height (WHZ)	2011/2	-0.126	-0.153	-0.047	1.41
	Wasting		-2.63	-4.05	0.861
	2014	-0.404	-0.348	-0.516	1.07
	Wasting		-2.73	-3.08	-1.970
	2016	-0.322	-0.232	-0.610	-1.241
	Wasting		-2.901	-3.08	
Weight-for-age (WAZ)	2011/2	-1.045	-1.154	-0.723	1.28
	Underweight		-2.79	-2.346	-0.165
	2014	-1.303	-1.345	-1.175	2.15
	Underweight		-2.846	-2.635	-0.628
	2016	-1.194	-1.161	-1.301	-1.236
	Underweight		-2.702	-3.007	-0.451

6. Econometric Results

As discussed in the empirical strategy section, we estimate the effect of connection to electricity on food consumption and dietary intake using a Difference in Difference approach (DID). We first matched households using propensity score matching on the baseline data (2011). We also use a random effects method as a comparison with the DID results.

Before the DID analysis, a discussion of connection to electricity will provide insight into what determines households' connection to electricity. The matching results of households' probability of being connected to electricity is shown in Table 6.

Table 6: Matching regression result of connection to grid electricity

Variables	Coef.	Std. Err.
Age of the household	-0.002	0.003
Marital status	0.259**	0.109
Education of the household head	0.042**	0.009
Total monthly expenditure	0.0001***	0.000
Household size	-0.009	0.021
Price of kerosene	0.001	0.001
Access to all weather road	0.709***	0.112
Access to microfinance service (1= yes, 0=no)	0.025	0.099
Do people immigrate to the community for work? (1= yes, 0=no)	-0.297***	0.084
Constant	-1.540***	0.2
No. of observation	1619	

***= significant at 1% level of significance, **= significant at 5% level of significance and *=significant at 10% level of significance

The results show that households who have higher income or higher consumption expenditure are also more likely to be connected to electricity. The presence of other infrastructure such as roads also increases the likelihood of community-level access to electricity. Furthermore, married households are more likely than unmarried households to be connected to electricity. This could be because married households are more likely to have their own house.

Next, we discuss the effect of connection to grid electricity on food, calorie consumption, protein intake, iron intake, and children's stunting and wasting. Table 7 presents the effects using the matched three waves of data. Because all the outcome variables are continuous, the estimated coefficients are also marginal effects. Table A in the appendix also shows the random effect estimation of the effect of connection to electricity on the outcome variables. Comparing the estimated coefficients of all outcome variables between the DID and random effect estimation, almost all the coefficients of connection to grid electricity are larger in magnitude than the DID estimates. In terms of precision, most of the random effect estimates are statistically significant, while a few of DID estimates are statistically significant. This implies that random effect estimates overestimate the true effect of electrification.

Although the random effect does control the unobserved characteristics, it does not remove the bias that comes from the correlation between households' connection to grid electricity and their unobserved characteristics (time-varying and time-invariant) such as an individual household's motivation to get connected to grid electricity. Difference in Difference approaches reduce such bias by differencing out the unobserved time-invariant household characteristics.

The coefficients of the access to electricity variable in Table 7 are the estimated mean difference in outcome variables (calorie intake, protein intake, iron intake, stunting and wasting) between connected and unconnected households at the baseline (2011). They represent whatever baseline differences existed between the two groups. The estimated coefficients of all outcome variables except the anthropometric measure of child stunting are statistically indistinguishable. This means that in the baseline (in the year 2011) there is no difference in calorie intake, protein intake, iron intake and child anthropometric measures of wasting between connected and unconnected households. However, a child in a household with access to electricity is found to be more stunted than a child in a household without access to electricity in the baseline (in the year 2011). This may look inconsistent given the expectations; however, as this is the baseline result, it could be due to the effect of multiple factors.

Further, the coefficients of the year dummies variable reflect expected mean change in the outcome variables over time for households that are not connected to electricity. This reflects the effect of the passage of time in the absence of the actual intervention, i.e., in the absence of connection to electricity. The result shows that calorie, protein, and iron intake per day decreased by 338.05Kcal, 6.7gm, and 2.8mg between 2011 and 2013 respectively, and by 286.13Kcal, 13.49gm, and 5.36mg between 2011 and 2016, respectively among households without connection to electricity. The decline in food consumption among households without connection to electricity in the years 2013 and 2016 is consistent with the periods of lower precipitation in the country, in particular in 2015-2016, when the country experienced one of the worst El Niño-induced droughts in decades, with below-average rainfall leading to 50–90% harvest failure affecting more than 10.2 million people. This suggests that households with connection to electricity may have had better access to water for irrigation and therefore may have been less affected by the drought conditions, or may also have other sources of income (Candelise et al., 2021).

Table 7: Difference in Difference regression result of the effect of connection to electricity on household food security and child nutrition

Variables	Food calorie Coef.	se	Protein Coef.	Se	Iron Coef.	se	Stunted (HAZ) Coef.	se	Wasted (WHZ) Coef.	se
Access to electricity	7.246	73.280	-0.497	5.899	-2.020	1.522	-18.054***	6.861	0.274	4.572
2013	-338.053***	41.862	-6.707**	3.375	-2.814***	0.870	-7.799**	3.914	5.423**	2.585
2016	-286.138***	40.512	-13.496***	3.265	-5.367***	0.842	-10.331***	3.832	10.324***	2.514
Electricity #2013	187.456**	94.591	6.625	7.624	0.207	1.965	26.407***	8.547	0.092	5.700
Electricity #2016	153.305*	90.401	8.774	7.282	2.323	1.878	22.527***	8.242	-0.299	5.433
Household head age	1.756*	1.058	-0.086	0.085	0.051**	0.022	0.184	0.124	-0.146*	0.080
Household head education in years	5.698	4.802	-0.117	0.386	0.241**	0.100	1.662***	0.406	1.014***	0.260
Household Size	-98.000***	7.501	-4.500***	0.602	-0.830***	0.156	0.767	0.780	-0.461	0.500
Marital Status	31.635**	15.519	0.960	1.247	0.302	0.322	-6.301***	1.793	4.395***	1.176
Gender of the household Head (1=male, 0=female)	118.487**	50.369	7.279*	4.047	1.329	1.045	1.738	4.826	7.817**	3.169
Livestock in TLU	27.331***	4.146	2.210***	0.333	0.402***	0.086	-1.726***	0.386	0.242	0.247
Household land size in hectares	38.280***	11.321	2.337**	0.911	-0.042	0.235	0.810	1.041	-0.511	0.664
Total food expenditure	0.098***	0.029	0.007***	0.002	0.002**	0.001	-0.003	0.002	0.000	0.001
Total food non-expenditure	0.034***	0.006	0.001**	0.000	0.000	0.000	-0.002***	0.000	-0.000	0.000
Agricultural labor worked per week	0.619**	0.266	-0.001	0.021	0.002	0.006	0.005	0.023	-0.041***	0.015
Non-agricultural labor worked per week	0.962	0.650	0.040	0.052	-0.005	0.013	-0.055	0.060	0.009	0.040
Constant	2,288.903***	93.968	80.459***	7.533	25.820***	1.949	68.376***	8.899	-2.626	5.771
Observations	3,302		3,301		3,301		1,533		1,560	
Number of hhid	215		215		215		194		193	

*** p<0.01, ** p<0.05, * p<0.1

The coefficient of the interaction term (Electricity#year) is the difference in differences (DID) estimator. It measures the effect of electricity connection on households' food consumption, dietary intake and children's growth. Accordingly, households' connection to grid electricity has a significant effect on households' calorie consumption and children's rate of stunting but an insignificant effect on household's protein intake and iron intake and children's likelihood of wasting. The result about children's stunting is consistent with the result for calorie consumption. The higher calorie intake of the electrified households implies that their children are less stunted because more calories are available. Protein deficiency is correlated with wasted growth in children. Hence, the insignificance of both protein intake and wasted growth in children are consistent.

The significance of calorie consumption may imply that access to electricity affects food consumption through the ease of using electricity for frequent cooking. Other fuel sources such as firewood are relatively time consuming to collect and prepare for use in baking. Smoke from firewood is also another source of inconvenience. This result is consistent with the recent cross-country study of Candelise et al. (2021). They found that access to electricity improves food availability and utilization.

The information and awareness channel of access to electricity was expected to create a difference in dietary diversity, such as intake of protein, iron rich foods, etc. The insignificance of protein intake and iron intake may imply that there is no difference in awareness among connected and unconnected households.

As shown in Table 7, in addition to electrification, there are also other socio-economic characteristics that have significant impact on households' food consumption. Gender of the head of the household, land size, and number of livestock are positively correlated with a household's calorie, protein and iron intake. As expected, household size is negatively correlated with calorie, protein and iron intake. The larger household size means more mouths to share a given amount of available food.

7. Conclusions

Access to energy is one of the components of the Sustainable Development Goals (Goal 7). Connection to electricity may have impacts on various dimensions of development and sustainability. This study focused on the impact of connection to electricity on households' food security and nutritional status of children under the age of five, using three waves (2011, 2013/14, and 2016) of the World Bank's Living Standard Measurement Survey.

Methodologically, we used a Difference-in-Difference approach. The DID approach is used to remove preexisting differences between treatment and control households. The method is best when the treatment is randomly assigned. However, communities were not randomly assigned for grid access at the village level. Further, households were not randomly selected for grid connection; there is self-selection into the electricity treatment, which violates the balance requirement of the DID approach. Hence, before we applied the DID approach, we created a group of control households that are not systematically different from the treated households, using nearest neighborhood propensity matching. Households are matched using the baseline data (2011).

The DID estimation shows that connection to grid electricity increased *households'* calorie intake by 153 kcal per day in 2013/14 and by 187 kcal in 2016. Differences in *children's* calorie intake are not statistically distinguishable. Children in households with connection to electricity are less likely to be stunted (an indicator of chronic malnutrition) than those in households without connection to electricity. However, there is no statistically distinguishable difference between connected and unconnected households in children's protein intake or in children's wasting (an indicator of acute malnutrition).

Our findings of less child stunting and higher household caloric intake in grid-connected households confirms these benefits due to Ethiopia's rural electrification program. Electrification may affect food security and child nutrition through a number of channels. One channel is through convenience of food availability, cooking, and preservation. It is more convenient to cook frequently with electricity than with fuelwood. Further, connection to electricity may affect the nutritional status of households through information exposure via TV viewing or radio, or through improved health care services. Connection to electricity may also affect access to food through income, including cross-sectoral productivity increases and the creation of new economic activities, generating income that in turn improves the economic access to food. These channels are left for further study.

In summary, expansion of electricity, in addition to providing lighting and other end use services, has an impact on improving household's food security and reducing children's undernutrition. Since grid electricity may take time and also may require substantial investment, off-grid, high-powered electric sources should be considered as a short-term intervention for these added benefits to be realized. Lower-power off-grid sources such as solar are useful for lighting and charging, but not for cooking.

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Appendix –

Table - A: Random effect regression result of the effect of connection to electricity on household food security and child nutrition

	Food calorie		Protein		Iron		Stunted		Wasted	
VARIABLES	Coef.	se	Coef.	se	Coef.	se	Coef.	se	Coef.	se
Connection to grid electricity	134.730***	40.775	7.826**	3.354	-0.740	0.842	19.497***	2.740	3.987**	1.575
Household head age	2.250**	1.070	-0.047	0.088	0.052**	0.022	-0.484***	0.058	-0.134***	0.033
Household head education in years	-11.842**	4.943	-0.416	0.406	0.168*	0.102	-1.159***	0.271	0.729***	0.156
Household Size	-94.882***	7.664	-4.267***	0.630	-0.876***	0.158	4.114***	0.413	0.489**	0.238
Marital Status	21.415	15.458	-0.186	1.276	0.220	0.321	-1.915**	0.842	1.159**	0.484
Gender of the household Head (1=male, 0=female)	119.340**	50.282	5.232	4.142	1.183	1.041	3.642	2.716	3.806**	1.563
Livestock in TLU	25.163***	4.281	2.152***	0.353	0.401***	0.089	-1.459***	0.226	-0.018	0.130
Household land size in hectares	41.248***	11.456	2.317**	0.946	-0.113	0.238	1.072*	0.623	-0.374	0.357
Total food expenditure	0.106***	0.029	0.007***	0.002	0.002***	0.001	-0.002	0.002	-0.000	0.001
Total food non-expenditure	0.026***	0.005	0.001*	0.000	0.000	0.000	-0.001***	0.000	-0.000	0.000
Agricultural labor worked per week	0.671**	0.278	0.003	0.023	0.005	0.006	-0.016	0.015	-0.020**	0.009
Non-agricultural labor worked per week	1.281**	0.644	0.063	0.053	0.004	0.013	-0.046	0.036	-0.026	0.020
2013	-269.644***	37.002	-4.454	3.077	-2.607***	0.774	3.623*	1.998	2.000*	1.144
2016	-228.421***	37.148	-10.292***	3.087	-4.733***	0.777	-1.369	1.996	3.723***	1.143
Village dummies	-71.565	78.357	-5.629	6.452	-4.088**	1.621	12.449***	4.225	2.289	2.426
Constant	2,347.569***	104.226	81.267***	8.536	28.254***	2.142	27.267***	5.614	0.495	3.250
Observations	3,292		3,291		3,291		3,007		3,008	
Number of households[i]	214		214		214		211		211	