

Energy and rural households well-being : Do the facts hold the promise of prosperity?

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Abstract

We review the evidence from the recent literature regarding the impact of electricity on rural households. We emphasize the importance of labor market and human capital transmission channels. Throughout the chapter, we argue that an important vehicle through which the benefits of electricity materialize is through their effects on the empowerment of women within households and within their communities. Our reading of the currently available evidence suggests that while access to electricity is necessary to support local economic development and stimulate a more inclusive labor market, it is however not sufficient. Complementary policies adapted to the specific needs of rural household economies must accompany access to affordable and reliable forms of modern energy.

1 Introduction

Throughout the 20th century the widespread access of firms and households to reliable and affordable energy, and electricity in particular, has been spurring the "engine" of socioeconomic development of the currently developed countries. Developed countries have achieved universal access to energy for decades. Rural areas, though targeted a bit later on, were electrified long before the beginning of the 21st

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century. Based on the experience of developed countries, it is often claimed that access to electricity is a preconditioning step, a necessary though not sufficient one, for the poorest countries to catch-up and enter at last an area of prosperity. As shown in Table 1 and Figure 1, while emerging countries in East Asia (including the Pacific) and Latin America (including the Caribbean) had reached in 2000 a level of 90% and 71% of the rural population electrified (as a % of the total rural population), Sub-Saharan Africa remains far behind with only 12% of its rural population being electrified (and only 64% of its urban population, vs 98% for the other two regions). Over the last 20 years, urban populations of sub-saharan Africa have been slowly catching to their Asian and South American counterparts but rural populations are still mostly off grid. As portrayed in Figure 1; access to electricity remains a bottleneck for the people in Sub-Sahara Africa and particularly for those living in landlocked countries.

Electricity access (% of population)

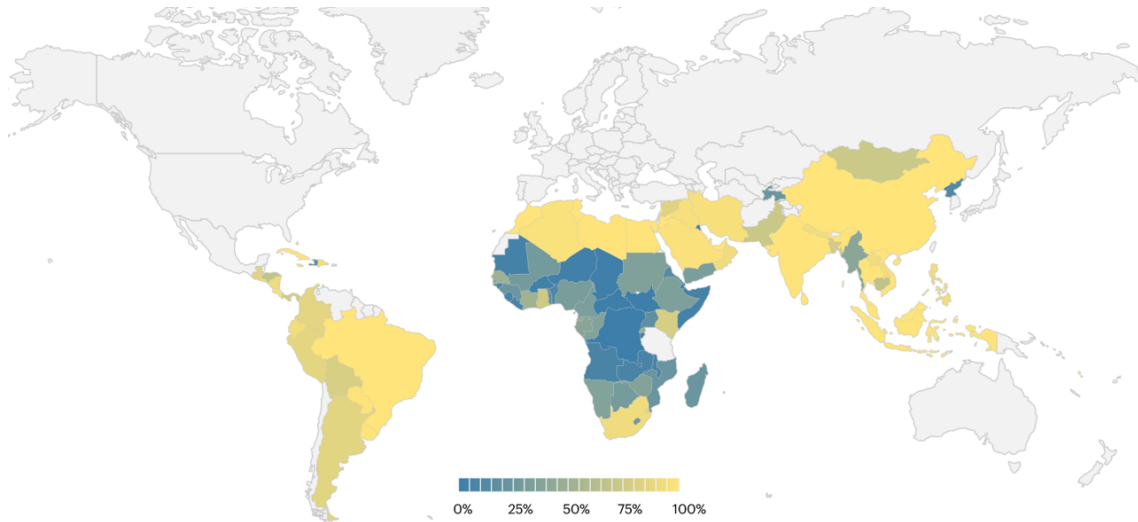
% of population	World	East Asia & Pacific	Latin America & Caribbean	Sub-Saharan Africa
total, 2019	90.08	98.13	98.42	46.75
total, 2000	78.74	93.34	91.70	26.03
urban, 2019	97.27	99.13	99.70	77.86
urban, 2000	95.28	98.83	98.43	64.11
rural, 2019	82.53	96.64	93.00	28.06
rural, 2000	66.48	89.95	70.96	11.83

Source: data obtained from the World Bank DataBank

Beside quantity, the quality of supply remains an issue, being too often limited, unreliable and discontinuous. According to the latest World Bank enterprise surveys, up to 77% of firms in SSA were declaring suffering from electrical outages. Such power outages are even more recurrent in rural areas. The quality of the supply is a bigger issue in urban areas, whereas rural ones are mostly suffering from insufficient access. African governments are striving to promote access to affordable and reliable energy, expecting a returns on these investments for the populations and the society as a whole. Following this goal, public and private sector initiatives are surging to increase household electrification rates particularly in rural

areas. These efforts are notably sustained by influential development policies such as the Sustainable Development Goal 7 from the United Nations, targeting universal access to energy by 2030, or the US Power Africa initiative among others.

Figure 1: **Proportion of the rural population with access to electricity**



Source: EIEA, 2022

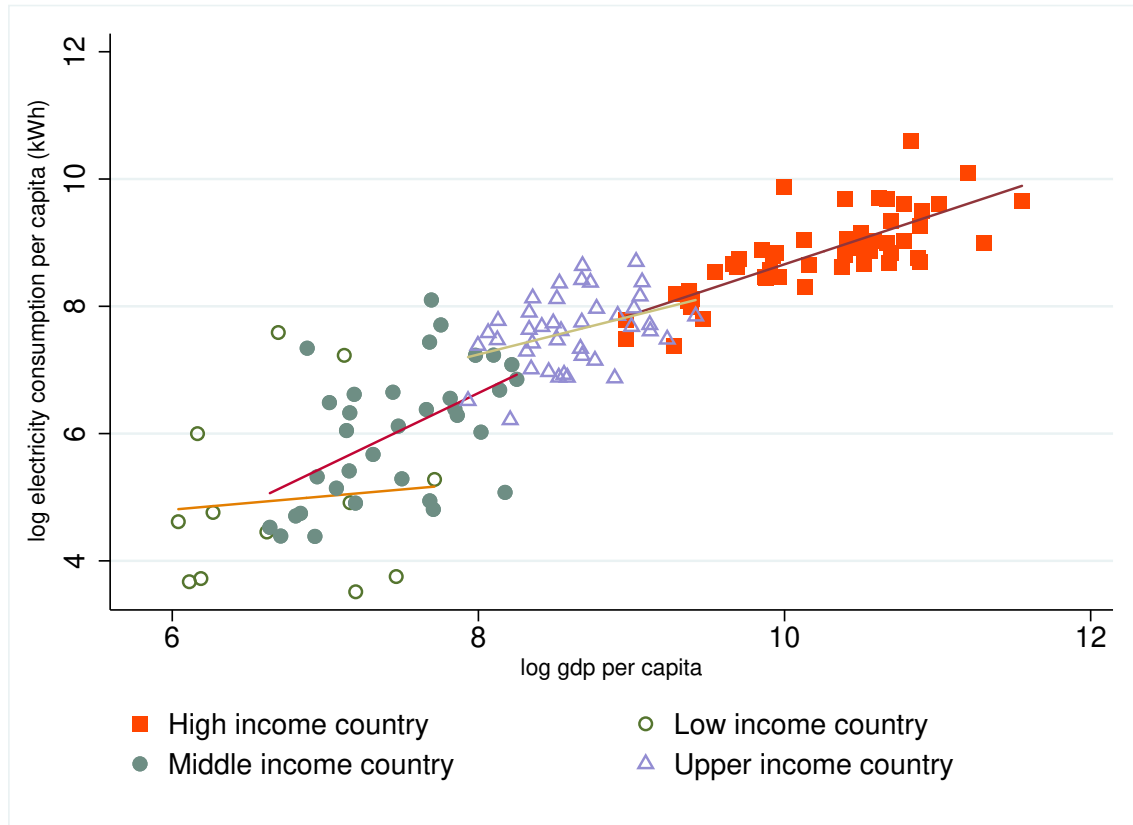
Electricity is an enabling technology at the household, firm, community and economic-wide level. At the household level, access to electricity is expected to open the door to a range of domestic and sanitary services that will alleviate daily constraints and improve household welfare. For instance thanks to better and more efficient indoor lighting with light bulbs, more efficient and secure indoor cooking with electric stoves, better and longer food conservation by generating cold with a freezer, welfare is expected to increase. All these services, provided by electricity-powered appliances, are expected to free valuable time for the household members: *e.g.* time spent getting biomass or fossil fuel (wood or kerosene are the main sources of non-electric fuel for lighting and cooking). Indoor lighting also means that children are able to study at home and at night, and do not have to participate to the household's chores as much. Overall they can better focus on their education. Additional lighting time and resources can be devoted to open independent businesses, and develop existing ones thanks to productivity gains embodied in capital equipments powered by electricity. At the firm level, access to electricity is expected to increase productivity, expand business-size operation and open access to new markets. Widespread access to electricity across communities can therefore unlock economic potential. New jobs are created in new sectors, trig-

gering a economy-wide process of structural transformations, as households and firms get more engaged in activities outside of agriculture, into the service and manufacturing industries.

There is thus a general acceptance among policy makers and the development community of a virtuous energy-prosperity nexus. This premise is rooted in the strong association between economic prosperity, as measured by GDP per capita, and electricity consumption as shown in Figure 2. This relation itself is grounded on the primary hypothesis that access to electricity will help accelerate local socioeconomic development in the communities. Interestingly though, Figure 2 also suggests that the electricity-income gradient is varying across income groups. For low income countries, that comprises most of Sub-Saharan African countries; this association is indeed rather flat and contrasts sharply with the strong correlation observed for other group of countries and in particular for the middle income countries. This figure highlights the fact that the benefits of access to electricity and the demand for electricity may depend on the country's level of development. Indeed if energy is necessary for development, development is also necessary to build the efficient and reliable infrastructures required to produce, transport and distribute energy to consumers. Development is also necessary to generate income that could be invested in assets complementary to energy for households and firms. This is particularly true in Africa where capital markets are under-developed and most of households are therefore credit constraint. There is thus a sensible fear that the complementarity between energy and development may translate into an energy-poverty trap for the poorer part of the world. This highlights the role of policies in promoting access to electricity. Considering the experience of developed countries, Lee et al. (2020b) underlined the correlation between a country's initial GDP per capita and the success of electrification policies. The interesting point to note is that historically, the most successful initiatives were those of governments that simultaneously implemented subsidies policies or micro-credit-access-facilitating policies to help households buy electric appliances.

Given the joint determination of energy and development, understanding the effect of electricity on populations means tackling the important issue of initial selection bias in the provision, access and demand for energy. As governments and operators both expect a return on investment, they are prone to choosing communities sufficiently developed to fully benefit from the arrival of the grid in their midst. Therefore

Figure 2: Electricity consumption and gdp per capita across income groups



Source: World Development Indicators, 2015-2019 or the latest data

access to electricity does not spread randomly across communities and may serve at first the better-off fringe of the populations, which may increase inequality and undermine the constituency needed to politically support the huge public investments needed to extend the grid (Min, 2015). Once electricity has arrived in a community, there is also a process of decision-making across and within households regarding the decision to connect and buy a variety of electric appliances. This process involves couples with different bargaining power. Thus, beside access at the community level, the process of demand for electricity at the household level raises a number of questions: Can the household afford a subscription to the grid? If so, who makes the decision within the household? Do men and women have the same bargaining power on this decision? Do they have the same constraints and preferences? Understanding the impact of electricity requires rationalizing the actions and investments that will lead households to make the most of an electricity connection. Answers to those questions differ given a number of contextual and

household-specific factors, such as the level of education of the household members, their income, the number of children, and the level of local economic development. Given the joint determination of electrification status and economic outcomes one should be cautious about interpreting the positive association between electricity access and economic well being measures. An emerging and important literature is now seeking to establish causation from the link observed between electricity and economic outcome using credible empirical research design relying on quasi-experimental approaches and more recently, with the advent of small scale electrification solutions, using randomized control trials. In this chapter, and taking a household decision-making perspective, we review the evidence that emerged from this recent literature regarding the impact of electricity. We focus on the household and its members, in particular female spouses and children. Throughout the chapter we argue that a vehicle through which the benefits of electricity materialize is through their effects on women's empowerment within households and within their local communities. Our reading of the currently available evidence also suggests that while access to electricity is necessary to sustain local economic development and a greater inclusion of marginal workers in the economy, it is not sufficient in itself. Complementary policies should accompany access to affordable and reliable modern forms of energy. The rest of the chapter is organised as follows. In a second section we provide a brief overview and lessons learned from the 20th century developed countries' experience, with a particular emphasis on the US. In a third section we dig into the impact of electricity on household well being in the low electrified rural areas of developing countries. We focus on human capital and labor market transmission channels. In a fourth section we provide some perspectives with respect to the future of energy use and provision in relation with sustainability and environmental challenges. We conclude in a fifth section.

2 Some lessons from developed countries experience : energy and women's empowerment

Women in developed countries went through what Goldin (2006) called a "quiet revolution". Throughout the 20th century, which happens to be the century of global electrification for rich countries, women (especially married women, for whom paid employment was frowned upon) went from a low and rela-

tively stagnating labor force participation before WWII to an increasing involvement in the labor market that started in the 1940s.¹ Young women had educational opportunities their mothers did not have, and this, coupled with the marketing of contraceptives, allowed women of all ages, married or not, to go to college and have a paying job afterwards, and even a career if they wanted to. After WWII, electric appliances freed time for women to work. At the beginning of the 1970s, women even started to anticipate having a job and a career, therefore they started planning accordingly. More women graduated high school and went to college, pushing the age of marriage further away and lowering their fertility. Women also started to diversify, studying "male" dominated fields like business administration and engineering. Women eventually had the possibility to access economic autonomy outside of their spouse relation, to forge an identity and have a career of their own. As shown by Greenwood et al. (2005b) the arrival of modern electric home appliances was central in triggering a "household revolution": the introduction of labor-saving consumer durables has initiated a process of women's liberation through their impact on the efficiency of domestic production freeing time for training, child rearing and labor market activities.

The effect of electrification on women labor market outcomes depends on how households responded to changes in shadow prices and productivity of home production. Researchers have assessed women labor supply behavior in that respect by looking at the decision to buy electric appliances and maid services to substitute time on domestic chores to paid labor market activities. Stancanelli and Stratton (2014) show that in France and the United-Kingdom the prices of electric appliances and maid services had an impact on women labor force participation. The higher the cost of a maid, the less likely households were to hire one, but the higher the electricity prices and the time opportunity cost of the working couple, the more likely they were to do so. Within couples, men's and women's wages affect positively their decisions to purchase maid services and dish-washers, though the effects have been found to be stronger for women than for men (Stancanelli and Stratton, 2014), as they are much often involved in hand-dish-washing. The magnitude of these effects is similar in both countries, suggesting that it would be true for most developed countries. As for the electrification-development nexus, the labor market-appliance nexus works both

¹The following statement from Frances Perkins, Secretary of Labor in Franklin D. Roosevelt's presidency, on the eve of the Great Depression of the 1930s helps to reconstruct the attitude toward working married women in the United States: "The woman 'pin-money worker' who competes with the necessity worker is a menace to society, a selfish, shortsighted creature, who ought to be ashamed of herself," Perkins said. (cited in MacLean's Canada Magazine see <http://archive.macleans.ca/article/1930/4/1/should-women-earn-pin-money>)

ways; labor market outcomes for men and women determine the decision of households on the quantity and type of consumer durables to acquire, which itself has an effect on their labor market outcomes.

The results of Stancanelli and Stratton (2014) are related to the earlier analysis of Gronau (1977) on the different factors entering the women's domestic production function in the United States and Israel. In developed countries, women's time at home depends on several factors: their income, their husband's income, and whether this time is spent doing leisure activities or housework also depends on income and education and the number of children. Gronau's work shows that in both countries, children can cause women to reduce their time on the labor market and spend more time at home caring for children which impact negatively their leisure time.² In the United States, if a husband's income increases and he spends more time working (and less time doing domestic work) then the wife's work hours decrease. Interestingly, this does not mean she spends more time doing housework, it is her free time that is positively impacted. Gronau (1977) also shows that the more educated women are, the less time they spend doing housework. The higher their income and wage rate, the more time married women spend on the labor market, resulting in a decreased leisure time. Gronau (1977), as Stancanelli and Stratton (2014), looks at the use of market substitutes like maids and finds that as maid services are cheaper in Israel than in the United States, Israeli women are more inclined to enter the labor market and hire a maid to do the work at home.

This discussion suggests that electrification, and household access to appliances, may also impact women labor force participation through its effect on fertility choices and/or labor market opportunities for her and her husband.³ Regarding fertility the impact of electricity is ambiguous; Greenwood et al. (2005a) apply an overlapping-generation-macroeconomic model to time series and cross-country data; they conclude that consumer durables powered by electricity have contributed to the baby boom. Indeed, access to electricity combined with appliances decreases the cost of having children, women's freed time from household chores can be reallocated to better child care, which, together with improvement in cooking

²However, there is clearly a simultaneous determination of fertility choices and labor force supply decisions. This is not until recently that researchers have provided credible tests to disentangle the causal mechanisms linking fertility to labor force participation, a seminal contribution is Angrist and Evans (1998)

³More directly de V. Cavalcanti and Tavares (2008) also studied the impact of electric appliances on women labor force. According to these authors a decrease in the price of household appliances represented 10% to 15% of the increase of women labor force participation from 1975 to 1999 alone, in the United Kingdom.

and sanitation, decreases infant mortality. Focusing specifically on rural areas in the US, Lewis (2018) did not validate the household "productivity effects" stressed by Greenwood et al. (2005a). From 1930 to 1960 US rural areas went from a situation where less than 10% of households were electrified to almost universal electrification. Using cross-county variation in the timing of electrification, and an instrumental variable based on a county-centroid distance to the nearest large power plant, Lewis find that rural electrification has indeed led to a large decline in infant mortality with little impact on fertility. It is important to remember that over the same period women labor force participation remained stable in the US rural areas. Productivity improvement in household production technology does not necessarily decrease total time households allocate to home production. Using historical time-diary studies and time-use surveys Ramey (2009) shows that per-capita time spent on home production has rather increased over the 20th century. Lower women involvement has been more than compensated by greater men participation in home production. One reason for the relatively small effect or even positive effect relates to the trade-off between quantity and quality. The increasing productivity of home production seems to have pushed households to seek a better quality of home production and notably invest more in children education and health care. It turns out that in the case of rural counties in the US, electricity has mostly benefited educational and employment prospect of daughters that have been raised in electrified communities (Lewis, 2018).

Beside transformative effects occurring within households, electrification can also affect welfare and different member of households by transforming the economic structure of local economies in the short and long term. Considering the short-term impacts first, Lewis and Severnini (2020) show, by exploiting county-level exogenous variation in US rural power grid extension from 1930 to 1960, that these concern mainly farm business; interestingly, benefits exceed the costs of grid extension even in low-density areas which is also a feature of most rural areas in Africa. Whether gains in agricultural productivity spill over to other sectors depends on the vicinity of areas with a metropolitan center. They do not observe any shift from agriculture in remote areas. However in areas closer to metropolitan centers, they do observe lower agricultural employment and higher employment growth in the construction, service and trade sectors; the local population also benefited from higher land value caused by the suburban expansion. It is important to stress, following Lee et al. (2020b), that the US-grid-extension policy was part of a full-

policy package; in particular, the federal government displayed countrywide consumer-credit-provision policies which have lightened the credit-constrained burden of households in acquiring domestic durables.

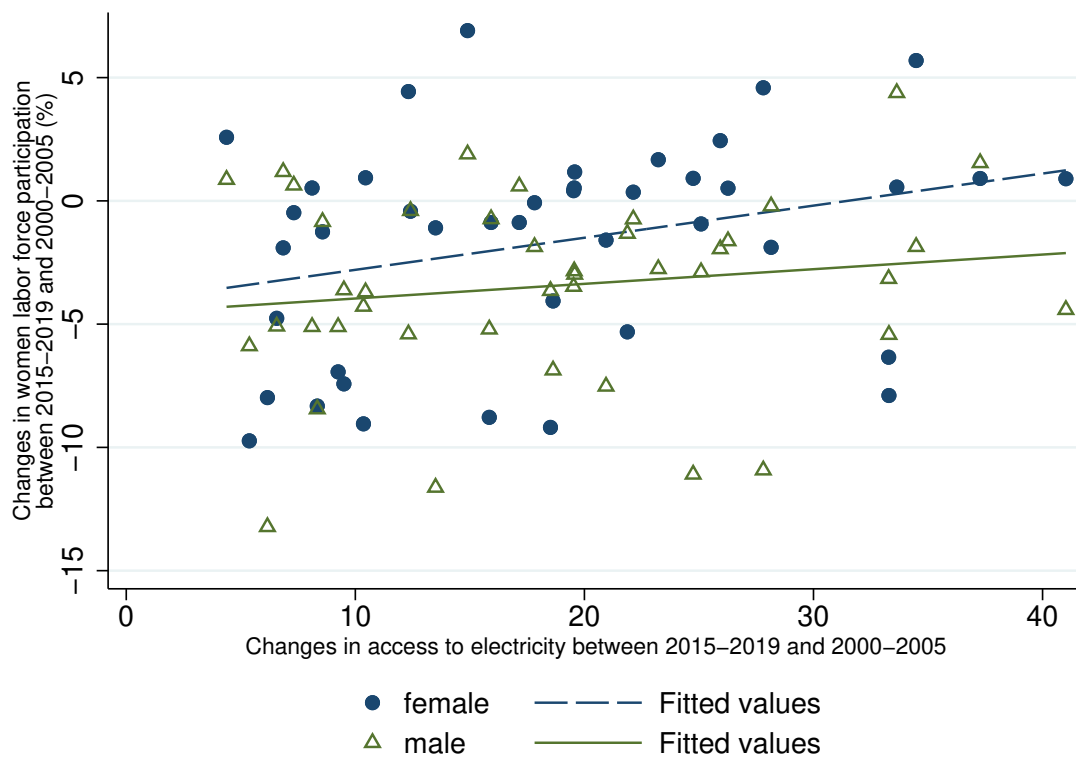
The case of developed countries, and the US experience in particular, suggest that greater productivity of home production, need not increase women labor force participation in the short term. In particular if households prefer to consume better quality home production, by investing for instance more time and resources in children human capital. Moreover the process of structural transformation of local communities and the shift from domestic to market production may require a more efficient farming sector, though this is not sufficient. It should be accompanied by complementary public policies to alleviate the credit constraints faced by the poorest households in acquiring assets complementary to electricity. Finally, we should stress the heterogeneity of these effects which call for an understanding of local contexts. Overall poor areas seem to have benefited less from electrification than richer and better connected areas. This does question the benefit of grid extension compared to other alternatives of electricity supply. The heterogeneity of effects is also a challenge for policymakers seeking to design energy access policies that generate economic returns while avoiding deepening inequalities between communities.

Figure 3 plots the change in women labor force participation and access to electricity between early 2000s and late 2015; we can see that progress made in access to electricity is only very weakly associated with greater women labor force participation. The situation in Latin America and Asia shows similar pattern.⁴. This lack of systematic association suggests a potential role for contextual factors at the household or local economy level as well as country-specific norms related to gender role within households. Indeed, beside their affordability, the decision to buy appliances is the outcome of a negotiation process within the couple. One can assume that in order for women to negotiate their part, especially if they do not work, there needs to be a certain level of initial gender equality between the couple. If the man does not take his wife's suggestions into consideration, he will decide how to spend the couple's allowance and he might favor leisure items, such as a TV, instead of a substitute for human labor that could free his wife's time and allow her to work or have more leisure time. The historical scenario is the one where the husband makes the decisions for the household, taking into account the budget constraint and his wife's

⁴Data and graphs are available upon request.

potential wage or future wage. The wife will likely comply in cases where labor markets are not inclusive and offer limited perspective for women. However, if the husband’s income is perceived as insufficient or risky, then the couple would adopt an insurance strategy (“added worker effect”), and women may enter the labor market (and may gain in empowerment) (Eckstein and Lifshitz, 2015). Overall, initial labor market inequality and women’s opportunities in the local labor market are key to understanding households’ decision to invest in the assets needed to fuel the engine of revolution within the household.

Figure 3: Access to electricity and labor force participation in Sub-Sahara Africa



Source: World Development Indicators, 2000-2005 and 2015-2019

3 The current landscape in developing countries

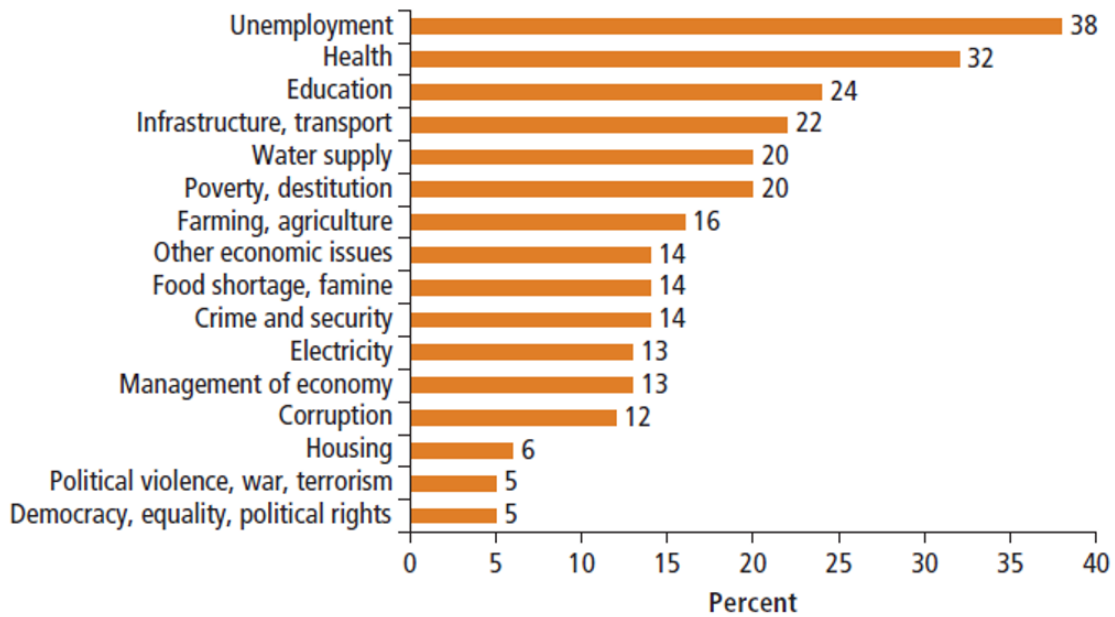
The will to widely extend energy access to all in developing countries stems from the postulate that electricity is essential to boost socioeconomic development. Communities can use it to develop infrastructures (which, in remote rural areas, are sometimes non-existent) and public goods, like street lighting and so-

cial services (health, education, entertainment); business can use it as an opportunity to grow, to go from manual to powered-mechanical, and households can benefit from modern appliances to reduce the time allocated to domestic chores.

Notwithstanding these potential benefits, the power grid landscape in developing countries is very unbalanced. Latin America, Asia and Africa all started their electrification processes much later, about a century later than their occidental counterparts. One could imagine that the use of advanced technology would have helped developing countries catch up rapidly with the rest of the world. However it was not the case, or at least not everywhere. While countries in Asia and Latin America have made huge strides towards universal access, a goal almost achieved in the 2000s, most countries in sub-Saharan Africa (SSA) lag far behind. People in rural areas of SSA are deprived of access, while urban populations struggle with an unreliable national electricity grid. Countries such as Nigeria, particularly famous for the catastrophic blackouts happening every day, or Ethiopia, suffer from low uptake due to unreliable grids. Since grid infrastructure relies on huge up-front investments and long-term commitment, political stability is one factor, but not the only one: designing policies targeted at households is also crucial. Lee et al. (2020b) demonstrate how much the coincidental application of electrification policies and access-facilitating-micro-credit policies can ensure the efficiency of electrification. This is what happened in the United States in the 1930s. The government, while providing electricity access for the rural populations through the Rural Electrification Administration (REA), developed programs to promote the use of electric farming equipment and eased micro-credit access to buy appliances for the households. However, it is important to note that GDP per capita was much higher than it currently is in African countries, and inequalities within the population were less pronounced in the United States in 1930s than what they are nowadays in low electrified countries. This raises the question of the level of initial development necessary in order to get a return on investment, and therefore the opportunity cost of electrification in poor rural areas. Characteristics of the household members may also account for the decision to get a subscription to the grid, and for the use made of the access to electricity. In the United States, having access to electricity was an important factor of the decision to purchase household appliances and fully benefit from having electricity. However, the social and economic context that favored women's decision to enter the labor market and the resulting choices regarding fertility is an equally important factor. Such favourable

context has not yet emerged in most of low electrified countries. Looking at specifically in sub-sahara Africa, we can see that indeed population view employment, health and education as the most pressing issue they are facing (see Figure 4). However, access to electricity appears rather as a secondary matter of worry. This suggests, at least from the perspective of the large share of people expected to be electrified in the near future, that there is no direct link between electricity and their stated socio-economic needs.⁵

Figure 4: **Most Important Problems in Sub-Saharan Africa**



Source: Calculations using Afrobarometer Round VI data 2014/15.

Note: The question is formulated as follows: "In your opinion, what are the most important problems facing this country that government should address?" The respondents could give up to three responses. The figure shows the percentage of respondents naming the problem as one of their three responses.

Source: Blimpo and Cosgrove-Davies (2019)

Depending on the political and economic environment, the electrification process of communities has therefore different ways of impacting the lives of the populations. A first channel through which the effect of electrification will transform local economies and household capability to produce resources is the labor market. First by stimulating local labor demand, employment and income is expected to increase. At the same time we may also observe a shift in labor supply driven by productivity gains in household production. Labor supply from new household members (women, the youth, etc.) may contribute to

⁵This also contrasts with firms' view. According to the World Bank Enterprise Survey, poor and unreliable access to electricity is one of the main reported bottlenecks for business development.

income diversifications outside the subsistence farming sector and serve as a source of informal insurance to households, making them less vulnerable to changes of agricultural prices or production.

For the above process to occur within communities, local labor market should become more inclusive so that women can earn an income on their own, as self-employed or worker. In the context of rural households, this will have consequences for household production and the distribution of resources among its different members. Labor market participation will affect fertility choices. Access to electricity can therefore undergo a process of changes in cultural and gender related norms, which may be amplified through access to information via TV and other sources (mobile phone). Opportunity costs of children's education can decrease if they do not have to help out as much with chores anymore, which pushes them to study more and longer time. Health can also be impacted if electric appliances and information access on toxic fuels modify behaviors (*e.g.* such as using an electric stove to cook instead of firewood or coal). These possible shifts in behavior depend on the context and policies. Households are more likely to reap higher benefits from having electricity access and the electrification policy can be a success if relevant and timely complementary policies are deployed. In particular those helping households to overcome credit constraints, and policies that stimulate productive use of electricity among small businesses as it has been the case for the United States more than a century ago. Developing countries do not all have such favorable context. However, favorable context does not necessarily imply immediate improvements in the lives of the populations. As seen before, women empowerment did not happen in the United States until the second half of the 20th century, several decades after rural electrification was completed. Long-term effects and short-term effects should therefore be considered separately, as they can differ from one another.

Electrification policies in developing countries vary across regions : electrification policies and programs differ from one country to another and have not started at the same time. For instance, in South Africa, the real work began after the end of the apartheid; the Integrated National Electrification Programme was implemented in 1994, after the election of the first democratic government. Eskom (the national electric utility) and other off-grid providers have managed to connect over 6.7 million households to the grid between 1994 and 2016, according to the South African government website. They also implemented the Non Grid Electrification Program to complete Eskom's work. In Asia, India's rural elec-

trification initiative was implemented in 2005 in order to provide electricity access to all households and infrastructure in rural India. The government also intended to provide free electricity to households below a fixed poverty threshold. Villages were selected depending on their population size which generated a discontinuity in access around the eligibility cut-off. In Lao, the government's electrification initiative (to give over 90% of the population an access to electricity, which they've accomplished) had a special focus on female-headed-households who, according to the World Bank, faced the most barriers. The World Bank installed a program called the P2P, where poor households were offered an interest-free loan (repayed monthly over three years) to cover 60% to 70% of their electricity connection fee. They implemented this program after conducting a pre-treatment survey which revealed that even though households were really anxious to get electricity access and were willing to pay for it (the same amount they paid for fuel), the entry costs were too high, especially for female-headed households which were poorer on average. This inspired the P2P program. The impact of this program was evaluated by Tuntivate (2013). Off-grid solutions are also surging, unlike the grid they are more flexible and can be tailored to the needs of poor and low electricity consumers, moreover they can be completed with targeted complementary policies. In most developing countries, the banking system remain underdeveloped and the rural poor are largely credit-constrained. They often do not have bank accounts but online banking can help change that. The Self-Employed Women's Association, created in India in 2013, targets women in off-grid rural areas and gives them credit access for financing the installation of solar home systems, and can also give them jobs in the company (created by the association) responsible for the marketing and installation of the solar home systems. Such different policies and initiatives lead to very heterogeneous results depending on the outcome and local context of interventions.

India as a nation is hosting the world's largest unelectrified population. More than any other part of the world, an abundant literature is devoted to the study of the Indian case. The impact of access to electricity and, although more recently, the quality of supply, has been examined on a wide range of factors affecting the well-being of households in the short and long term. Burlig and Preonas (2022) use a regression discontinuity design to estimate the impact of the "Rajiv Gandhi Grameen Vidyutikaran Yojana" Indian electrification roll-out program (RGGVY program) enacted in 2005 and covering over 400,000 villages

in 27 states. They compare "barely eligible" to "barely ineligible" villages, eligibility to grid connection being defined with respect to a population-based threshold. They also use a difference-in-difference approach to estimate the impact between treated and non-treated districts through time, allowing for the presence of spillover effects within districts to be detected. This case study is interesting since India's per-capita income during the RGGVY period was similar to current income levels in countries with significant unelectrified populations. Their estimates show that over time, despite meaningfully expanding electricity access and consumption in rural India, impact on consumption expenditures are low and the effects on employment are also limited. They do not also observe any detectable effect on asset ownership. Full electrification generate per capita-expenditures gains only in large villages. The authors provide suggestive evidence that electrification driven structural transformation happens only in large villages. These somehow surprising and new results contrast with those obtained in earlier studies. In particular, van de Walle et al. (2017) have considered long-run effects at both regional and household level for the Indian grid roll-out program. Their time period concerned early electrified populations since it runs from 1982 to 1999, a time-frame along which the share of connected households increased substantially. They find long-term effects on both connected households and significant positive spillover effects on non-connected households in connected communities. Consumption increases as well as school enrollment rates and years of schooling improve for girls, and both men and women supply more labor. According to these authors, men shift their leisure time from daytime to the evening and are engaged in more regular work during daytime. Women, in contrast, supply more casual work, including unpaid domestic work. They do not find any change in wages suggesting little effect on labor demand. The contrasting results of Burlig and Preonas (2022) and van de Walle et al. (2017) lead us to be cautious about external validity of studies run at different point in time, even if they concern the same countries. Burlig and Preonas (2022) study is mostly representative of electricity impact on the so-called 'last mile' populations. Instead the treated populations in van de Walle et al. (2017) are a selective share that has been electrified relatively early. In most cases these populations are better off and benefit from more complementary infrastructure. One way to reconcile both findings is that to note that the early electrified areas considered by van de Walle et al. (2017) are more likely to resemble the larger villages of Burlig and Preonas (2022) for whom the authors have found substantial positive effects. Last mile populations are more likely to live in more remote areas, and may lack important complementary communication, transport and public

infrastructures. As has been observed in the United States (Lewis and Severnini, 2020), the areas furthest from a metropolitan area have benefited much less from the ERA program. In a recent study in India, Thomas et al. (2020) using a sample which is more similar to the broader national population of India, and relying on a distance based IV identification strategy have found results that differ from that of Burlig and Preonas (2022). Importantly, the authors specifically focus on legal electrification, which is an important issue since in India as much as one third of electricity generated may be lost due to theft. Unlike Burlig and Preonas (2022) their results rather suggest that electrification, over a four years time horizon, has a significant and positive impact on household expenditures, adult household activity and also appliance ownership.

In Vietnam, Khandker et al. (2013) use a panel data on rural electrification between 2002 and 2005, they found positive (but short-term) effects of electrification on household income and expenditures. According to Tuntivate (2013), household electrification in Lao has increased production activities at home for women; women married to husbands who have home-based professional activities are more likely to subscribe to the grid.

Evidence from long term effect that complement van de Walle et al. (2017) are those of Lipscomb et al. (2013). According to the authors, Brazil's roll-out rural electrification programme from 1960 to 2000, has generated positive impact on income, for both urban and rural populations. They also found large effects on county-level Human Development. They also provided evidence that the most relevant mechanism at work is the effect of electricity access on employment and income as well as literacy and school enrollment. Regarding gender disparities, Grogan and Sadanand (2013) have shown that electrification causes rural women to be about 23% more likely to work outside the home, no such effect is found for men. This effect is concentrated among younger women.

The impact of electricity on household well-being is much less studied in the African context where national electrification programs are more recent. Dinkelman (2011) is a seminal and very influential study. She analyses the effects of rural electrification on employment in South Africa. Her long lasting contribution is due to her original identification strategy. She uses an instrumental variable approach relying on variable costs of grid extension across villages, from the point of view of the provider, owing to their dif-

ferences in land elevation. She finds that female out-of-farm employment does increase significantly (9.5 percentage points) following a household connection to the grid. She attributed this to a shift away from non-market (i.e. household production) to market activities. However she does not find evidence of an increase in labor demand, which suggests little productive use of electricity outside household production. This result was later confirmed in Rwanda (Lenz et al. (2017)): in the wake of the Rwandan Electricity Access Roll-Out Program (EARP), household expenditures on energy have significantly decreased, except for cooking fuel, which means Rwandan households also have an increase of their disposable income; they also engage in more independent production activities and create small businesses, though not necessarily using electric machinery. These studies show indeed positive effects of electrification on the labor market in different countries of the developing world though these effects vary depending on the level of development of communities. Better-off communities seem to benefit more from electrification owing to complementary factors. The impact of electrification on the domestic production of households happens through different channels. The interesting point to note is that, whenever positive effects are found, most of these effects occur despite very low productive appliances acquisition. This suggests that mechanisms at work are different than those observed in the US a century ago. This is even more true in African context than in any part of the world. The prevalent mechanism works through labor supply changes, to date there is little evidence of a positive effect on labor demand. One possibility is that simply having electricity for light may trigger a shift in household resource allocation that could lead women to seek to engage in income-generating activities outside the home. In turn, and in currently deprived rural areas, the possibility for women to earn money with their time can allow them to buy fuel on the market instead of gathering firewood.

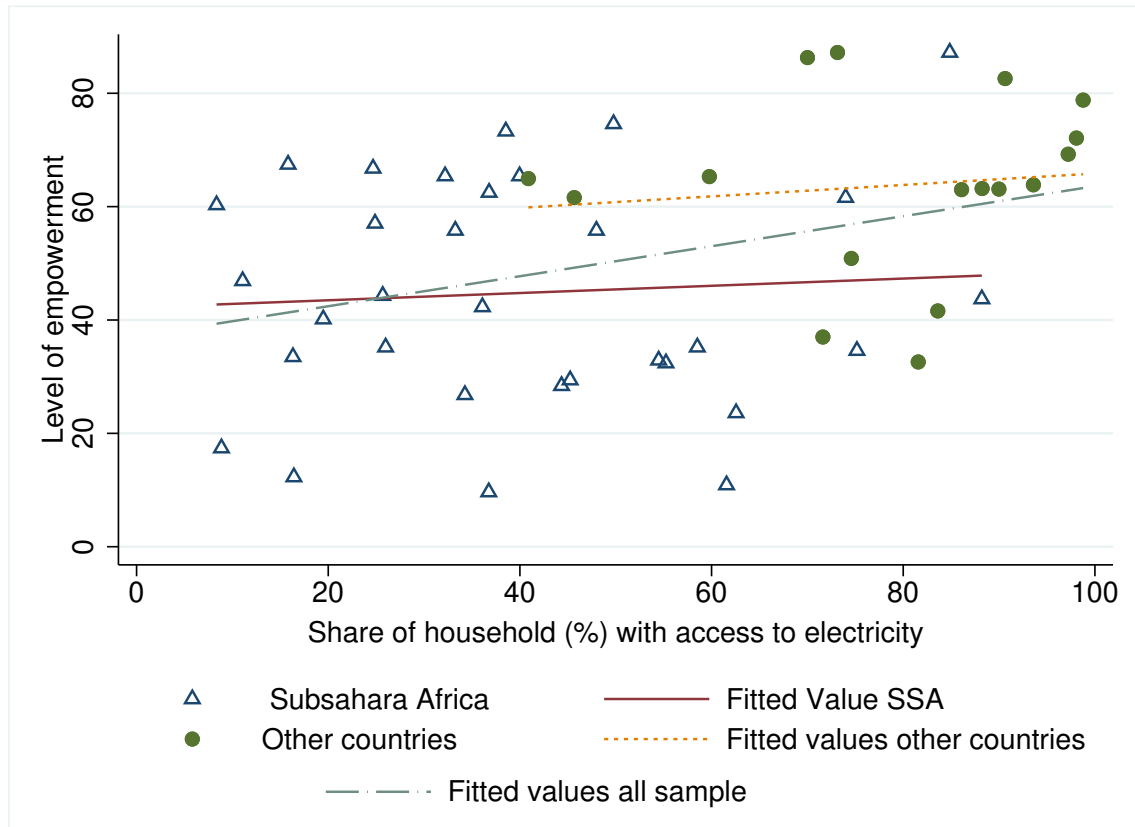
The electrification experience of developed countries taught us that the transformative potential of electricity depends as much on how it affects the household economy as on how it affects the local economy. In developing countries the traditional household model is still prevailing. The household is usually run by a man who makes the decisions for the other household members, and who works. The wife and children are in charge of the domestic chores which include cooking, fetching wood for cooking or fuel, fetching water, etc. All those time-consuming tasks must be executed during the day, as the night prevents

them from being done after dark. When households do get access to a grid or stable electricity source, indoor lighting appliances are usually the first product to be purchased. Then, choices must be made between domestic appliances (fridge, stove, rice-cooker...) and leisure appliances (TV, radio...). Whether the household head is male or female, and whether the head couple bargains cooperatively or not affects the purchasing decisions. The arrival of electricity has the potential to trigger a technology shock for the household production which may benefit women. Samad and Zhang (2019) define women empowerment as "women's decision-making ability, mobility, financial autonomy, reproductive freedom, and social participation". It means women are empowered if they are able to make their own decisions regarding their health, the number of children they will have (and therefore the use of contraceptives), whether they will work for a living or not and how they will spend their money. In Figure (5) we take as a proxy of women empowerment the share of women aged 15-49 in each country that declare participating in the following three decisions: (1) own health care, (2) major household purchases and (3) visiting family. This proxy for "empowerment" is plotted against the share of electrified households. While over the whole sample we observe a slight positive relationship between electrification and our proxy of empowerment, the relation is entirely driven by the difference between sub-sahara African countries and the rest of the sample. Considering Subsahara Africa countries only we do not observe any relation between women empowerment within the household and electrification at the country level.

True having electricity opens the possibility to power electric appliances, including a stable and efficient source of lighting, which can change household member resource allocation, and may eventually help free women from time-consuming chores. Moreover the access and spreading of information (via TV, radio or the internet) may help them make informed decisions on their own lives and could contribute gender norms change. However it should be stressed that the level of appliances is very limited among african households, beside lighting the next more common appliance is TV. The very low level of electric equipment may indeed hinder the potential for electricity to trigger a noticeable change in women empowerment in SSA. Nevertheless, some case studies tend to portray a more positive relationship between electrification and women's empowerment. Samad and Zhang (2019) study the situation of women in rural India, using propensity score matching, and find that electrification does contribute to a significant increase of women's empowerment, mostly through labor markets and education channels. Samad and

Zhang (2019) work on panel data and create a multidimensional empowerment index. They find that the index increases by 10.7 percentage points when household gain access to electricity.

Figure 5: **Women empowerment and electrification**



Source: World development indicators

Note. Women empowerment is defined as the share (in %) of women aged 15-49 in each country declaring participating in the three decisions: own health care, major household purchases and visiting family. Only countries with a level of electrification below full electrification are considered. Data are averaged over the period 2010-2019.

The effect of information has been examined through the access to TV. Fujii and Shonchoy (2020) examines the impact of electrification on fertility in Bangladesh where women’s fertility rate was reduced by 1.2 in most cases, the authors argue that television was a probable causal channel. Women who owned a television were more likely to see their fertility decline. This recent study confirms earlier analysis on the effect of quality of electricity on fertility. Burlando (2014) and Fetzer et al. (2018), both using household-level data, show that power outages in Zanzibar and urban Columbia respectively affected positively fertility rates. Negative effects of electrification on fertility have also been found in Columbia

(Grogan, 2016) and Indonesia (Grimm et al., 2015).

The decline in fertility associated to electricity can potentially mirror a positive effect on schooling and children health following the Beckerian's quantity-quality arguments. Moreover, more lighting time can increase children's home-studying. A study conducted in Madagascar by Daka and Ballet (2011) showed that household electrification tended to reduce gender inequalities for children in school. The time freed for their mothers by the arrival of electric appliances allowed girls to spend more time focusing on school work instead of helping out in the house. In India, van de Walle et al. (2017) shows the positive effects of electrification on schooling for girls : more educated women are less likely to marry as teenagers or undergo teenage pregnancies and are more likely to have a paying job. There was a positive impact on the duration of schooling of boys and girls in Vietnam (Khandker et al. (2013)) and Brazil as well (Lipscomb et al. (2013)). However in Rwanda (Lenz et al. (2017)), besides a shift in the homework schedule from daytime to after nightfall thanks to electric indoor lighting, there is no significant positive effect on education.

Health is another key aspect of the potential impact of electricity in rural areas. A direct effect, through rarely explored, may be due to improved nutritional status due to wealth gains attributable to electricity. Evidence of nutritional impact has been recently explored by Fujii et al. (2018). Using five rounds of Bangladesh Demographic and Health Survey from 2000 to 2014 they show that access to electricity has a positive impact on the nutritional status of children under five. Their results also indicate that the quality of electricity influences the size of this positive impact. Health effect has mostly been explored through the effect of indoor-air quality that is impacted by the type of technologies and fuel used for burning and cooking. The WHO states that cleaner energy access can help reduce air pollution which in poor rural areas are often above recommended thresholds. The pollution created by toxic fuels (such as kerosene or coal) used for cooking, mostly, have a negative impact on health and connecting people to cleaner energy sources can help reduce this hazard. However Mobarak et al. (2012) show through a randomized control trial on cookstove prices that women do not necessarily consider air pollution to be nefarious. They would rather invest in other electric appliances and keep resorting to traditional cooking, no matter the impact

on health. The situation is different in El Salvador according to the experiment conducted by Barron and Torero (2017) who runned a randomized control trial on households during a grid extension program in Northern El Salvador. Through subsidies, they managed to render the access to the grid exogenous and could therefore estimate the impact of electricity access on air pollution. They found substantial improvements in indoor air quality of households, resulting in a decrease in respiratory diseases among children. They also found a small though significant increase in total study-time per day for both school boys and girls.

Tuntivate (2013) finds that in Lao switching from kerosene-burning lamps to electric lighting and buying rice-cookers helped decrease in-door pollution (see ESMAP (September 2017)). Surprisingly, not such positive impact on health has been found in Brazil (Lipscomb et al. (2013)). This variety of results illustrates the heterogeneous effects of electrification depending on the context and country. Cooking habits and the availability of alternative cooking fuels may also be important aspects driving the heterogeneous effects observed across countries.

Two additional factors of household electrification are important to understand the impact of electricity on household well being: the quality of the connection to the grid and its cost. Having a spotty and hazardous connection or an expensive one can discourage individuals from investing in electric appliances that would improve their quality of life significantly.

Lee et al. (2020a) find that in Kenya, propensity to pay for electricity declines when the price rises. As for the quality of the grid, to date, most studies have focused on access to electricity and the quality of access remains largely overlooked. For the case of rural India, Chakravorty et al. (2014) estimated that being connected increases non-agricultural incomes of rural households by about 9%. However, a grid connection and a higher quality of electricity (fewer outages and more hours per day) increases non-agricultural incomes by about 28.6% from 1995 to 2005. The extensive and intensive margin of electricity provision may also explain the contrasting results found in the Indian context. Gains in extensive coverage may have been detrimental to the quality of services provided.

Having back-up sources of energy such as solar-powered generators or kerosene-fueled generators can become necessary in countries where electricity is only available a few hours a day due to low-quality grid

and frequent blackouts. However diesel generators are becoming important sources of pollution. Thus through the adoption of these polluting energy sources alternatives, unreliable energy provision may generate important negative externalities. Lee et al. (2017) also mention the nuances between electricity sources, from solar lamps to minigrids to the national grids; solar home systems cannot fulfill a household's energy demand, the needs will only be partially met. A minigrid in the community will offer more power and the national grid should be the final step in meeting the demand for electricity completely. If the national grid is not functional 100% of the time, people will have to resort to back-up electricity sources and switch from one source to another depending on the quality of the connection. Power outages of the national grid usually happen because of a lack of investment in the infrastructure. The grid cannot meet the demand. It is especially problematic for businesses relying on electric machinery, who need a back-up generator to function during blackouts.

Lately, beside effects occurring at the household level, human capital (health and schooling) is also impacted through the provision of health and schooling infrastructures powered by the grid. Electrified facilities provide better services and can operate during longer hours. Overall the impact of electricity on the quality of public good provision remain largely overlooked in the literature, this is partly due to data limitations on hospital and schooling outcomes. Social capital is also another important dimension for development which may be impacted by electricity through the way people interact within the community inside or outside their home. Again thanks to lighting social relationship can be maintained during longer hours and become more extensive. For instance non-electrified households may spend longer time with electrified households to benefit from entertainment services (i.e. TV) which can typically be shared between several households.

The labor market participation, household expenditures, income, fertility and human capital are all dimensions of well being and capability that policy makers expect to be impacted by electrification programmes in rural areas. Predicting and estimating their magnitude is key in helping governments better calibrate their electrification program to maximise the return on investment for all parties (state, operators and households). Expanding a grid to the "last-mile" or to really remote areas raises the question of the opportunity costs of these new connections since these households often lack basic services (Lee et al., 2020b). Finding sustainable solutions is also a priority given the dependency of non yet electrified rural

areas to their local natural environment: this raises the question of how can populations engage in the energy transition needed to reach a better level of socio-economic development without generating massive carbon emissions which may threaten the quality of their local environment.

4 Energy transition and sustainable household well being : is the low carbon transition the road ahead?

The existing literature on impact evaluation of electrification has not yet focused on the increase of CO₂ emissions due to accrued electricity consumption from the newly connected populations. A few studies estimates the environmental impact on individual health, as deflecting from kerosene and coal means cleaner air for the household, especially indoor. There is evidence of benefits, as ESMAP (September 2017) show in Lao, and Barron and Torero (2017) in El Salvador. The difference between this energy transition in developing countries and the one in western countries a century ago is the large variety of electricity sources available. Households can be connected to a grid powered by hydroelectricity or gaz, or have access to local solar minigrids or solar generators (or kerosene generators, though more polluting). Households can have access to electricity even before the national grid reaches their village. The cost of connecting the "last-mile" villages does not mean the populations cannot have some electricity, even if it is just enough to charge a cellphone. These options can help populations compensate for power outages of the national grid, too, in countries like Nigeria where they occur daily. The use of cellphones allows for access to online banking to remote communities who cannot go to a regular bank. Online banking can also facilitate micro credit access which is itself used to provide access to energy but can also ease the acquisition of costly consumer durables. In Burkina Faso, the Fondation Energies pour le Monde (Fon-dem) implemented in 2016 a microcredit access program to help households buy solar kits to meet their energy demand. Households had the choice between four different kits, each with a different capacity. The smaller kit cost only 30€ and the most expensive one 2,500€, all four were payable in monthly installments over three years. Each kit was partially subsidized, up to 60% of the total price for the cheaper one, and 45% for the most expensive kit (logically destined for wealthier households). The Barefoot College NGO working in Asia, Africa and Latin America, trains women in rural areas to become solar engineers

capable to install solar home systems for everyone in their village. In Indonesia, the Kopernik non-profit organized the Wonder Women program to train women to cover the last-mile off-grid by implementing off-grid solutions such as solar home systems. In Tanzania, the Energy Change Lab supports projects and initiatives for Productive Use of Energy, to help people develop businesses using the electric solutions they have. Training women to become part of the energy sector is fundamental; women all over the world only represent 32% of the renewable energy sector workforce, according to the IRENA (2019). In developing countries, not only could training give women career opportunities, but it helps developing electricity access as well. In some countries, it can be considered improper for male workers to come fix broken appliances in the homes of women if their husbands are not present. Training female workers to become electricians could help change this issue.

There are a number of such initiatives in developing countries which have not yet extended electricity access to their entire population. Solar devices are unequivocally a good alternative to kerosene-fueled, polluting generators, for both human health and the environment. However in cases like Barron and Torero (2017), there might be a need to raise awareness about environmental impacts of the use of polluting fuels in order to nudge people toward cleaner energy sources from the beginning. Otherwise the energy transition will take the exact same path as it did in western countries, switching from no electricity to fossil fuels to renewable energy. This could still be avoided.

5 Conclusion

Progressively embracing the credibility revolution in empirical economics (Angrist and Pischke, 2010), research on the effects of rural electricity on the well being of populations in the developing world has produced meaningful results. Notwithstanding this progress, Bayer et al. (2020) published a systematic literature review revealing the need for electricity access impact evaluation. Their study of the existing literature showed a lack of causal inference studies, they point to the lack of randomized experiments falsely swayed the general consensus to a more positive tendency than randomized experiments would find. They strongly recommended to use more randomized studies when possible, to help guide public policies into this crucial matter for development. Their conclusions are especially true of gendered impact

evaluations to help governments and NGOs better target their energy access and development initiatives. As we have seen, electrification can indeed truly help rural populations which have trouble reaching stable economic growth without a reliable source of energy; it can empower women by liberating them from time-consuming domestic tasks, allow them to focus on their education as young girls and have an economic activity later as an adult to earn a living and become more independent. Gendered impact evaluation is needed in today's literature to shed light on the impact of the many electrification policies and initiatives in developing countries. Households need flexible solutions to adopt electricity in a durable way in spite of the potentially unreliable grids or the cost. Complementary policies can alleviate the credit-constraint of households, as it did in the United States rural electrification programme a century ago. Since electrification is an infrastructure investments long-term impact assessment are needed, while most of studies are focused on short term effects. As forcefully stressed by Lee et al. (2020b) this long term evaluation would guide governments in their strategy to implement complementary policies along electrification program to ensure a durable efficiency of their electrification program. There is clearly not a one fit all solution, beside the grid, there is a gradient of combined energy and policy options that ought to be tailored to the diversity of the needs of the billion population awaiting the prosperity promises of a reliable and clean energy.

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