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Power Investments & Welfare Benefits

Describing Pathways to Impact from a Literature Review

Final Report

July 2019

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Contents

1 INTRODUCTION

1.1 Background

Electricity is a fundamental component of a strong, dynamic economy. It allows private sector firms to produce goods and provide services. It also enables residential consumers to read, watch TV, cook or listen to the radio. However, access to electricity in much of the world remains out of reach – an estimated 1.1 billion people still do not have electric power (IEA, 2017).

To address this need for energy, development finance institutions (DFIs) invest in energy projects around the globe, such as on-grid generation technologies, solar home solutions (SHS), micro-grids or network connections. Their intent is to increase the availability of affordable, clean energy and thereby improve incomes for business and the overall wellbeing of households. But in such a complex sector, it is unclear how investments in power support business growth in the private sector and welfare benefits in the households, such as higher incomes, improved health, and more education.

This study provides a framework identifies different pathways through which power investments support impact on the private sector and households. For each pathways we identify if they support a positive or negative effect, and if the effect is conditional on specific technical or contextual factors. The literature review should also contribute to improved understanding of what effects other factors such as the chosen investment technologies or country contexts have on the impact supported. The goal is to provide insights into the ways in which power investments can positively impact businesses and households.

1.2 Report methodology

This study relies on a literature review of relevant papers, articles and reports surrounding topics in energy, private sector development and human development. Nearly 80 sources were used in this report. Sources were screened based on their relevance to specific topics, the influence of the paper on the research topic, the quality of the outlet, the credibility of the authors publishing the source, and the date in which the paper was published, with preference given to more recent works. Articles were accessed through Google and Google Scholar web searches using key terms such as, among others, "energy", "access", "price", "welfare", "consumption", "growth" and "outages".

As sources were accumulated, we codified their characteristics by logging each paper's topic and sub-topic of focus, the effect result (positive, negative, debatable), the date it was published, and the country or regions the study was conducted in. In this way, were able to determine which areas within the framework were the most widely studied, what the factors that influence the effects are, and whether the effects are likely to be positive, negative or debatable. For a full list of the sources used in this literature review, please see the references section.

1.3 Report structure

The rest of the study is as follows. In Section 2.1 we present the theoretical framework, with an explanation of each of the pathway's effects flow. We then try to show in Section 2.2 whether the effects are positive, negative or debatable, meaning they could have either positive, negative or no effects depending on different factors. In Section 2.3 and Section 2.4 we present the academic literature supporting whether the effects are positive, negative or debatable for the private and household sector sides of the framework respectively. Section 3 provides a brief conclusion, with recommendations for further study and applying the framework.

2 PATHWAYS TO IMPACT FROM INVESTMENTS IN POWER

2.1 Theoretical Framework

The power sector is linked to a country's economic development and the general wellbeing of its population both literally and metaphorically through numerous inter-connections. To simplify these relationships, Figure 1 provides a theoretical framework for understanding how investments in the power sector could lead to developmental impacts for the private and household sectors. The left-hand side of Figure 1 shows the pathways for firms in the private sector whereas the right-hand side shows the pathways for consumers in the household sector. Figure 1 is intended to be read starting in the middle, with "Power investment", then read outward, following the arrows, which represent relationship flows, and their corresponding numbers.

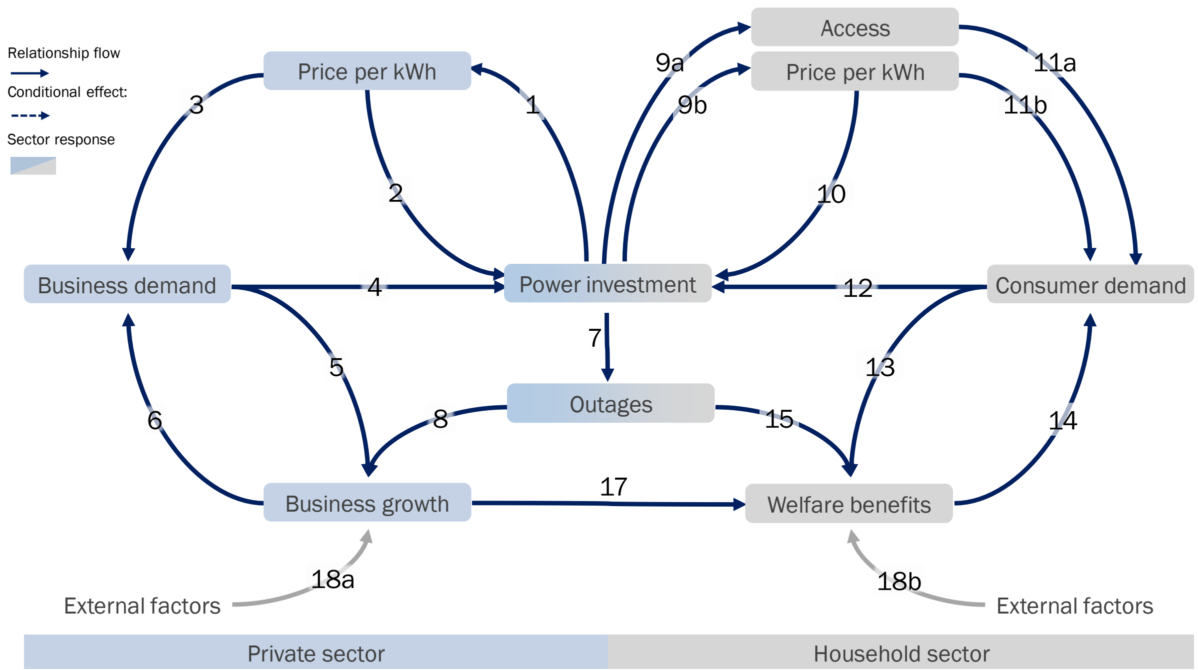

Figure 1: Theoretical framework

Relationship flows for the private sector

[1] & [2]: Power investments to price per kWh & price per kWh to power investments

Power investments affect electricity price by raising supply. Low cost electricity could displace costlier electricity sources, lowering average cost of generation. Generation price level drives investment revenues.

[3] & [4]: Price per kWh to business demand & business demand to power investment

Firms respond to electricity price changes depending on their price elasticity of demand for power. Industrial firms, for which electricity is a variable cost, are more sensitive to price changes than other sectors. Increased business demand translates to revenues for the power investment.

[5]: Business demand for power to business growth

Since electricity is a key production input, more consumption would induce firms to produce more, expand operations, hire workers and support economic growth.

[6]: Business growth to business demand for power

Business growth could increase business demand for power. As firms expand, they require more inputs, including electricity.

[7]: Power investments to outages change

Insufficient energy supply causes load shedding. By raising supply, the reliability of power in a system improves, changing the frequency and duration of outages that occur.

[8]: Outages change to business growth

Changes in outages affect businesses by reducing interruptions of operation, which raises the amount of output from firms, thereby expanding their business or avoid damages to appliances from sudden outages.

[17]: Business growth to welfare benefits

Business growth raises employment levels and supports economic growth. This improves welfare of households by supporting incomes.

[18a]: External factors to business growth

External factors such as firm size, capital intensities, and firm (sub)sector affect how businesses grow.

Relationship flows for the household sector

[9a] & [11a]: Power investments to electricity access and electricity access to consumer demand

Power investments might increase household's access to electricity either through network expansion programs or through off-grid solutions. Increased access to electricity could raise electricity consumption. Note that the relationship flow through access is only included on the right-hand side of the chart. This is because of the low electrification rate for residential consumers in many developing countries compared to private sector firms, which tend to require a grid connection to operate.

[9b] & [10]: Power investments to and from the price per kWh

Power investments affect electricity price by raising supply. Low cost electricity displaces costlier electricity, lowering average cost of generation. Price changes affect investment revenues.

[11b] & [12]: Price per kWh to consumer demand & consumer demand to power investment

Households respond to electricity prices changes depending on their demand for power, access to it and ability to pay for it. Households substitute other energy sources for electricity in varying degrees.

[13]: Consumer demand to welfare benefits

Welfare benefits, comprising income, health and education, could be improved as electricity consumption increases. Daytime domestic work or leisure shifts to the evening, allowing more time for income generating activities. Health and education outcomes could also increase.

[14]: Welfare benefits to consumer demand

Improved welfare, particularly higher incomes but also desire for a better quality of life, could encourage consumers use more electricity. It could also encourage buying appliances (radio, TV, etc.).

[7]: Power investments to outages change

Insufficient energy supply causes load shedding. By raising supply, the reliability of power in a system improves, changing the frequency and duration of outages that occur for households with connections.

[15]: Outages change to welfare benefits

Frequent and/or long outages reduce the time households can spend on welfare improving activities at night such as studying or leisure, forcing them to substitute daytime income generating activities. Outages also damage appliances and cause spoilage of food, thus fewer outages reduce the costs to households.

[18b]: External factors to welfare benefits

External factors such as household size, household head occupation, rural/urban location, and culture all affect the potential welfare benefits to households from power investments

2.2 Describing the pathways in the literature

Results from the literature review are broadly summarized by Figure 2. It shows three characteristics of the relationship flows: 1) the nature of each of the relationship flows, using colours to indicate positive (green) or negative (red) effects; 2) the degree to which they are studied in the literature, with thicker lines indicating a relationship that is more extensively studied; and 3) whether an effect is conditional on technical or contextual factors (such as technology used and policy environment). It is important to note that a red line, i.e. a negative relationship, is not necessarily a negative effect. For example, in Figure 2 the red line from power investment to price per kWh means that more supply tends to decrease the price. By the same token, a lower price per kWh causes more demand, hence again the red line. The combined positive effect of a power investment to more consumer demand is thus the net result from the multiplication of two negative relationships.

Some flows we can say with confidence are positive or negative. However, the literature review shows that the nature of many relationship flows is positive or negative conditional on various technical or contextual factors such as the specific power technology utilized, whether the price of electricity reflects the cost of generation, or the degree to which kerosene lamps are used. While this may seem obvious, it runs counter to the often-cited rationale that power investments in developing countries unconditionally lead to improved access, affordability and reliability of power. Despite this conditionality, we have assigned a positive or negative effect on most of the relationships based on the prevailing evidence. In the sections below, we have explained the conditional factors for each flow.

In Sections 2.3 and 2.4 we describe findings from the literature review that relate to each of the significant relationship flows for both the private and the household sector sides of the framework. Trivial flows, which are not described, relate to flows towards the power investment ([2], [4], [10] and [12] in Figure 2), which are related to project revenues rising or falling depending on the price or consumption of power rising or falling, and the effect that external factors have on business growth or welfare benefits ([18a] and [18b]).

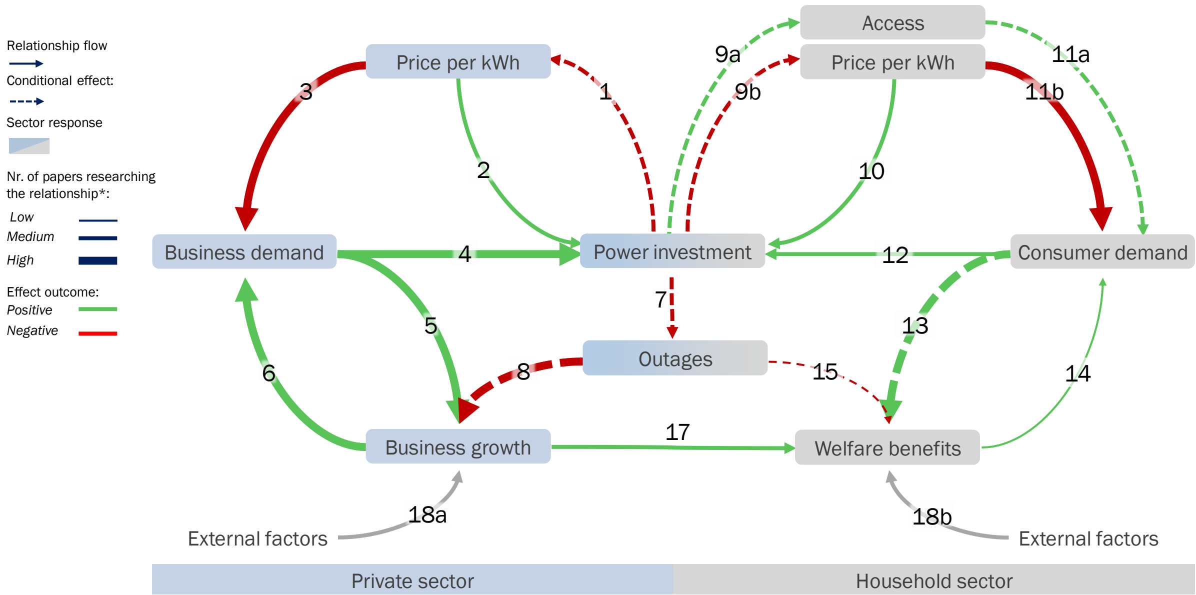

Figure 2: Theoretical framework, including the degree to which a relationship is studied and the nature of the relationship flow

2.3 Private sector linkages

2.3.1 Effect on price per kWh

Power investments lower electricity prices [1][1] by raising the supply of energy. This negative relationship is conditional on two things: whether the energy generating technology invested in is cheaper than existing ones and whether or not the price of generating electricity is subsidized.

The effect of investments in on-grid energy generation on electricity prices also depends on the price of generation relative to the generation prices of suppliers already in-place. For example, feeding the grid with renewable energy, which is cheaper conventional thermal energy, allows an overall decrease of the average energy generation price (Ketter, 2014; IRENA, 2018). This price effect reduces the end user price of electricity in markets where prices are unsubsidized and thus reflect the costs of generation (Steward Redqueen, 2015).

To ensure affordability, electricity prices are often subsidized by national governments (Kojima et al., 2014; Huenteler et al., 2017). Electricity subsidies are still present in most Sub-Saharan markets (International Monetary Fund, 2013). Likewise, in many Latin American and Caribbean countries, electricity subsidies remain common (IADB, 2016). Although, several Asian countries have made progress on phasing out subsidies from their energy markets (Asian Development Bank, 2016). In countries with price subsidies, an investment in on-grid energy does not affect the end-user price of electricity, and therefore impacts neither business demand nor business growth. Although, the lower wholesale price might have positive effects on the financial health of the government (Steward Redqueen, 2018a; 2018b).

Investments in off-grid energy generation are not normally impactful for businesses, since the largest businesses require a connection to the grid to meet their high energy needs. Although, small businesses in developing countries generate their own electricity (often to mitigate outages), which is usually produced using car batteries or diesel generators. For an average diesel generator that consumes about 0.3 l/kWh the costs vary between 0.12 USD/kWh (Angola) and 0.36 USD USD/kWh (Rwanda) (Szabó et al., 2011). As an alternative to diesel generators, some small businesses use solar home solutions (SHS) with high capacity (>100 Watt peak (Wp)) to power productive use appliances such as refrigerators or water pumps, or use smaller appliances to sell mobile phone charging (GOGLA, 2018).

Another alternative to on-grid generation is mini-grid technology. Like on-grid generation technologies, installing a mini-grid requires a large upfront capital investment (alongside operating costs) that is repaid over time through end-user tariffs. These tariffs tend to be higher than grid electricity in many countries, with levelized costs of electricity (LCOE) around 0.55 USD/kWh (ESMAP, 2019), which would actually raise price of electricity for firms. Although, a combination of increased productive uses of electricity, especially by rural SMEs, economies of scale and improvements in technology are anticipated to bring the price down as far as 0.22 USD/kWh by 2030 (ESMAP, 2019).

Beside increasing energy supplies (on-grid and off-grid), power investments can be directed to the expansion of the grid network.

Investments in rural network expansions do not affect the price of electricity, although, they are costly since such investments strongly depend on the project location. For example, Deichmann et al. (2010) argue that in urban areas in Sub-Saharan Africa expanding the grid might be more price competitive than developing decentralized off-grid energy generation systems. Similarly, Nerini et al. showed the improved cost-effectiveness of grid-based solutions in regions with high population densities. (Nerini et al., 2016). However, grid extensions are also known to be extremely expensive and thus might not be better than decentralized systems in rural areas (Taneja, 2018).

[1] In the following sections, brackets around numbers – [1] – have been inserted as a reference to the respective relationship flow depicted in the framework.

2.3.2 Effect on business demand

Businesses consume more electricity when the price per kWh declines [3]. The magnitude of this negative relationship is driven by firms' responsiveness to changes in price, which is measured by the price elasticity of demand for electricity. The firm characteristics, including size or grid connection, firm sector and macro-economic conditions also affect firm demand for electricity.

The price elasticity of electricity demand describes how firm electricity consumption responds to changes in electricity price. Price elasticities of demand by businesses are on average negative and increasing in the long-term (Labandeira et al., 2017). Labandeira et al. (2017), who conducted an extensive meta-analysis of academic literature measuring price elasticities for electricity demand, estimate that the price elasticity of demand for industrial consumers is -0.168 on average in the short-run, i.e. demand is very price inelastic.

Other factors affect business demand for electricity too. Naturally, firms without a grid connection will not be affected by any change in price. Also, different sectors demand different quantities of electricity. For some sectors, electricity is a fixed cost of production where a change of price does not affect firm output (e.g. retail trade), whereas for other sectors, such as manufacturing, it is a variable cost. Thus, as the price changes, these firms respond by changing their output levels as their costs per unit change. The industrial sector is the most affected by changes in electricity prices since energy is a necessary input for it (Inglesi-Lotz et. al., 2011). Finally, multiple studies point out how in addition to the changes in electricity prices, the electricity consumption of businesses is also affected by external factors in the economy such as total output or GDP (Egorova and Volchkova, 2013; Bianco et al., 2010).

2.3.3 Effect on business growth

As mentioned above in Section 2.3.1, investments into on-grid electricity stimulate broad economic activity since the largest firms cannot meet high energy demands from off-grid generation sources. Although, for small, rural firms off-grid technologies, such as mini-grids, can supply their energy needs.

Having a grid connection enables firms to meet their electricity demands, which, in turn, translates into a positive effect on business growth through increased output [5]. Such firms also produce more output in response to a decrease in outages [8] (as described below in Section 2.3.4). Increased output by businesses expands their need for inputs, including electricity, creating a positive relationship between business growth and electricity demand [6].

The relationship between business demand for electricity and business growth is complicated by the fact that the effects could go in one of four directions: 1) from consumption to growth, the growth hypothesis; from growth to consumption, the conservation hypothesis; in both ways, with growth and consumption causing each other, the feedback hypothesis; and no relationship between the two, the neutrality hypothesis (Lemma et al., 2016).

Lemma et al. (2016), in a study for CDC Group, reviewed the academic literature on the relationship between energy and economic growth. They observe that, depending on the country and time period studied, each of the four different hypotheses are supported. Because the neutrality hypothesis seems less prevalent than the other three, they conclude that in most cases power plays, if not a facilitating role, then at least an enabling one in economic growth. Wolde-Rufael (2006), looking at 17 African countries, concluded that for the period 1971-2004, for three countries the (Granger) causality ran from electricity consumption to GDP per capita growth; for six countries the causality was from GDP per capita growth to electricity consumption; for three countries there was a bidirectional causality; and for 5 countries there was no relationship. However, the study only considered grid electricity, which covered a very small fraction of total energy consumed, and the author advised that the results be interpreted with caution. More broadly, Adhikari and Chen (2012) found a strong relationship running from energy consumption to economic growth for upper-middle income countries and lower-middle income countries, and a strong relationship running from economic growth to energy consumption for low income countries. Nondo et al.

(2010) found support for the feedback hypothesis for a panel of 18 COMESA countries in the long run and for the neutrality hypothesis in the short run.

A positive relationship between electricity consumption and business growth is especially strong in the manufacturing industry, which is highly sensitive to changes in electricity prices (as mentioned above) (Soytas and Sari, 2007; Bekhet and Harun, 2012; Kwakwa, 2015; Nelson, Mukras and Siringi, 2013).

For small firms, obtaining an on-grid connection might not be as impactful as being part of a mini-grid. A large evaluation of a grid expansion in Rwanda showed that for small firms, grid access had small but positive effect on new business creation, productivity and firm income (Lenz et al., 2015). In comparison, mini-grids are thought to be more beneficial for small, rural firms since they might be more reliable and better suited to their energy needs. In Sub-Saharan Africa, where grid electricity is notoriously unreliable, hybrid mini-grids can provide electricity for small businesses electricity in rural areas 24/7 using remote monitoring and smart meters (ESMAP, 2019; Azimoh et al., 2016). Finally, declining costs for firms of mini-grid electricity could incentivize investments in productivity enhancing appliances that can help firms grow (ESMAP, 2019).

2.3.4 Effect on outages

The relationship between power investments and outages [7] is conditionally negative. Power investments into on-grid capacity in countries where load shedding occurs will reduce outages by raising the reserve margin. A reserve margin is the surplus amount of electricity supply that grid operators will maintain above electricity demand. Thus, by adding electricity supply to a system, capacity investments reduce the frequency and duration of outages. (Steward Redqueen, 2015; 2016; 2018b). For example, in Cape Verde, investments in 25.5 MW wind generation (9 MW effective capacity, equal to 14% of the country's effective capacity) reduced the total amount of outage time, measured as the frequency times the duration of outages, by 60%, increasing firm production by 0.8% (Steward Redqueen, 2018b).

In contexts where there is minimal or no load shedding (unplanned outage that occurs when the supply of electricity in a grid is unable to meet demand) there will be no impact on outages from power investments into generation technology or network expansions. Similarly, the relationship between outages and business growth [8] is conditionally negative, depending on whether firms are connected to the grid.

Business growth related to firms with grid connections is negatively affected by outages since it reduces the amount of time that they can operate or damages their machinery [8]. Outages constrict firms' ability to operate, damages their machinery, causes spoilage, and in extreme cases, can even contribute to an economic downturn in the industrial sector (Qazi et al., 2012). In Africa, the number of outages per month can range from 1 to 24 and can last up to 7 hours on average (Ramachandran et al., 2018). In an environment with such unreliable supply, evidence shows that the production efficiency of firms is negatively affected by the number of power outages experienced (Abotsi, 2016; Cole et al., 2018).

The negative effects of outages can be burdensome on economic growth and private sector development. In a sample of 39 African countries, GDP was found to decrease by 1.5% on average for every 2.3 outages per month that occur (Anderson and Dalgaar, 2012). A common indicator of the impact of outages is the so-called "Value of Lost Load" (VoLL). The VoLL expresses the value lost per kW of power load, although it is more commonly expressed as the value lost per kWh of foregone electricity consumption (Value of Lost Consumption, VoLC). It can be expressed for an individual firm, for an economic sector or for an entire economy. When expressed as loss of value added per kWh, it is essentially the inverse of electricity intensity. For example, in Uganda it was found to be 11.85 USD per kWh (Steward Redqueen, 2016). Using three different methods, Oseni and Pollitt (2013) estimate the outage cost to African firms to be in the range 0.87 – 4.81 USD/kWh.

However, firms respond differently to outages based on their industry or ability to mitigate losses through self-generation (Alam, 2013). Using data from 10 African countries, Abotsi (2016) found that the frequency of power outages negatively impacts firm efficiency. Firms whose operations are the most sensitive to power supplies often have backup diesel generation systems that mitigate the effect of outages (Steward Redqueen 2015; 2016). In Senegal, Cissokho (2013) showed that generator ownership rises with power outages and that small firms are more easily able to mitigate outage effects than larger ones. A study in Ethiopia also found that outages negatively affect larger firms more than smaller ones (Abdisa, 2018).

2.4 Household sector linkages

2.4.1 Effect on access

Whether a power investment increases access to electricity is conditional on the type of the intervention [9a]. Investments into (rural) electrification programs or off-grid home technologies will extend household access to electricity. Capacity investments alone do not contribute to better electricity access.

Globally 11% of the population does not have access to electricity, with the highest share in Africa (56%).[2] To achieve electricity access, expansion of distribution network and investments in household connections are required. Grid-based electrification is attractive for densely populated areas where the expected electricity demand is relatively high. However, rural areas, constituting the largest share of population without access to electricity, are sparsely populated with many households on low income levels. The cost of residential connections in such places is high. In these areas, off-grid systems, including mini-grids and stand-alone systems, play a vital role in improving access (Lucas, Dagnachew, Hof, 2017).

SHS have been shown to provide rural and/or low-income households access to bright, reliable lighting and the ability to charge their mobile phones by replacing kerosene lanterns or flashlights (Gogla, 2018). Mini-grids have similarly been shown to increase access to reliable electricity for rural consumers, especially in Southern and East Asia (ESMAP, 2019). Furthermore, as the cost of mini-grids continues to fall, in terms of both capital and operating expenditures, mini-grids are anticipated to provide access to electricity to many more consumers. By 2030, mini-grids are anticipated to provide the cheapest option for grid-quality electricity for more than 60 percent of the population in Sub-Saharan Africa, assuming national utilities do not drastically change their operations (ESMAP, 2019).

2.4.2 Effect on price per kWh

Investments in power reduce the price of electricity for household consumers [9b] under the same conditions as private sector consumers: whether the power generation technology produces cheaper electricity than existing sources and whether the price of electricity is subsidized or not.

Investments in on-grid power supply often target new technologies such as wind or solar power, which are cheaper than conventional, thermal electricity sources in a country's existing energy mix (IRENA, 2018). By displacing costlier energy sources, such investments lower the average generation price[3] (Steward Redqueen, 2015). In markets where prices are unsubsidized, this decrease translates into end-user price reductions. In many developing markets, however, this is not the case since subsidies are prevalent (as mentioned above in Section 2.3.1).

Off-grid technologies, such as home solutions or mini-grids, will also bring down the cost of energy when they offer lower prices than other energy sources, such as kerosene. The latter is often used as a source of lighting for unconnected households. In Uganda, 55% of respondents without connections were found to use kerosene for lighting, followed by solar technology (Steward Redqueen, 2016). Solar lights and home solutions have become cheaper over the years, which in turn has made them an affordable and efficient technology for people living in rural areas (Harrison, Scott and Hogarth, 2016). Similarly, the costs of renewable mini-grids has been declining, making the cost competitive with on-grid energy (IRENA, 2016).

[2] Data from 2017 from the World Bank Development Indicators. Retrieved on July 8,2019. https://data.worldbank.org/indicator/eg.elc.accs.zs

[3] Naturally, the price effect from on-grid technology investments will only be felt by household consumers who have an existing connection.

Investments in (rural) electrification programs that connect households to the grid provide consumers with a relatively cheap source of energy. However, in many cases, the cost of providing new users grid connections is high, especially if unsubsidized[4].

2.4.3 Effect on consumer demand

Household demand for electricity is a function of electricity price, income levels, and other variables such as appliance ownership (Halvorsen, 1972; Villareal et al, 2016; Wolfram, Shelef and Gertler, 2012).

Similar to the effect on business consumers, the relationship between price and demand for household consumers [11b] is negative – a decrease in the price of electricity will lead to an increase in demand for it and vice versa. The magnitude of this effect is expressed in the price elasticity of electricity demand. For residential consumers, Labandeira et al. (2017) estimate short-term price of electricity of -0.216 and a long-run elasticity of -0.620. This finding supports other estimates for negative price elasticities in other country contexts. In South Africa, Sri Lanka, Saudi Arabia, price elasticities were estimated in the lower range of -0.05 to -0.1 (Inglosi-Lotz, 2011; Amarawickrama and Hunt, 2008; Diabi, 1998). In China, Shi et al (2012) estimated a price elasticity of -2.477.

It is important to keep in mind that price is not the only driver for electricity consumption of households.

Studies of the relationship between income and electricity consumption show that demand for electricity increases as income increases – the income elasticity of electricity is positive, inelastic and strongly significant (Kolawole, Adesola, De Vita, 2017 and Khanna, Rao, 2009). Estimates vary by country and time period of study. Short-run income elasticities of demand have been estimated in multiple countries, including Mexico (0.66), Jamaica (1.21), India (0.88) and Taiwan (0.23) (Khanna, Rao, 2009). Kolawole, Adesola and Devita (2017) estimate that the long-run income elasticity of demand for electricity is 0.55 for households in 12 Sub-Saharan African countries. This is in line with results for other studies in Ghana (0.58) and Namibia (0.59) (Expo, et al, 2011; De Vita et al, 2006). The authors also showed that for specific energy sources, including kerosene[5], income elasticity of demand changes in magnitude but remains positive, except for biomass, which was negative (Kolawole, Adesola, De Vita, 2017).

Residential electricity consumption has been anticipated to grow in the near future as household incomes increase in large developing countries such as India, China, Brazil. As they do so, these households will buy appliances, raising their demand for electricity (Wolfram, Shelef and Gertler, 2012). For instance, growth in refrigerator ownership in Mexico between 1996 and 2008 is estimated to have doubled electricity expenditures for the poorest 25% of households in the country (Wolfram, Shelef and Gertler, 2012).

These contextual factors are important to defy the assumption that simply providing households with access will automatically increase their electricity consumption [11a]. This seems to not be the case in countries across Sub-Saharan Africa. In Uganda, residents reported not increasing their electricity consumption after initially obtaining a grid connection because of issues with affordability and reliability (Steward Redqueen, 2016). Another reason could be that although many households aspire to own larger appliances, like TVs or refrigerators, these products remain out of reach for many consumers (Lee, Miguel and Wolfram, 2016). In addition, for some households, especially rural ones, after becoming electrified through grid expansion, consumption increases initially, then flattens out as household demand for electricity becomes satiated (Fobi et al., 2018). In Kenya, data on electricity use between 2009 and 2015 shows that the peak in consumption of new users occurs sooner after obtaining the connection (Taneja, 2018). Therefore, it is important to note that increased demand after obtaining access to electricity is not a

[4] In Kenya, the real cost of providing a grid connection is estimated to range from USD 1,400 - 1,900. (Parshall et al., 2009; Lee et al., 2016; Taneja, 2018). Whereas the subsidized fee charged to residents in Kenya within 600 meters of a transformer is USD 350 and in neighbouring Tanzania it is USD 200 (Taneja, 2018; Chaplin et al., 2017).

[5] Kolawole, Adesola, and De Vita (2017) estimated kerosene to have an income elasticity of demand for 0.61. They argue that the positive result is due to households choosing to use kerosene instead of traditional biomass sources like charcoal or firewood as incomes increase. They also argue that the relatively inelastic result suggests kerosene is the cheapest form of modern cooking fuel, making households less sensitive to price changes.

given. Consumption can be stimulated by enabling initiatives that encourage positive electricity habits, develop rural (home-based) enterprises and improve system reliability.

Off-grid electricity companies, as part of their business model, try to raise household consumption by providing product packages that include progressively larger appliances. This in theory allows households to move up the so-called energy staircase – a framework for assessing the level of household electricity access and consumption. At the lowest consumption level, households rely on kerosene lamps and at the highest level households own multiple large appliances (large TV, fridge etc.) (ESMAP, 2015). To illustrate, households that upgrade from kerosene to a basic SHS (includes phone charger, light and radio) move from up to the next level (Gogla, 2018). Despite this step-wise approach by SHS companies, many consumers do not upgrade further after initially purchasing a SHS. Users of SHS systems report that they do not upgrade because the current systems either meet their needs or the costs to upgrade are too high (Gogla, 2018).

2.4.4 Effect on welfare benefits

The relationship between household welfare and consumption of electricity is widely studied [13]. The empirical evidence varies from limited to highly positive impacts on household livelihoods, leading us to mark the relationship in green in our framework.

The primary benefit of electrification for households is improved lighting, which enables people to extend the number of productive hours in the day (van de Walle, Ravallion, Mendiratta and Koolwa, 2013; Toba, 2003; Khandker, Barnes, and Samad, 2009). As such, household welfare is in theory a function of total consumption - including domestic work, electricity use and other consumption - and household recreation time spent with and without lighting (van de Walle, Ravallion, Mendiratta and Koolwa, 2013).

Having more time to work, study, or relax due to more lighting time imparts both financial and non-financial benefits. With electricity, people might spend less time during the day on domestic labour and more time in income generation activities (Aevarsdottir, Barton, and Bold, 2017; Khandker, Barnes, and Samad, 2009; Khandker, Barnes and Samad, 2012; Gogla, 2018). There are reported health benefits from replacing the use of kerosene, or other bio-fuels (wood, charcoal, dung, etc.) with electricity since these sources emit harmful smoke into the household (Lam et al, 2017; Lam, Smith, Gauthier and Bates, 2012) Using a radio or television can provide households with access to information, such as news or family planning stories, and entertainment (IEG, 2008; Peters and Vance, 2012). Finally, electrification also improves feelings of safety and overall subjective wellbeing (Aevarsdottir, Barton, and Bold, 2017; Gogla, 2018).

While the effects of electrification are mostly positive, the magnitudes of the different benefits vary depending on technology source(s) consumers use and the contexts in which they live (Peters and Sievert, 2015). This variability makes the relationship between consumer demand and welfare benefits conditional since, all things being equal, power investments will not necessarily raise household welfare.

A core debate within the literature on the welfare effects of electrification surrounds whether households increase their incomes after obtaining access to electricity. Studies have found incomes gains from on-grid electricity access are due to the fact that with electricity people can switch domestic activities to the evening hours, freeing time during the day to perform income-generating activities. In India, income gains have been estimated to range from 25-50%, in Bangladesh they ranged from 9-30% and in Vietnam, the effect was estimated to be 36% (van de Walle, Ravallion, Mendiratta and Koolwa, 2013; Khandker, Barnes, and Samad, 2009; Khandker, Barnes and Samad, 2012). Positive income effects are also found in Latin America, in countries such as Nicaragua and Brazil (Grogan and Sadanand, 2012; Lipscomb et al., 2013). Off-grid technology is shown to raise incomes, with a positive relationship between the size of the SHS unit purchased and incomes gains, implying the benefits vary by household income (Gogla, 2018).

However, some argue that these effects are overstated, and not transferrable to other contexts, such as in Sub-Saharan Africa. Pieters and Siever (2015) showed evidence from surveys of rural households in Benin, Burkina Faso, Senegal, Rwanda, Uganda and Zambia that impacts on income are modest at best. Many rural households do not switch from agricultural work to non-agricultural work after electrification since there is limited market access. At the same time, households do not use the electricity for productive, income generating activities. The authors argue that difficult access to markets is the main hinderance on potential income gains from electrification to households in Sub-Saharan Africa. A study of the impact of mini-grid electrification across 262 households in the West Nile in Uganda found that the median household income and spending in parishes with electricity access were 2-3 times higher than in unconnected ones. The causality, however, was primarily that an already higher income explained the electricity connection status of a household, rather than vice versa (Steward Redqueen, 2016).

The magnitude of health and education benefits are widely disputed too. The health effects of replacing kerosene lamps or stoves depends on the degree to which they are used for lighting or cooking. Conflicting findings from studies in Tanzania show that on-grid electricity access does not affect health whereas off-grid technology does (Chaplin et al., 2017; Aevarsdottir, Barton, and Bold, 2017). It seems that households who rely on off-grid technology are more likely to have health benefits than on-grid users. Off-grid technology users report that air quality improves after purchasing a SHS and that SHSs replace 1.7 kersone lamps on average (Gogla, 2018). Although, others argue kerosene lamp usage is already declining, regardless of additional electricity access (Pieters and Siever, 2015).

The education benefits from increased access to electricity are found to vary by gender and in magnitude. In Vietnam, on-grid electrification was found to improve enrolment rates for boys more than girls, raising both enrolment rates 11% and schooling years by 0.7 (Khandker, Barnes, and Samad, 2009). Whereas in India, improvements in enrolment and schooling years were found only for girls (van de Walle, Ravallion, Mendiratta and Koolwa, 2013). In Peru, grid access raises children's study time by 1.6 to 2.3 hrs (Aguirre, 2017). In Uganda, children in households with mini-grid connection spent 10-35 minutes more on education than children in households without electricity (Steward Redqueen, 2016). Off-grid technology is reported to increase study time overall (Gogla, 2018). Studies in Sub-Saharan African countries of SHS show that increases in study times after electrification range from 2.2 hrs in Zambia to 0.7 hours in Tanzania (Harrison, Scott and Hogarth, 2016).

Whether increased welfare benefits result in more consumption of electricity [14] is not well studied, although, available evidence indicates there is a positive relationship. As household income goes up, demand for electricity increases, which is illustrated by the positive income elasticities of demand (Kolawole, Adesola, De Vita, 2017 and Khanna, Rao, 2009). Studies of household welfare also show that household electricity use increases upon initially gaining access to on- or off-grid electricity (Khandker, Barnes, and Samad, 2009; van de Walle, Ravallion, Mendiratta and Koolwa, 2013; Pieters and Siever, 2015). However, it is important to note that there is a limit to the demand that households have. As mentioned previously, after initially consuming more electricity, on-grid users flatten out their consumption in the long run (Fobi et al., 2018; Steward Redqueen, 2016). Similarly, despite the efforts of SHS companies, after initially purchasing a SHS package, off-grid users do not often move up the energy consumption ladder (Gogla, 2018).

2.4.5 Effect on outage change

The premise that additional power supply will reduce outages to the benefit of households is conditional on the electrification rate in a country [7]. By definition, residents cannot be affected by outages unless connected to the electricity grid [15]. Therefore, in countries with low electrification rates, unplanned outages caused by load shedding should not affect the household sector as much as the private sector.

For grid connected households that do experience outages, however, the cost can be significant. A common approach to determining the cost of outages to households is by measuring their willingness-to-pay (WTP) for more reliable power. There are not many studies focusing on developing country contexts in this area. One study in South Africa of household's WTP for fewer unplanned outages, which could last from two to eight hours, found that the biggest costs were damage to electrical appliances and spoiled food (Nkosi, 2016). Households were willing to pay from $2 to $6 more on their monthly electricity bill for fewer unplanned outages, although more than 40% were not willing to pay anything. WTP was highest during the winter, at peak hours, and during the day (Nkosi, 2016).

3 CONCLUSION

In this study we have attempted to identify the pathways through which investments in power impact businesses and households. The theoretical framework illustrates these pathways, starting with two main channels: through a change in price and through a change in outages. Firms and households might respond to changes in price by consuming more electricity, which in turn could generate positive impacts on business growth or household welfare. Whereas changes in outages reduce the burdens they cause to firms and households with grid connections, which can raise firm output or save families costs.

However, in practice, the pathways to impact are not straightforward and depend on different factors such as the technology and country context of the investment. To illustrate, consider a hypothetical investment into renewable, on-grid electricity generation in a country where there are few grid connections, prices are subsidized, and outages are not caused by load shedding. Based on the literature review, we show that such an investment would likely have little impact on firms or households because of the interplay of technological and contextual factors. In comparison, in the same hypothetical country context, an investment into off-grid, SHS technology that provides good lighting, replaces kerosene use and increases productive activity would have a positive impact on household welfare but would likely have little impact for firms.

We conclude that:

1. A growing body of literature shows that the impacts of increased access to electricity are mixed, especially for households.
    a. On the private sector side, firms benefit by producing more output from either lower energy prices or fewer interruptions from outages. However, the benefits are not equally shared across the economy, with more energy intensive sectors benefiting the most.
    b. On the household sector side, welfare benefits from access to electricity are generally positive but might be overstated and should be interpreted cautiously, especially for income and education gains.
2. Certain conditions provide better environments for supporting impacts of different investments in power because of role of technical and contextual factors.
    a. In country contexts with large manufacturing sectors, cost reflective energy prices, frequent load shedding, and high rates of grid connections, on-grid technology investments could be more impactful than off-grid technology investments.
    b. In country contexts with large rural populations, low grid connection rates, non-cost reflective prices and common kerosene or other bio-fuel usage, off-grid technology investments could be more impactful than on-grid technology investments.

Future research should work to test the framework with data from actual power investments in order to further quantify and qualify the illustrated linkages, and determine the degree to which various contextual factors result in higher or lower impacts for firms and/or households. This will help determine how investments can be screened based on their impactfulness ex-ante, raising the efficiency of development finance in terms of impact in the power sector.

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