Energy and Economic Growth
Applied Research Programme

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Thematic Note: The Linkages between Electricity Supply and Economic Growth

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EEG will commission rigorous research exploring the links between energy, economic growth and poverty reduction in low-income countries. This evidence will be specifically geared to meet the needs of decision makers and enable the development of large-scale energy systems that support sustainable, inclusive growth in low income countries in South Asia and SSA.

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List of abbreviations

EEG	Applied Research Programme on Energy and Economic Growth
GDP	Gross Domestic Product
HRV	Hausmann Rodrik and Velasco
PAYG	Pay As You Go
PV	Photovoltaic
SSA	Sub-Saharan Africa

1 Introduction

This Thematic Note is one of six produced in the first year of the Applied Research Programme on Energy and Economic Growth (EEG). Each summarises a set of EEG State-of-Knowledge Papers that explore current understanding around one aspect of a theme related to large-scale energy infrastructure and economic development. This Thematic Note summarises the State of Knowledge Papers produced under EEG's Theme 1 – The Linkages between Electricity Supply and Economic Growth. It highlights the key findings and research gaps that were identified by State of Knowledge Paper authors through their literature review and their engagement with policymakers and industry practitioners at the EEG Policy Workshops and Research & Matchmaking Conference.

Increasing the scope and reliability of electricity supply may prove to be an attractive solution to unlocking economic growth potential in developing countries. Electricity offers numerous advantages over other energy carriers as a general purpose technology, enabling more efficient lighting (Fouquet, 2008), information and communication technologies, and more efficient organization of manufacturing industries (Kander, Malanima, and Warde, 2014). Over time and as income increases across countries, there is a tendency to use higher quality – more productive, cleaner, and more flexible – energy carriers (Burke, 2013; Csereklyei, Rubio, and Stern, 2016). Electricity is the highest quality energy carrier and an increased share of energy use in the form of electricity is associated with higher incomes.

Many developing countries have engaged in reform of their electricity sectors in the last few decades but these reform efforts have only been partially successful both in terms of promoting more efficient pricing and greater electricity access (Jamasb, Nepal, and Timilsina, 2017). There is generally less evidence available for SSA and South Asia than for other regions, and these regions face significant energy challenges, with potential economic and human development implications for many millions of people. Studies assessing the effects of electricity sector reform on economic growth and poverty are scarce; so far we see that effects on growth seem positive, while the effects on poverty are mixed (Jamasb, Nepal, and Timilsina, 2017).

To justify intervention by development agencies and governments in improving electricity access and reliability, it is necessary to show that this intervention would have a causal effect on growth, poverty, or other development indicators of interest. Our research reviews the existing evidence on the effects of electricity availability and quality on growth and poverty reduction and identifies the knowledge gaps in order to develop projects for the following years.

In principle, it should be easier to find evidence for causal effects using more disaggregated data at the micro-economic level as some variables can more easily be considered exogenous and randomized trials and other field experiments are possible. Several quasi-experimental studies have found that electrification improves economic outcomes, and recent and on-going experimental and quasi-experimental studies are generating new insights on the impacts of electricity (Dinkelman, 2011; Lipscomb, Mobarak, and Barham, 2013: Lee et al., 2016). On the other hand, growth is an economy-wide, dynamic, and long-term process and such growth effects cannot usually be captured in micro-economic studies. Both micro- and macroeconomic analysis is needed to assess the effect of electricity access on economic growth.

Therefore, research in the first year of Theme 1 includes both macro- and microeconomic analysis. The first paper in the theme focuses on macroeconomic evidence and the second on microeconomic evidence. The latter includes both analysis at the individual household or firm level and the community or county level where some "spill overs" to non-connected households, businesses etc. can also be accounted for. A central gap in our global understanding of the role of electricity supply in economic growth is when insufficient electricity supply becomes a binding constraint on growth, and whether less developed countries are at or near this point. Therefore, the third paper reviews the evidence for whether electricity supply can be a binding constraint on growth with a focus mainly on the grey literature.

Our research also combines the literature review with input from stakeholders to identify the priority themes for research in following years. We find that reliability of supply is the top priority. Existing research is limited but suggests the benefits of improved reliability could be large. The relative benefits of electrification of rural households versus the provision of more reliable electricity to urban areas should also be researched. Electricity can also be provided by grid and off-grid technologies and we recommend investigation of the demand for, and costs of, providing electricity via these different methods to various population groups. This agenda is not only of interest for academic researchers but should provide practical guidance to policy-makers in developing countries on the relative costs and benefits of different electricity provision strategies. Research should also be carried out on identifying the causal effect of electricity on growth and development and particularly how benefits accrue over time as this underpins any recommendations to invest in improving electricity provision.

The three State-of-Knowledge papers that are reviewed in this Thematic Note are:

1. Stern, D., Burke, P. & Bruns, S. (2016) The Impact of Electricity on Economic Development: A Macroeconomic Perspective. Energy and Economic Growth Applied Research Programme.

2. Lee, K., Miguel, E & Wolfram, C. Electrification and Economic Development. Energy and Economic Growth Applied Research Programme.

3. McCulloch, N. & Zileviciute, D. (2016) Is Electricity Supply a Binding Constraint to Economic Growth in Developing Countries? Energy and Economic Growth Applied Research Programme.

The papers under this theme focus on the following questions:

- How serious do electricity supply side problems have to be in order to constitute a serious brake on economic growth?

- What can be learned from analysis of energy infrastructure and supply relationships to better reflect differences in costs and quality of service?

- To what degree is a binding constraint of inadequate electricity supply problems reflected by very high average prices for electricity (including privately generated electricity), or indeed high costs of other inputs including labour?

- What can be learnt from additional econometric work with more disaggregated data? Does it provide further insights into how electricity investments affect economic development? Does the quality of such data support such analysis? For example, triangulation of sector investment, electricity prices and other prices and outputs.

- What can be learnt from historically successful countries, including in Asia and Latin America, which have invested successfully in energy systems, and the degree to which this has prolonged economic growth and maintained competitive average electricity prices?

2 Key insights from the State of Knowledge Papers

2.1 Paper 1: The Impact of Electricity on Economic Development: A Macroeconomic Perspective

While electricity access may not be a sufficient condition for economic growth, the data show that electricity use and GDP growth tend to go hand-in-hand. Theory also suggests that electricity access is likely to be an important enabler of broad-based economic growth. But the review found limited high quality research especially in terms of establishing causal effects.

The simple empirical analysis in this paper finds that GDP and electricity use per capita have a strong positive correlation across countries with economic growth having a roughly one to one proportional effect on electricity use. There are also strong positive correlations between the level of GDP per capita and both electricity access and electricity reliability. There are negative correlations between the costs of both electricity connections and electricity use with GDP per capita. Correlations between the rate of economic growth and other electricity and development outcome variables are weak and often negative because there is a weak negative correlation between the level and rate of growth of GDP per capita. This implies that if there are actually strong connections between the rate of economic growth and electricity availability, more sophisticated techniques will be needed to uncover them.

The time series literature on electricity use and economic growth that uses the Granger causality approach is large but mostly inconclusive. However, the paper suggests that further meta-analyses or time series studies of the existing type would probably not be productive. Existing studies almost all suffer from omitted variables bias – testing the effect of electricity on growth while not controlling for other energy sources. Even a well conducted study will struggle with the likely small size of the effect of electricity on growth compared to the effect of income on electricity use and the various opposing ways that changes in electricity use might be related to changes in GDP. Estimation of structural models that can isolate and identify different channels of influence might be helpful.

The paper also found few methodologically strong studies on electricity infrastructure and growth. Even the best study using international data (Calderón, Moral-Benito, and Servén, 2015), however, does not identify the effect of electricity infrastructure but instead aggregates electricity infrastructure with other infrastructure indicators. The results from the best quality studies find that the elasticity of GDP with respect to electricity generation capacity is between 0.03 and 0.1. Andersen and Dalgaard (2013) analyse the effect of electricity quality on economic growth in countries in SSA. Their results imply very large changes in the economic growth rate due to outages – a one standard deviation increase in outages is associated with a reduction in the rate of economic growth of 1.5 percentage points. This surprisingly large effect warrants further investigation.

Finally, while case studies of the growth outcomes of electrification success stories are suggestive, firm conclusions on the role of electricity in economic development would benefit from more rigorous statistical evidence. This is because in countries such as Vietnam or China many other policy changes accompanied the drive for greater electrification. Even in countries like Egypt,

South Africa, and Ghana, which have been more successful in electrification, reliability remains a serious issue. Anecdotal evidence suggests that reliability has restricted the growth dividends resulting from electrification.

2.2 Paper 2: Electrification and Economic Development

The paper differentiates between the different "margins" of increasing electricity access and use and the different issues associated with them. The extensive margin refers to providing access to new, previously un-electrified communities and also to additional households or firms within nominally connected communities. The intensive margin refers to increasing electricity use and reliability within connected establishments. Key issues on the intensive margin are reliability, tariff structures, and corruption, which reduce the benefits and increase the costs of electricity use. Some of these issues also apply to connecting additional establishments within connected communities. Regarding the question of connecting new communities, the key issues are around the most cost effective way of doing this. The first tier is to provide access to home solar technologies. These are relatively low cost, but benefits are probably low as well. Costs and benefits of connection to the grid will vary between "undergrid" establishments that are close to existing transmission lines and more remote communities. However, research shows that in Ghana and Nigeria the optimal solution for the vast majority of unconnected communities or households is to be connected to the grid. Spill overs mean that connecting one community may reduce the costs of connecting another, while within a community the benefits of additional connections could be reduced by households sharing access to a single connection.

Electricity reliability is affected by the ability of electric utilities to raise revenues. In SSA only 2 out of 39 countries collected enough revenue to cover the total cost of providing electricity. Corruption, incorrect data on bills etc. tend to reduce collections. Utilities in SSA are transitioning to pre-paid meters, which reduce electricity consumption but improve revenue collection. Theme 3, and to some extent 2 and 6, addresses these issues in detail.

Electricity usage is also closely connected to the uptake of electricity using appliances. Adoption tends to follow an S-shaped function of per capita income. Adoption can be increased by PAYG innovations, which reduce credit constraints. Gender roles and heterogeneous preferences especially around cooking options likely slow uptake.

Electricity extends the workday and allows more daylight hours to be used for market activities as household tasks and leisure can be pushed into the night. It can also improve schooling outcomes by letting children study at night more. This allows women in particular to engage in the market, work outside of home and produce marketable products at home. The effect is large in Africa but not in Asia, though there do seem to be other positive effects in Asia.

Studies of the impacts of electrification focus on grid connections rather than alternatives such as home solar. Most studies use instrumental variable techniques. These instruments are usually geographical variables, such as distance from main transmission lines, or gradient. As these may be correlated with other relevant variables such as existing wealth or human capital, the validity of the instruments is questionable. Experimental evidence is limited so far, but a number of studies are underway. Some studies examine household level effects while others "account for spill overs" by

analysing community or county level data. The very varied settings and model designs make results hard to compare.

Data on accessibility of electricity is available is mainly for households. There is a need for data on business use of electricity, which often substitutes for other modern energy carriers such as diesel power for grain milling.

2.3 Paper 3: Is Electricity Supply a Binding Constraint to Economic Growth in Developing Countries?

There is a large empirical literature on "binding constraints," much of it using the Haussmann-Rodrik-Velasco (2005) framework and applying it to particular countries. There is also a large literature on the quality of the investment climate, much of which draws on the World Bank Enterprise Surveys. This paper undertakes a systematic review of the published and grey literature that has applied the HRV framework at the country level in order to ascertain how frequently electricity supply is identified as a binding constraint to growth (and differentiating between access, reliability, and price). It also examines the rankings of constraints provided in the World Bank's Enterprise Surveys in order to assess the extent to which businesses regard electricity as a major constraint.

Almost all of the 55 studies reviewed mentioned electricity with around two-thirds discussing electricity access and reliability. Well over half of the studies cited infrastructure as a binding constraint to growth (second only to "micro risks" as a constraint) and 40% of all studies identified electricity as a binding constraint.

The studies reviewed clearly highlight the extremely low levels of access in SSA and South Asia, particularly in rural areas, and the poor quality and reliability of supply. The existence of electricity as a binding constraint is revealed in several countries through high shadow prices, significant economic costs associated with outages, widespread attempts to avoid the constraint – notably by the use of generators, and, in all likelihood, the relatively poor performance of energy intensive sectors (although the evidence for this in this review is thin). Moreover, the importance of electricity as a constraint is confirmed by data from the World Bank's Enterprise Survey, which suggests that it is the second most important obstacle for firms in SSA and the most important obstacle in South Asia. Finally, the limited data available on electricity prices suggests that prices are slightly higher on average in countries where electricity is a binding constraint, but that prices are a poor proxy for electricity being a binding constraint. However, very high prices do appear to be associated with poor quality and reliability.

3 Priority Research Questions

The EEG workshops held in Dar Es Salaam and Kathmandu highlighted the following questions/points relevant to this theme as being of key relevance to policy makers:

1. What is the direction of causality between electricity and growth and how exactly does electricity promote growth?

2. Is there a trade-off between promoting more access and focusing on growth of use – i.e. between the intensive and extensive margins? What are the most productive applications in terms of promoting development and employment, reducing poverty, and increasing gender equity? Would focusing on electrification in healthcare, education etc. have greater payoffs than electrification of households.

3. How does politics affect setting of electricity tariffs and how do they affect the viability of utilities and the viability of rural electrification?

4. How do unreliable systems affect productivity?

5. Data collection is important for both research and for forecasting electricity supply and demand. Much data may be available from electric utilities including smart meter data and data on outages, but is currently underutilised.

The Research & Matchmaking Conference in Washington, DC, highlighted the following top three topics in order of importance:

1. How do impacts of electricity provision change over time? Does this differ across countries and sectors?

2. What impact does the reliability of electricity have on economic growth and development? How does this vary across different country contexts and sectors?

3. To what extent does the impact of energy on inclusive economic growth and development depend on which sector of the economy is growing? Should we prioritize electricity for manufacturing, services, agriculture, household access, etc.?

4. How do we factor rapid, disruptive technology change (and decline in PV costs) into our analysis of energy and growth and development?

The individual state of knowledge papers list a total of 14 future research questions. Here I focus on those that best relate to the themes that emerged from the three workshops. Each of these topics could use a variety of research methodologies:

1. *What is the effect of electricity supply disruptions on economic growth?* The potential large role for electricity reliability found by Andersen and Dalgaard (2013) and suggested by several of the case studies in Paper 1 warrants more thorough investigation.

2. *Trade-offs between electrification of rural households versus providing more reliable electricity to urban areas etc*. What is the best strategy for enhancing growth and development?

3. *What is the demand for and costs of providing grid and off-grid technologies to different population groups?* How are these changing? Are there important path dependencies that should be considered?

4. *Identifying the causal effect of electricity on growth:* Do electrification programs really boost economic growth? How do the effects vary over time? This should be examined both at a cross-country macroeconomic scale and at a micro-economic scale.

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