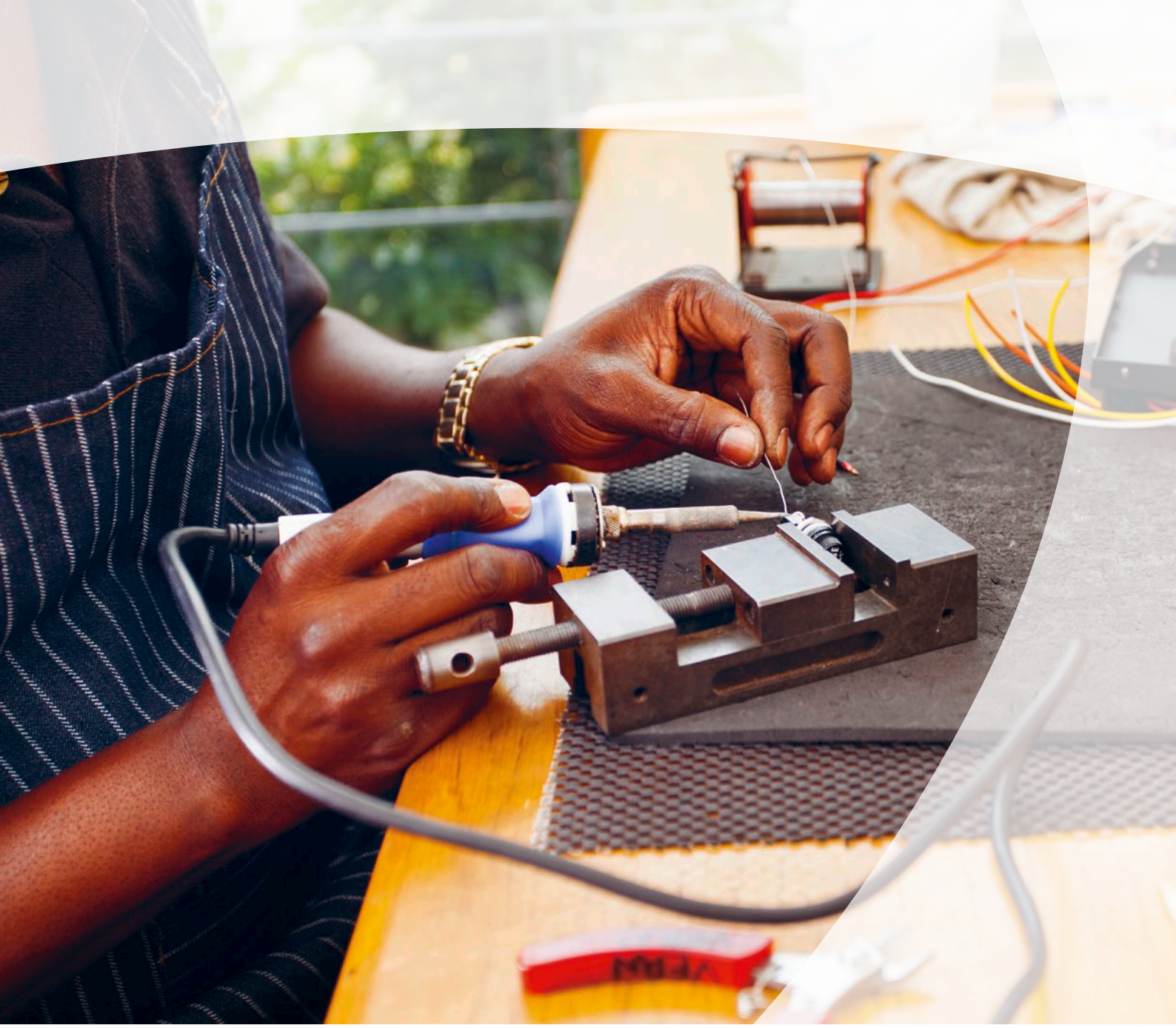

Productive Use of Energy – PRODUSE

The Impact of Electricity Access on Economic Development: A Literature Review

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of BMZ Federal Ministry for Economic Cooperation and Development

ESMAP Energy Sector Management Assistance Program

THE AFRICA ELECTRIFICATION INITIATIVE

L'INITIATIVE D'ELECTRIFICATION DE L'AFRIQUE

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Productive Use of Energy – PRODUSE

The Impact of Electricity Access on Economic Development: A Literature Review

By Benjamin Attigah and Lucius Mayer-Tasch[10]

1. Introduction

Policy makers around the world believe that access to modern energy (both electrical and non-electrical) is a necessary requirement for sustainable development. This belief is based on three basic arguments, which often appear in non-empirical literature on energy for development:

(i) modern energy may be a crucial input to achieving several of the Millennium Development Goals (MDGs)
(ii) modern energy use may enable the poor in developing countries to engage in improved or new income-generating activities (often called 'productive use of energy', as opposed to 'consumptive use'), thereby eventually leading to an improvement in their living conditions (Practical Action 2012, UNDP/WHO 2009, DFID 2002, UN 2002, UN Millennium Project 2005, Brew-Hammond and Kemausuor 2009) and
(iii) exclusion from modern energy might be a direct indicator of poverty based on definitions which refer to living standards – for instance, access to electricity is included in a recently published 'Multidimensional Poverty Index' by the UNDP (2010).

Of all modern energy types, electricity access is included most frequently as an explicit objective of national development strategies. Hence, the focus in this chapter is on access to electricity.

Empirical evidence which can be used to validate the arguments above is surprisingly scarce. In particular, little direct evidence has been published to underpin the second argument, i.e. the claim that electrification can reduce poverty through enabling 'productive uses' of electricity (IEG 2008, Kooijman-van Dijk 2008, ADB 2005, Meadows et al. 2003, Martinot et al. 2002). Moreover, quantitative evidence of the impact of electricity on economic development (especially in comparison to other publicly provided services) hardly exists. Stronger evidence is needed for better-informed policy decisions, such as the priorities of public investment options (World Bank 2010).

The few studies that do exist on the topic often lack a reliable methodology (Meadows and Riley 2003). ADB (2005) and Estache (2010) present two recent reviews of academic literature on the impact of infrastructure on poverty reduction: both conclude that most existing studies on electrification impacts are of 'uncertain value' due to a series of shortcomings in the applied methodologies, such as a lack of control groups and/or before-after data and a general failure to track the effects on poverty over a long enough time period.[11]

The lack of robust evidence to date can partly be attributed to the fact that electricity is a 'quintessential' intermediate good. Electricity does not represent an end in itself: it is an input factor to a large set of activities ('uses') that can improve welfare, increase productivity or generate income. The complex interactions and synergies between multiple development factors, including other infrastructure investments next to electricity and enabling political, socio-economic and cultural conditions, pose major methodological challenges to isolating and quantifying the impact of electrification. Indeed, it is increasingly recognised that certain "complementary" inputs or services – such as business development services (BDS) or access to finance – can increase the chances that access to electricity leads to significant income generation and poverty alleviation (ADB 2005, IEG 2008, Motta and Reiche 2001, Peters et al. 2009). However, knowledge about the extent to which these complementary factors contribute to improving the impacts of energy investments on poverty reduction and under which circumstances is at best incomplete (Kooijman-van Dijk 2008).

The debate on the precise role of electricity in economic development, thus, remains disputed.

This chapter provides a short review of relevant recent literature in order to better understand the contribution of energy (in particular, electricity) to economic growth and development. It looks at both macro and micro-level research analysing the links between energy and development. The chapter will discuss only in-depth qualitative and quantitative research. The fairly large number of policy papers citing purely anecdo-

10) The authors thank Anna Brüderle, Mike Enskat, Elizabeth Elizondo, Nadja Kabierski-Chakrabarti, Sophia Kamarudeen, Nicolas Korves, Jörg Peters, Kilian Reiche and Peggy Schulz for valuable inputs.

11) Some recent studies have begun to apply more comprehensive research methods (e.g. World Bank 2009a, World Bank 2009b). Nevertheless, these studies are still few in number and they represent mostly 'grey literature' which is not yet established in more academic research.

tal evidence on 'productive use of electricity' is not taken into account here. The review focuses on the role of electricity access; questions of service quality or reliability of energy supply will only be considered as far as they influence the uptake and impact of (newly provided) energy access. In line with the general focus of the PRODUSE Study, the chapter takes a one-dimensional perspective on development with economic parameters like income generation, growth and productivity, inter alia, as the best measurable development indicators. Impacts on education or health for example obviously form important aspects of development – but their measurement requires more complex methodologies and therefore they are not discussed here.

The remainder of this chapter is structured as follows: the next section provides a basic conceptual background by outlining the steps that lead from energy supply to poverty reduction. *Section 3* discusses some methodological issues. This is followed by an overview of the existing empirical evidence at the macro-level (*Section 4*) and at micro-level (*Section 5*). *Section 6* contains concluding remarks.

2. Conceptual Background: The Steps from Electricity Supply to Poverty Reduction

As Kooijman-van Dijk (2008) points out, one of the reasons why there is little understanding of the links between electricity supply and poverty reduction through income generation is because the relationship consists of several steps and many factors influence each of these steps. The first step towards a business benefiting from electricity supply is the physical provision of electricity and the entrepreneur's decision to make use of it. However, it is the steps that follow, namely the actual use of electricity and the subsequent changes that electricity use brings in the enterprise (e.g. increased productivity), which can ultimately lead to impacts at enterprise level, such as increased income. The theory regarding the causal chain from energy supply infrastructure to development outcomes is displayed in *Figure 1* (adapted from Kooijman-van Dijk 2008: 6). This concept is discussed in more detail in the methodology developed for the empirical research of the study at hand.

Obviously this figure shows only a *hypothesis* of interaction and direction of impact. However, it provides a useful framework for further analysis, as the structure makes clear the relationships between the different *variables* that are typically analysed in the literature (energy supply – quality and reliability of energy supply - energy consumption/use – productivity – growth/GDP/income (inequality) – poverty reduction). For purposes of empirical investigation, these variables can in turn be measured by different indicators. The empirical findings presented in subchapters 4 and 5, for both macro and micro-level, are structured along these lines.

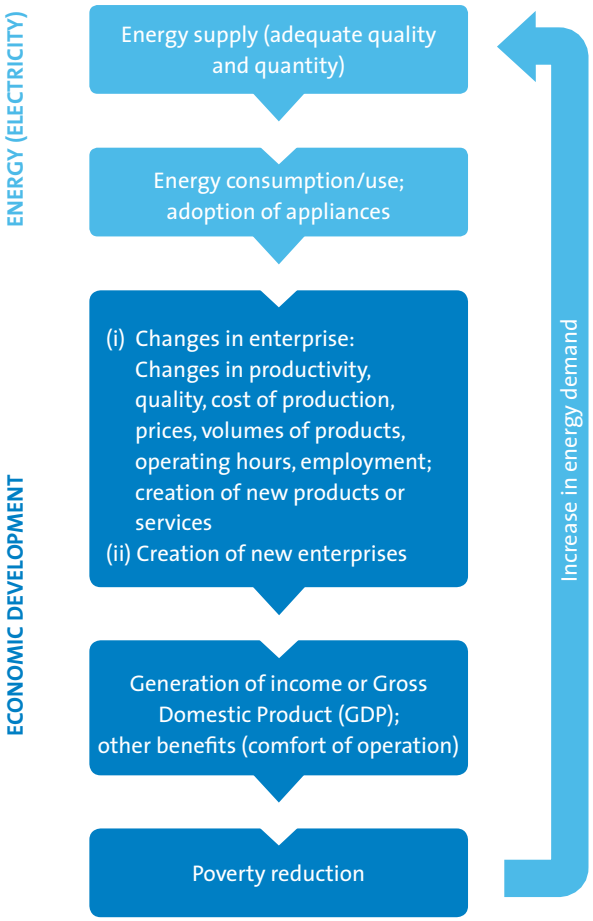
3. Methodological Issues

Evidence of the contribution of energy to economic development is often presented in the form of simple *correlations* between electricity and welfare indicators such as GDP or the Human Development Index (HDI) at the macro-level (e.g. IEA 2004) or household income at the micro-level. Such correlations are then presented as evidence that energy causes positive development outcomes. For example in a study by White (2002: 34) the figure below is presented as evidence that 'human development responds dramatically to initial electricity additions'.

It is important to point out, however, the simple but all too often neglected fact that correlation does not imply *causality*! In our example, it is just as plausible that improvements in the HDI lead to increases in energy consumption and not just the other way around.

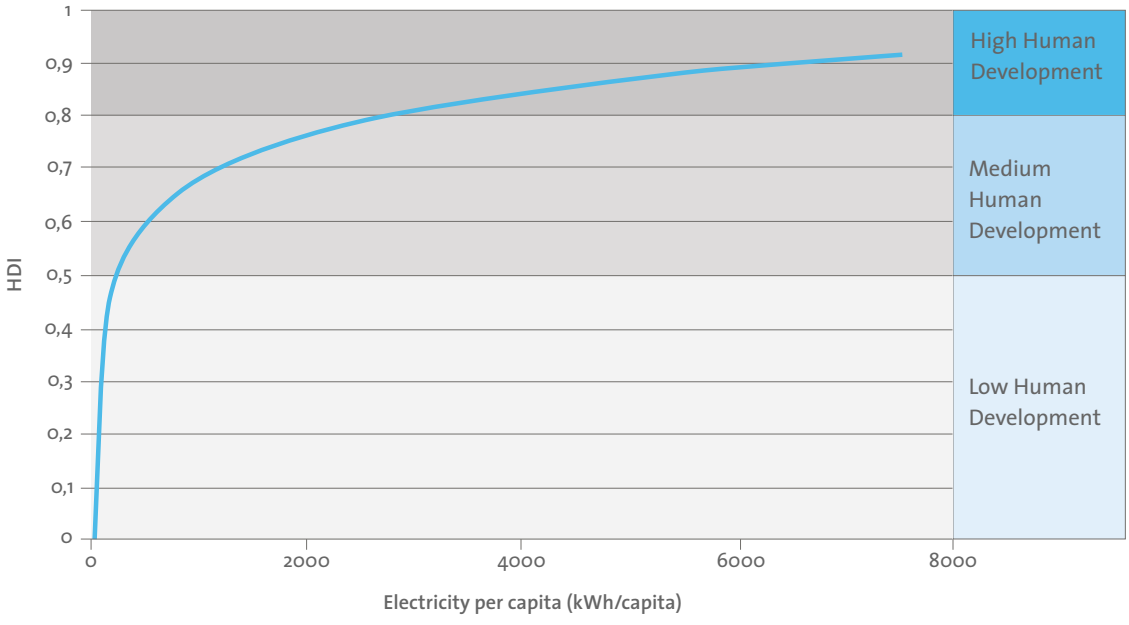
Academic research commonly uses *regression analysis* to test the magnitude and direction of causal relationships between variables in a data set.[12] In the literature on the link between electricity (or on a more general level, infrastructure) and economic development, the main explanatory variable is usually either electricity consumption or electricity supply. The dependent variables analysed in the literature are productivity, output, growth, income (inequality), employment or poverty reduction.

Figure 1: The Theory: Steps from Electricity Supply to Poverty Reduction



Source: adapted from Kooijman-van Dijk (2008)

Figure 2: Macro-Level Correlation Between Electricity and Human Development



Source: White (2002)

A common methodological framework to research the electricity-development link is the production function. Within the framework of the production function, the impact of electricity on (aggregate) output is usually modelled in two main ways: firstly, directly when electricity services enter production as an additional input and secondly, indirectly when they raise total factor productivity by reducing transaction and other costs, thus allowing a more efficient use of conventional productive inputs (Straub 2008a). Examples for such indirect effects of electricity infrastructure are: (i) well-maintained infrastructure may reduce operating costs of private capital or extend its life span, such as machines connected to stable voltage lines, (ii) high-quality infrastructure can reduce private adjustment costs to unreliable electricity services, e.g. investments in power back-up systems, (iii) it can increase labour productivity, e.g. through a more efficient structuring of business processes as a result of improved information and communication technology. It is important to point out, that adverse effects of investments in electricity infrastructure may also occur, e.g. when public investment crowds out private investment.

4. Macro-Level Research

4.1. Introduction

The macro-level literature analysing the link between electricity and economic development so far remains limited, as the 'mainstream' economic literature on growth and development pays little attention to the role of energy (Estache 2010). There are, however, a number of studies from the field of energy economics that look at the causal relationship between energy consumption and economic growth. A second distinct body of literature, as mentioned in the section above on methodological issues, focuses on investigating the impacts of infrastructure investments on a variety of development outcomes (such as growth, productivity or poverty reduction). Most of these studies include energy infrastructure as one variable of interest.[13]

In the context of the aforementioned body of literature, it will be of interest to not only look at the direct impacts of energy infrastructure on different development outcomes, but also to analyse its impact compared with other publicly provided infrastructure services. Such an assessment will be relevant from a policy perspective as it allows policy makers to better evaluate and prioritise different types of investments in order to allocate public funds as efficiently as possible.

4.2. Empirical Evidence

This section surveys the empirical evidence on the impact of electricity on different development outcomes, manifested in three broad categories of impacts: productivity, growth and poverty.

Impacts on Productivity

The literature examining the development impact of infrastructure, most of which includes electricity infrastructure as one variable of interest, started with the seminal work of Aschauer (1989). He finds that the stock of public infrastructure capital – including electricity – is a significant determinant of aggregate total factor productivity (TFP). His results suggest that infrastructure played an important role in the 'productivity slowdown' in the U.S. which started around 1973. Earlier studies exploring this phenomenon had ignored the role of infrastructure and focused on other factors such as energy prices or R&D (Gramlich 1994). Critics of Aschauer's

12) Regression analysis is a method for numerical data analysis where the relationship among the variables in a data set is summarised as an equation. In this equation the variable of interest, or the dependent variable, is expressed as a function of one or several explanatory variables.

13) Infrastructure typically includes energy, transport, telecommunications, water, irrigation and sanitation.

work pointed out that the economic significance of his results was considered implausibly large and that he failed to address several methodological issues.[14] Later studies applied more sophisticated econometric techniques to correct for these methodological problems (see Gramlich 1994, Romp and de Haan 2005 and Estache and Fay 2009 for an overview of these studies).

Table 1 summarises the studies reviewed in this section, which look at electricity as a variable of interest next to other infrastructure services like transport and telecommunications. Different electricity indicators are employed, including electricity generation, electricity generation capacity and investment in electricity infrastructure. The overall effect of electricity on productivity varies across countries. Positive effects of electricity on productivity are found in various geographic areas (Fedderke and Bogetic 2006, Noumba Um, Straub and Vellutini 2009), while only insignificant or even negative impacts also emerge for some other regions (Fan, Zhang and Zhang 2002, Fan, Hazell and Thorat 1999, Straub, Vellutini and Warlters 2008). The evidence also shows that in some countries such as China, India and Thailand electricity displays a smaller productivity effect than other infrastructure investments, notably agricultural research and development.

Table 1: Effects of Infrastructure and Energy on Productivity

Source	Country/ Region	Output Indicator(s)	Conclusion
Edquist and Henrekson (2006)	Germany, Sweden, UK, US	Rate of productivity growth	Productivity growth occurs with a distinct time lag following electrification (about 40–50 years for electrification and the ICT revolution and about 140 years for the steam engine). No clear evidence of high productivity growth rates for both electric machinery industry and the steam engine producing industry was found.
Fan, Hazell and Thorat (1999)	India	Agricultural productivity	Additional government spending on rural electrification has low productivity effects. Government expenditure on rural roads and agricultural research and extension promote greatest growth in agricultural productivity.
Fan, Jitsuchon and Methakunnavut (2004)	Thailand	Agricultural labour productivity	Investments in rural electrification have the second largest impact on agricultural productivity growth after agricultural research and development.
Fan, Zhang and Zhang (2002)	China	Agricultural productivity	No significant effect of electricity on agricultural productivity. Agricultural research has largest effect on productivity.
Fedderke and Bogetic (2006)	South Africa	Labour productivity and TFP growth	Electricity generation is positively related to labour productivity and TFP growth.
Noumba Um, Straub and Vellutini (2009)	North Africa and Middle East	TFP	Electricity production helps explain cross-country differences in TFP growth.
Straub, Vellutini and Warlters (2008)	East Asia	TFP growth	No significant contribution of electricity generating capacity. Indonesia (as a relatively poor country) is the only exception and shows negative impacts.

Source: adapted from Pinstrup-Andersen and Shimokawa (2007)

14) The most important issue concerned the potential of reverse causation from public capital to productivity and output. Neglect of this potential endogeneity is likely to cause an upward bias in the estimated returns to infrastructure (Romp and de Haan 2005).

Impacts on Growth

The literature on electricity and growth can be split into (a) the energy economics literature analysing the causal relationship between electricity consumption and growth and (b) the literature on infrastructure and development which often includes electricity infrastructure as a variable of interest. Studies in the first category, which analyse the relationship between electricity consumption and GDP growth, produce conflicting results in terms of the existence and direction of causality between the two variables. This conclusion is drawn by Ozturk (2010) who has undertaken an extensive review of this body of literature of more than a hundred studies from a wide range of countries, including both country-specific and multi-country analyses, covering the period 1978 to 2009 and applying a variety of methodological approaches. Ozturk distinguishes between four types of relationships: no causality, uni-directional causality running from economic growth to electricity consumption, uni-directional causality running from electricity to growth and bi-directional causality between economic growth and electricity consumption.

With regard to methodology, Ozturk suggests in line with Karanfil (2009) that researchers should use more appropriate econometric techniques in the future, as the methods most often applied to date are of limited value with regard to the issue in question. The traditional methods (i.e. ordinary least squares) will not yield the required insight but rather increase the number of conflicting results and cast doubt on the reliability of their policy recommendations. A number of recent studies have sought to apply more comprehensive econometric techniques and address key methodological issues. For instance, in his study on the nexus between electricity supply, employment and real GDP in India, Gosh (2009) makes a case for electricity supply being a more meaningful indicator than electricity demand in countries with high levels of non-technical transmission and distribution losses (e.g. as a result of theft or pilferage of electricity), as the use of official data may lead to a systematic underestimation of real electricity consumption. Next to findings in relation to employment effects of electricity, the author establishes short-run causality running from growth to electricity supply (based on use of electric appliances in the industrial, commercial and domestic end-use sectors) but finds no causality running from electricity supply to real GDP.

The second category of studies that examine the electricity-growth-nexus, i.e. those that try to quantify the contribution of different kinds of infrastructure to income and growth, find mostly positive effects of electricity on economic growth. In a recent survey of the literature on infrastructure and growth in Africa, Foster and Briceno-Garmendia (2010), conclude that there are strong indications of a positive impact of infrastructure on growth. Several of the reviewed studies include electricity in their estimations and show a beneficial growth effect of electricity (e.g. Ayogu 1999, Calderón and Servén 2008, Estache, Speciale and Veredas 2005).

Table 2 summarises a number of empirical studies that examine the effects of electricity infrastructure on growth.

As can be seen from the table, only a few studies report relatively small impacts of electricity compared to other infrastructure investments (Fan, Zhang and Zhang 2002) or fail to find significant impact of electricity on growth (Straub, Vellutini and Warlters 2008). Despite the evidence pointing towards positive growth effects of electricity infrastructure, some authors suggest to interpret such results with caution. For instance, Straub, Vellutini and Warlters (2008) state that results from aggregate macro-level data should generally be interpreted with care. They point out that the primary function of infrastructure investments may not be to directly promote economic growth but rather relieve constraints and bottlenecks to growth as they arise. Other authors such as Ayogu (2007) voice more fundamental concerns about the infrastructure-growth literature. Ayogu conducts an extensive review of the empirical literature and he concludes that the question of whether infrastructure matters for growth has not been satisfactorily resolved. Moreover, in his view this is only a marginally important issue, 'way beyond what could be the value added from totally resolving the issue'. Instead, the author proposes to focus future research efforts on much more relevant policy issues, such as analysing how much infrastructure matters exactly in different contexts.

Table 2: Effects of Infrastructure and Electricity on Economic Growth

Source	Country/ Region	Output Indicator(s)	Conclusions
Ayogu (1999)	Nigeria	GDP	Strong association between infrastructure, including electricity and output in panel data was found.
Binswanger, Khandker and Rosenzweig (1993)	India	Agricultural investment and crop output	Electrification has a clear effect on agricultural investment (e.g. in pumps) and thereby also on agricultural output.
Calderón and Servén (2008)	Africa	GDP growth per capita, Gini coefficient	Infrastructure stocks as well as infrastructure service quality have positive impacts on long-run growth and income equality - electricity is included in the estimations as part of aggregate infrastructure indices.
Calderón (2009)	Africa	Growth in GDP per capita	With Mauritius' infrastructure Africa's growth per capita would be enhanced by 2.2 percent per year. African countries would gain more from larger stocks of infrastructure than better quality of existing infrastructure. The largest payoffs are for telephone density, electricity-generating capacity, road network length and road quality.
Canning and Pedroni (2004)	Various	GDP per capita	Long run effects of investment in electricity generating capacity are positive in a large number of countries, with negative effects being found in only a few.
Easterly and Levine (1997)	Various	GDP growth rate	Infrastructure, measured by telephones per worker and electricity losses, is strongly and significantly correlated with growth. However, no significant impact is found when measured as electricity generating capacity.
Esfahani and Ramirez 2003	Various	GDP growth per capita	Substantial impact of infrastructure, measured by electricity and telecommunications infrastructure, on GDP growth; this impact in turn depends on institutional and organisational capabilities.
Estache, Speciale and Veredas (2005) [15]	Africa	GDP per capita	Roads, power and telecommunications infrastructure – but not sanitation – contribute significantly to long-run growth in Africa.
Fan, Zhang and Zhang (2002)	China	Agricultural growth	Electricity has a positive effect on agricultural GDP but much weaker one than the other factors analysed
Noumba Um, Straub and Vellutini (2009)	Middle East and North Africa	GDP growth per capita	Impact of growth of electricity production on GDP growth. MENA countries demonstrate lower returns than developing countries as a whole, probably due to higher levels of investment and subsequent diminishing returns.
Seethepalli, Bramati and Veredas (2007)	East Asia	GDP per capita	Positive and significant effects for electricity on growth were determined.
Straub, Vellutini and Warters (2008)	East Asia	GDP growth per capita	No robust impact of electricity production on growth was detected.

Source: adapted from Foster and Briceno-Garmendia (2010) and Pinstrup-Andersen and Shimokawa (2007)

Impacts on Poverty

There are several empirical studies that focus on the question of whether increased electricity access actually benefits the poor or whether it tends to increase incomes of the upper income strata disproportionately. In this context it will be of interest to specifically compare the impact of energy infrastructure with the impact of other infrastructure services. This might allow policy makers to evaluate and prioritise infrastructure investments in order to allocate public funds as efficiently as possible.

A general observation from these studies is that electricity has a relatively small effect on poverty as compared to other infrastructure investments, notably roads. *Table 3* provides an overview of the cited studies on the nexus between electricity infrastructure and poverty reduction.

Table 3: Effects of Infrastructure on Poverty Reduction in Developing Countries

Source	Country/ Region	Output Indicator(s)	Conclusions
Balisacan 2001	Philippines	Proportion of the rural population living below the provincial poverty line	No significant effect of electricity access; roads have highest impact.
Fan, Hazell and Thorat (1999)	India	Number of poor reduced per million rupees infrastructure investment	Additional government spending on rural electrification has no discernible impact on poverty reduction. Spending on roads has largest impact on poverty reduction, followed by agricultural research.
Fan, Jitsuchon, and Methakunnavut (2004)	Thailand	Number of poor reduced per million bahts infrastructure investment	Among different public investments (agricultural R&D, irrigation, rural education, road infrastructure) investments in rural electrification have the largest poverty reduction impacts.
Fan, Zhang and Zhang (2002)	China	Number of poor reduced per 10,000 yuans infrastructure investment	Positive effects of infrastructure investments in rural electrification, which are however smaller than those of investments in rural education, agricultural research and roads.

Source: adapted from Pinstrup-Andersen and Shimokawa (2007)

Fan, Hazell and Thorat (1999), for example, using data for 1970 to 1993 from India, conclude that government spending should focus on rural roads and agricultural research and extension, as these types of investments have the greatest poverty impact (i.e. the number of people raised above the poverty line for each additional million rupees spent). Regarding rural electrification (as well as irrigation), they state that additional government spending has no discernible impact on poverty reduction.

One exception to these findings is a study by Fan, Jitsuchon and Methakunnavut (2004) on Thailand. Their results show that out of different types of public investments (agricultural R&D, irrigation, rural education, road infrastructure and electricity infrastructure), investments in rural electrification have the largest poverty reduction impacts. The authors suggest that this differing result is due to Thailand's status as a middle-income country. They state that in lower-income countries returns from road investments usually are higher than from electricity or telecommunications. However, as Thailand had already invested heavily in rural roads, additional investments in roads will only yield diminishing returns. This can explain why in the case of Thailand the returns on investment in electricity are higher than for investments in roads.

15) It should be noted that the reliability of this finding is questionable because the control group of non-electrified households was very small (31 households, compared to 1,012 electrified households) and the authors

5. Micro-Level Research

5.1. Introduction

As far as impacts of electrification on the micro-level are concerned, the empirical research has taken different methodological approaches, looking at different units of analysis. There are a number of energy-specific studies and general *enterprise surveys* looking at various types of businesses (formal and informal, small and large) and *household surveys* analysing economic indicators such as income from home businesses among other impacts of electrification.

Impacts of electricity on the micro-level are often examined using the same indicators as on the macro-level (enterprise creation, business activity, firm productivity, employment, income (equality), gender and poverty reduction) and the conceptual framework of the second subchapter also applies here. The main difference lies in the level of aggregation.

Besides a key methodological weakness of macro-level research, very few micro-level studies so far go beyond showing correlations by attempting to employ rigorous methods that are suitable for proving electrification impacts on MSMEs by providing robust evidence for a causality between electrification and MSME performance.

This subchapter will first discuss which factors have been found to influence whether and how electricity impacts on enterprise performance emerge. It will then review the literature that provides evidence on impacts of electricity on enterprises, looking at different forms in which such impacts can be measured on the firm and household level: the creation of new businesses, productivity, employment, poverty and income of businesses and households.

5.2. Factors Influencing Impacts of Energy

The uptake of electricity (i.e. the decision for connection and the magnitude of kWh use) and the impacts of electricity use on MSMEs depend on various external and internal factors including access to markets (international, national and local), company location, income levels in the local economy, quality of supply and financial as well as other assets of the entrepreneur/firm.

Using an adapted version of the Sustainable Livelihoods Framework, Kooijman-van Dijk (2008) distinguishes between financial, physical, human and social assets that influence an entrepreneur's ability and willingness to connect to and use electricity. The same assets influence if/how electricity is used for productive activities which translate an electricity connection into economic benefits. She also differentiates between the strategies pursued by entrepreneurs who were forced to engage in a certain (non-farm) income-generating activity due to a lack of other opportunities (coping strategies) and those with a clear growth orientation (accumulation strategies).

Quality and reliability of electricity supply is an important factor both for the decision to connect and for the impact on MSME performance. In some countries the reliability is so low that electricity-reliant businesses have no choice but to invest in diesel generators if they want to maintain business operations at a minimum level of steadiness. Foster and Steinbuks (2009) estimate that generators owned by firms account for about 6 % of total installed generation capacity in Sub-Saharan Africa and up to 20 % in low-income countries. According to the World Bank's Doing Business report, firms in low-income countries are affected by electricity supply interruptions on average 18 times in a typical month. The resulting workflow interruptions and the damage of sensitive electrical equipment such as computers caused by voltage fluctuations can curtail profits significantly. Business managers interviewed for the Doing Business project in the various countries estimated that losses due to electricity outages amount to an average of 3.2 % of annual sales and as much as 22.6 % in Malawi (World Bank 2010). Studies on the impact of unreliable power supply on firm productivity are reviewed in the subchapter 'Impact on productivity' below.

5.3. Empirical Evidence

Impact on Creation of Enterprises

The creation of new, often informal (home) businesses triggered through access to electricity has been analysed in a number of countries using data from household surveys. Some of these studies do find positive correlations between electrification and (increase in) numbers of MSMEs; however, such results must be interpreted with care, as prioritisation of economically dynamic areas for electrification can easily result in a bias among the surveyed treatment (i.e. electrified) and control (non-electrified) areas. For example, an ESMAP study conducted in the Philippines found that across four provinces, 25 % of the households in electrified areas are running a home business (mainly small retail shops but also tailoring etc.) compared to 15 % in non-electrified areas and that the variety of these businesses is greater in electrified areas (ESMAP 2002). However, as pointed out by Kooijman-van Dijk (2008), it does not show whether this was a result of electrification or whether the electrified areas where selected precisely because of more favourable socio-economic characteristics in the target area.

The reviewed studies on business creation through electricity access are summarised in *Table 4*.

Table 4: Effects of Electricity Access on Number of Businesses

Source	Country/Region	Data Source/Sample Size	Conclusion
Arnold, Mattoo and Narcisco (2008)	10 African countries	Approx. 1,000 manufacturing enterprises	Unreliable electricity supply has a significant negative impact on a firm's total factor productivity, while generator possession has a significant positive effect.
Barnes and Binswanger (1986)	India	Surveys conducted in 108 villages in 1966 and 1980	Rural electrification had a direct impact on agricultural productivity through private investment in electric pumps.
Blalock and Veloso (2007)	Indonesia	20,000 manufacturing enterprises	Significant positive effect of energy consumption on firm productivity was found.
Eifert et al. (2008)	17 African countries	Enterprise surveys	Indirect costs (of which energy costs comprise the largest share) are a major factor for explaining the low productivity of enterprises in Africa.
Escribano et al. (2009)	26 African countries	Investment climate surveys	Infrastructure quality has a significant negative impact on total factor productivity.
Fernandes (2008)	Bangladesh	575 manufacturing enterprises	Power supply problems are of considerable relevance to firm productivity.
Hill and Kalijaran (1993)	Indonesia	2,250 small clothes producers	Significant positive effect of energy consumption on technical efficiency
Kirubi et al. (2009)	Kenya	12 carpentry and 5 tailoring workshops	Use of electricity can increase productivity per worker by approx. 100-200 % for carpenters and by 50-170 % for tailors, depending on the item being produced.

Impact on Productivity

There are a number of studies that find evidence of positive impacts of both electricity access and of the quality of electricity supply on productivity of MSMEs. Nevertheless, such impacts are highly country and context-specific.

Table 5 provides an overview of the empirical evidence on impacts of electricity access and quality of supply on firm productivity.

Table 5: Effects of Electricity Access/Quality on Firm Productivity

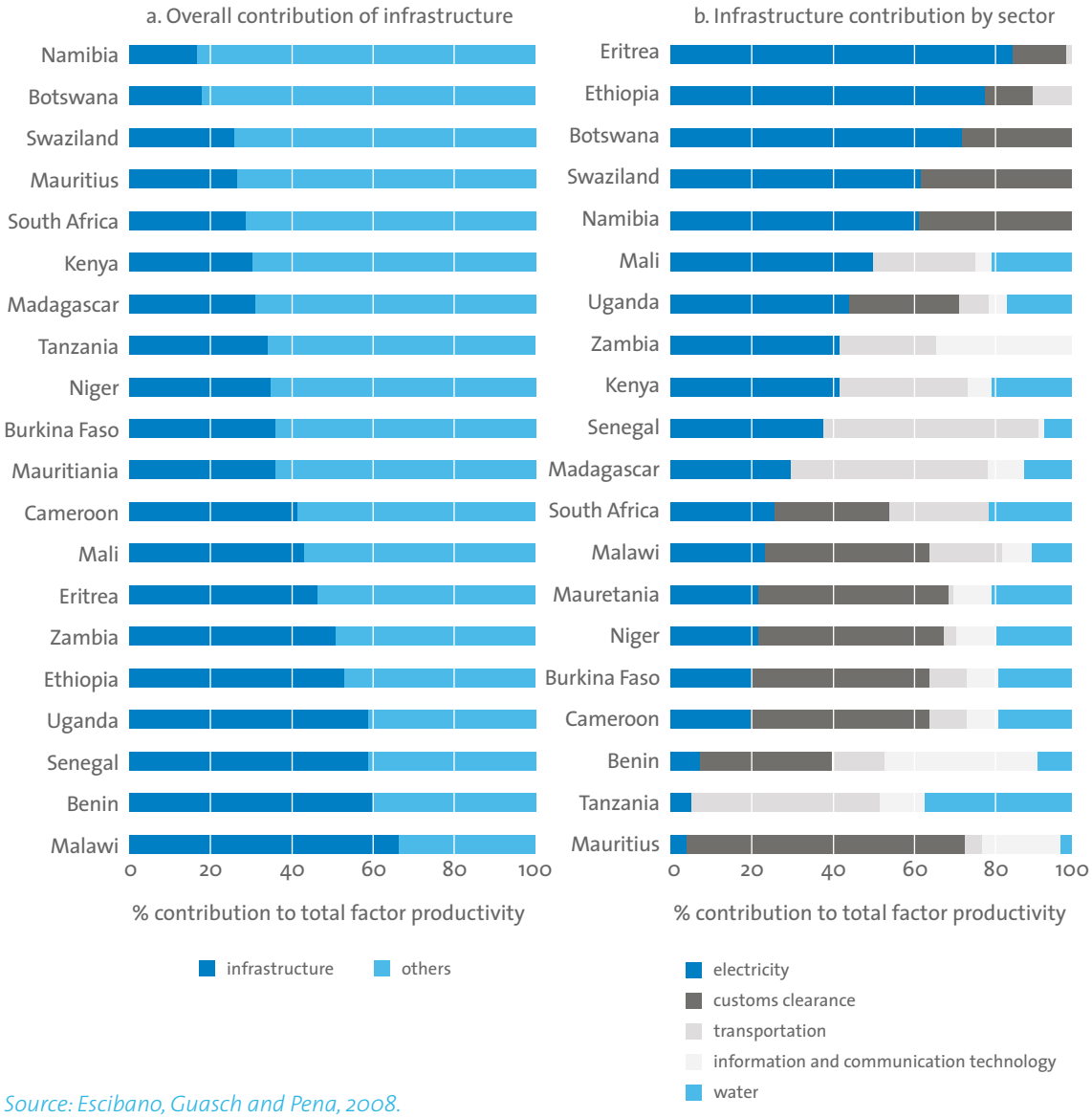
Source	Country/Region	Data Source/Sample Size	Conclusion
Arnold, Mattoo and Narcisco (2008)	10 African countries	Approx. 1,000 manufacturing enterprises	Unreliable electricity supply has a significant negative impact on a firm's total factor productivity, while generator possession has a significant positive effect.
Barnes and Binswanger (1986)	India	Surveys conducted in 108 villages in 1966 and 1980	Rural electrification had a direct impact on agricultural productivity through private investment in electric pumps.
Blalock and Veloso (2007)	Indonesia	20,000 manufacturing enterprises	Significant positive effect of energy consumption on firm productivity was found.
Eifert et al. (2008)	17 African countries	Enterprise surveys	Indirect costs (of which energy costs comprise the largest share) are a major factor for explaining the low productivity of enterprises in Africa.
Escribano et al. (2009)	26 African countries	Investment climate surveys	Infrastructure quality has a significant negative impact on total factor productivity.
Fernandes (2008)	Bangladesh	575 manufacturing enterprises	Power supply problems are of considerable relevance to firm productivity.
Hill and Kalijaran (1993)	Indonesia	2,250 small clothes producers	Significant positive effect of energy consumption on technical efficiency
Kirubi et al. (2009)	Kenya	12 carpentry and 5 tailoring workshops	Use of electricity can increase productivity per worker by approx. 100-200 % for carpenters and by 50-170 % for tailors, depending on the item being produced.

In an analysis of investment climate surveys from 26 African countries, Escribano et al. (2009) find, for example, that particularly in low-income countries, a low infrastructure quality has a significant negative impact on total factor productivity, which is at least as important as other factors such as crime, red tape and access to finance (see *Figure 3*). They also find that poor-quality electricity supply is the infrastructure element that has the strongest negative effect on enterprise productivity, especially in poor African countries such as Eritrea, Ethiopia, Mali, Senegal, Uganda and Zambia.

Impact on Employment

Overall, the literature shows that there is some micro-level evidence on positive labour market effects of electricity use. However, results differ across time, across countries and in some studies across different segments of the labour force. Goedhuys and Sleuwaegen (2010) studied the growth performance of a large set of firms in ten manufacturing sectors of eleven Sub-Saharan African countries and found that grid connection in combination with a generator causes mean employment growth of about 2 %. In a study on the effects

Figure 3: Contribution of Infrastructure to Total Factor Productivity of Firms



Source: Escibano, Guasch and Pena, 2008.

of South Africa's post-apartheid rural electrification programme, Dinkelman (2008) found an increase in female employment by 13.5 % but no significant positive impact on male employment. Grogan (2008) found that the positive effect of electrification on women's labour force participation as well as men's and women's probability of being engaged in more skilled labour in Guatemala take time to unfold. Female labour force participation rates were found to be about two thirds higher (0.34 versus 0.52) in communities which have been electrified for at least ten years.

The evidence on employment effects of electrification cited above is summarised in *Table 6*.

Impact on Enterprise Income

Studies on the effects of income through electricity use must generally be divided into two broad categories: those that examine firm income or profits and those that examine the effects of electricity on different sources of household income (see following section), e.g. agriculture or home-businesses.

Table 6: Effects of Electricity Access on Employment

Source	Country/Region	Data Source/Sample Size	Conclusion
Dinkelman (2008)	South Africa	Census and other data on electrified and non-electrified areas in KwaZulu-Natal province	Increase in female employment through electrification but no significant positive impact on male employment.
ESMAP (2005)	Tanzania	Enterprise survey with 320 connected and non-connected SMEs	Small enterprises shift from using family members to recruiting non-family full-time employees after electrification but no net increase in employment after electrification was found.
Goedhuys and Sleuwaegen (2010)	11 African countries	Firm-level data from the World Bank Investment Climate Survey	Electricity connection in combination with generator causes employment growth
Grogan and Sadanand (2009)	Guatemala	LSMS individual and community-level data	Adoption of labour saving household technologies (e.g. electric cookers, electric lights, propane gas) leads to significant reduction of time spent on household activities and of the fertility rate as well as to a significant increase of time spent on economic activities.
Grogan (2008)	Guatemala	LSMS individual and household level data, plus community-level survey of 485 communities	Positive effect of electrification on women's labour force participation & men's and women's probability of being engaged in more skilled labour after at least ten years was found.
Kooijman-van Dijk (2008, 2012)	India	Qualitative survey of 264 small businesses	Overall positive effect of electricity access on employment, despite some cases in which manual labour is substituted with the use of electrical appliances. Enterprises that extended their working hours after electrification hardly ever recruit more staff and tend to use family members during evening hours who are not paid.

To date the existing evidence on the impacts of electricity on firm income is too sparse to allow for substantial conclusions.

In their analysis of data from different types of informal businesses in six West African countries and a more recent survey of informal tailors in Ouagadougou, Grimm et al. (2011) find no systematic and uniform influence of electricity access on firm profits. However, they found that tailors with access to electricity in Burkina Faso have 51 % higher revenues than tailors without electricity and attribute this to the use of electric sewing machines and longer working hours.

In a detailed qualitative survey of 264 small businesses in three Indian states, Kooijman-van Dijk (2008, 2012) differentiates between different uses of electricity by small enterprises: a) for products and services and b) for lighting, comfort, entertainment and communication. She found a positive correlation between income and electricity use for products and services but no positive effect of electricity use for lighting, comfort, entertainment and communication on incomes. However, she argues that the direction of causality between the use for products and services and incomes is not clear and found that the enterprises in her sample were far from exploiting the full potential of productivity gains associated with the use of appliances powered by electricity due to market constraints. Overall, she sees the main benefit from electricity use in reduced efforts and increased comfort of operation. In her view the effects on income generation in rural areas therefore do not justify the extension of modern energy infrastructure solely on financial grounds.

The cited enterprise-level evidence on income effects through electricity use is summarised together with the empirical studies on household-level income effects in *Table 7* in the following section.

Impact on Household Income

Other studies, however, found no positive effects on farm income. A study conducted in Bhutan (ADB 2010) also found positive effects of electrification on non-farm income but not on farm income. Non-farm incomes of electrified households were found to be 50-72 % higher than those of unelectrified households, but these accounted for only 21-29 % of household income. The aforementioned study conducted in the Philippines did also not find any impact of access to electricity on agricultural output or income (ESMAP 2002). According to the authors, this can be explained by the fact that the study area was experiencing a severe drought during the survey and that only one of the four surveyed provinces had irrigation infrastructure. On average, however, the study found incomes to be significantly higher for home businesses using electricity than those who do not use electricity. Nevertheless, it should be mentioned again that this study does not control for other factors that could have influenced the distribution of incomes (in fact, the same is true for a study by Fan et al. (2005) looking at household income and poverty effects in Tanzania).

A similar study in Bangladesh, based on cross-sectional household survey data from 2005, also found that the incomes of households in electrified areas are 12.2 % higher than those of comparable households in non-electrified areas (Khandker 2009b). The authors found positive effects on both farm and non-farm incomes, but do not explore the actual causes of these effects. Another finding of the studies from Vietnam and Bangladesh is that the positive impact increases with the duration of electricity access during the first 8 to 9 years, after which it levels off.

A study conducted in Bhutan (ADB 2010) also found positive effects of electrification on non-farm income but not on farm income. Non-farm incomes of electrified households were found to be 50-72 % higher than those of unelectrified households, but these accounted for only 21-29 % of household income. This stands in contrast to the findings of the aforementioned study conducted in the Philippines, which did not find any impact of access to electricity on agricultural output or income (ESMAP 2002). On average, however, the study found incomes to be significantly higher for home businesses using electricity than those who do not use electricity. Nevertheless, it should be mentioned again that this study does not control for other factors that could have influenced the distribution of incomes (in fact, the same is true for a study by Fan et al. (2005) looking at household income and poverty effects in Tanzania).

A number of studies also report a negative impact of electrification on equality. The study carried out in Bangladesh, for example, found that the positive effect on incomes is four times higher for wealthier households than for poorer households. A study conducted by ADB (2005) also found a negative correlation between electrification and equality in Thailand and India.

Table 7 provides an overview of the studies on income effects of electricity use at firm and household level.

Impacts on Poverty Reduction

The literature on the effects of electricity access on poverty reduction is still scarce. One exception is the aforementioned study by Koijiman-van Dijk (2008, 2011) that analyses enterprise data to draw conclusions on poverty effects of electricity use. She found that the financial starting position of the entrepreneur is a key determinant of the impact of electricity access on incomes. Positive impacts were significant for higher income groups but no positive impact on the incomes of the poorest was found.

Other empirical research examines the poverty impacts of electricity access on households, yet often the specific channels through which poverty reduction may take place are not analysed. This means that it is hard to establish whether poverty reduction occurs through the 'productive' process chain as described in subchapter 2 or rather through other channels such as reduced expenditures for energy appliances. One example is the above-mentioned study conducted by the Asian Development Bank (ADB 2005). The ADB case studies conducted in India and Thailand found a positive impact of electricity access on ownership of physical assets, especially electric appliances, by poor households but not on incomes. The authors found a negative relationship between electricity access and poverty only in some districts. The China case study found faster income growth among the electrified than the non-electrified poor in the province of Shaanxi but no positive effect of electricity access on poverty levels.

Table 7: Effects of Electricity Use on Income at Firm and Household Level

Source	Country/Region	Data Source/Sample Size	Conclusion
ADB (2005)	India, Thailand	India: survey of approx. 2,600 rural households, Thailand: survey of approx. 1,100 rural and urban households	Equity: Thailand: the degree of electricity access is negatively correlated with the incomes of poor households. India: income inequality in electrified villages is higher than in unelectrified villages.
ADB (2010)	Bhutan	1,276 electrified and 822 unelectrified households	Access to electricity has a significant effect on nonfarm income.
ESMAP (2002)	Philippines	Survey of approx. 28,000 domestic, commercial, industrial and irrigation units with and without electricity	Average incomes of home businesses using electricity are significantly higher than those who do not use electricity but no positive impact of electrification on incomes from agriculture was found.
ESMAP (2005)	Tanzania	Enterprise survey of 320 connected and non-connected SMEs; focus groups	90 % of connected SMEs stated that their business income increased since electrification and 85 % of them stated that this can be attributed to the use of electricity. 80 % of focus group discussants stated that the volume of their business and the number of clients had grown.
Fan et al. (2005)	Tanzania	Household Budget Survey (HBS) of approx. 22,000 households; Multistage; stratified sample	Access to electricity significantly increases household income in all zones.
Grimm et al. (2011)	6 African countries	Survey of 5,409 informal enterprises and 248 informal tailors	No systematic and uniform influence of electricity access on enterprise performance across different types of businesses found, but significant influence on tailors.
Grogan (2008)	Guatemala	LSMS individual and household level data, plus community-level survey of 485 communities	Positive effects of electrification on women's incomes increase over time. Women in communities which have been electrified more than 10 years ago earn about 4 times more than women in more recently electrified communities. However, there is no such effect on men's incomes.
Khandker (2009a)	Vietnam	Panel survey data (2002 and 2005) from 1,100 rural households	Grid electrification increased household incomes by at least 25 %; strong increase in farm income but hardly any effect on non-farm income.
Khandker (2009b)	Bangladesh	Cross-sectional survey of approx. 20,000 rural households	Incomes of households in electrified areas are 12.2 % higher than those of comparable households in non-electrified areas, positive effects on both farm and non-farm incomes. Equity: positive effect on incomes is four times higher for wealthier households than for poorer households.
Kooijman-van Dijk (2008, 2012)	India	Qualitative survey of 264 small businesses	Positive correlation between electricity use for products and services and incomes, but causality is not clear.
UNDP (2011)	Nepal	Household survey conducted in communities with and without access to electricity from micro-hydropower schemes	Significantly higher incomes in villages served by micro-hydropower schemes was found; electricity access explains about 30 % of the increase.

A study on the impact of electrification in Ethiopia (Bernard et al. 2009) took differences in household expenditure as a proxy for poverty levels and found no significant positive effect. This stands in contrast to the aforementioned study on the impact of different forms of public investments in Tanzania (Fan et al. 2005), which did find a positive impact of electrification on poverty reduction and it concludes that a 1% increase in the electrification rate would lift approx. 140,000 people out of poverty.

Table 8: Effects of Electricity Use on Poverty

Source	Country/Region	Data source/Sample Size	Conclusion
ADB (2005)	China, India, Thailand	China: panel survey data of 1,143 households, field survey of 624 households India: survey of approx. 2,600 rural households; Thailand: survey of approx. 1,100 rural and urban households	China: faster income growth among the electrified than the non-electrified poor in the province of Shaanxi, no positive effect of electricity on poverty levels was found. India and Thailand: positive impact of electricity access on ownership of electric appliances by poor households but not on incomes was found.
Bernard et al. (2009)	Ethiopia	Survey of 800 households	No significant effect of electrification on changes in household expenditure
Fan et al. (2005)	Tanzania	Household Budget Survey (HBS) of approx. 22,000 households; multi-stage, stratified sample	1% increase in the electrification rate would lift approx. 140,000 people out of poverty.
Koijiman-van Dijk (2011)	India	Qualitative survey of 264 small businesses	Low uptake of electricity for production of goods and services among low-income entrepreneurs was found. Substantial share of enterprises with low income despite productive use of electricity were identified, but direction of causality not clear.

Micro-Level Evidence – Other Issues

Nexus between *improved lighting* and enterprise performance

For many small enterprises especially in rural areas the first and main use of electricity is lighting. Enterprises switching from traditional forms of lighting such as candles and kerosene lamps to electric light obtain a better lighting service - as measured in lumen hours consumed - at a lower price per unit (ESMAP 2002). In addition, electric lighting is more convenient and less risky in terms of negative health effects from indoor air pollution and fire accidents than conventional alternatives.[16] Certain businesses such as electric repair shops require high-quality light even during daytime, while others use electric light only to extend business hours during times of peak demand or to improve the appearance of their shop (Kooijman-van Dijk 2008).

Numerous studies state that access to electric light by small businesses leads to longer operating hours which in turn leads to increased income by these businesses. For example, informal tailors with access to electricity in Burkina Faso were found to work around 17% or four labour hours more per day than their counterparts without access (Grimm et al. 2001). Similarly, service sector MSMEs using solar home systems (SHS) in rural Uganda work for approx. 1 hour longer, attract more customers and their monthly profits are approx. 8 US $ higher than a comparable group of matched businesses in a control region (GTZ 2009).

While the link between access to electric light, longer operating hours and increased income is often taken for granted, an overall positive impact cannot always be proven. For many small businesses in rural areas, it does not make sense to operate at night, if there is no specific demand for their products/services during evening hours and the market cannot absorb an increased output. Accordingly, the Uganda study therefore concludes that whether it pays off for an enterprise to invest in a SHS or not is a question of the economic sector in which the firm operates. The study found that overall, rural manufacturing enterprises – which usually cannot realise higher sales or profits by extending operating hours beyond day-time, are less likely to invest in electric lighting

16) See Cabraal et al. (2005) for a summary of the benefits of improved lighting.

as compared to service providers such as retail shops (GTZ 2009). This is because there is a demand for their services at night when customers are home from work and better light enables them to attract more customers. However, this may come at the expense of their competitors using traditional lighting, so at village/regional level the net effect of electricity use by entrepreneurs on overall income levels may amount to zero.

Bundling access to electricity with *complementary services*

Some authors argue that a targeted 'bundling' of electricity access and other services such as BDS and micro-credits could improve the impact of electrification programmes (Motta and Reiche 2001, Peters et al. 2009).

Escobal (2005) analyses the impact of rural infrastructure investment on market development for the enhancement of income generation opportunities for the poor in rural Peru. Based on regional time series data and data from national household surveys he finds that the benefits of particular investments in rural infrastructure (roads, electricity, telecommunication, water or sanitation services) in terms of growth in rural incomes are significantly higher if they take place in combination with other infrastructure investments. Similarly, Barnes et al. (2002) found that the positive impact of access to electricity and education on nonfarm income can be amplified by 2.3 times if both services are delivered together. In their analysis of informal tailors in Burkina Faso, Grimm et al. (2011) found that access to electricity only exerts a significant positive impact on firm performance if these are not credit constrained.

6. Summary and Conclusion of the Literature Review

This chapter has reviewed the relevant empirical literature on the contribution of electricity to economic growth and development on the macro and micro-level. At both levels, the multitude of (often grey) literature is of very limited methodological quality. Drawing clear-cut conclusions is complicated further by the fact that the various studies look at different indicators, units of analysis and time frames and results vary from country to country.

(a) Macro-Level

At the macro-level, empirical research shows a modestly positive impact of electricity on productivity which seems to vary across countries. The literature on poverty reduction reports a relatively small impact of electricity compared to other infrastructure investments (most importantly roads). The empirical research on electricity and growth presents an ambiguous picture. The energy economics literature analysing the energy-growth nexus is generally inconclusive: there seems to be no consensus on the existence or the direction of causality between energy (or electricity) consumption and economic growth. The studies on infrastructure and growth report a mostly positive effect of electricity on economic growth.

(b) Micro-Level

The micro-level-literature on productive use impacts of electrification programmes is generally inconclusive. According to the research done so far, access to and use of electricity by MSMEs does not *automatically* lead to intended development results such as increased productivity, profits and income, and knowledge on the conditions under which this is the case are still sketchy.

There is some evidence that electricity access can lead to the creation of informal (sometimes home-based) and formal enterprises. However, more research applying rigorous methods to avoid/control for any selection bias would be needed to confirm this finding. A growing body of literature shows positive impacts of both electricity use and electricity quality on firm productivity. Nevertheless, the magnitude of such impacts is highly country and context-specific. Concerning the impact of electricity on business income it is hardly possible to draw any conclusions at this point, as the available literature is very thin. There are significantly more studies measuring effects on household income. In this case there seems to be an overall positive impact yet results vary, e.g. regarding gender differences or differences between farm and non-farm income. The micro-level evidence on employment effects, too, is not quite clear. While some studies report a signifi-

cant total increase in employment, others find that increased labour market participation is restricted to women or family members who are not paid. Regarding poverty reduction effects, the micro-level evidence does not yet provide a sound basis for the assumption that investing in electricity is an effective approach to lift people out of poverty. Overall, it seems that the full potential of the economic impact of electricity can only be exploited if certain necessary preconditions are fulfilled, such as a certain endowment with capital e.g. for investment in electric appliances and access to markets and transport infrastructure.

(c) What Are the Explanations for the Variation of Results?

For one, the immense variation across results of different studies is not surprising given the very distinct country contexts and stages of development from which the evidence originates (Estache and Fay 2009). Moreover, the different indicators that are employed to measure electricity input into the economic system as well as the different economic outcome indicators are an obvious source of differences in the emerging conclusions.

There are, however, also several empirical and methodological issues that underlie the variations in results: firstly, quality of electricity supply (and other infrastructure) is highly heterogeneous but rarely measured or described (World Bank 2010). Secondly, the quality and nature of the data analysed also differs enormously across studies. Most importantly, many studies do not control for endogeneity of the measured outcomes. Endogeneity can in turn have different origins, for instance, measurement error problems, potentially unobserved effects or omitted variables or reverse causality. The latter occurs, for example, when public capital (like electricity infrastructure) may affect productivity and output, and at the same time, economic growth can increase the demand and supply of energy services.

To allow for sound conclusions, these methodological issues need to be addressed through more sophisticated econometric techniques. Studies should not focus on detecting correlations between electricity input and development measures but test the direction, magnitude and significance of the causality. Other relevant methodological approaches are estimations of panel models or simultaneous equation models or the use of instrumental variables.

(d) Conclusion

Perhaps most importantly, most of the studies addressing the question of whether or how much electricity (or more generally infrastructure) matters for economic development, are often not relevant from a policy perspective (Ayogu 2007, Straub 2008a, Estache and Fay 2009). The relevant question for policy makers would be whether an optimal level of electricity provision can be identified in a specific context which could then serve to derive the corresponding investment and funding priorities.

Especially macro-level data is limited in this regard. Data at that level of aggregation cannot provide guidance on detailed investment decisions for particular projects (Straub 2008b). Micro-level data will allow for a better understanding on how exactly other factors and complementary services such as BDS and access to financial services influence the economic impact of electricity. This is of particular concern for policy makers who need to understand how their policies on infrastructure interact and depend on policies relating to other sectors of the economy.

It can be concluded that rather than investing more money in macro-level research on the impact of electricity infrastructure on economic development, further micro-level research is needed to investigate the indirect channels through which electricity enhances productive uses and improves livelihoods. In the energy sector, such micro-level research should comprise among others the role of complementary services such as BDS, financial and ICT services as well as other factors that create an enabling environment for the use of electricity for socio-economic development. Future micro-level research should also be extended to analyse impacts at levels beyond firm and household level (e.g. community, district, national, regional and international levels), since the impact on one level could have intended or unintended effects on another level. In addition, it should further explore potential negative impacts on employment opportunities and inequalities. All this can only be done with rigorous qualitative and quantitative micro-level research methods, as highlighted above.

The PRODUSE study 'Measuring Impacts of Electrification on Small Businesses in Sub-Saharan Africa' attempts to contribute to a better understanding of some of these issues.

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