Correlation and causation between energy development and economic growth

Economic Consulting Associates

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Report Summary

This study summarises current economic literature that attempts to analyse the relationship between electricity access/availability and economic growth. According to the extensive literature review that was conducted for this purpose, there is a strong causal relationship between the two variables, but there is no consensus regarding the direction of the causality. There is also inconclusive evidence on the impact of higher availability of modern energy services on poverty reduction and income equality.

The study also explores how energy policies have contributed to the development of the energy and economic growth. Deregulation, energy conservation and clean energy policies such as energy efficiency and renewable energy were found to have a positive macroeconomic impact, while according to the literature, energy subsidies are likely to cause fiscal imbalances and discourage investment in the energy sector.

SECTION 1

Introduction and purpose of this report

This paper presents the evidence from a rapid desk based study of the literature on the impact of higher energy access and consumption at a macro-economic level on economic growth and poverty reduction, as well as providing insights regarding the role of energy policies in enhancing the impact of energy on economic growth. The focus is on electricity, but the impact of other forms of commercial energy is also considered. The objective of the paper is to provide the Department for International Development (DFID) and potentially other agencies with an appreciation of the contribution of the energy sector on the process of economic growth and development, based on which policy implications regarding future energy policies could be derived.

The first part of this report (Section 2) provides an overview of the current situation regarding access to modern sources of energy and the quality of the energy services. The second part (Section 3) discusses the possible channels through which energy can affect development and prosperity and provides a thorough comparison of empirical evidence supporting the various hypotheses on the causal relationship between energy and growth. The third part (Section 4) discusses the availability of studies on the impact at a macro-economic level of the relationship between energy, GDP and poverty/equality, while Section 5 provides evidence for the impact of energy policies on the relationship between energy and GDP. The final part (Section 6) provides conclusions on policy implications and next steps.

There are also two appendices. The first (Appendix A) provides an overview of the literature discussing how the author has assessed the quality of the evidence presented by the studies. The second (Appendix B) contains a list of literature and other references consulted.

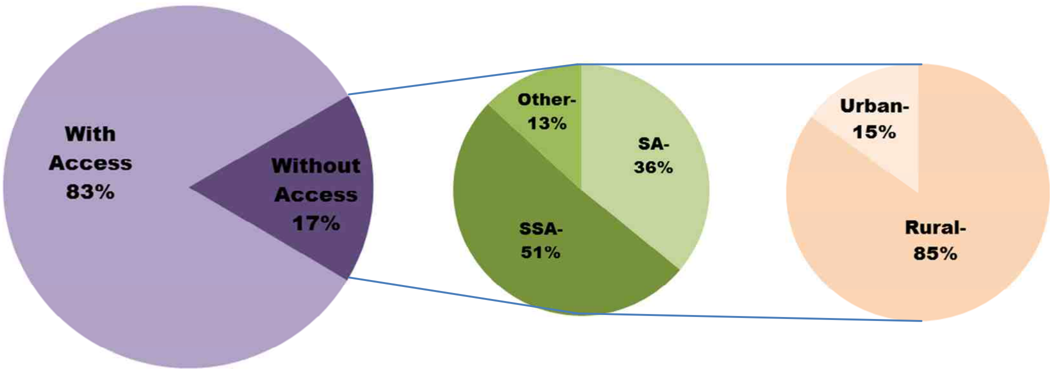
SECTION 2

Electricity access- the current picture

Despite all the efforts made at an international level to increase electricity access, there are currently around 1.2 billion people (or 17% of the global population) who have no access to electricity. As Figure 1 shows around 85% of them live in rural areas, mostly in Sub-Saharan Africa (SSA) and Southern Asia (SA) (World Bank 2013).

Those lacking access to modern energy services rely on kerosene, candles, and batteries to satisfy their energy needs. The groups of people who are mostly affected by the lack of energy access are women and school- aged children, who may be required to spend many hours carrying fuel and water (IIASA 2012).

Figure 1 Electricity access around the world



The is a great disparity in the regional electrification rate varying from 25% in Oceania to 32% in Sub-Saharan Africa to nearly 100% in developed countries. As

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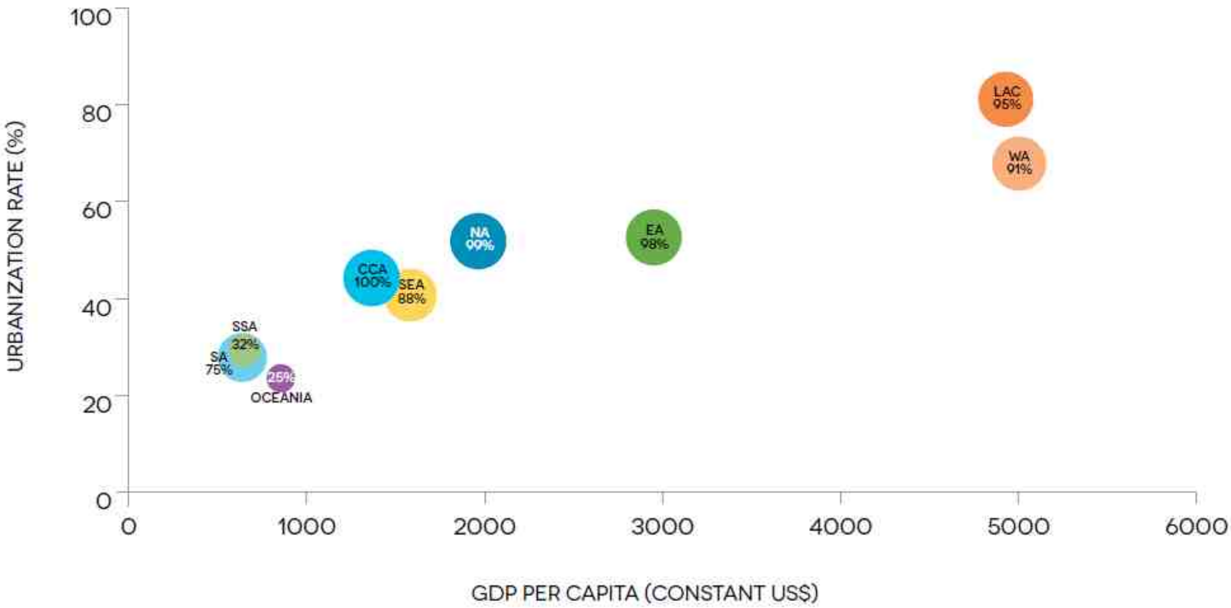
Figure 2 shows, higher rates of urbanisation and GDP exhibit higher electrification rates, with the exception of Western Asia and Latin America which report higher incomes and urbanisation rates, yet lower electrification rates, than Eastern Asia and Northern Africa.

Figure 2 Regional electrification by GDP and urbanisation



Source: World Bank 2012

According to the Energy Development Index (EDI) developed by the International Energy Agency (IEA), all sub-Saharan African countries, with the exception of South Africa, feature in the bottom half of the EDI ranking. The EDI was developed to track the progress in country's or region's transition to the use of modern energy and to better understand the role that energy plays in human development.

Reliability of grid services

Even among the 83% of the global population that is seemingly connected to the grid there are a large number of people who experience intermittent and unreliable electricity, which severely constrains the productive use of electricity. One third of the 125 developing countries that reported on power outages in the World Bank Enterprise Surveys reported experiencing at least 20 hours of outages per month.

As a result of the shortage of electricity supply in India, which in 2012 was approximately 8% of energy demand, self-supply of power, through expensive and highly polluting diesel generators, represents around 17% of total installed capacity (Banerjee et al. 2012). In Sub-Saharan Africa, around 30 countries experience erratic electricity delivery with associated economic losses estimated at around 5% of the GDP (Foster et al 2010).

SECTION 3

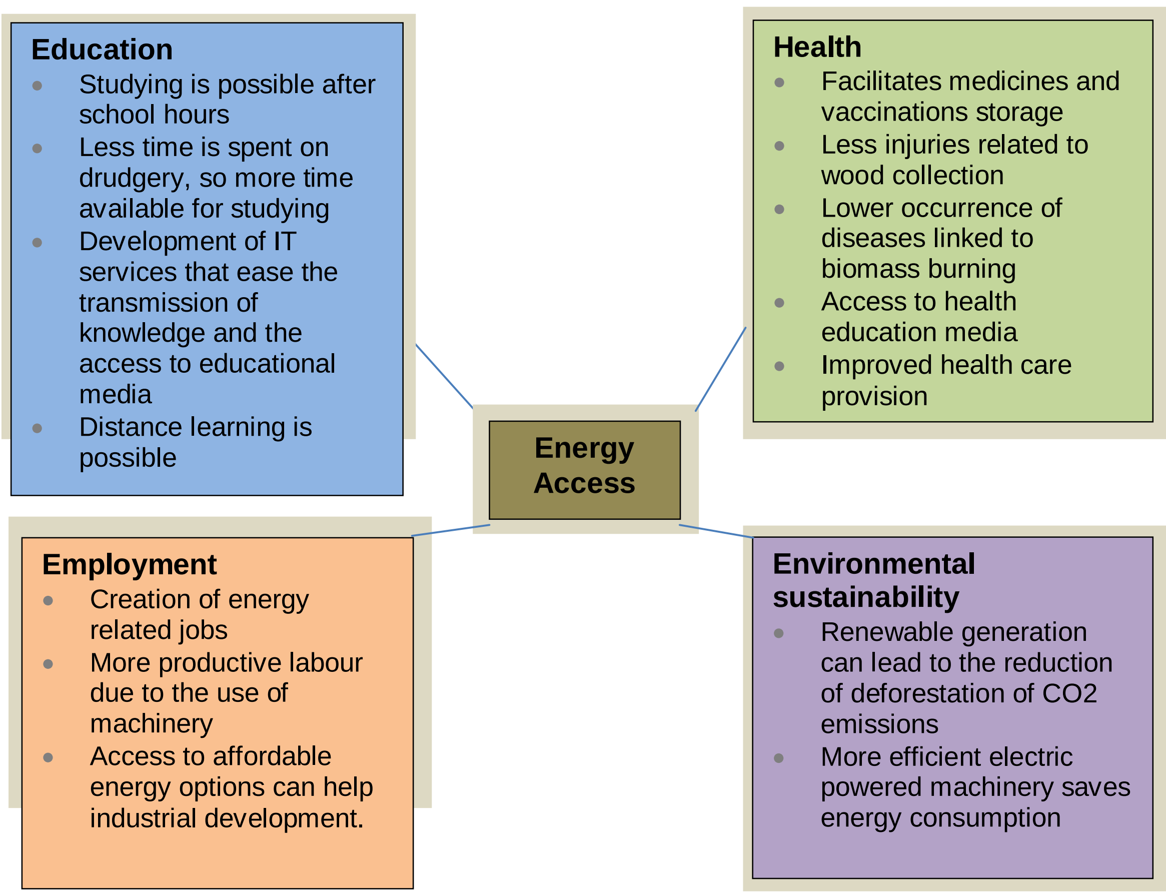
Energy and economic growth

How energy influences economic growth and development

Access to modern forms of energy, even though it is not by itself a panacea to economic development, is believed to be a pre- requisite for alleviating poverty, increasing employment and, in general, promoting better living standards (IIASA 2012).

While there is no Millennium Development Goal (MDG) on energy, the access to modern and reliable energy services is an essential input to achieving most of the MDGs, including poverty alleviation, productivity, health, education, communication services and gender equality governance (UNIDO 2011; Modi 2006). According to DFID (2002), increased energy access directly contributes to freeing up women's time that was previously wasted in gathering fuelwood and cooking with inefficient stoves and alleviates adverse health impacts related to burning of wood and dung. The extra time created as a result of higher energy availability provides the opportunity for women to get involved with income generating activities and ultimately leads to higher gender equality (Kanagawa 2005). Figure 3 , below, illustrates the relationship between energy access and the MDGs.

Figure 3 The impact of energy on development goals



A number of developing countries acknowledging the importance of energy access have set targets for enhancing access to modern forms of energy and cleaner fuels. As shown in Table 1, almost half of the 140 developing countries, according to UNDP and WHO (2009) have established targets for access to electricity; 35 of these were in sub- Saharan Africa. This represents an increase in the number of countries with electricity access targets by 57% relative to 2005 data (UNDP 2007).

Energy source	Number of developing countries with energy access target	Number of SSA countries with an energy access target
Electricity	68	35
Modern fuels	17	13
Improved cookstoves	11	7
Mechanical power	5	5

Table 1 Developing countries with targets for energy access

Energy- growth nexus

As discussed above, energy plays a crucial role in the process of development and economic growth. Therefore, it is important to understand the nature and direction of the causality between energy consumption and economic growth, through empirical evidence, in order to design successful interventions and effective energy and environmental policies.

Over the past few decades, the energy - economic growth nexus has been analysed extensively by energy economists. However, the empirical evidence offers conflicting explanations for the relationship between the two variables.

The findings of the studies show that there is a strong relationship between modern energy (i.e electricity) and economic growth. However, the nature of a causal dependence between the two focus variables has been a point of disagreement in the literature. The mixed and controversial evidence from empirical research regarding the direction of the causality and the strength of the impact of higher energy access on economic growth could be the result of the different methodological approaches, time periods and country groups examined, as well as the choice of variables (Ouedraogo 2013).

The empirical literature has emphasised four possible relationships between energy consumption and economic growth (Yildirim 2012):

- ***Growth hypothesis***; assumes uni-directional causality from energy to economic growth, emphasising the crucial role that energy access and consumption play on GDP growth. This relationship denotes an energy dependent economy and as such no access or limited access to modern energy supply can limit economic growth and may result in poor economic performance (Tsani 2010). Under this scenario, national and regional development programmes should invest in innovative approaches aimed at improving access to affordable and modern energy for all populations and productive sectors (Squalli 2007).

- ***Conservation hypothesis***; signifies that economic growth is the dynamic which causes the development of energy sector and indicates an economy which is less energy dependent. The hypothesis is empirically verified if there is uni- directional causality from economic growth to energy consumption. Under this hypothesis, energy conservation policies, such as investments in energy efficiency and demand management policies will have no adverse impact on GDP growth (Ouedraogo 2013).

- ***Feedback hypothesis***; implies a mutual and complementary relationship between energy and economic growth and is empirically supported if there is a bi-directional causality between energy and GDP growth.

- ***Neutrality hypothesis***; indicates that the energy sector has no impact on economic growth. The absence of causality between energy consumption and economic growth provides evidence for the validity of the neutrality hypothesis. In this scenario, policies to promote energy access and higher levels of consumption will not have an influence on economic growth (Ouedraogo 2013).

An important study on the impact of energy consumption on economic growth was conducted by Adhikari and Chen (2012). The study examined the long-run relationship between the two variables for 80 developing countries, divided into three income groups, from 1990 to 2009. Panel unit root test, panel co-integration test and panel dynamic ordinary least squares (DOLS) were applied. The use of panel data sets enhances the degrees of freedom and minimises the co-linearity among the independent variables, which improves the efficiency of econometric estimations. The Dynamic Ordinary Least Squares (DOLS) method used to estimate the long-run relationship between the variables reduces the OLS bias of endogeneity and serial correlation. Also, the large dataset used in the study and the long time period increase the power of the co-integration tests and provide more robust estimates. The empirical estimates showed that there is a strong long run co-integrated relationship between the two variables running from energy consumption to economic growth for upper middle income countries and lower middle income countries, and a strong co-integrated relationship of the opposite direction for low income countries.

More specifically, the study found that in upper middle income countries increasing energy consumption by 1% increases GDP by 0.82%, while for lower middle income countries, a 1% increase in energy consumption increases GDP by 0.81%. For lower income countries, a 1% increase in GDP increases energy consumption by 0.73%. All the results were statistically significant. The implications of this study are that upper middle and low middle income countries are more energy dependent than low income countries.

Another important study was conducted recently by Campo and Sarmiento (2013), examining the long run relationship between energy consumption and economic growth in the context of 10 Latin American countries from 1971 to 2007. Pedroni's panel co-integration test was employed to determine the long- run relationship between the two variables, which offer advantages over time series data, by providing a greater number of degrees of freedom, improving statistical efficiency and overcoming the problem of bias that is caused by unobserved heterogeneity in the regression. According to the findings, a 1% increase in total energy consumption increases real GDP in the region by 0.59%, while, at the same time, a 1% increase in GDP causes an increase in total energy consumption by 0.59%. This result supports the feedback hypothesis[1]and provides empirical support for policies that promote energy conservation and efficiency.

Table 2 summarises other pertinent empirical studies that have examined the energy consumption – income growth nexus and shows that the empirical results have not resulted in a consensus among economists. Although there is no conclusive evidence on the

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[1] When long-run relationships are estimated using co-integration tests the magnitude of the co-efficients represents the direction of the causality

direction of causality, most studies reveal that there exists a strong relationship between the access to modern forms of energy and economic growth.

For OECD countries, all four hypotheses have been evidenced in the literature. For instance, Soytas and Sari (2003) found that in Turkey, France, Germany and Japan there is uni-directional causality from energy to economic growth. Lee (2006) found, on the other hand, that the causality runs from GDP growth to energy (conservation hypothesis). Evidence of the feedback hypothesis was found in Bartleet and Gounder (2010), using the error correction model with data from New Zealand. Menegaki (2011) found no evidence of causality between the two variables in a pan European study using one-way random effect model and panel causality tests.

A similar picture appears in the literature review of the energy- growth nexus in the emerging markets. More specifically, Siddiqui (2004), Pradhan (2010) and Masih (1998) found evidence of causality from energy to income for Pakistan and Sri Lanka, while a causal relationship of the opposite direction was concluded by the studies of Chiou-Wei (2008) in Philippines and Singapore and Ghosh (2002) in India. A large study conducted by Ozturk (2010) on 51 countries reported that in lower and upper middle income countries there exists a bi- directional causality. Yalta and Cakar (2012) reported neutrality between the focus variables in the case of China.

Okonkwo and Gbadebo (2009) and Adeniran (2009) concluded that in Nigeria there is causal relationship flowing from energy to GDP growth. The Growth hypothesis was also reported by Sarkar (2010) in a study based on Bangladesh. Odhiambo (2010) and Esso (2010) concluded that higher economic growth influences energy consumption and availability in Congo. Kahsaia et al. (2012) and Ebohon (1996) all established a bi-directional causality between energy and income growth, using data from Sub-Saharan African countries. Akinlo (2008) and Wolde-Rufael (2005) found no evidence of a co-integration between energy and GDP growth in a number of African countries.

Given the wide range of estimates in the literature on the energy consumption- GDP growth nexus, no general conclusions can be made regarding the differences in results between developed and developing countries and between resource endowed and non- resource endowed countries.

Electricity has become the dominant form of modern energy supply and it has been a major factor in the improvement of the standard of living and has made a significant contribution in technological and scientific progress (Gurgul et al. 2011). Thus, electricity consumption is considered to be especially important for economic growth and as such many researchers have used electricity consumption as an indicator of access to modern energy sources (IIASA 2012, UNIDO 2007 and Ouedraogo 2012). For instance Halicioglu (2007) and Ghosh (2002) found evidence for a causal relationship running from GDP to electricity consumption in Turkey and India, respectively.

Study	Methodology	Period	Country	Effect on energy on economic growth
OECD countries				
Electricity- growth nexus				
Shahbaz et al. (2011)	Granger causality	1971–2009	Portugal	EL ↔ GDP
Halicioglu (2007)	Granger causality	1968–	Turkey	EL ←

Study	Methodology	Period	Country	Effect on energy on economic growth
		2005		GDP
Energy- growth nexus				
Yu and Choi (1985)	Granger causality	1950–1976	UK, USA, Poland	E ≠ GDP
Erol and Yu (1987)	Granger causality	1952–1982	Japan	E ↔ GDP
			Italy, Germany	E ← GDP
			Canada	E → GDP
			France, UK	E ≠ GDP
Stern (1993)	Co-integration, Granger causality	1948–1994	US	E → GDP
Soytas and Sari (2003)	Error-correction model	1950–1992	Italy Turkey, France, Germany and Japan	E ← GDP E → GDP
			United States, United Kingdom and Canada	E ≠ GDP
Fatai et al. (2004),	Granger causality, Toda and Yamamoto test	1960–1999	New Zealand	E ≠ GDP
Hatemi-J and Irandoust (2005)	Leveraged bootstrap simulation	1965–2000	Sweden	E ← GDP
Lee (2006)	Toda and Yamamoto	1960–2001	Japan	E ← GDP
Lise and Van Montfort (2007)	Co-integration test	1970–2003	Turkey	E ← GDP
Huang et al. (2008)	Generalized method of moment system	1972–2002	High- income countries (World Bank categorisation)	E ≠ GDP
Payne (2009)	Toda–Yamamoto causality	1959–2006	US	E ≠ GDP
Bartleet and Gounder (2010)	Error-correction model	1960–2004	New Zealand	E ↔ GDP
Belke et al. (2011)	Panel Granger causality	1981–2007	25 OECD countries	E ↔ GDP
Menegaki (2011)	One-way random effect model, panel causality tests	1997–2007	27 European countries	E ≠ GDP
Fuinhas and Marques (2012)	ARDL bounds test	1965–2009	Portugal, Italy, Greece, Spain and Turkey	E ↔ GDP
Emerging economies				
Electricity- growth nexus				

Study	Methodology	Period	Country	Effect on energy on economic growth
Acaravci and Ozturk (2010)	Pedroni panel cointegration	1990–2006	Albania, Belarus, Bulgaria, Czech Republic, Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Russian Federation, Serbia, Slovak Republic and Ukraine	EL ≠ GDP
Ghosh (2002)	Granger causality	1950–1997	India	E ← GDP
Shiu and Lam (2004)	Johansen cointegration	1971-2000	China	EL → GDP
Chen et al (2007)	Error correction model	1971–2001	Hong Kong, India, Indonesia, Korea, Malaysia, the Philippines, Singapore,	EL ↔ GDP
Energy- growth nexus				
Siddiqui (2004)	Granger causality and ARDL	1971–2003	Pakistan	E → GDP
Soytas and Sari (2003)	Error-correction model	1950–1992	Argentina South Korea Turkey	E ↔ GDP E ← GDP E → GDP
Pradhan (2010)	Cointegration and ECM	1970-2006	Pakistan, Sri Lanka	E → GDP
			India, Nepal	E ← GDP
			Bangladesh	E ↔ GDP
Khan and Qayyum, (2007)	Bound testing and ARDL	1972-2005	Bangladesh, India, Pakistan and Sri Lanka	E → GDP
Chiou-Wei et. al., (2008)	Granger causality tests	1954-2006	Philippines and Singapore	E ← GDP
			Taiwan and Hong Kong	E → GDP
Mehrara (2007)	Error correction model and Toda-Yamamoto	1971-2002	Saudi Arabia	E → GDP
			Iran and Kuweit	E ← GDP
Yu and Choi (1985)	Granger causality	1950–1976	Philippines	E → GDP
			Korea	E ←GDP
Masih (1998)	Johansen–Juselius	1955–1990	India	E → GDP
		1955–1990	Pakistan	E → GDP
		1960–1990	Indonesia	E ← GDP
		1955–1990	Malaysia	E ≠ GDP
		1960–1990	Singapore	E ≠ GDP
		1955–	Philippines	E ≠ GDP

Study	Methodology	Period	Country	Effect on energy on economic growth
		1991		
Cheng (1999)	Granger causality	1952–1995	India	E ← GDP
Lee and Chang (2008)	Panel error-correction model	1971–2002	16 Asian countries	E → GDP
Gurgul and Lach (2012)	Linear and non -Linear Granger vcausality	2000-2009	Poland	EL ↔ GDP
Fang (2011)	OLS	1978–2008	China	E → GDP
Tiwari (2011)	Structural VAR	1960–2009	India	E → GDP
Yalta and Cakar (2012)	Maximum entropy bootstrap	1971–2007	China	E ≠ GDP
Ozturk et al. (2010)	Panel Granger causality	1971–2005	Lower and Upper middle income countries	E ↔ GDP
Apergis and Payne (2009)	Pedroni Panel cointegration, error correction model	1980–2004	6 Central American countries	E → GDP
Developing countries				
Electricity- growth nexus				
Sarkar et. al., (2010)	VAR model, Granger causality test and cointegration	1973-2006	Bangladesh	E → GDP
Jumbe (2004)	Granger causality and Error-correction model	1970–1999	Malawi	E ↔ GDP and E →GDP
Energy- growth nexus				
Okonkwo and Gbadebo (2009)	Cointegration technique	1970-2005	Nigeria	E → GDP
Loganathan et al. (2010)	OLS-EG, DOLS, ARDL, Error Correction Model (ECM)	1971-2008	Malaysia	E ↔ GDP
	Granger causality	1980-2006	Nigeria	E → GDP
Kahsaia et al. (2011)	Granger causality	1980–2007	40 Sub-Saharan African countries	E ↔ GDP
Ebohon (1996)	Engle–Granger causality approach	1960–1984	Nigeria, Tanzania	E ↔ GDP

Study	Methodology	Period	Country	Effect on energy on economic growth
Esso (2010)	Threshold cointegration	1970–2007	Ivory Coast Congo and Ghana Cameroon, Nigeria, Kenya, South Africa	E ↔ GDP E ← GDP E ≠ GDP
Ouedraogo (2012)	Panel unit root, Panel cointegration and Granger causality	1980 to 2008	15 West African States	E → GDP
Huang et al. (2008)	Generalized method of moment system	1972–2002	Low Income Countries	
Odhiambo (2010)	Autoregressive distributed lag (ARDL) bounds test, Granger causality	1972–2006	South Africa and Kenya Congo	E → GDP E ← GDP
Eggoh et al. (2011)	Panel cointegration and panel causality tests	1970–2006	21 African countries	E ↔ GDP

Table 2 Summary of recent literature review for energy consumption and economic growth

Note (1) *'E' stands for energy, 'EL' stands for electricity*

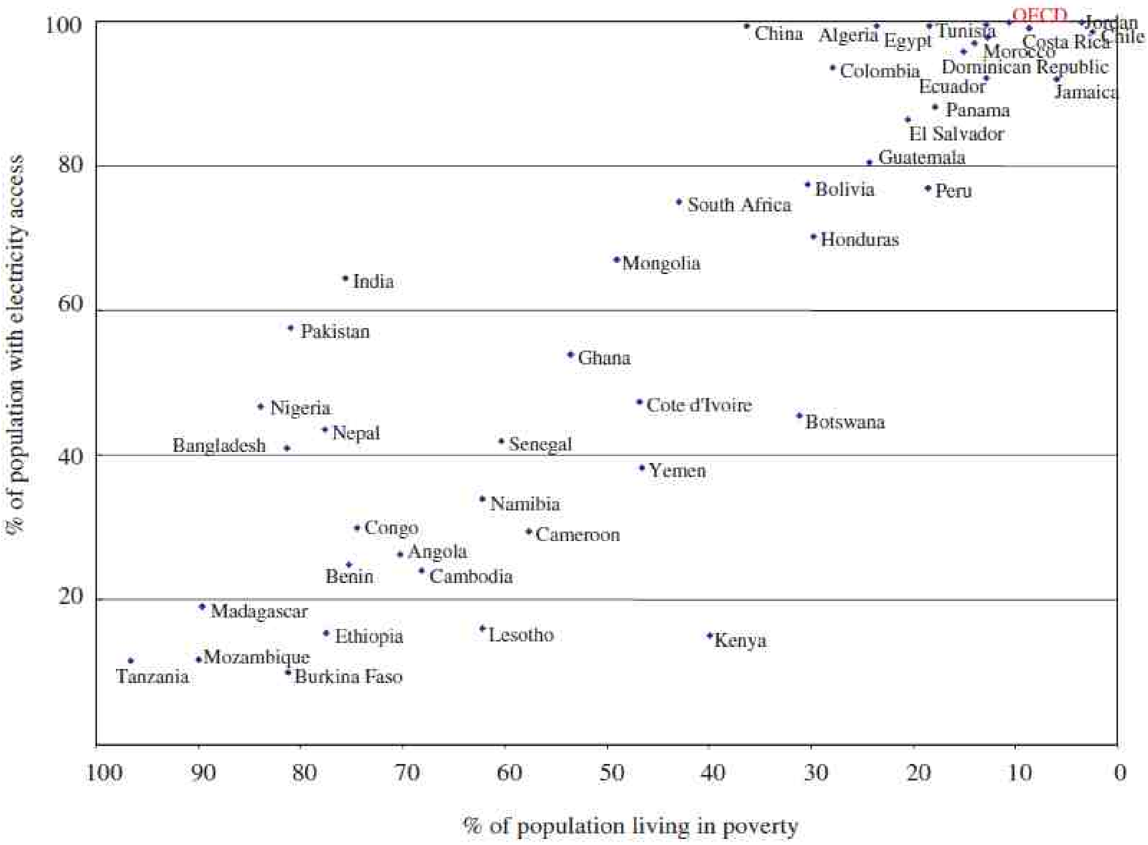
(2) E(L) → GDP means that the causality runs from energy/ electricity consumption to growth (Growth hypothesis). E(L) ← GDP means that the causality runs from growth to energy/ electricity consumption (Conservation hypothesis). E (L)↔ GDP means that bi-directional causality exists between energy/ electricity consumption and growth (Feedback hypothesis). E (L)≠ GDP means that no causality exists between energy/ electricity consumption and growth (Neutrality hypothesis).

SECTION 4

Electricity access and poverty reduction

In most countries, lack of access to adequate levels of energy services are correlated with higher levels of poverty, as shown in Figure 4. This is particularly true in African and South Asian countries, where the number of people who lack access to modern sources of energy is the greatest (IEA 2010).

Figure 4 Electricity access and poverty levels



Source: IIASA 2012

The literature investigating the relationship between energy and GDP is silent on the impact on equality and poverty. The author assumes this is because energy is only one of the factors impacting GDP and because the relationship between GDP and equality/poverty is a complex subject in its own right and it is very difficult to separate empirically the impact of energy-GDP-poverty drivers from more general GDP-poverty drivers. This is an interesting area of research and there are certainly examples of countries with high energy resource endowment with high levels of inequality and poverty, such as Nigeria (Washington Post, 27 September 2013) and Angola (Energy Economist 10 February 2011).

SECTION 5

Energy policy agenda

The focus of countries' energy policies around the globe during the past three decades has been threefold- achieving universal access to modern and reliable energy services, encouraging energy efficiency and increasing the share of renewable energy in the total energy consumption, while at the same time promoting private sector participation.

Governments' role in both energy sector development and in energy efficiency is to provide incentives and information, and to help remove barriers to markets operating effectively. Through National Energy Policies and Energy road maps, governments aim to create the right policy, regulatory and contractual frameworks that will establish the necessary foundation for the development of the energy sector, climate- smart energy solutions.

The next sub-sections provide an outline of the impact of a number of energy policies on macroeconomic goals.

Energy efficiency

Improvements in energy efficiency are seen as the most cost- effective means of expanding the reliability and affordability of energy supply, becoming less dependent on fossil fuels, while at the same time curbing environmental damage. There is a great variety in the options available for increasing energy efficiency, ranging from investing in rehabilitating the existing energy infrastructure, to moderating demand for energy and adopting more efficient technologies.

Numerous energy efficiency policies and programmes have been implemented in many countries around the world during the past decade with demonstrable success. These policies aim at the removal of informational, institutional, policy, regulatory, and market-related barriers to improving energy efficiency in industry. They also provide fiscal environments which enable industrial enterprises more easily to implement energy efficient technologies, practices, and measures.

A recent study conducted by the Climate Institute (2013) investigated empirically the relationship between energy efficiency and economic growth based on data from 28 diverse economies over a period of three decades and found strong statistical evidence that energy efficiency positively contributes to economic growth. More specifically, they found that a 1% increase in the level of energy efficiency causes a 0.1 percentage point increase in the rate of economic growth in that year.

A report from the UK Energy Research Centre (2008) on the impact of energy efficiency on GDP in the UK found that the UK's energy efficiency policies between 2000 and 2010 produced additional real annual GDP that was 0.1 percent above that for a base case scenario in which no energy efficiency policies had been implemented.

However, one of the main barriers to making energy efficiency improvements relates to the conflicting goals of long term sustainability versus short term political prerogatives. Investments in energy efficiency at a national level require governements to spend a relatively large share of the public budget in the short run, while the benefits of energy efficiency investments are accrued over a long period of time, thus making them less potitically attractive. In developing countries, institutional barriers and underpricing of energy prices due to government subsidies, diminishes the potential for investment in energy efficiency even further (World Bank 2013).

Renewable energy

The key challenge of making modern and cleaner forms of energy that can support economic growth and prosperity, while minimising the environmental impacts of energy supply, has resulted in a focus on cleaner energy systems and the drive to diversify the energy supply mix to include more renewable sources to address energy security and climate change concerns.

As a result, support policies for renewable energy technologies have increased dramatically over the last decade and include feed- in tariffs (FiTs), net metering and renewable portfolio standards (RPS) or quotas. FiTs remain the most widely adopted policy to support renewable energy. Currently, 99 FiT policies are now in place worldwide at the national or state level (Worldwatch Institute 2014). Renewable portfolio standards or quotas for a specific required minimum share of renewable energy now exist in 76 countries, states, or provinces, up from 34 in 2004. Tax incentives have also been used to spur developments in the renewable energy sector in some 66 countries as of early 2013.

Fang (2011) examined the welfare impact on increasing the share of renewable energy consumption in China based on data from 1978 to 2008 and estimated that a 1% increase in renewable energy consumption increases real GDP by 0.120% and GDP per capita by 0.162%.

According to the Employ-RES research project conducted on behalf of the European Commission (2009), achieving a share of RES in final energy consumption of 20% by 2020 in the EU-27, will lead to a net increase in GDP of about 0.24%, compared to the hypothetical scenario in which all RES support policies are abandoned. Net additional GDP compared to the no-policy scenario would amount to 0.44% of GDP in 2030.

Energy subsidies

Despite the fact that energy subsidies are likely to increase energy affordability and constitute a politically favoured policy tool, research suggests that they aggravate fiscal imbalances, crowd- out priority public spending and discourage private investment in the energy sector, while proving detrimental for the financial sustainability of power producers (IMF 2013). There is also evidence that they reinforce income inequality, since the benefits of higher energy subsidies are mostly accrued by higher income households.

In SSA the average cost of electricity subsidies, according to IMF (2013), represents 1.7 % of GDP, while the losses incurred by electricity suppliers as a result of subsidised prices have led to low service quality and have hampered the ability to invest in new electricity infrastructure.

Also, Holton (2012) concluded, through econometric analysis based on a large sample of countries and data covering the period 2002- 2009, that a 10 cent per litre gasoline subsidy decreases GDP per capita by 0.015%. Another recent study by Dartanto (2013) showed that in Indonesia, 72% of energy subsidies between 1998 and 2013 were enjoyed by the 30% of the richest population. The same study found through rigorous econometric techniques that removing 25% of energy subsidies would increase the rate of poverty by 0.259 percentage points, whereas if this money were allocated to government spending it would lead to a reduction in poverty by 0.27 percentage points.

Market reform

Evidence for the benefits of electricity market reform in achieving policy objectives (lowering energy price, improving access, improving reliability, higher economic growth) is limited. Reforms have been introduced in many developing and emerging economies with mixed results. Because change, whether positive or negative, occurs for many reasons it is often difficult to disentangle the outcome of reforms from other factors and there have been few systematic studies in developing countries[2]. A systematic analysis of the reforms in India was, however, published by Sen et al (2010). India is unique among developing countries in having comparable data covering a number of States with differing reform programmes. Using panel data for 19 states and covering the period 1991 to 2007, the paper analysed the impact of electricity sector reforms on key economic variables that affect economic efficiency, prices and investment flows. Some findings of the Study that are useful include:

- Improvements have occurred most visibly in terms of transmission and distribution losses in the states implementing power reforms.
- Gross generation as an indicator of investment in electricity supply shows increases only during the latter half of reform measures.
- Political economy can reverse any impact brought about by a reform programme.
- Overwhelmingly, it is the implementation of a regular policy on tariff rationalisation that has had the most direct positive impact.
- Industrial consumption of electricity has shown a tendency to increase with the implementation of a complete reform.
- Once begun, if left half-way, the impact of reforms could become negative.
- Substantial changes in economic variables begin to occur only once a baseline level of reform has been undertaken.

Whiteman (1999) studied the impact of electricity reform on economic growth in Australia using Data Envelopment Analysis and Stochastic Frontier Analysis techniques to measure inefficiency. According to the results of the study, the direct benefit gained from electricity reform is equivalent to a 0.39% increase in GDP.

Zhang et al (2008) provided an econometric assessment of the effects of privatisation, competition and regulation on the performance of the electricity generation industry using panel data for 36 developing and transitional countries, over the period 1985 to 2003. The main finding of the study was that electricity privatisation and regulation alone do not have a positive macroeconomic impact, but introducing competition stimulates electricity sector development.

Another report published by the Australian Bureau of Agricultural and Resource Economics (ABARE 2001) reviewed the regulatory reform programmes in the electricity supply industries in Japan, Korea and Chinese Tapei and examined their implications for economic growth. According to the findings, deregulation enhanced competition, increases productivity and leads to lower electricity prices in all three economies, which ultimately results in higher GDP growth relative to the reference case scenario. Also, Paredes (2001) and Fisher et al.

[2] One example is Reforming Power Markets in Developing Countries: What Have We Learned?, John Besant-Jones, World Bank, Energy & Mining Board Discussion Paper no. 19, September 2006. This analyses lessons from reforms and provides suggestions on how reforms should be implemented, but does not provide a systematic analysis of the benefits.

(2003) found that, in Chile, privatisation resulted in higher investment, lower unit costs, lower energy losses and higher labour productivity.

Conclusions

Based on this rapid desk based study the author believes that there is generally a gap in the evidence relating to impact of energy policies on the energy markets and economic growth. If time series are sufficiently long or panel data is sufficiently wide, then it would be feasible to introduce dummy variables in the estimation framework to represent significant changes in energy policy and to analyse the impact of these policy changes on energy/GDP.

It may also be possible to obtain evidence based on individual country case studies before and after energy policies are introduced or by comparing two otherwise similar countries adopting different energy policies. The author has not identified studies that have attempted to do this in a systematic way. Also, to do this systematically, it would be necessary to isolate specific policies, which may be difficult (policies are generally a mixture of measures, and often linked with other more general measures relating to private participation, competition policy, or other wider market reforms).

SECTION 6

Conclusion

Bearing in mind the vital role that energy is believed to play in the process of development; this study has reviewed literature that analysed the link between energy access/consumption of modern sources of energy and economic growth.

The literature finds a strong causal relationship between consumption of modern energy and GDP growth but is inconclusive as to the direction of the causality and the magnitude of the impact. Further research on this topic is needed in order to provide policy makers with a better understanding of the energy consumption- growth nexus which will allow the establishment of more effective donor interventions.

Moreover, the literature does not provide evidence for a causal relationship between higher energy access and income equality, which the author attributes to the lack of reliable data, mainly in developing countries, where the issue of low electrification rates and inequality are most prominent and where there are difficulties in disentangling the impact of energy sector on income equality from other factors, such as education and political reform.

Empirical research suggests that investments in energy efficiency and renewable energy have a positive impact on the economy, while at the same time minimising the environmental damage. On the other hand, the use of energy subsidies has hampered energy sector development. More research is required, however, on the impact of electricity market reform on energy sector development.

APPENDIX A

Literature review

This Appendix provides more information on the methodologies used to estimate the relationship between energy and income growth and the author's assessment of the strength of the evidence provided by the different studies.

Overview of the literature

The authors collected a total of 51 studies, all of which are from academic sources, i.e. journal articles, some are reports by donor agencies and others are university research papers. A comprehensive list of these resources including online links is available in Appendix B.

Most of these include a review of previous literature available as part of the background to the study.

In addition, through the literature review of the abovementioned 51 documents, further estimates were gathered, raising the number of data sources to approximately 65. Searches for the publications and papers were carried out on ScienceDirect and Google scholar.

Limitations

All the methodologies used to examine the energy – growth nexus have several limitations in their applicability. These limitations, together with the lack of a commonly agreed methodology, largely explain different conclusions regarding the nature and causality of the focus variables across the literature. The main limitations of the estimation methodologies include:

- ***Availability of data*** – Most methods require extensive data sets. These may be time series, panel data sets or project specific survey data. In some cases the data is difficult to obtain or not available, requiring the use of proxies or instrumental variables. This limitation is especially problematic in the developing countries context, where data on energy access and consumption is less available.
- ***Statistical difficulties*** – Statistical inconsistencies can exist even if a suitable data set is found. Most notably these include: (i) the conventional F-statistic used to test for Granger causality may not be valid as the test does not have a standard distribution when the time series data are integrated or cointegrated (Toda and Yamamoto 1995); (ii) the omitted variable bias: the analyses may not take into account external factors such as labour inputs and investment to infrastructure, since those inputs are important determinants of economic growth, making it difficult to isolate the impact of higher energy availability on income growth
- ***Assumptions justifying energy consumption as a proxy to energy access and availability may not be valid –*** Even though recent studies focusing on the energy-growth causality have used energy consumption as a proxy for energy access the results might be biased since higher energy consumption is more prevalent in non-poor societies, whereas those that gain access to modern energy services are more likely to be part of poorer societies.

Approach to quality assessment

In assessing the quality and validity of the studies examining the energy- growth nexus, there are a number of sub-concepts which can be considered, not all of which are relevant to this study. Identifying the extent to which individual estimates should be considered, in order to conclude on the nature and causality of the energy- growth relationship and provide policy implications, was considered the primary goal of the assessment. With this in mind, the following elements were identified as being important:

- External validity: How generalizable is the result? Or, to what populations, settings, variables, etc., can the effect be generalized? Whilst a given estimate may be valid for a very narrow set of circumstances, for the derivation of policy implications, it is important that the estimate is not so narrow as to not apply to other situations. Thus, the more generalizable the result, the more weight that should be applied in including it in an average estimate.
- Population validity (as part of an assessment of external validity): Does the sample populations represent the entire population? Is the sampling method acceptable?
- Internal validity: How much confidence can be placed in the cause and effects? Could the analysis include other variable that could affect economic growth and which are ignored in the analysis?
- Reliability: Do the differences between the underlying circumstances and variables seem to explain the differences in the results? Why are there outliers?

Although reliability and validity form the main part of any assessment of the quality of the indicators, conceptual framing, openness/transparency, and cogency should likewise be considered.

Obviously, such an assessment of each estimate of a causal relationship between energy and growth is not possible within the scope or timescale of this report.

APPENDIX B

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