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The effect of education on a country's energy consumption: Evidence from developed and developing countries

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Abstract

Education has been regarded throughout history as one of the main drivers of economic development and innovation, and can be viewed as one of the means available to nations for encouraging energy education, implementation of renewable energy and reduced energy consumption. This paper analyses the causal and empirical relationship between primary energy consumption and education for a group of developed and developing countries as well as an aggregate panel of the developed and developing country groups for the period 1980-2013. The results confirm a unidirectional relationship between energy consumption and education, flowing from education to energy consumption. Another interesting result is the confirmation of a non-linear relationship between energy consumption and education: energy consumption is increased by higher education levels in developing countries while energy consumption falls with higher education levels in developed countries. Lastly this paper provides a brief description of the impact of these results on energy policy and recommends that developed countries implement pro-education policies to reduce energy consumption while developing countries should make use of education coupled with environmental awareness programs to reduce the effect increased education will have on energy consumption.

Keywords: energy consumption; education; developed and developing countries

1 Introduction

The need to reduce the negative environmental change the world is experiencing has driven many economies towards rethinking their energy strategy, or rather towards reconsidering how their energy strategy affects the environment,

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in order to reduce global energy consumption and emission levels. Many determinants and policies can be used to achieve this global goal, however, education is perhaps one of the most essential and perhaps best suited tools available.

Throughout history, education has been viewed as one of the main drivers of economic development and innovation (Marshall, 1920) enabling societies to become more advanced by improving production processes, standards of living, efficiency levels, (Barro, 1997) and economic growth (Marshall, 1920; Nelson & Phelps, 1966; Gylfasson, 2000). Education has also been viewed as one of the means available which nations can use to encourage energy education for consumers and firms together with the generation and implementation of renewable energy.

The intuition behind how education affects energy consumption of a country is relatively straight forward. By improving education levels, production processes and technology should theoretically become more efficient. This leads to the rationale that education affects energy consumption in the following ways. *A priori*, it could be seen as increasing energy consumption of relatively poor nations as these nations seek to catch up to their more developed and urbanised counterparts, while making headway in escaping a historically poor or even agrarian economy. On the other hand, education can reduce energy consumption in already developed countries as these countries seek to reduce their energy footprint and develop better, more environmentally friendly production processes. Furthermore, education can also affect energy consumption by enabling energy consumers to substitute between fuels used for energy generation and by improving the adaptability and ability of society to process complex information regarding energy pricing and usage. Individuals from an underprivileged background in rural areas may use less efficient energy resources such as wood, however, as education levels rise, these individuals have the opportunity to migrate to urban areas in search of better jobs and education. This in turn aids individuals in substituting from relatively primitive energy generating fuels to being serviced by an efficient electricity grid. Additionally, these improved "awareness" levels in society lead to more informed consumers and public planners who will make better energy purchasing, generation, usage and distribution decisions, which may in turn reduce energy consumption levels.

It can therefore be argued that education may have different effects on energy consumption for different countries according to their levels of development. *A priori* education may increase energy consumption for developing countries while it may help in reducing energy consumption in developed countries

Figure 1 shows a comparison of total primary energy consumption and education levels[1] for the panel of 21 countries to be examined for the period 1980-2013 converted into their natural logarithms. There appears to be a direct, positive relationship between energy consumption and education levels. This elementary analysis is necessary as it provides further evidence that education levels may be a useful key to unlocking and solving the energy consumption

[1] Education levels defined as average total enrolment in secondary education, regardless of age, expressed as a percentage of the population of official secondary age.

puzzle faced by countries internationally

Insert Figure 1

There has been evidence that education is a determinant of economic growth (Nelson & Phelps, 1966; Gylfasson, 2000; Ben Abdelkarim, Ben Youssef, M'henni & Rault, 2014), and economic growth has furthermore been found to have a positive effect on energy consumption (Poumanyvong & Kaneko, 2010). Due to this, Ben Abdelkarim et al. (2014) argue that if education is a determinant of economic growth, and economic growth is in turn a determinant of energy consumption, then education may be a determinant of energy consumption using economic growth as its instrument (Ben Abdelkarim et al., 2014). Such an argument leads to the uncertain belief that every determinant of economic growth is a driver of energy consumption, assuming a constant relationship between economic growth and energy consumption. This, however, is not true for all countries across all time periods. Therefore, further examination into the dynamics of the relationship is necessary. Education, however, not only affects energy consumption through economic growth but also affects energy consumption through the purchasing decisions of consumers, technological advancements, adaptation, and fuel substitution. Thus, coupling the possible spill-over of education on energy consumption through economic growth, the improvement in "awareness" levels of informed individuals within a society, fuel efficiency, technological development, and due to improving education levels particularly in developing nations, more complex goods and services being demanded and supplied (Ben Abdelkarim et al., 2014), it can be seen that countries' overall economic and energy consumption structure may be modified. Through these channels education may affect energy consumption levels significantly, however, whether the direction of the possible effect remains to be determined.

Energy is necessary for an economy to produce goods and services which will later be consumed. In the literature, various drivers are responsible for changes in energy consumption. Factors such as education urbanisation, industrialisation and population can be viewed as important determinants of how a nations' growth will be shaped in the future (Apergis & Payne, 2011)

This paper aims to narrow the gap in the literature by firstly analysing the causal relationship between energy consumption and education for two country groups, namely: a developed and developing country group, and a third, aggregate global country group for the period of 1980-2013. The 21 countries included are separated into 10 developed and 11 developing countries. These countries are: Algeria, Austria, Bulgaria, Chile, China, Ecuador, Egypt, Finland, France, India, Indonesia, Japan, Malaysia, Netherlands, New Zealand, Norway, Philippines, Republic of Korea, Sweden, Thailand and Turkey. Both developed and developing economies were included to achieve a better representation of the world and examine the differences between the country groups. The specific countries included were chosen based on data availability, especially for the education variable where most countries lack information. Thereafter the empirical effect that education has on energy consumption in these three country groups will be estimated.

In order to carry out this analysis, an econometric approach will be used to examine the Granger causal relationship between energy consumption and education Subsequently this paper will make use of the Stochastic Impacts by Regression Population Affluence and Technology (STIRPAT) model developed by Dietz and Rosa (1997) to determine the effect that education has on energy consumption as well as determining whether the relationship between education and energy consumption is non-linear

The remainder of the paper is structured as follows. **Section 2** provides the main results obtained in the literature. **Section 3** explains the data and methodology used. **Section 4** shows the empirical results. **Section 5** discusses the policy implications **Section 6** concludes the paper and summarises the results.

2 Related Literature

The literature determining the causal relationship between energy consumption and economic growth is vast. However, there is no consensus on what the relationship should be. This has led to four main hypotheses being postulated in the literature on the relationship between energy consumption and economic growth. The type of hypothesis confirmed by each country or region is crucial from a policy perspective (Ghosh, 2002; Narayan & Singh, 2007). The four hypotheses are the Growth, Conservation, Feedback and Neutrality hypotheses.

The Growth hypothesis postulates one-way Granger causality from energy consumption to economic growth, implying energy consumption causes economic growth (Apergis & Payne, 2011; Ozturk & Acaravci, 2011). This implies that countries which confirm this hypothesis should expand their energy generating capacity to bolster economic growth. This could be done in several ways, either through the traditional route of building fossil-fuelled power plants, or by expanding their renewable energy potential by building solar or wind farms.

The Conservation hypothesis, implies one-way causality from economic growth to energy consumption, therefore indicating that economic growth causes higher energy consumption (Wolde-Rufael 2006; Ciarreta & Zarraga, 2010; Wolde-Rufael 2014) The Conservation hypothesis is particularly intricate as it implies that the country's economic structure is energy independent. Economic growth, however, would increase energy consumption. Thus, policies that aim to increase energy generating capacity in countries which exhibit the Conservation hypothesis will not have the desired effect of promoting economic growth. In fact, countries exhibiting this hypothesis should instead implement policies aimed at improving economic growth directly, unlike in the case of the Growth hypothesis where economic growth could alternatively be targeted through increased energy generation and in turn consumption.

The Feedback hypothesis, occurs when there exists a two-way causal relationship between energy consumption and economic growth (Yoo & Kwak, 2010; Apergis & Payne, 2011; Ozturk & Acaravci, 2011). Countries exhibiting this type of causal relationship can target economic growth in two ways, directly, as was the case with the Conservation hypothesis, or by promoting policies targeting energy capacity improvements, such as with the Growth hypothesis.

The Neutrality hypothesis, occurs when no causal relationship exists between energy consumption and economic growth, implying that energy consumption has no effect on economic growth and vice versa (Yoo & Kwak, 2010; Ozturk & Acaravci, 2011) Although particularly difficult to understand, the Neutrality hypothesis can be explained by using poorer countries as an example. The economic growth of countries in which the population primarily consists of subsistence farmers would be dependent on natural events rather than energy consuming activities such as mining and manufacturing. This implies that policies attempting to promote energy generation, and therefore consumption, within the borders of countries exhibiting the Neutrality hypothesis would have no effect on economic growth, and should therefore be avoided or used at a later stage should the economic structure of the country and the causal relationship between the variables change.

The empirical support for these four hypotheses within the literature further emphasises the need to address the differences and drivers of the causal relationship between countries or regions

Table 1 provides a concise summary of selected studies in the literature which analyse the causal relationship between energy consumption, or a proxy thereof, and economic growth. These papers were included from a vast body of literature as they include all available econometric data formulations and the majority make use of the traditional Granger causality methodology or a modified version thereof, which this paper will use. In simple terms, the Granger causality methodology was developed to aid in the prediction of variables such as Y_t, by making use of alternative variables, X_t. In order to determine whether a variable such as X_t Granger causes Y_t, the variable X_t should contain information that allows the prediction of the value of Y_t (Granger, 1969).

From a time series perspective, the studies carried out by Ghosh (2002), Shiu and Lam (2004), Yoo (2005), Narayan and Singh (2007) and Ciarreta and Zarraga (2010) found evidence that the relationship between energy consumption and economic growth confirms all four of the energy causality hypotheses. The studies by Shiu and Lam, (2004), focusing on China, and Narayan and Singh (2007), focusing on Fiji, both found evidence confirming the Growth hypothesis. These studies are interesting, as Fiji is a small island economy with its GDP being highly dependent on electricity consumption (Narayan & Singh, 2007) while China is the fourth largest country with an industry focused mainly towards manufacturing. In fact, industry value added to GDP for China constitutes approximately 40% of GDP over the last four decades, while the industry value added to GDP for Fiji over the same period has been approximately 20% (World Bank, 2016). Interestingly, Ghosh (2002) found that economic growth causes energy consumption for India using the Johansen and Juselius cointegration technique and vector autoregressive (VAR) models. Furthermore, the studies carried out by Yoo (2005) making use of the Johansen and Juselius cointegration and vector error correction models (VECM) and Ciarreta and Zarraga (2010) using the Granger causality technique, both found evidence of the Feedback hypothesis.

Condensing the literature focusing on panel data methodologies, Wolde-Rufael (2006) and Behmiri and Manso (2013) focused on a panel of African and Sub-Saharan African countries respectively. While Wolde-Rufael (2006) found evidence substantiating all four hypotheses, Behmiri and Manso (2013) found evidence confirming only the Feedback and Growth hypotheses. On the other hand, the studies by Chen et al. (2007) and Mishra et al. (2009) focused on countries within the Asian continent and found evidence confirming the four causal hypotheses and the Feedback hypothesis respectively. Further studies by Ozturk and Acaravci (2010) and Wolde-Rufael (2014), focusing on European countries, Yoo and Kwak (2010) focusing on South American countries and Apergis & Payne (2011) focusing on an international panel of countries separated by income, found evidence confirming all four causality hypotheses For example, Venezuela as well as the high and upper middle-income country panels confirmed the Feedback hypothesis; Albania, Peru and Serbia exhibited the Neutrality hypothesis; Argentina, Ukraine and the lower-middle income country panel confirmed the Growth hypothesis; and lastly Latvia and Lithuania, displayed evidence of the Conservation hypothesis.

Numerous studies have found evidence justifying different hypotheses on the relationship between energy consumption and economic growth throughout the world however, no consensus has been reached on what determines this causal relationship. Evaluating the findings and concepts included within the literature, education may be useful in determining the energy consumption structure of an economy and which policies are best suited to address each country's needs.

The STRIPAT model was developed to evaluate how different variables affect an energy or environmental variable and was derived from the $IPAT$ identity postulated by Ehrlich and Holdren (1971) (Dietz & Rosa, 1997). The $IPAT$ identity, although useful, faced limitations leading to a number of improvements being brought forward, with the STIRPAT model being perhaps the most successful modified model, as it reformed the original $IPAT$ identity into a stochastic identity. The evolution of the $IPAT$ identity into the STIRPAT model allowed Dietz and Rosa to maintain the relationships found between driving factors, while simultaneously allowing for non-proportionate impacts of variables on environmental pressure (Li, Liu & Li, 2014).

In order to make assumptions with regards to the structure of the model to be estimated and *a priori* conclusions, the literature contained within **Table 2** will first be discussed.

Table 2 provides a concise summary of various papers that have analysed the effects of different variables on both energy consumption and emissions by using the STIRPAT methodology.

Curiously, Poumanyvong and Kaneko (2010) found urbanisation decreased the level of energy consumption for the low-income group countries, while it had the expected negative effect of increasing energy consumption for the middle and high-income country panels. The studies carried out by York, Rosa and Dietz (2003), Lin, Marinova and Zhao (2009) and Wang, Wei, Wu and Zhu (2013) report similar results making use of the STIRPAT methodology. Across all the studies, urbanisation, population and GDP per capita were found to have a negative effect on emission levels. Thus, an increase in these variables leads to an increase in the level of emissions for the region studied. Furthermore, Poumanyvong and Kaneko (2010) found that urbanisation increased the level of carbon dioxide emissions for all income groups.

Per the literature presented in **Table 2** one can see that numerous variables have been considered and in particular the effect across countries seems to be similar; urbanisation and population are detrimental to the environment as they increase emissions, however the effect of education has not been considered

3 Data and Methodology

3.1 Data

The dataset this paper will use covers the period 1980-2013 for three country groups, an aggregate international panel of 21 countries, and a panel of 10 developed and 11 developing countries respectively. The 21 countries included are the following: Algeria, Austria, Bulgaria, Chile, China, Ecuador, Egypt, Finland, France, India, Indonesia, Japan, Malaysia, Netherlands, New Zealand, Norway, Philippines, Republic of Korea, Sweden, Thailand and Turkey[2].

Country-selection was influenced by severe data limitations, namely overlapping data available for energy consumption and education for the same years, as well as data available for service and industry levels. The 21 countries included in this paper were prone to a reduced number of missing observations leading to a relatively strong, balanced panel. Thereafter, country-classification with regards to developed and developing countries, was conducted using the list of developing countries from the International Union of Geodesy and Geographics (IUGG, 2015), bringing about two separate panels including 10 developed and 11 developing countries respectively. The IUGG (2015) classifies countries into developed and developing countries based on income per capita with US$ 11,905 considered the threshold between developed and developing countries. The country division regarding developed and developing can be found in **Table A2** of the **Appendix**, while **Figure 2** illustrates the geographical location of the countries included

The dataset was compiled using data from the World Bank's *World Development Indicators* and *Country Indicators* (World Bank, 2016) and the *BP Statistical Review of World Energy* (BP, 2016).

In particular, the data used for energy consumption is aggregate primary energy consumption measured in mtoe. This data was collected from the *BP Statistical Review of World Energy* (2016), while the data for population, education, measured as the total enrolment in secondary education, regardless of age, expressed as a percentage of the population of official secondary education

[2] Countries such as the United States and the United Kingdom which are traditionally included as representatives of the developed nations were not included due to lack of information within the chosen data sources.

age, GDP and urbanisation, measured as the percentage of population living in urban areas, come from the *World Development Indicators* (World Bank, 2016). Lastly industrial and service levels percentage of value added to GDP data are obtained from the World Bank's *Country Indicators* (World Bank, 2016). All variables will be converted into natural logarithms, following the STIRPAT methodology from Poumanyvong and Kaneko (2010) which will be described in **Section 3.2.**

Total population enrolled in secondary education, regardless of age expressed as a percentage of the total official population of secondary education schooling age, was selected as the measure of education, rather than quality of education or even tertiary education enrolment as it allows for reasonable inference between developed and developing countries. This is done in order to avoid making unfair comparisons as quality of education or even tertiary education enrolment levels may differ significantly due to differences in the structure of the countries' education systems. **Table 3** shows the descriptive statistics of the variables contained within the dataset[3].

Table 4a shows the correlations between the variables for the aggregate global panel of countries for the period 1980-2013. As can be observed education is found to have a positive correlation with energy consumption. Furthermore, urbanisation exhibits a negative correlation with energy consumption, which can be explained by the urban-compaction theory postulated in the literature. This theory suggests that a higher degree of urban compaction allows cities to exploit economies of scale for urban public infrastructure, such as water supply and public transport.

This exploitation of economies of scale ensures a decrease in: vehicle usage, distance travelled, as well as reduced distribution losses in electricity supply. These reductions subsequently reduce overall energy consumption.

Tables 4b and **4c** show the panel correlations for the developing and developed countries respectively for 1980-2013 **Table 4b** shows the panel correlations for the 11 developing countries within the sample. Education and urbanisation are both negatively correlated with energy consumption. This implies that as education and urbanisation levels increase, energy consumption within developing countries decreases. This result is contrary to that postulated by the catch-up effect and *a priori* expectations. **Table 4c** shows the panel correlations for the 10 developed countries. Education has a positive correlation with energy consumption, implying that higher levels of education within developed countries are associated with higher energy consumption contradicting *a priori* expectations On the other hand, urbanisation has a negative correlation with energy consumption. Implying that increased urbanisation levels are associated with decreased energy consumption within developed countries.

[3] A detailed description of the variables used in this paper can be found in **Table A1** of the **Appendix.**

3.2 Econometric Method

The empirical analysis this paper will conduct follows two methodologies considered to be unrelated by the literature. This paper, however, argues that they should be used together in order to provide accurate policy discussion. To obtain useful estimates on the effect of education on energy consumption, the causal relationship between the variables needs to be determined first. In order to do this the Granger causality methodology will be used to determine the causal relationship between energy consumption and education. Thereafter the STIRPAT methodology will be used to determine the empirical effect education has on energy consumption. Using the STIRPAT methodology a model will be estimated with energy consumption as the dependent variable to empirically determine how economic and demographic factors affect energy consumption This econometric interpretation allows for valuable policy discussion as the efficacy of policies implemented to reduce energy consumption by targeting education hinges on the causal relationship between the variables as well as the sign and significance of the estimates.

Prior to the panel Granger causality analysis being carried out, a prerequisite for the Granger causality test is to carry out stationarity and cointegration tests. Should the variables be stationary once differenced, or I(1) and not cointegrated, then traditional pairwise Granger causality tests are valid. Should the variables be I(1) and cointegrated, an error-correction model should be estimated rather than the traditional pairwise Granger causality analysis (Yoo & Kwak, 2010)

3.2.1 Unit Root Tests

To determine the univariate properties of energy consumption and education three unit root tests will be carried out namely, the Levin, Lin & Chu (LLC) (2002), Breitung (2000) and the Phillips-Perron (PP) (1988) tests.

The LLC test is widely used within the literature for panel unit root testing and takes the following form:

$$\Delta Y_{it} = \alpha_i + \delta_i Y_{it-1} + \Sigma_{j=1}^{n} \rho_i \Delta Y_{it-1} + \varepsilon_{it} \tag{1}$$

Within Eq. 1, Δ represents the first difference operator. For the LLC test, the null hypothesis $H_0 : \delta_i = \delta = 0$ for all i,of non-stationarity is tested against the alternative hypothesis of stationarity, $H_A : \delta_i = \delta < 0$ for all i. Furthermore the LLC test assumes that for all regions, or countries in this case, δ is homogenous.

The test statistic for the LLC test is then calculated as follows:

$$t_{\delta}^{*} \frac{t_{\delta - n\tilde{T}\hat{S}_n \sigma_{\varepsilon}^{2} STD(\hat{\delta}) \mu_{m}^{*} \breve{T}}}{\sigma_{m\breve{T}}^{*}} \tag{2}$$

Where $\mu_{m\breve{T}}^{*}$ and $\sigma_{m\breve{T}}^{*}$ are the mean and standard deviation adjustments calculated by Levin, Lin and Chu (2002). The validity of the LLC test is explained in Levin, Lin and Chu (2002), the authors advocate for the use of the LLC test if the panels used are of moderate size with $10 < n < 250$ and $25 < T < 250$. For the analysis this paper will carry out, $n = 21$ and $T = 34$. Therefore the LLC (2002) test is suitable. The Breitung (2000) unit root test takes the following form:

$$y_{it} = \alpha_{it} + \Sigma_{k=1}^{p+1}\beta_{ik}x_{i.t-k} + \varepsilon_t \tag{3}$$

In Eq. (3) the Breitung (2000) test statistic tests the null hypothesis which shows the process is difference stationary: $H_{0:}\Sigma_{k=1}^{p+1}\beta_{ik} - 1 = 0$ against the alternative hypothesis which shows the panel series is stationary prior to differencing: $H_{A:}\Sigma_{k=1}^{p+1}\beta_{ik} - 1 = 0$ for all i. In order to construct the test statistic, Breitung (2000) makes use of the transformed vectors Y_i^* and X_i^* to construct the test statistic for the test: $Y_i^* = AY_i = [y_{i1}^*, y_{i2}^*, \ldots\ldots, y_{iT}^*]'$ and $X_i^* = AX_i = [x_{i1}^*, x_{i2}^*, \ldots\ldots, x_{iT}^*]$.

This in turn leads to the Breitung (2000) test statistic, which follows a standard normal distribution:

$$\lambda_\beta \frac{\Sigma_{i=1}^{N}\sigma_1^{-2}Y_{i*}'X_{i*}'}{\sqrt{\Sigma_{i=1}^{N}}\sigma_1^{-2}X_{i*}'AX_i^*} \tag{4}$$

The PP test is known for being robust for various serial correlations and time-dependent heteroscedasticities (Yoo & Kwak, 2010) and is therefore chosen for its beneficial properties The PP test, tests the null hypotheses of non-stationarity against the alternative hypothesis of stationarity.

Should the reader wish to obtain further information regarding the Phillips-Perron (1988) test used in this paper, which is well documented in the literature one can access the original paper listed in the bibliography (Phillips & Perron, 1988).

3.2.2 Pedroni Cointegration

Once the stationarity of the variables, lEnergy and lEduc is determined, the second step is to test for cointegration between the variables. Cointegration refers to the existence of a long-run relationship between energy consumption and education within the country groups. In order to test for cointegration the Pedroni (2000) approach will be used. The Pedroni (2000) test for cointegration in heterogeneous panels provides seven statistics to determine whether the null hypothesis of no cointegration is accepted or rejected in favour of the alternative hypothesis of cointegration. These test statistics can be separated into two distinct groups, the first can be referred to as the "within dimension" (panel tests) while the second group of tests can be referred to as the "between dimension" (group tests). The "within dimension" tests account for common time factors while allowing for heterogeneity amongst countries. The "between dimension" tests on the other hand are "group mean cointegration tests" (Mishra et al., 2009) and allow for the heterogeneity of parameters across countries.

Pedroni's (2000) test statistics are based on the residuals estimated from Eq. 5.

$$lEnergy_{it} = \alpha_i + \beta_i lEduc_{it} + \varepsilon_{it} \quad (5)$$

For all $i = 1, \ldots, N$ with $\varepsilon_{it} = n_i \varepsilon_{i(t-1)} + \mu_{it}$.

The $H_0 : n_1 = 1$ is tested against thee $H_A : n_1 \neq 1$. Furthermore, the finite sample distribution of the Pedroni (2000) test statistics are derived using Monte Carlo simulations tabulated within Pedroni (2004). The null hypothesis of no cointegration is rejected if the Pedroni (2000) test statistic exceeds the critical values tabulated in Pedroni (2004).

The Pedroni (2000) test statistics are shown in **Table A3** of the **Appendix** Should cointegration exist, this would imply that there exists a long-run relationship between energy consumption (lEnergy) and education (lEduc).

3.2.3 Granger Causality

In order to test for Granger causality when the variables are I(1) and not cointegrated following Yoo and Kwak (2010), two bivariate models must be specified, one for lEnergy and a second model for lEduc.

The pairwise Granger causality test is therefore specified as follows:

$$\Delta lEnergy_{it} = \alpha_{11} + \Sigma_{i=1}^{L11} \gamma_{11i} \Delta lEnergy_{t-i} + u_{11t} \quad (6)$$

$$\Delta lEnergy_{it} = \alpha_{12} + \Sigma_{i=1}^{L11} \gamma_{11i} \Delta lEnergy_{t-i} + \Sigma_{j=1}^{L12} \gamma_{12j} \Delta lEd\,\mathrm{uc}_{t-j} + u_{12t} \quad (7)$$

$$\Delta lEd\,\mathrm{uc}_{jt} = \alpha_{21} + \Sigma_{j=1}^{L21} \gamma_{21j} \Delta lEd\,\mathrm{uc}_{t-j} + u_{21t} \quad (8)$$

$$\Delta lEd\,\mathrm{uc}_{jt} = \alpha_{22} + \Sigma_{j=1}^{L21} \gamma_{21j} \Delta lEd\,\mathrm{uc}_{t-j} + \Sigma_{i=1}^{L22} \gamma_{22i} \Delta lEnergy_{t-i} + u_{22t} \quad (9)$$

In Eqs. 6, 7, 8, 9, Δ is the difference operator, L is the number of time lags, α and Y are the parameters to be estimated, while u_t is the error term. Eqs. 7 and 9 are in unrestricted form, while Eqs. 6 and 8 are restricted, that is $\gamma_{12j} = 0$ and $\gamma_{22j} = 0$, respectively.

Following Yoo and Kwak (2010), Eqs. 6 and 7 are paired to determine whether the coefficient of the past lags of lEduc are zero, or rather to determine if lEduc is insignificant in explaining part of the variance of lEnergy unexplained by the previous lags of lEnergy. It follows that Eqs. 8 and 9 are then paired to determine if the coefficients of the lags of lEnergy insignificant in explaining part of the variance of lEduc unexplained by the lags of lEduc. Should lEduc and lEnergy be significant in explaining part of the variance left unexplained by the lags of lEnergy and lEduc respectively then it can be concluded that the variables lEnergy and lEduc Granger cause each other.

To test for Granger causality, the F-statistic is calculated to test whether the coefficients of the lagged values of lEduc and lEnergy are zero respectively.

3.2.4 STIRPAT

In order to investigate the impact of demographic and economic factors, on the environment, Ehrlich and Holdren (1971) proposed making use of a simple mathematical identity, called the $IPAT$ identity. In this simplistic equation, Irepresented the environmental impact, equally dependent on three factors namely, population size (P),per capita affluence (A)and the level of environmentally damaging technology (T).Affluence (A) acted as a proxy for per capita consumption.

Although useful, the $IPAT$ identity demonstrated a very simplistic relationship, based purely on a mathematical equation, therefore the results obtained using the $IPAT$ identity could not be statistically interpreted. Secondly the $IPAT$ identity assumes that the elasticities of population, affluence and technology on the environmental impact are one (Dietz & Rosa, 1994; Poumanyvong & Kaneko, 2010) this is not necessarily true for all countries across all time periods

Dietz and Rosa (1997) noted the shortcomings of the $IPAT$ identity and modified the identity into the so called STIRPAT model (Dietz & Rosa, 1997). The STIRPAT model Dietz and Rosa (1997) postulated took the following form: $I_i = aP_i^b A_i^c T_i^d u_i$. The level of technology (T) has proven to be difficult to measure, and due to this the literature has advocated for the use of different variables as proxies for the level of technology (T). This paper employs the structure postulated by Shi (2003) and Poumanyvong and Kaneko (2010) to proxy for technology levels, namely the share of value added by the industrial and service sectors in the economy to GDP will be used.

The models this paper will estimate follow those postulated by Poumanyvong and Kaneko (2010), however, education squared is included for the aggregate global panel to determine if there exists a non-linear relationship between energy consumption and education, while education is added as an explanatory variable to the regressions of all country groups. These model specifications are shown in Eqs 10 and 11.

$$\begin{aligned} lEnergy_{it} &= \beta_0 + \beta_1 lEduc_{it} + \beta_2 lEducsq_{it} + \beta_3 lUrb_{it} + \beta_4 lPop_{it} \\ &\quad + \beta_5 lInd_{it} + \beta_6 lServ_{it} + \beta_7 lGDP_{it} + Y_t + C_i + \varepsilon_{1it} \end{aligned} \tag{10}$$

$$\begin{aligned} lEnergy_{it} &= \alpha_0 + \alpha_1 lEduc_{it} + \alpha_2 lUrb_{it} + \alpha_3 lPop_{it} + \alpha_4 lInd_{it} \\ &\quad + \alpha_5 lServ_{it} + \alpha_6 lGDP_{it} + Y_t + C_i + \varepsilon_{2it} \end{aligned} \tag{11}$$

In Eqs. 10 and 11, β_0 and α_0, represent the constant terms. Eq. 10 will be estimated for the aggregate, global country group while Eq. 11 will be estimated for the developed and developing country panels respectively. **Table A1** in the **Appendix** explains the variables in greater detail. Following Poumanyvong and Kaneko (2010) a year dummy variable, Y_t, which captures the time-spefic effect, as well as a country dummy variable, C_i, are added to Eqs. 10 and

11. Including yearly dummy variables aids in removing possible cross-sectional dependency within the panel. On the other hand the country dummy variables, C_i, are used to capture country-specific effects such as geographical location and resource endowments which may aid in explaining how energy consumption is affected.

Furthermore, the addition of year and country dummy variables minimizes spurious regression problems and heterogeneity bias (Wooldridge, 2007; Poumanyvong & Kaneko, 2010). This in turn ensures that Eqs. 10 and 11 are not prone to omitted variable bias and are therefore robust.

4 Empirical Results

The following section will show the empirical results as follows. Firstly, the unit root, cointegration and Granger causality test results will be reported and explained. Thereafter the estimation results of the STIRPAT models will be described.

4.1 Unit Root Tests

Table 5 shows the unit root test results obtained by using the LLC (2002), Breitung (2000) and PP (1988) tests. Additionally, it must be noted that the lag length selected for conducting the unit root tests was chosen using the Akaike information criterion (AIC). Energy consumption is shown to be stationary once differenced by the three unit root tests used.

For the education variable the PP test indicates that lEduc is stationary prior to being differenced for the developing country group, however, the LLC and Breitung tests indicate that lEduc is not stationary prior to first differencing. Due to two of the three tests indicating lEduc is I(1) for the developing country group and I(1) for the developed and aggregate country groups, this paper concludes that education is in fact stationary once differenced or I(1).

Due to the stationarity test results indicating that both variables, lEnergy and lEduc are I(1), the following requirement prior to testing for Granger causality is to determine whether the variables are in fact cointegrated.

4.2 Pedroni Cointegration Test

Table 6 shows the results of the Pedroni (2000) panel cointegration test. As can be seen with the exception of the panel v-statistic, the remaining six Pedroni (2000) test statistics fail to reject the nullhypothesisof no cointegration. Indicating that for all country groups, lEnergy and lEduc are not cointegrated. This result indicates that energy consumption and education levels do not exhibit a long run relationship over the period 1980-2013 for all country groups.

Since the variables are stationary once differenced and there exists no long run relationship between energy consumption and education, the traditional pairwise Granger causality test can be estimated. Should the variables have been cointegrated an error-correction model would have been estimated to determine causality between the variables.

4.3 Granger Causality Test

Table 7 shows the results of the bivariate pairwise Granger causality test between energy consumption and education for the aggregate global country group, as well as the developed and developing country groups The null hypothesis, education levels do not Granger cause energy consumption is rejected for all country groups. Indicating that education levels do in fact Granger cause energy consumption. However, the null hypothesis that energy consumption does not Granger cause energy consumption is not rejected, indicating that in turn, energy consumption does not Granger cause education. This implies that education Granger causes energy consumption for the aggregate global, developed and developing country groups

Although there exists one-way Granger causality flowing from education to energy consumption, further analysis is required to determine the empirical relationship between energy consumption and education.

The STIRPAT model is advantageous as it allows for interpretation into the significance of determinants in explaining energy consumption as well as defining how these determinants affect energy consumption using a stochastic model which allows for different elasticities between energy consumption and its determinants.

4.4 STIRPAT

To determine the empirical effect education has on energy consumption, four econometric models are estimated. These four models are the traditional OLS model, the OLS model with year fixed effects, fixed effects (year and country) and lastly the random effects model with year and country effects.

The results for the global country panel are shown within **Table 8.** These models are estimated without control variables to determine which model specification is better suited for estimating the empirical relationship between energy consumption and education.

Due to country heterogeneity within the panel, the OLS models may be prone to suffer from heterogeneity bias (Wooldridge, 2007). Therefore, the OLS model specifications cannot be used. To correct for this heterogeneity bias, in addition to incorporating dummy variables controlling for possible year and country specific effects postulated by Poumanyvong and Kaneko (2010), the fixed and random effects models are estimated.

In determining whether the fixed or random effects model specification is more appropriate, there are two main arguments. The first, is postulated within the literature whereby having a sufficiently long time series dimension within the panel, in this case 34 years, the fixed effects model is preferred ahead of the random effects model even though the results vary by small amounts. Secondly, following Wooldridge (2007) the Hausman test can be used to econometrically determine the correct model specification to be used. The Hausman test results indicate that the fixed effects model should be used ahead of the random effects model.

Due to this, the remaining results presented in this paper will be those obtained by making use of the fixed effects model, adding control variables in a stepwise fashion. Including control variables in this manner shows how the coefficient of education changes as other determinants of energy consumption are included in the regressions.

4.4.1 Global Panel

Table 9 shows the effect education (lEduc) and education squared (lEducsq) have on energy consumption for the aggregate global country group. As can be observed, education levels are positive and significant for all the models while education squared is negative and significant. This implies that for the 21 countries, as education increases so will energy consumption until a point is reached in terms of enrolment in secondary education after which energy consumption will decrease, shown by the negative coefficient of education squared (lEducsq) This result confirms that there is in fact a non-linear relationship between energy consumption and education, which follows a similar path to that of the well documented energy and environmental Kuznets curve. Using the results from **Table 9**, the relationship between the natural logarithms of energy consumption (measured in mtoe) and education (measured in percent) for the global panel of countries, taking into account the effect of the control variables, is shown in **Figure 3**. The natural logarithms are used rather than the levels of the variables as the results are those obtained from the fixed effects estimation of the STIRPAT model, estimated using natural logarithms following Poumanyvong and Kaneko (2010), using the aggregate country group[4]. It can be seen clearly that energy consumption increases until the turning point is reached, which occurs when 74.44% of the population is enrolled in secondary education[5].

(lEduc = 4.31), and subsequently decreases when a higher percentage of the population is enrolled in secondary education. The magnitude of the coefficient of education decreases as more control variables are added, however, the sign and significance of the coefficients remain unchanged. This implies that education increases energy consumption, however, once a sufficiently high enrolment level in secondary education is reached, education brings about decreased energy consumption. Is this relationship confirmed by developed and developing countries?

The average enrolment in secondary education in developed countries far surpasses the turning point shown in **Figure 3**, with an average of 103.93% of

[4]Within the sample the maximum education enrolment was 156.61% and the lowest 27.78% translating into 5.05 and 3.32 being the bounds for lEduc. Education levels can exceed 100% due to inclusions of over and under-aged students due to either late/early school entrance and grade repetition.

[5]Education measured as total enrolment in secondary education, regardless of age, expressed as a percentage of the population of official secondary age.

the population enrolled in secondary education[6]. Developing countries on the other hand have an average of 63.73% of the population enrolled in secondary education, implying that developing countries find themselves on the increasing section of **Figure 3**.

Figure 3 provides evidence confirming the *a priori* expectations that education should decrease energy consumption in developed countries while it should increase energy consumption in developing countries. However, to confirm this finding, the fixed effects model will be estimated for developed and developing countries respectively in **Section 4.4.2** without education squared (lEducsq) to determine if developed and developing countries do in fact find themselves on these areas of **Figure 3** and how their position affects policy implementation and success.

Consensus in the literature on the relationship between urbanisation and energy consumption has not been reached with evidence to support the urban-compaction theory postulated by Newman and Kenworthy, (1989) Jenks, Burton and Williams, (1996), Burton, (2000), Capello and Camagni, (2000) and Poumanyvong and Kaneko (2010). Poumanyvong and Kaneko (2010) found a negative relationship between urbanisation and energy consumption in low-income group countries. This relationship appears to be counter intuitive as low-income countries have less efficient energy infrastructure and urban planning than high-income countries, and should therefore exhibit a positive relationship between energy consumption and urbanisation. Scepticism arose against the urban-compaction theory through the rationale that increasing urban population brings about increased air pollution and traffic congestion (Rudlin & Falk, 1999; Breheny, 2001). Instead Poumanyvong and Kaneko (2010) argue that this negative relationship between urbanisation and energy consumption could be brought about through the effects of modernisation, in particular through the effect of improved access to modern and more efficient forms of energy generating fuels. These findings are supported by Pachauri, (2004) and Pachauri and Jiang, (2008) who found that fuel substitution from relatively inefficient solid fuels, such as wood, to modern, more efficient forms of energy brings about lower per capita household energy consumption in urban areas than in rural areas. The magnitude of the coefficient of urbanisation decreases as more control variables are added, however, the positive sign and statistical significance of these coefficients remains unchanged. This result provides further evidence disproving the urban-compaction and fuel efficiency theories postulated within the literature. Population, industrial share and GDP have positive, statistically significant coefficients, implying that as they increase so will energy consumption while service level share on the other hand is positive, but statistically insignificant.

[6] Education measured as total enrolment in secondary education, regardless of age, expressed as a percentage of the population of official secondary age. Education levels can exceed 100% due to inclusions of over and under-aged students due to either late/early school entrance and grade repetition.

4.4.2 Developed and Developing Countries

For the global initiative of reducing energy consumption to be achieved successfully policies implemented in the developed world should be used as a learning tool by developing countries in policy formulation. Policy effects may differ according to a country's economic, energy generation and consumption structures and due to this, observing successful and failed policies will help developing countries in designing adequate, likely heterogeneous policies which will successfully reduce energy consumption without being detrimental to economic growth. **Tables 1** and **11** show the stark differences between developed and developing countries.

In the case of developed countries, education has a negative and statistically significant coefficient, confirming the *a priori* expectation that through education and therefore improved technology levels energy consumption will in fact decrease. For developing countries on the other hand education has a positive, statistically significant coefficient, implying that with increased education comes increased energy consumption, likely due to increased income This in turn indicates that policies aimed at improving education will not translate into reduced energy consumption.

These results confirm the stark contrast between the developed and developing country groups postulated by the non-linear relationship between energy consumption and education shown in **Figure 3**

The relationship between education and energy consumption in developing countries highlights the catch-up effect postulated within the economic development field of macroeconomics. In their attempt to catch-up to their developed country counterparts, developing countries through increased education levels income, urban populations and economic growth will increase energy consumption. On the other hand the stance taken by developed countries to decrease energy consumption, driven by high levels of income and human capital is confirmed by the results.

This analysis confirms that developing countries find themselves to the left of the turning point on the increasing portion of **Figure 3** while developed countries find themselves on the decreasing portion of the curve.

For developed and developing countries as the control variables are added urbanisation remains positive and statistically significant, once again providing evidence against the urban-compaction and fuel modernisation theories postulated in the literature. However, the magnitude of the coefficient in developed countries is larger than that of developing countries indicating that urbanisation affects energy consumption to a higher extent in developed countries. Population and GDP follow *a priori* expectations being positive and statistically significant, with the coefficient of population for developed countries once again being higher than their developing country counterparts while the converse is true for GDP. Industrial and service level share are positive and statistically significant in explaining energy consumption in developed countries while for developing countries only industrial share is positive and statistically significant while service level share although positive is statistically insignificant.

5 Policy Implications

The results shown in **Section 4** show evidence of the current global state. Developing countries face a much tougher task in meeting climate policy goals than their developed counterparts. Policies which are successful in developed countries may not be successful in developing countries. Specifically, the effect of policies aimed toward increasing education levels will have significantly different effects based on the development level of the countries that implement them according to the results in **Section 4**. This in turn places additional strain on developing countries to develop alternative policies to those implemented by the developed world.

The differences between developed and developing countries is driven by income per capita, therefore education may be a successful tool once developing countries make the transition into developed countries. Nevertheless, for the time being policies designed to increase education in developing countries will in fact increase energy consumption. The results, however, indicate that the use of education as a tool to reduce energy consumption needs to be implemented and further explored in developed countries.

The recent Paris climate agreement seeks to reduce global emission levels and will therefore play a crucial role for policy design in both developed and developing countries in the near future. The results clearly indicate that education will be a successful tool in decreasing energy consumption in developed countries. For developing countries, the findings lead to this paper making different recommendations with regards to policy implementation. Although education is important for the growth and progress of developing countries, the improvement of human capital might lead to a significant increase in income (escaping poverty in most cases) and hence, to increased energy consumption. Traditional education, thus, should be complemented by awareness programs to ensure individuals make informed decisions when it comes to energy consumption taking into account its environmental consequences. Although certain groups of individuals may have little scope for fuel substitution, environmental awareness programmes such as energy education in schools, renewable energy and energy efficiency campaigns by Government in residential areas will have positive effects in reducing energy consumption. Doris et al. (2009) identified labels and user education to raise public awareness as one of the most frequent used policies to improve the energy usage. At the same time, Nejat et al. (2015) stress the importance of the barriers that current policies face nowadays, especially that of low public awareness of the positive effects of energy efficiency and negative consequences of uncontrolled energy usage that results in low willingness to change behaviour and adopt new technologies.

This paper calls for further research into determining the effect education has on energy consumption in developed and developing countries, as well as considering interaction terms and higher order effects of determinants such as education on energy consumption.

6 Conclusion

This paper has evaluated the causal and empirical relationship between energy consumption and education for three groups of countries for the period 1980-2013. These three country groups were namely an aggregate global panel of 21 countries, a developed and developing country panel, composed of 10 and 11 countries respectively to provide a balanced, fair representation of the effects of education in both developed and developing countries.

The Pedroni (2000) approach to cointegration was used to determine whether there exists a long-run relationship between energy consumption and education levels once the order of stationarity of the variables was determined. The results indicate that there is no longrun relationship between energy consumption and education advocating for the use of traditional pairwise Granger causality tests ahead of an error correction model. The bivariate panel Granger causality tests show that there is one-way Granger causality flowing from education to energy consumption, implying that education levels cause energy consumption for all three country groups.

Once the Granger causal relationship was determined the STIRPAT model was employed to empirically measure the effect education has on energy consumption for all three country groups. The STIRPAT estimation results show that education levels increase energy consumption levels for the global country group, however, due to the non-linear relationship between education and energy consumption, energy consumption will fall once a sufficiently high level of enrolment in secondary education is reached, in this case 74,44%. Thereafter, the analysis was conducted for developed and developing countries respectively to determine if in fact education would increase or decrease energy consumption as postulated by the non-linear relationship confirmed by the aggregate global country group. The results show that education increases energy consumption for the developing country group, while decreasing energy consumption in the developed country group confirming the *a priori* expectations. This paper also presented conclusive evidence that population, GDP and urbanisation levels increase energy consumption for all three country groups, providing evidence against the urbancompaction and energy modernisation theories.

Lastly, this paper provided a brief insight into the effects of the STIRPAT results on policy design and implementation in both developed and developing countries while advocating for the use of heterogeneous policy implementation amongst different countries to reduce energy consumption.

Education is considered by many as the main driver of economic growth and technological development. For energy consumption to decrease, education is crucial, however, it is only a successful tool once countries become developed. For developing countries, the evidence postulated by this paper indicates that merely increasing education levels will be unsuccessful in reducing energy consumption. However, using traditional education in tandem with environmental awareness programs and energy education may in fact have the desired effect of reducing energy consumption or at least reducing the increase in energy consumption. Developed countries on the other hand should encourage and implement policies aimed at increasing education levels as these policies will in turn reduce energy consumption. This is due to improved technological development as well as improved awareness levels by energy consumers brought about by high levels of human capital and greater environmental conscience exhibited by consumers, as shown by the found energy consumption- education Kuznets-type curve.

This paper, however, notes that further research is necessary into the non-linear relationship between energy consumption and education to provide further evidence on the effect of education on energy consumption both at macro/aggregate level but also in a more micro-based framework. Considering alternative determinants, higher order effects and interactions of determinants will aid in determining the difference in the effect of education within developed and developing countries as well as explaining how this result affects policy implementation and efficacy

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Table 1: Causality Literature

Study	Region	Time Period	Methodology	Results
Ghosh (2002)	India	1950-1997	Johansen & Juselius; VAR	India: ELC ← GDP
Shiu & Lam (2004)	China	1971-2000	Johansen & Juselius; VEC	China: ELC→GDP
Yoo (2005)	Korea	1970-2002	Johansen & Juselius; VEC	Korea: ELC↔GDP
Wolde-Rufael	Africa	1971-2001	Toda-Yamamoto Causality	Algeria: ELC ≠ GDP Benin: ELC→GDP (+) Cameroon: ELC ← GDP (+) Congo DR: ELC → GDP (+) Congo, Rep: ELC ≠ GDP Egypt: ELC↔GDP (+) Gabon: ELC ← GDP (+) & ELC → GDP (-) Ghana: ELC ← GDP (+) Kenya: ELC ≠ GDP Morocco: ELC↔GDP (+) Nigeria: ELC ← GDP (+) Senegal: ELC ← GDP (+) South Africa: ELC ≠ GDP Sudan: ELC ≠ GDP Tunisia: ELC→GDP (-) Zambia: ELC ← GDP (+) Zimbabwe: ELC ← GP (+)
Chen, Chen & Kuo (2007)	Asia	1971-2001	Johansen-Juselius; Pedroni panel cointegration; VEC	China: ELC ≠ GDP Hong Kong: ELC↔GDP Indonesia: ELC→GDP India: ELC ← GDP Republic of Korea: ELC ← GDP Malaysia: ELC ← GDP Philippines: ELC ← GDP Singapore: ELC ← GDP Taiwan: ELC ≠ GDP Thailand: ELC ≠ GDP
Narayan & Singh (2007)	Fiji	1971-2002	Granger Causality	Fiji: ELC → GDP LF → GDP

Mishra, Smyth & Sharma (2009)	Pacific Islands	1980-2005	Granger Causality	LR Panel: ELC ↔ GDP
Yoo & Kwak (2010)	South America	1975-2006	Granger Causality	Argentina: ELC → GDP Brazil: ELC → GDP Chile: ELC → GDP Colombia: ELC → GDP Ecuador: ELC → GDP Venezuela: ELC ↔ GDP Peru: ELC ≠ GDP
Ozturk & Acaravci (2010)	Europe	1990-2006	Error-correction based causality test	Albania: ELC ≠ GDP Belarus: ELC ≠ GDP Bulgaria: ELC ≠ GDP Czech Republic: ELC ≠ GDP Estonia: ELC ≠ GDP Latvia: ELC ≠ GDP Lithuania: ELC ≠ GDP Macedonia: ELC ≠ GDP Moldova: ELC ≠ GDP Poland: ELC ≠ GDP Romania: ELC ≠ GDP Russian Federation: ELC ≠ GDP Serbia: ELC ≠ GDP Slovak Republic: ELC ≠ GDP Ukraine: ELC ≠ GDP
Ciarreta & Zarraga (2010)	Spain	1971-2005	Granger Causality	Spain: ELC ↔ GDP

Apergis & Payne (2011)	World	1990-2006	Panel Error Correction Model;	High income & upper-middle income panel (SR & LR): ELC ↔ GDP

			Panel Vector Autoregressive model	Lower-middle income panel (SR): ELC → GDP Lower-middle income panel (LR): ELC ↔ GDP Low-income panel: ELC → GDP
Behmiri & Manso (2013)	Sub-Saharan Africa	1985-2011	Causality	Net oil importing region (SR & LR): COC ↔ GDP Net oil exporting region (SR): COC → GDP Net oil exporting region (LR): COC ↔ GDP
Wolde-Rufael (2014)	Europe	1975-2010	Bootstrap Panel Causality	Belarus: ELC → GDP Bulgaria: ELC → GDP Czech Republic: ELC ← GDP Latvia: ELC ← GDP Lithuania: ELC ← GDP Russian Federation: ELC ← GDP Ukraine: ELC → GDP Albania: ELC ≠ GDP Macedonia: ELC ≠ GDP Moldova: ELC ≠ GDP Poland: ELC ≠ GDP Romania: ELC ≠ GDP Serbia: ELC ≠ GDP Slovak Republic: ELC ≠ GDP Slovenia: ELC ≠ GDP

Notes: definitions of notation: →, ↔, and ≠ represent, unidirectional causality, bidirectional causality and no causality, respectively, (+) indicates a positive relationship, (-) indicates a negative relationship. Abbreviations are defined in the following manner: ELC: electricity consumption, LF: labour force, GDP: country's GDP. Methodology abbreviations: VAR: vector autoregressive model, VEC: vector error correction model, Johansen-Juselius: Johansen and Juselius cointegration.

Table 2: STIRPAT Literature

Study	Region	Time Period	Methodology	Results
York, Rosa & Dietz (2003)	World	1996	STIRPAT	Population, structure of population, latitude, per capita land area, GDP per capita & urbanisation ↑ ecological impact. State environmentalism, political rights, civil liberties, service sector development, and the presence of a capitalist system no significant effects on ecological impact.
Lin, Marinova & Zhao (2009)	China	1978-2006	STIRPAT	Population, urbanisation, industrialisation, GDP per capita and energy intensity large (-) effect on environmental impact.
Poumanyvong & Kaneko (2010)	World	1975-2005	STIRPAT	Urbanisation ↓ energy use in low-income group. Urbanisation ↑ energy use in middle & high-income groups. Urbanisation → emissions (+) for all income groups.
Wang, Wei, Wu & Zhu (2013)	China	1980-2010	STIRPAT	Population, urbanisation, GDP per capita, industrialisation and service level ↑ CO_2 emissions. Technology, energy consumption structure and foreign trade degree ↓ CO_2 emissions.

Notes: definitions of notation ↑, ↓, indicates that the variable respectively increases or decreases the dependent variable. (+) and (-) indicate whether the variables have a positive or negative relationship.

Table 3: Descriptive Statistics 1980-2013

Variables	Obs	Mean	SD	Min	Max
lEnergy	714	4.01	1.24	1.18	7.97
lPop	714	17.32	1.58	14.95	21.03
lInd	712	3.53	0.22	2.98	4.18
lServ	712	3.98	0.24	3.08	4.37
lUrb	714	4.07	0.37	2.96	4.53
lEduc	670	4.37	0.37	3.32	5.05
lEducsq	670	19.20	3.07	11.05	25.54
lGDP	714	25.89	1.43	22.85	29.88

Table 4: Correlations
Table 4a: Global Panel Correlations 1980-2013

Variables	lEnergy	lPop	lInd	lServ	lUrb	lEduc	lEducsq	lGDP
lEnergy	1							
lPop	0.73	1						
lInd	-0.01	0.12	1					
lServ	0.01	-0.43	-0.76	1				
lUrb	-0.17	-0.69	-0.21	0.65	1			
lEduc	0.03	-0.53	-0.28	0.67	0.84	1		
lEducsq	0.03	-0.54	-0.30	0.67	0.84	1	1	
lGDP	0.88	0.50	-0.21	0.33	0.11	0.27	0.28	1

Table 4b: Developing Countries Panel Correlations 1980-2013

Variables	lEnergy	lPop	lInd	lServ	lUrb	lEduc	lGDP
lEnergy	1						
lPop	0.87	1					
lInd	0.16	-0.03	1				
lServ	-0.22	-0.23	-0.75	1			
lUrb	-0.42	-0.72	0.11	0.30	1		
lEduc	-0.08	-0.35	0.08	0.27	0.73	1	
lGDP	0.90	0.82	0.08	-0.02	-0.32	-0.04	1

Table 4c: Developed Countries Panel Correlations 1980-2013

Variables	lEnergy	lPop	lInd	lServ	lUrb	lEduc	lGDP
lEnergy	1						
lPop	0.89	1					
lInd	-0.23	-0.12	1				
lServ	0.37	0.16	-0.91	1			
lUrb	0	-0.02	-0.06	0.13	1		
lEduc	0.12	-0.17	-0.43	0.53	0.13	1	
lGDP	0.93	0.80	-0.36	0.53	0.08	0.26	1

Table 5: Unit Root Tests

	lEnergy (Levels)			**lEnergy (First Difference)**		
Panel	LLC t*	Breitung t-stat	PP	LLC t*	Breitung t-stat	PP
Global	2.16	2.07	35.68	-14.43***	-8.19***	670.04***
Developed	2.50	2.20	16.25	-11.44***	-7.57***	522.62***
Developing	0.69	1.52	19.43	-9.49***	-4.91***	147.42***
	lEduc (Levels)			**lEduc (First Differences)**		
Panel	LLC t*	Breitung t-stat	PP	LLC t*	Breitung t-stat	PP
Global	0.05	0.37	52.56	-7.02***	-2.94***	165.57***
Developed	1.23	1.49	8.22	-6.00***	-2.58***	87.10***
Developing	-1.19	-0.52	44.34***	-4.19 ***	-1.63***	78.47***

Optimal lag length was selected using the AIC, following Yoo & Kwak (2010). * (**) (*) represent rejection of the null hypothesis of stationarity at the 10%, (5%) and (1%) level of significance.**

Table 6: Pedroni Cointegration Test

Panel	Global		Developed		Developing	
Variables	lEnergy lEduc		lEnergy lEduc		lEnergy lEduc	
Panel Statistics	Statistic	Weighted Statistic	Statistic	Weighted Statistic	Statistic	Weighted Statistic
v-stat	9.03***	5.18***	4.27***	1.59*	7.52***	6.97***
rho-stat	2.54	0.63	0.49	-0.16	2.52	1.55
PP-stat	2.35	0.44	0.37	-0.06	2.46	1.03
ADF-stat	1.95	1.16	-0.16	0.43	2.23	1.54
Group Statistics						
rho-stat	2.64		1.12		2.59	
PP-stat	1.94		0.57		2.14	
ADF-stat	3.56		3.76		1.33	

***** (**) (*) denote statistical significance at the 10% (5%) (1%) levels of significance.**

Table 7: Pairwise Granger Causality Test

Hypotheses	Global	Developed	Developing
lEduc does not Granger cause lEnergy	17.48***	7.28***	7.22***
lEnergy does not Granger cause lEduc	0.48	0.94	1.33

Granger causality carried out using 3 lags. * (**) (*) denote statistical significance at the 10% (5%) (1%) level of significance.**

Table 8: Model Comparison

	OLS	OLS with Year FE	FE	RE
Dependent Variable	lEnergy	lEnergy	LEnergy	lEnergy
lEduc	-3.55	-5.68*	5.75***	5.75***
	(2.53)	(2.51)	(0.60)	(0.60)
lEducsq	0.43	0.64*	-0.59***	-0.60***
	(0.30)	(0.30)	(0.07)	(0.07)
_cons	11.21*	16.49**	-10.03***	-9.36***
	(5.30)	(5.28)	(1.20)	(1.22)
N	670	670	670	670
R-sq.	0.00	0.09	0.74	
Country	No	No	Yes	Yes
Year	No	Yes	Yes	Yes

Standard errors in parentheses

***** (**) (*) denote statistical significance at the 10% (5%) (1%) level of significance.**

Table 9: Global Panel Fixed Effects for lEnergy

Dependent Variable	lEnergy	lEnergy	lEnergy	lEnergy	lEnergy	lEnergy
lEduc	5.75***	3.53***	2.26***	1.97***	1.60**	3.06***
	(0.60)	(0.62)	(0.51)	(0.49)	(0.49)	(0.41)
lEducsq	-0.59***	-0.36***	-0.24***	-0.21***	-0.17**	-0.36***
	(0.07)	(0.08)	(0.06)	(0.06)	(0.06)	(0.05)
lUrb		1.02***	0.95***	0.87***	0.76***	0.65***
		(0.12)	(0.10)	(0.09)	(0.10)	(0.08)
lPop			1.62***	1.19***	1.18***	1.29***
			(0.09)	(0.10)	(0.10)	(0.08)
lInd				0.56***	0.77***	0.17*
				(0.07)	(0.09)	(0.08)
lServ					0.34***	-0.07
					(0.10)	(0.08)
lGDP						0.41***
						(0.02)
_cons	-10.03***	-8.92***	-33.00***	-26.60***	-27.41***	-38.20***
	(1.20)	(1.14)	(1.66)	(1.75)	(1.75)	(1.55)
N	670	670	670	668	668	668
R-sq.	0.74	0.76	0.84	0.86	0.86	0.91
Country	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Standard errors in parentheses						

***** (**) (*) denote statistical significance at the 10% (5%) (1%) level of significance.**

Table 10: Developed Country Panel Fixed Effects for lEnergy

Dependent Variable	lEnergy	lEnergy	lEnergy	lEnergy	lEnergy	lEnergy
lEduc	-0.11	0.04	-0.68***	-0.66***	-0.50***	-0.38***
	(0.16)	(0.15)	(0.11)	(0.10)	(0.09)	(0.09)
lUrb		1.92***	1.91***	1.75***	1.12***	0.98***
		(0.27)	(0.18)	(0.17)	(0.16)	(0.16)
lPop			3.98***	3.74***	3.36***	2.88***
			(0.21)	(0.21)	(0.19)	(0.21)
lInd				0.45***	1.42***	1.17***
				(0.08)	(0.12)	(0.13)
lServ					2.53***	2.25***
					(0.25)	(0.25)
lGDP						0.18***
						(0.04)
_cons	4.68***	-4.34**	-66.54***	-63.87***	-69.52***	-64.43***
	(0.75)	(1.44)	(3.45)	(3.42)	(2.98)	(3.14)
N	331	331	331	329	329	329
R-sq.	0.54	0.61	0.83	0.84	0.89	0.89
Country	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

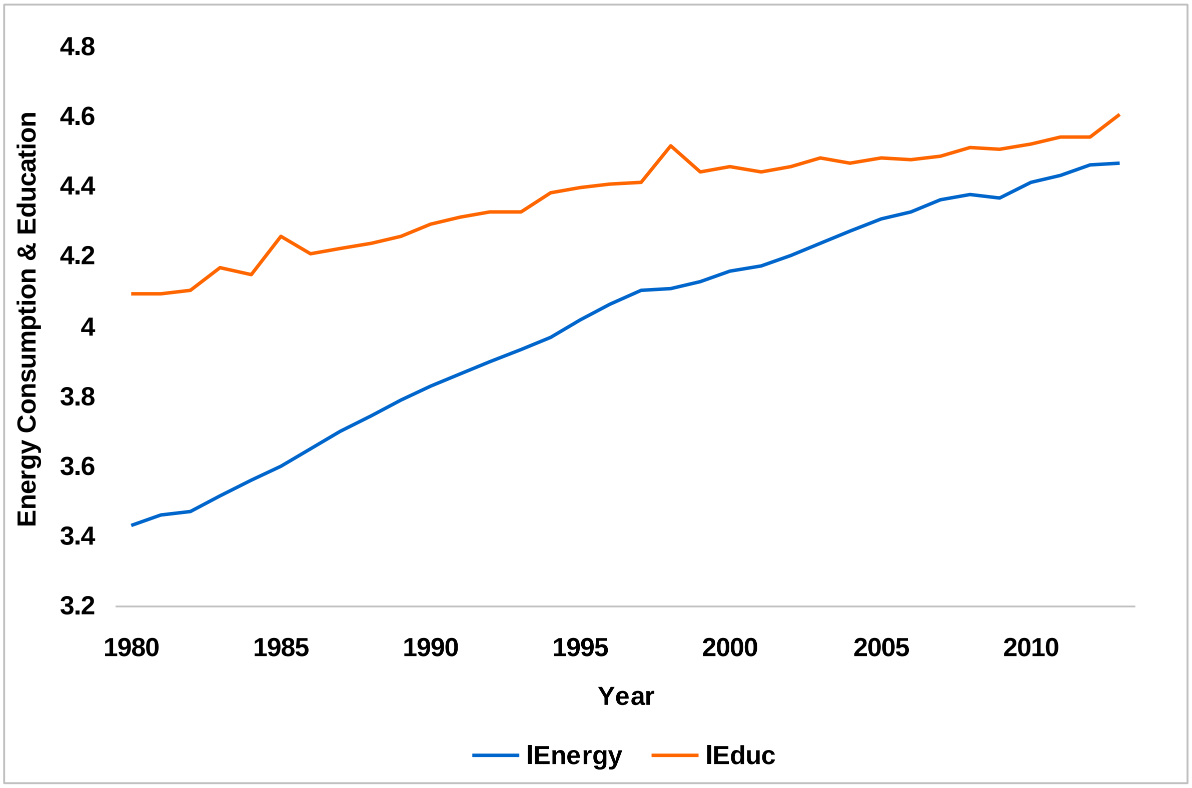
***** (**) (*) denote statistical significance at the 10% (5%) (1%) level of significance.**

Table 11: Developing Country Panel Fixed Effects for lEnergy

Dependent Variable	lEnergy	lEnergy	lEnergy	lEnergy	lEnergy	lEnergy
lEduc	0.93***	0.68***	0.49***	0.38***	0.45***	0.35***
	(0.09)	(0.10)	(0.08)	(0.07)	(0.07)	(0.07)
lUrb		0.78***	0.95***	0.84***	0.72***	0.69***
		(0.15)	(0.12)	(0.11)	(0.11)	(0.10)
lPop			1.63***	1.09***	1.30***	1.24***
			(0.12)	(0.14)	(0.14)	(0.13)
lInd				0.56***	0.98***	0.39**
				(0.09)	(0.12)	(0.13)
lServ					0.65***	0.12
					(0.14)	(0.13)
lGDP						0.32***
						(0.04)
_cons	0.23	-1.73**	-31.14***	-22.41***	-29.95***	-32.65***
	(0.38)	(0.53)	(2.13)	(2.44)	(2.85)	(2.60)
N	339	339	339	339	339	339
R-sq.	0.81	0.82	0.90	0.91	0.91	0.93
Country	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Standard errors in parentheses						

***** (**) (*) denote statistical significance at the 10% (5%) (1%) level of significance.**

Figure 1: Energy Consumption and Education Levels Yearly Average



Source: BP Statistical Review of World Energy (2016) and World Bank (2016). Energy consumption measured as primary energy consumption in million tonnes oil equivalent (mtoe). Education measured as the percentage of population of adequate age enrolled in secondary education. Missing observations for education have been omitted.

Figure 2: Geographic Location of Countries

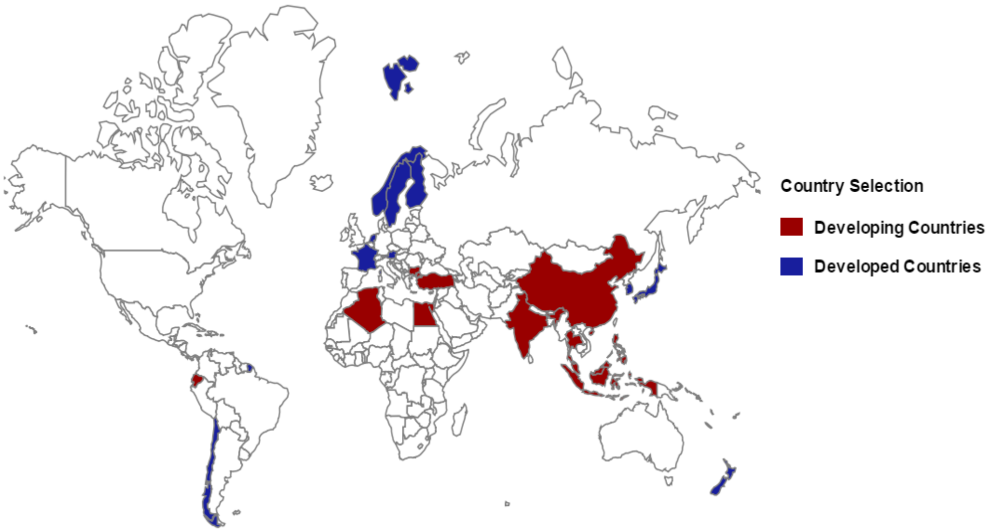


Figure 3: Energy Consumption and Education "Kuznets Curve"

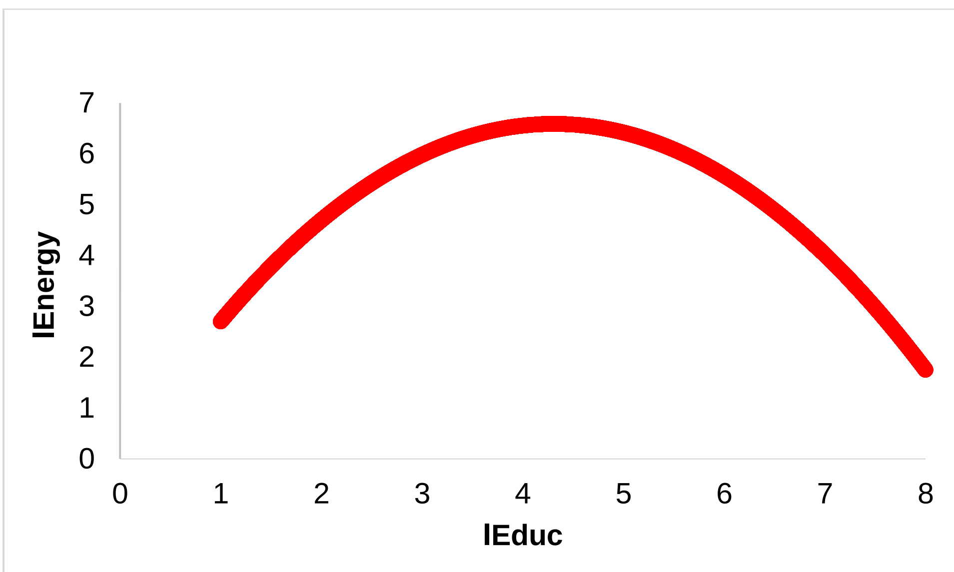


Table A1: Summary of Variables

Variables	Measure
lEnergy	Primary Energy Consumption
lCO2	CO_2 Emissions
lPop	Population
lInd	Industry Percentage Value Added to GDP
lServ	Service Percentage Value Added to GDP
lUrb	Urbanisation
lEduc	total enrolment in secondary education, regardless of age, expressed as a percentage of the population of official secondary age
lEducsq	as total enrolment in secondary education, regardless of age, expressed as a percentage of the population of official secondary age, squared
lGDP	GDP

Notes: l denotes the natural logarithm of the variables, thus all variables are converted into their natural logarithms following Poumanyvong and Kaneko (2010).

Table A2: Countries

Countries	
Developed	Austria, Chile, Finland, France, Japan, Netherlands, New Zealand, Norway, Republic of Korea and Sweden
Developing	Algeria, Bulgaria, China, Ecuador, Egypt, India, Indonesia, Malaysia, Philippines, Thailand and Turkey

Table A3: Pedroni (2000) Test Statistics

Group 1: Within dimension	Group 2: Between dimension
Panel v-statistic	Group Phillips–Perron type rho-statistics
Panel Phillips–Perron type rho-statistics	Group Phillips–Perron type t-statistic
Panel Phillips–Perron type t-statistic	Group ADF type t-statistic
Panel Augmented Dickey–Fuller (ADF) type t-statistic	
Panel v-statistic **(Weighted)**	
Panel Phillips–Perron type rho-statistics **(Weighted)**	
Panel Phillips–Perron type t-statistic **(Weighted)**	
Panel Augmented Dickey–Fuller (ADF) type t-statistic **(Weighted)**	