The University Of Sheffield.

Department Of Economics.

Sheffield Economic Research Paper Series.

The Effect of Energy Consumption and Human Capital on Economic Growth: An Exploration of Oil Exporting and Developed Countries

Fatema Alaali, Jennifer Roberts and Karl Taylor

ISSN 1749-8368

SERPS no. 2015015

June 2015

www.sheffield.ac.uk/economics

The Effect of Energy Consumption and Human Capital on Economic Growth: An Exploration of Oil Exporting and Developed Countries

Fatema Alaali, Jennifer Roberts, Karl Taylor*

Department of Economics, University of Sheffield, UK

June 1, 2015

Abstract

Energy has long been argued as an essential factor for the development of the economy and therefore it should be brought in line with the other production factors of neoclassical economics, capital and labour. Using panel data for 130 countries from 1981 to 2009, this paper explores the impact of multiple forms of energy consumption and human capital on per capita GDP growth. Generalized method of moments is applied to estimate an augmented neoclassical growth model that includes education and health capital as well as energy consumption. The key outcomes from this study show that education and health capital have a significant effect on economic growth. Energy consumption is also found to support higher growth. The results on the differential effects of energy and human capital on the economic growth of the developed and oil exporting countries indicate that energy consumption has a significant positive effect in both types of countries. Education capital affects the developed countries positively while health capital affects the oil exporting countries' economic growth negatively. These results are useful for policy makers, especially in less developed countries encouraging them to implement, for example, compulsory secondary education and child immunizations in order to reach higher standards of living. Moreover, energy must be used more efficiently to ensure sustainable growth.

Keywords: Growth, Education, Health, Human Capital, Mortality Rates, Energy Consumption.
JEL classification: I15, I25, Q43

*Corresponding author E-mail: k.b.taylor@sheffield.ac.uk

1 Introduction

The role of energy consumption in economic growth has been a point of debate since the seminal work of Kraft and Kraft (1978). On the one hand, the assumptions of the neoclassical growth model consider energy as an intermediate input, ultimately produced by the primary factors of production, capital, labour and land. On the other hand, the environmental view treats energy as an essential factor in determining income, which translates into a significant impact of energy consumption on both, net exporters and net consumers of energy (see Cleveland et al., 1984, among others). In line with the second view, Beaudreau (1995) states that previous studies underestimated the role of energy in the process of economic growth and argues that production is not possible without energy consumption. According to Ghali and El-Sakka (2004, p. 226) energy is a "limiting factor to economic growth". Lee and Chang (2008) also agree with this conclusion because economic activities regard energy as a mandatory input in the production process. Pokrovski (2003) states that energy must be deemed not only as a regular intermediate product that adds to the price of produced items, but also a value-creating component that has to be listed as a production factor in line with the fundamental factors, capital (K) and labour (L).

Most previous studies have applied Granger causality or unit root and cointegration techniques to investigate the link between energy consumption and economic growth. There have been contradictory results on causation, as different time spans, variable selection, econometric specification and countries under study affect these outcomes. Most of the studies use time series data, and panel data studies are less common (see Chen et al., 2012, for a review). For example, Niu et al. (2011), who assess the direction of causality between energy consumption, GDP growth and carbon emissions for eight Asian-Pacific countries (four developed and four developing) from 1971-2005 using panel data, conclude that GDP is a source of the increase in energy consumption. However, Narayan and Smyth (2008) who investigate the relationship between capital formation, energy consumption and real GDP on a panel of G7 countries using panel unit root, panel cointegration, panel Granger causality tests and long run structural estimation for the period 1972-2002, find that the three variables are cointegrated and that in the long run, real GDP is positively Granger-caused by capital formation and energy consumption. Lee et al. (2008) examine the relationship between energy consumption and income using an aggregate production function for 22 OECD countries and apply panel cointegration and panel vector error correction models. Their theoretical structure depends on Pokrovski (2003) and Beaudreau (1995), who argue that there is a strong correlation between output and input factors and that the value of production has to be determined by productive energy, capital stock and labour. Sharma (2010) is the only study that has investigated the role of energy in the context of a growth model. The sources that are used to generate energy, as well as the proportion of energy consumed, conceivably differ from one country to another. In addition, not all countries possess the same type of energy sources and some countries may need to import energy products. Therefore, Sharma (2010) utilizes six proxies for energy, as well as other production factors, to gauge the robustness of the relationship between economic growth and energy.[1] Adopting a neoclassical growth model provides a strong theoretical basis for the empirical analysis presented below. Moreover, this approach helps estimate both the short run and long run effects of the variables of interest.

In this paper, we explore the effect of energy consumption on economic growth and our analysis is distinguished from previous studies by three key features. Firstly, we use an augmented neoclassical growth model that incorporates different measures of energy consumption on a panel of 130 countries over the period 1981 to 2009; this allows for greater data variability, less collinearity between the variables and higher degrees of freedom. Alternative proxies for energy consumption allow us to investigate the robustness of the results. The approach that we adopt in this paper is to estimate the short run effects of the variables under concern and report the long run effect through the "catch up term" (the initial value of GDP per capita). In order to correct for the endogeneity that may emerge as a consequence of the reverse causality between energy consumption and economic growth, a generalized method of moments (GMM) estimator is used.

The second key feature of this paper is the investigation of the differential impact of energy consumption on output growth of the developed and oil exporting countries. On the one hand, the level of development of an economy may have an impact on the response of economic growth to the level of energy consumption. For example, Chontanawat et al. (2008) find that energy consumption is a stimulus to economic growth in the developed OECD economies, in contrast with other developing non-OECD economies; which implies that applying a policy of energy consumption reduction to help decrease

[1] The six measures that Sharma (2010) used are: energy use (kg of oil equivalent per capita), energy use (kt of oil equivalent), electric power consumption (kW h), electricity production (kW h), energy production (kt of oil equivalent), and fossil fuel energy consumption (as a percentage of total consumption).

greanhouse gas emissions, will affect the economic growth of the developed countries more than the developing economies. On the other hand, the level of endowments and natural resources that the state owns, and as a consequence the availability of cheap energy sources, may affect economic growth. For example, in the long run, most oil rich countries, show slower growth than less endowed countries. This was explained by Gylfason (2001), who illustrates that countries that are rich with natural resources usually build a false understanding of security and consider this wealth their most significant asset, ignoring investment in other sources of growth represented in inexhaustible resources such as human capital. This may inadvertently lead to neglect of other resources for development, such as expenditure on education, since education persistently expands labour efficiency (Barro, 1996, 1998). To explore these issues, the third feature of this study is to examine the differential impact of various measures of human capital (along with energy consumption) on nations' economic growth.

The results show a significant positive impact of the secondary school enrolment ratio and average years of schooling on economic growth, which suggests that economic development might be aided more by secondary education, than by investment in comprehensive primary education alone. Moreover, improvements in health contribute positively to the economic advancement of nations. Energy consumption also affects economic growth positively in general, as well as having a greater impact on both oil exporting and developed countries.

Section 2 reports the empirical models and the methodology employed, the data and descriptive statistics are in section 3. The results are discussed in section 4, while section 5 concludes the study.

2 Empirical Models and Methodology

Drawing upon Mankiw et al. (1992) and Barro (1996), the growth equation is based upon the neoclassical model. We model GDP per capita $Growth_{it}$ in country $i = (1, \ldots, N)$ over time $t = (1, \ldots, T)$ augmented with a set of $j = (1, \ldots, J)$ controls given in the vector X_{jit} as follows:

$$Growth_{it} = \alpha_0 + \sum_{j=1}^{J} \gamma_j X_{jit} + \sum_{k=1}^{K} \phi_k^c D_k^c \times X_{kit} + \epsilon_{it} \tag{1}$$

The vector X_{jit} includes controls for: initial GDP per capita; total investment as a percentage of GDP; education capital; health capital; energy consumption - which are our primary covariates of interest - and a set of additional covariates, all variables are defined below. The influence of each covariate upon growth is given by the estimate of γ_j.

The model is flexible allowing for differential effects of energy consumption and human capital variables upon economic growth in developed countries and oil exporting countries, whereby we define two dummy variables, allowing for $k = (1, \ldots, K)$ interactions. Firstly, considering whether a country is developed or developing, where $C = DC$, if the country is developed then $D^{DC} = 1$ otherwise $D^{DC} = 0$. Conversely, in the case of whether a country is oil exporting or not, where $C = OC$, if the country is an exporter of oil then $D^{OC} = 1$ otherwise $D^{OC} = 0$. We define country samples in Table A.1. In order to allow for differential slopes, the dummies are interacted with the variables of interest as shown in equation (1).

Initially we estimate a restricted version of equation (1) without incorporating differential effects, i.e. $\phi_k^c = 0$. In terms of whether differential effects exist across different groups of countries, we are explicitly testing the following null hypothesis:

H_0^C: The influence of the regressors on growth is the same across developed and developing countries, $C = DC$ (oil and non-oil producing exporting countries, $C = OC$), i.e. $\phi_k^c = 0$.

Estimating these models by pooled OLS may not be appropriate due to endogeneity. Endogeneity may arise as a consequence of the reverse causality between the explanatory variables, such as energy consumption and human capital, and the growth rate of GDP. In view of this, an instrumental variable (IV)-type estimator, system GMM, that is proposed by Blundell and Bond (1998), is estimated to correct for endogeneity. The system GMM estimator addresses endogeneity by simultaneously solving level and difference equations with the utilization of instruments in first differences for the level equation in addition to the use of instruments in levels for the first difference equations. Lags of endogenous variables are used as instruments. The instruments utilized in the first differenced estimator comprise information about the endogenous variables in first differences and the lagged first differences are informative instruments for the endogenous variables in levels. This will result in capturing the variations between countries' characteristics in addition to controlling for individual heterogeneity. The validity of the instruments is evaluated by utilizing a J test of overidentification restrictions (Hansen, 1982), where the null hypothesis is that the model is valid. However, the authenticity of the instruments is only asserted if the residuals do not manifest second-order serial correlation AR(2) (Arellano and Bond, 1991). The xtabond2 command in STATA 11.2 is used to estimate these models.

3 Data

The basic dataset consists of an unbalanced panel of annual observations from 130 countries over the period 1981 to 2009. The sample contains 22 developed countries[2] and 10 oil exporting developing countries.[3] For the list of countries and subsamples see Table A.1.

All the variables that are used are based on annual data. 5-year averages of the variables are adopted in estimation. Thus, the first observation is the average for the 1981-1985 period, the second observation covers the years 1986-1990, and so on. The last observation only comprises the years 2006-2009. The use of 5-year averages helps decrease measurement error. Temple (1999) and Lindahl and Krueger (2001) underline the diffusion of measurement errors in the indicators of human capital and its effect on empirical estimates of the relationship between economic growth and human capital. Moreover, 5-year averages allow for smoothing temporal fluctuations in annual growth rates, stabilize business cycle variation in output growth and reduce noise in the data (Caselli et al., 1996).

The dependent variable is the average annual growth rate of GDP based on purchasing-power-parity (PPP) per capita GDP in current international dollars from the World Economic Outlook (WEO), September 2011.[4] The annual growth of GDP per capita is obtained by differencing the annual data after taking its natural logarithm. Then the annual growth data are averaged over time. The initial logarithm of income per capita is used to control for the expected reduction in the growth rates as the GDP per capita increases (Barro, 1991, 1996, Keller, 2006, Baldacci et al., 2008).

For the capital stock, we follow the previous literature (Barro, 1991, Levine and Renelt, 1992, Gyimah-Brempong et al., 2006, Baldacci et al., 2008) using total investment

[2] World Economic Outlook (October 2010), Human Development Report 2010, and World Development Indicators (October 2010).

[3] Energy Information Administration (`http://www.eia.gov/countries/index.cfm?topL=exp`)

[4] The World Economic Outlook (WEO) database contains selected macroeconomic data series from the statistical appendix of the World Economic Outlook report, which presents the International Monetary Fund (IMF) staff's analysis and projections of economic developments at the global level, in major country groups and in many individual countries.

as a percentage of GDP from the WEO, which is measured as gross capital formation as a percentage of GDP.

Education capital is measured using gross secondary and tertiary enrollment rates, respectively. These data are obtained from the World Development Indicators (WDI), 2011 in annual form and averaged over each 5-year period.[5] In addition, regressions are also estimated using another measure of schooling, the average years of schooling at secondary and tertiary levels obtained from Barro and Lee (2013), where these data are available in 5-year average form. The enrollment rate captures educational flows, whereas years of schooling are considered to be stocks of education, and the use of both measures provides a check on the robustness of the results.

The health capital variable is the infant mortality rate per 1,000 live births and it is acquired in annual form from the WDI.[6]

For the energy consumption variables, three different measures are employed to enable us to explore the robustness of the relationship between energy consumption and economic growth. The first measure is total primary energy consumption per capita in annual form measured in quadrillion British Thermal Unit (BTU)[7] and extracted from the International Energy Agency webpage.[8] Narayan et al. (2011) also employed data on total primary energy consumption in their study. The other measures are electric power consumption (in KWh) and fossil fuel consumption (% of total consumption) (Sharma, 2010); these two measures are obtained from the WDI.

Other control variables included in the model are population growth, changes in terms of trade and inflation. These variables have been used as determinants of economic growth by Levine and Renelt (1992) and Barro (1996); Keller (2006) and Baldacci et al. (2008) used them as control variables. Terms of trade, as an indicator for the openness of the economy and external competitiveness, is calculated as the ratio of the exports value index to the imports value index, where WDI data are used. The inflation index that

[5]The World Development Indicators (WDI) is the primary World Bank collection of development indicators, compiled from officially-recognized international sources. It presents the most current and accurate global development data available, and includes national, regional and global estimates.

[6]Life expectancy has been used as a health capital measure in some previous studies (e.g Gyimah-Brempong and Wilson, 2004, McDonald and Roberts, 2006) but it is excluded here due to its high multicollinearity with the education measures.

[7]A quadrillion is a unit of energy equal to 10^{15} BTU or 1.055×10^{18} joules in System International units. The unit is used by the U.S. Department of Energy in discussing world and national energy budgets.

[8]Energy Information Administration: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=44&pid=44&aid=2$

captures the impact of inflation and the effects of fiscal-monetary policy is from the WEO.

Table 1 presents the descriptive statistics for the full sample as well as oil exporting, non-oil exporting, developed and developing countries. The infant mortality rate is significantly different across the developed and developing countries. Specifically, the developed countries have a lower infant mortality rate than the developing countries, (6.4 vs. 48.4 per 1000 live births). The average secondary school enrolment ratio is only about 80% in the oil exporting countries, whereas it is higher than 100% in most of the developed countries.[9] The largest dispersion is found in the tertiary education level where the difference between the developed and developing countries is substantial.

Energy consumption is expressed using three different measures, total primary energy consumption per capita, electric power consumption and fossil fuel energy consumption. Average levels of total primary energy consumption per capita and fossil fuel energy consumption for the developed and oil exporting countries are higher than their counterparts.

4 Empirical Results

4.1 The Impact of Human Capital on Economic Growth

Table 2 presents the results of GMM estimation of the restricted model of equation 1 that shows the impact of physical and human capital on the growth of GDP per capita along with the effects of other determinants of economic growth.[10] Equation 1 is initially run without the energy variables to focus on the effect of human capital on economic growth. Particularly, we estimate the model using the two different levels of education, secondary and tertiary with two different measures, specifically, enrolment ratios and average years of schooling; Models I, II and III of Table 2 show the results for the enrolment ratios, and Models IV, V and VI summarize the results for average years of schooling.

The appropriateness of the obtained system GMM results is based on the validity of the instruments used for both equations, in levels and first differences. Panel B of Table 2 shows the results of the J-test of overidentification (Hansen, 1982) and the Arellano and Bond (1991) AR(2) serial correlation test. The p-value of both tests indicate that their null hypotheses cannot be rejected, which confirms the validity of the instruments.

Model I of Table 2 includes the secondary and tertiary enrolment ratios. It can

[9]The gross enrolment ratio can exceed 100% due to the inclusion of over-aged and under-aged students because of early or late school entrance or grade repetition.

[10]These models have also been estimated using OLS and the results are very similar to the GMM results reported in Table 2 and are available upon request from the authors.

be seen that only the secondary enrolment ratio is significant at the 10% level, and it positively affects economic growth. In Models II and III, we have used only one measure of education, secondary and tertiary enrolment ratios, respectively. The two variables are significant at the 5% level when included individually. The estimates imply that if the secondary and tertiary enrolment ratios increase by 1%, the growth rate of GDP per capita will increase by 0.042% and 0.022%, respectively. Both levels of education are important for higher levels of growth, where tertiary education is needed to create technology and secondary education is needed to use the technology in the workplace (Johnson, 1991). Models IV, V and VI summarize the results of another proxy for education capital, secondary and tertiary average years of schooling. The obtained results are consistent with those for enrolment rates, confirming the importance of education capital.

For health capital, measured by the infant mortality rate, all the models of Table 2 show a negative impact of the infant mortality rate on economic growth at a significance level of 10%. These results are consistent with those of McDonald and Roberts (2006).

The coefficient on total investment as a percentage of GDP is positive and highly significant in all the Models of Table 2 suggesting that increases in physical capital cause an increase in per capita GDP growth. Specifically, a 1% increase in the investment ratio results in an average increase in per capita GDP growth of 0.05%. Levine and Renelt (1992) find that the relationship between growth and most of the macroeconomic determinants other than the investment ratio is insignificant.

All the models of Table 2 predict a negative and significant coefficient on the log value of initial GDP per capita. This coefficient shows the conditional rate of convergence. When holding other explanatory variables constant, the economy reaches its long run position at the rate indicated by the magnitude of the coefficient. Most of the models suggest a conditional rate of convergence of approximately 0.05% over 5 years period which is consistent with that of Barro (1991).

The coefficient on population growth appears as expected; it has a negative sign but has an insignificant effect on economic growth in all the models of Table 2. The terms of trade has a positive and significant impact on growth in most of the models, whereas the inflation rate has an inverse effect; it reduces growth. The sign of the control variables accord with the results of Baldacci et al. (2008).

4.2 The Impact of Energy Consumption on Economic Growth

Table 3 reports estimates for models similar to those in Table 2 except that we now concentrate on the effects of total primary energy consumption per capita on economic growth. Comparing the coefficients and significance of the enrolment ratios and average years of schooling in Table 3 with that of Table 2, we find that there is almost no change in the coefficients of the education variables when the energy consumption measure is added. The infant mortality rate becomes insignificant when the average years of schooling and energy consumption are both included.

From the results of Table 3, it can be seen that total primary energy consumption per capita is significant in all the models and it affects growth positively. Specifically, as total primary energy consumption increases by 1% the GDP growth will increase by an average of 0.015%.

Having established the positive effect of total primary energy consumption on economic growth in Table 3, equation 1 is estimated using other measures of energy consumption. Model I of Table 4 is the same as that of Model III of Table 3, but it is reported in Table 4 to facilitate the comparison between the different measures of energy consumption. In Model II of Table 4, electric power consumption is used to proxy energy consumption. It has a positive and significant impact on economic growth. Fossil fuel consumption as a percentage of total consumption is used in Model III. The results show a significant and positive effect on economic growth. GDP per capita growth increases by 0.028% if fossil fuel consumption increases by 1%. These findings provide consistent evidence for the positive and significant effect of energy consumption on economic growth. These results are in line with that of Sharma (2010).

4.3 The Differential Effect of Human Capital and Energy Consumption

To examine the differential effect of being an oil exporting country or a developed country, the D_k^c dummy is included in the model and interacted with the underlying variables as shown in equation 1.

4.3.1 Oil versus Non-Oil Exporting Countries

In Model I of Table 5, human capital and energy consumption variables are interacted with the oil exporting countries dummy D_k^{OC}. The secondary enrolment ratio is used as a proxy for the education capital as it appears from the previous results as the most important level and the infant mortality rate is employed to measure health capital. Energy consumption is measured by total primary consumption per capita.

Focusing on the differential effect of the human capital variables it can be seen that the infant mortality rate has a differential negative impact on growth in these countries.

The energy interaction appears positive and significant. As total energy consumption per capita increases by 1%, GDP per capita growth increases by 0.021%=(0.013+0.008) in oil exporting countries compared to 0.013% in non-oil exporting countries. This significant result may be due to the reliance of the oil exporting countries on natural resource available in running their economies.

4.3.2 Developed Versus Developing Countries

The full sample contains 22 developed countries. Thus, a dummy D_k^{DC} that equals one for the developed countries and zero otherwise is generated. To inspect the differential impact through developed and developing countries, this dummy is interacted with the variables under concern.

Model II of Table 5 shows the results of the differential impact of developed countries, and the coefficient of the education interaction term shows a significant positive impact. To be specific, the GDP per capita growth of developed countries increases by 0.041%=(0.012+0.029) compared to only 0.012% for the developing countries when the secondary enrolment ratio rises by 1%. On average, around half of the economic growth in OECD countries is linked to labour income growth at the higher levels of education. Evidence suggests that 60% of GDP growth in France, Norway, Switzerland and the United Kingdom is estimated to be produced by those who have attained higher education levels (OECD, 2012). The infant mortality rate does not show any differential impact in the developed countries, which is not surprising given that these countries have uniformly low rates of infant mortality. Finally, the total primary energy consumption differential effect appears significant with a positive impact on economic growth of 0.04%=(0.018+0.022) compared to only 0.018% in the developing countries.

5 Conclusion

The primary purpose of this study is to explore the impact of the multiple forms of human capital and energy consumption on per capita income growth. An augmented neoclassical growth model, panel data and different measures for all the key variables under consideration are used. This study estimates the individual effects of secondary and tertiary enrolment ratios as well as average years of schooling. In addition, the effect of health capital on GDP per capita growth is examined. Moreover, total primary energy consumption per capita affects GDP per capita growth positively and significantly.

The consensus from the studies that examine the relationship between the different forms of energy and GDP is that there is cointegration between energy consumption and GDP. The evidence is mixed regarding the direction of causality between energy consumption and income. Kraft and Kraft (1978) find unidirectional causality running from income to energy consumption for the US; as did Al-Iriani (2006) for Gulf Contribution Council (GCC) countries, among others. In contrast, Stern (2000) concludes that a quality-weighted index of energy input Granger-causes GDP growth in the US. Moreover, recent studies have sought to explore the dynamic direction of causality between energy consumption and income using an aggregate production function and argue that energy is an essential factor in production and hence contributes positively to growth (Oh and Lee, 2004, Lee and Chang, 2008). Since energy production and consumption have an impact upon all the components of aggregate demand (investment, exports and imports), energy consumption is considered as an input in the production process and hence in the growth model of this paper.

The contribution of this study is three-fold. First, the joint impact of human capital and energy consumption upon economic growth is examined through an augmented neoclassical growth model, which is estimated using GMM to correct for the endogeneity that may rise due to the reverse causality between energy consumption and economic growth. Second, it investigates the differential effects of both the stock and flow measures of education capital and health capital. Third, it scrutinizes the impact of three different measures of energy consumption and its differential impact on nations' economic growth.

For international policy makers, more and better education should be the top priority because it empowers people to help themselves and this may help to improve governance and reduce corruption (Tumwebaze and MacLachlan, 2012). A concentrated effort for much more secondary education combining national and international forces would appear the most promising route out of poverty and toward sustainable development. Health capital contributes positively in increasing the economic growth of nations, which is consistent with the theory that the healthier is the worker, the more productive. In addition, energy consumption may be planned in a way that keeps the environment clean and decreases the amount of emissions (Lee and Chang, 2008).

Energy consumption per capita has a significantly larger effect in both oil exporting and developed countries than for the countries on average. Secondary education affects the developed countries to a large extent but there is no differential impact on the oil exporting countries. Behbudi et al. (2010) investigate the relationship between human capital and economic growth in a number of petroleum exporting countries and conclude that human capital can be major feature to explain the lag in growth of resource-rich countries. This issue warrants further investigation to explore whether the oil exporting countries use their wealth effectively in augmenting their human capital.

Table 1: **Descriptive Statistics for the full,oil and non-oil exporting and developed and developing countries samples**

	Statistics					
Variable	**Sample**	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
GDP per capita growth	Full	738	372.83	520.88	-2352.4	3904.06
(current international dollars)	Oil	56	338.99	1029.51	-2352.4	3904.06
	Non-oil	682	375.61	455.98	-646.04	3010.42
	Developed	132	889.55	330.11	162.15	2220.64
	Developing	606	260.28	485.77	-2352.4	3904.06
Investment ratio %	Full	744	22.59	7.43	2.96	69.17
	Oil	57	24.8	6.51	9.11	39.94
	Non-oil	687	22.4	7.48	2.96	69.17
	Developed	132	22.04	3.26	16.45	32.24
	Developing	612	22.7	8.05	2.96	69.17
Pop. Growth %	Full	780	1.66	1.55	-4.88	16.65
	Oil	60	2.93	3.14	-2.75	16.65
	Non-oil	720	1.55	1.28	-4.88	11.96
	Developed	132	0.61	0.45	-0.23	1.8
	Developing	648	1.87	1.6	-4.88	16.65
Life expectancy at birth	Full	780	66.61	10.24	28.4	82.59
	Oil	60	69.93	4.67	50.75	77.69
	Non-oil	720	66.34	10.53	28.4	82.59
	Developed	132	77.51	2.18	72.32	82.59
	Developing	648	64.39	9.8	28.4	82.45
Secondary enrolment ratio	Full	698	67.57	32.44	2.98	155.58
(% of population)	Oil	53	79.09	16.41	39.47	106.62
	Non-oil	645	66.63	33.24	2.98	155.58
	Developed	127	104.55	15.41	58.73	155.58
	Developing	571	59.35	29.35	2.98	109.96
Tertiary enrolment ratio	Full	679	23.46	21.5	0	96.97
(5 of population)	Oil	57	26.05	17.65	3.66	78.43
	Non-oil	622	23.22	21.82	0	96.97
	Developed	126	48.7	19.47	12.14	93.11
	Developing	553	17.71	17.42	0	96.97
Average years of secondary	Full	780	2.23	1.44	0.02	7.76
schooling	Oil	60	2.64	1.28	0.73	5.84
	Non-oil	720	2.2	1.45	0.02	7.76
	Developed	132	3.69	1.18	1.13	7.76
	Developing	648	1.94	1.31	0.02	5.91
Average years of tertiary	Full	780	0.33	0.3	0.004	1.71
schooling	Oil	60	0.45	0.32	0.04	1.58
	Non-oil	720	0.33	0.3	0.004	1.711
	Developed	132	0.68	0.34	0.14	1.71
	Developing	648	0.26	0.24	0.004	1.58
Total primary energy consumption	Full	751	96.77	141.12	0.46	1173.89
per capita (quadrillion Btu)	Oil	56	290.22	289.01	41.4	1173.89
	Non-oil	695	81.19	107.88	0.46	744.53
	Developed	132	209.77	96.46	49.02	592.92
	Developing	619	72.68	137.43	0.46	1173.89
Electric power consumption	Full	695	105000	365000	8.15	4130000
($KWh \times 10^6$)	Oil	58	115000	233000	3010	990000
	Non-oil	637	104000	375000	8.15	4130000
	Developed	132	331000	703000	3410	4130000
	Developing	563	51600	186000	8.15	3020000
Fossil fuel energy consumption	Full	650	68.92	28.46	3.02	102.07
(% of total)	Oil	58	97.84	3.41	87.74	100.03
	Non-oil	592	66.09	28.26	3.02	102.07
	Developed	132	75.02	18.92	18.54	97.72
	Developing	518	67.37	30.24	3.02	102.07

Notes: The gross enrolment ratio can exceed 100% due to the inclusion of over-aged and under-aged students because of early or late school entrance or grade repetition.

Table 2: **GMM results of the baseline model of GDP growth from 1981 to 2009**

Regressors	**Model I** Coef.	Std.Err	**Model II** Coef.	Std.Err	**Model III** Coef.	Std.Err	**Model IV** Coef.	Std.Err	**Model V** Coef.	Std.Err	**Model VI** Coef.	Std.Err
constant	-0.218	(0.152)	-0.276	(0.236)	-0.112	(0.217)	0.159	(0.324)	0.175	(0.240)	0.304	(0.254)
Initial GDP	-0.038***	(0.014)	-0.059**	(0.024)	-0.050**	(0.022)	-0.069***	(0.025)	-0.058***	(0.017)	-0.061***	(0.020)
Investment	0.056***	(0.018)	0.108***	(0.029)	0.076***	(0.017)	0.052**	(0.025)	0.058***	(0.017)	0.089***	(0.016)
Pop. growth	-0.002	(0.002)	-0.006	(0.004)	-0.001	(0.003)	-0.005	(0.008)	-0.004	(0.005)	-0.011*	(0.006)
Sec. Enrol	0.035**	(0.016)	0.034**	(0.015)								
Tert. Enrol	-0.004	(0.008)			0.023**	(0.011)						
Sec. Y. Sch							0.068**	(0.031)	0.048***	(0.014)		
Tert. Y. Sch							-0.035	(0.024)			0.018**	(0.008)
Mortality	-0.020*	(0.011)	-0.036*	(0.019)	-0.025*	(0.014)	-0.059**	(0.029)	-0.031*	(0.016)	-0.037*	(0.020)
Terms of trade	0.077***	(0.015)	0.104***	(0.034)	0.082***	(0.019)	0.089***	(0.021)	0.057**	(0.026)	0.035	(0.031)
Inflation	-0.088***	(0.028)	-0.038*	(0.023)	-0.033***	(0.012)	-0.025	(0.074)	-0.072	(0.059)	-0.148**	(0.068)
Observations	370		478		535		426		426		426	
Countries	119		125		125		127		127		127	
Panel B: Diagnostic tests												
J-test	27.79		22.95		26.34		21.50		13.96		10.59	
J, p-value	0.183		0.151		0.285		0.121		0.175		0.226	
AR(2)	-1.05		0.42		-1.24		0.26		-0.86		-1.45	
AR(2), p-value	0.295		0.676		0.213		0.794		0.388		0.146	

Notes: ***, **, * denote statistical significance at 1%, 5% and 10% respectively. J test is overidentification test (Hansen, 1982) that follows a χ^2 distribution with a null hypothesis of valid instruments. AR(2) is the second order serial correlation test in the residuals proposed by Arellano and Bond (1991). The models have varying sample sizes due to differential availability of years of data; the models of this Table have been estimated with the same number of observations for all the models to check whether the missing data are affecting the results. No difference in the results is found, these results are available upon request.

Table 3: **GMM results of the baseline model of GDP growth including total energy consumption from 1981 to 2009**

Panel A: Results of estimation

	Model I		**Model II**		**Model III**		**Model IV**		**Model V**		**Model VI**	
Regressors	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std.Err
constant	-0.259*	(0.137)	-0.093**	(0.200)	0.098***	(0.267)	-0.140	(0.154)	-0.328	(0.241)	0.050	(0.247)
Initial GDP	-0.040***	(0.012)	-0.063***	(0.017)	-0.064***	(0.020)	-0.045***	(0.011)	-0.034**	(0.014)	-0.058**	(0.023)
Investment	0.081***	(0.020)	0.096***	(0.025)	0.079***	(0.023)	0.065***	(0.011)	0.076***	(0.016)	0.091***	(0.023)
Pop. growth	0.002	(0.002)	0.002	(0.003)	-0.0004	(0.002)	-0.006	(0.006)	-0.003	(0.003)	-0.001	(0.008)
Sec. Enrol	0.017*	(0.009)	0.042**	(0.021)								
Tert. Enrol	-0.001	(0.005)			0.022**	(0.011)						
Sec. Y. Sch							0.038*	(0.021)	0.024*	(0.012)		
Tert. Y. Sch							-0.009	(0.009)			0.012	(0.012)
Mortality	-0.016**	(0.007)	-0.020**	(0.010)	-0.017**	(0.008)	-0.005	(0.009)	0.004	(0.013)	-0.014	(0.015)
Tot. En./Capita	0.012*	(0.006)	0.015*	(0.008)	0.019***	(0.007)	0.015**	(0.007)	0.014*	(0.008)	0.022**	(0.010)
Terms of trade	0.073***	(0.025)	0.049**	(0.020)	0.040	(0.029)	0.067***	(0.024)	0.080**	(0.036)	0.044	(0.030)
Inflation	-0.039*	(0.021)	-0.105**	(0.054)	-0.063**	(0.031)	-0.110	(0.069)	-0.107*	(0.064)	-0.126*	(0.069)
Observations	426		522		502		426		426		426	
Countries	122		125		125		127		127		127	

Panel B: Diagnostic tests

	Model I	Model II	Model III	Model IV	Model V	Model VI
J-test	32.35	20.45	26.18	22.53	19.73	15.17
J, p-value	0.260	0.117	0.200	0.127	0.182	0.126
AR(2)	-0.55	-0.48	-1.43	-0.97	-0.80	-1.53
AR(2), p-value	0.585	0.634	0.151	0.331	0.423	0.127

Notes: ***, **, * denote statistical significance at 1%, 5% and 10% respectively. J test is overidentification test (Hansen, 1982) that follows a χ^2 distribution with a null hypothesis of valid instruments. AR(2) is the second order serial correlation test in the residuals proposed by Arellano and Bond (1991).

Table 4: **GMM results of the model of GDP growth including energy consumption (3 measures) from 1981 to 2009**

Panel A: Results of estimation						
	Model I		**Model II**		**Model III**	
Regressors	Coef.	Std.Err	Coef.	Std.Err	Coef.	Std.Err
constant	-0.093**	(0.200)	-0.611*	(0.328)	-0.314	(0.238)
Initial GDP	-0.063***	(0.017)	-0.054**	(0.024)	-0.039***	(0.015)
Investment	0.096***	(0.025)	0.094**	(0.042)	0.055*	(0.031)
Pop. growth	0.002	(0.003)	-0.0005	(0.003)	-0.001	(0.003)
Sec. Enrol	0.042**	(0.021)	0.054**	(0.021)	0.035**	(0.018)
Mortality	-0.020**	(0.010)	-0.0001	(0.023)	-0.007	(0.014)
Tot. En./Capita	0.015*	(0.008)				
Elec. Consum.			0.012**	(0.006)		
Fossil fuel					0.028**	(0.013)
Terms of trade	0.049**	(0.020)	0.072***	(0.022)	0.067**	(0.026)
Inflation	-0.105**	(0.054)	-0.083**	(0.042)	-0.137**	(0.066)
Observations	522		446		313	
Countries	125		115		107	
Panel B: Diagnostic tests						
J-test	20.45		18.14		13.39	
J, p-value	0.117		0.255		0.572	
AR(2)	-0.48		-0.03		-0.32	
AR(2), p-value	0.634		0.973		0.751	

Notes: ***, **, * denote statistical significance at 1%, 5% and 10% respectively. J test is overidentification test (Hansen, 1982) that follows a χ^2 distribution with a null hypothesis of valid instruments. AR(2) is the second order serial correlation test in the residuals proposed by Arellano and Bond (1991).

Table 5: **GMM results for the oil exporting and developed countries via interaction terms**

Panel A: Results of estimation				
	Model I		**Model II**	
Regressors	Coef.	Std.Err	Coef.	Std.Err
Constant	-0.117	(0.113)	-0.036	(0.099)
Initial GDP	-0.025***	(0.009)	-0.038***	(0.009)
Investment	0.064***	(0.012)	0.070***	(0.011)
Pop. growth	-0.003	(0.003)	-0.001	(0.003)
Sec. Enrol	0.018**	(0.009)	0.012**	(0.005)
Mortality	0.008	(0.008)	0.001	(0.008)
Tot. En./capita	0.013*	(0.007)	0.018***	(0.006)
Terms of trade	0.012	(0.010)	0.019***	(0.007)
Inflation	-0.045**	(0.019)	-0.061***	(0.013)
$D^{OC} \times Sec.Enrol.$	0.002	(0.008)		
$D^{OC} \times Mortality$	-0.021**	(0.009)		
$D^{OC} \times Tot.En./capita$	0.008*	(0.005)		
$D^{DC} \times Sec.Enrol.$			0.029***	(0.011)
$D^{DC} \times Inf.Mort$			0.021	(0.013)
$D^{DC} \times Tot.En./capita$			0.022**	(0.009)
Observations	395		395	
Countries	124		124	
Panel B: Diagnostic tests				
J-test	40.81		28.97	
J, p-value	0.230		0.467	
AR(2)	-1.29		-0.98	
AR(2), p-value	0.198		0.326	

Notes: ***, **, * denote statistical significance at 1%, 5% and 10% respectively. J test is overidentification test (Hansen, 1982) that follows a χ^2 distribution with a null hypothesis of valid instruments. AR(2) is the second order serial correlation test in the residuals proposed by Arellano and Bond (1991).

Table A.1: **List of countries included in the samples**

		Full Sample			Developed	Oil-Exporting
Algeria	Czech Republic	Iran	Mozambique	Slovenia	Australia	Algeria
Argentina	Cte d'Ivoire	Italy	Namibia	South Africa	Austria	Kazakhstan
Armenia	D. Republic of Congo	Jamaica	Nepal	Spain	Belgium	Kuwait
Australia	Denmark	Japan	Netherlands	Sri Lanka	Canada	Libya
Austria	Dominican Republic	Jordan	New Zealand	Sudan	Denmark	Iran
Bahrain	Ecuador	Kazakhstan	Niger	Swaziland	Finland	Qatar
Bangladesh	Egypt	Kenya	Norway	Sweden	France	Russia
Barbados	El Salvador	Korea	Pakistan	Switzerland	Germany	Saudi Arabia
Belgium	Estonia	Kuwait	Panama	Syria	Greece	UAE
Belize	Fiji	Kyrgyz Republic	Papua New Guinea	Tajikistan	Iceland	Venezuela
Benin	Finland	Latvia	Paraguay	Tanzania	Ireland	
Bolivia	France	Lesotho	Peru	Thailand	Italy	
Botswana	Gabon	Libya	Philippines	The Gambia	Japan	
Brazil	Germany	Lithuania	Poland	Togo	Netherlands	
Brunei Darussalam	Ghana	Luxembourg	Portugal	Tunisia	New Zealand	
Bulgaria	Greece	Malawi	Qatar	Turkey	Norway	
Burundi	Guatemala	Malaysia	Republic of Congo	Uganda	Portugal	
Cambodia	Guyana	Maldives	Yemen	Ukraine	Spain	
Cameroon	Haiti	Mali	Romania	UAE	Sweden	
Canada	Honduras	Malta	Russia	UK	Switzerland	
C. African Republic	Hong Kong SAR	Mauritania	Rwanda	USA	United Kingdom	
Chile	Hungary	Mauritius	Saudi Arabia	Uruguay	United States	
China	Iceland	Mexico	Senegal	Venezuela		
Colombia	India	Moldova	Sierra Leone	Vietnam		
Croatia	Indonesia	Mongolia	Singapore	Zambia		
Cyprus	Ireland	Morocco	Slovakia			

References

Al-Iriani, M. A. (2006). Energy–GDP relationship revisited: an example from GCC countries using panel causality. *Energy Policy 34*(17), 3342–3350.

Arellano, M. and S. Bond (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies 58*(2), 277–297.

Baldacci, E., B. Clements, S. Gupta, and Q. Cui (2008). Social spending, human capital, and growth in developing countries. *World Development 36*(8), 1317–1341.

Barro, R. J. (1991). Economic growth in a cross section of countries. *The Quarterly Journal of Economics 106*(2), 407–443.

Barro, R. J. (1996). Determinants of economic growth: A cross-country empirical study. *NBER Working Paper* (w5698).

Barro, R. J. (1998). Human capital and growth in cross-country regressions. In *Economic Growth-Literature Surveys. Downloadable at http://hassler-j. iies. su. se/conferences/papers/barro. pdf (January 18, 2006).*

Barro, R. J. and J. W. Lee (2013). A new data set of educational attainment in the world, 1950–2010. *Journal of Development Economics 104*, 184–198.

Beaudreau, B. C. (1995). The impact of electric power on productivity: a study of US manufacturing 1950–1984. *Energy Economics 17*(3), 231–236.

Behbudi, D., S. Mamipour, and A. Karami (2010). Natural resource abundance, human capital and economic growth in the petroleum exporting countries. *Journal of Economic Development 35*(3), 81.

Blundell, R. and S. Bond (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics 87*(1), 115–143.

Caselli, F., G. Esquivel, and F. Lefort (1996). Reopening the convergence debate: a new look at cross-country growth empirics. *Journal of Economic Growth 1*(3), 363–389.

Chen, P.-Y., S.-T. Chen, and C.-C. Chen (2012). Energy consumption and economic growth−new evidence from meta analysis. *Energy Policy 44*, 245–255.

Chontanawat, J., L. C. Hunt, and R. Pierse (2008). Does energy consumption cause economic growth?: Evidence from a systematic study of over 100 countries. *Journal of Policy Modeling 30*(2), 209–220.

Cleveland, C. J., R. Costanza, C. Hall, and R. Kaufman (1984). Energy and the US economy: A biophysical perspective. *Science 225*, 890.

Ghali, K. H. and M. I. El-Sakka (2004). Energy use and output growth in Canada: a multivariate cointegration analysis. *Energy Economics 26*(2), 225–238.

Gyimah-Brempong, K., O. Paddison, and W. Mitiku (2006). Higher education and economic growth in Africa. *The Journal of Development Studies 42*(03), 509–529.

Gyimah-Brempong, K. and M. Wilson (2004). Health human capital and economic growth in Sub-Saharan African and OECD countries. *The Quarterly Review of Economics and Finance 44*(2), 296–320.

Gylfason, T. (2001). Natural resources, education, and economic development. *European Economic Review 45*(4), 847–859.

Hansen, L. P. (1982). Large sample properties of generalized method of moments estimators. *Econometrica: Journal of the Econometric Society*, 1029–1054.

Johnson, S. D. (1991). Productivity, the workforce, and technology education. *Journal of Technology Education 2*(2), 32–49.

Keller, K. R. (2006). Investment in primary, secondary, and higher education and the effects on economic growth. *Contemporary Economic Policy 24*(1), 18–34.

Kraft, J. and A. Kraft (1978). Relationship between energy and GNP. *J. Energy Dev.;(United States) 3*(2).

Lee, C.-C. and C.-P. Chang (2008). Energy consumption and economic growth in Asian economies: a more comprehensive analysis using panel data. *Resource and Energy Economics 30*(1), 50–65.

Lee, C.-C., C.-P. Chang, and P.-F. Chen (2008). Energy-income causality in OECD countries revisited: The key role of capital stock. *Energy Economics 30*(5), 2359–2373.

Levine, R. and D. Renelt (1992). A sensitivity analysis of cross-country growth regressions. *American Economic Review 82*(4), 942–963.

Lindahl, M. and A. B. Krueger (2001). Education for growth: Why and for whom? *Journal of Economic Literature 39*(4), 1101–1136.

Mankiw, N. G., D. Romer, and D. N. Weil (1992). A contribution to the empirics of economic growth. *The Quarterly Journal of Economics 107*(2), 407–437.

McDonald, S. and J. Roberts (2006). Aids and economic growth: A human capital approach. *Journal of Development Economics 80*(1), 228–250.

Narayan, P. K., S. Narayan, and R. Smyth (2011). Energy consumption at business cycle horizons: The case of the United States. *Energy Economics 33*(2), 161–167.

Narayan, P. K. and R. Smyth (2008). Energy consumption and real GDP in G7 countries: new evidence from panel cointegration with structural breaks. *Energy Economics 30*(5), 2331–2341.

Niu, S., Y. Ding, Y. Niu, Y. Li, and G. Luo (2011). Economic growth, energy conservation and emissions reduction: A comparative analysis based on panel data for 8 Asian-Pacific countries. *Energy policy 39*(4), 2121–2131.

OECD (2012). How does education affect the economy? In *OECD, Education at a Glance 2012: Highlights, OECD Publishing, Paris.*

Oh, W. and K. Lee (2004). Causal relationship between energy consumption and GDP revisited: the case of Korea 1970–1999. *Energy Economics 26*(1), 51–59.

Pokrovski, V. N. (2003). Energy in the theory of production. *Energy 28*(8), 769–788.

Sharma, S. S. (2010). The relationship between energy and economic growth: empirical evidence from 66 countries. *Applied Energy 87*(11), 3565–3574.

Stern, D. I. (2000). A multivariate cointegration analysis of the role of energy in the US macroeconomy. *Energy Economics 22*(2), 267–283.

Temple, J. (1999). The new growth evidence. *Journal of Economic Literature 37*, 112–156.

Tumwebaze, C. and M. MacLachlan (2012). Motivating the teacher workforce in Uganda. *Humanitarian work psychology*.