The world energy production, consumption and productivity in the energy sector, population and the per capita growth: Regression analysis

Josheski, Dushko; Lazarov , Darko ; Koteski, Cane and Sovreski V. , Zlatko
Goce Delcev University-Stip

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Dushko Josheski(dushkojosheski@gmail.com),Darko Lazarov (darko.lazarov@ugd.edu.mk), Zlatko V.Sovreski (zlatkosovre@yahoo.com),Cane Koteski (cane.koteski@ugd.edu.mk) [1]

Abstract

In this paper was investigated the relationship between GDP per capita growth and Log of energy production, energy consumption per capita, the log of productivity in energy sector and population. Data covered sample for 220 countries and world regions, years covered from 1980 to 2002.The results showed that if energy consumption increases by 1% GDP per capita growth will decline by 0,57%, if energy production will rise by 1% growth will rise by 1,51%, if population rise by 1% growth will decline by 0,098%, although this coefficient is statistically here below significance. If productivity in energy sector rise by 1% growth will rise by 1,32%.

Key words: Energy, economic growth, population, sustainable growth

[1] “Goce Delcev” University –Stip ,

Introduction

Energy is a key input for the production of goods and services. Physical capital uses energy to provide its contribution to production. Energy prices exert a wide influence on overall price level. This sector is open to innovations and a heavily investor in R&D.

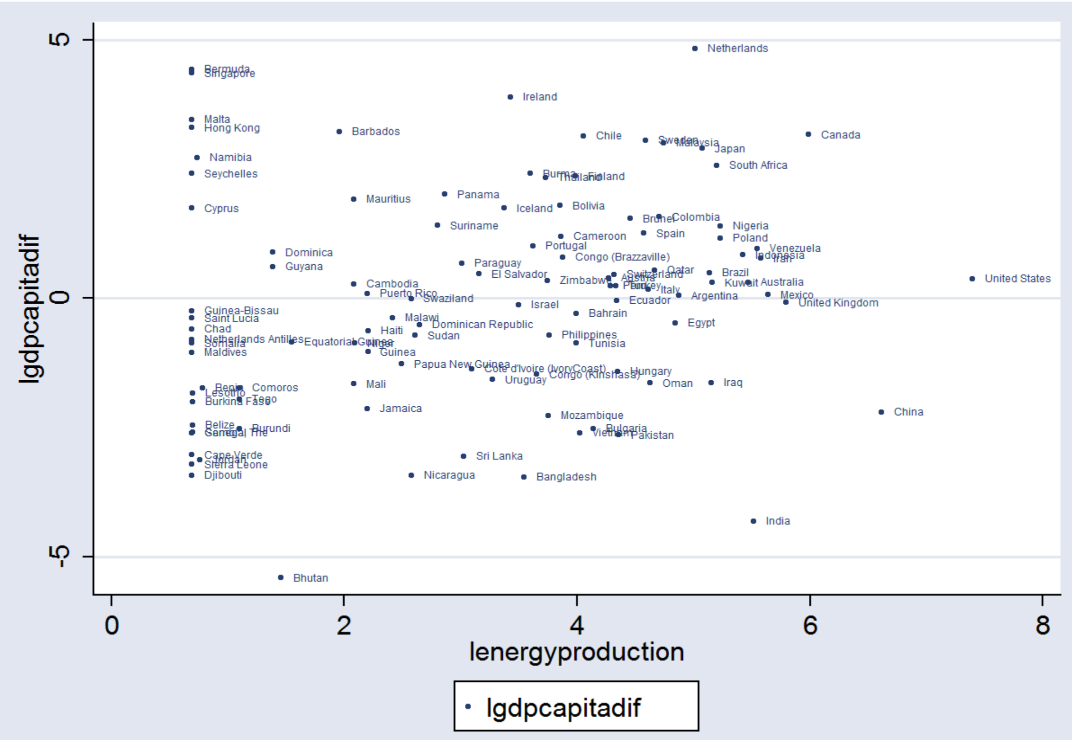
In this sector cost structure exhibits strong economies of scale. Large firms cover most of the market which turns out to be concentrated oligopoly. In some areas there even exists monopoly. Electrical grid of countries is usually a monopoly.

Energy is traded on a globalized market, with national regulations and taxation.

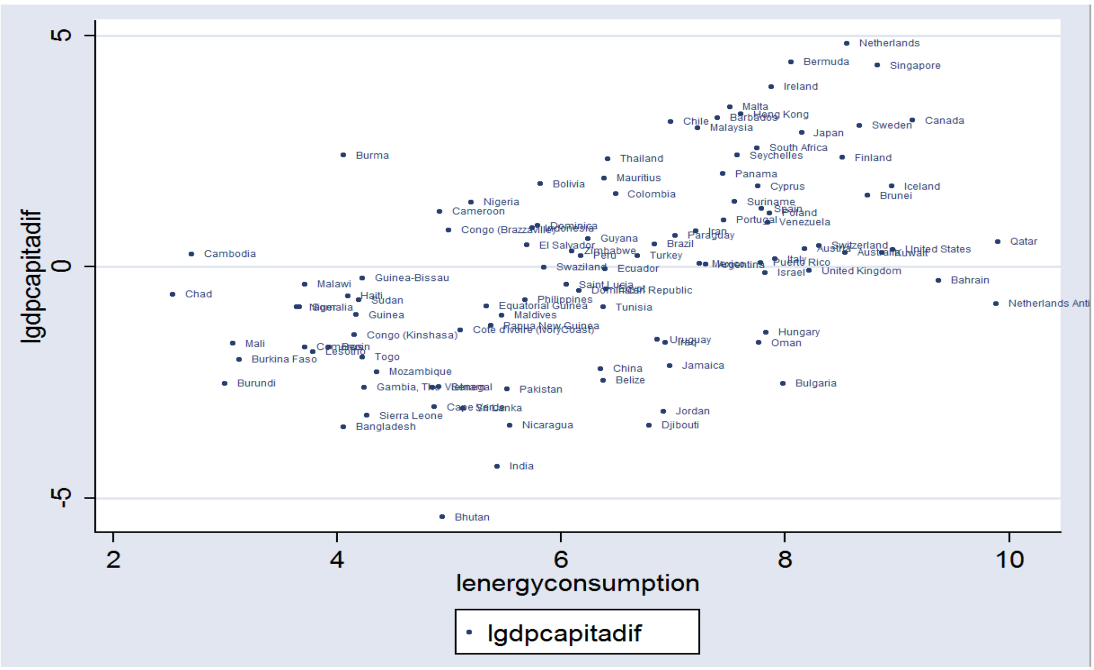
Demand for energy is more or less proportional to GDP.

Energy productivity (i.e. the coefficient of energy for unit of output in a given sector) depends on the technology used. For instance, the energy needed for civil buildings is very high in skyscrapers and much lower in ecological architecture. In developed countries, rich and poor tend to consume the same amount of domestic electricity, so this expenditure item is irrelevant (in percentage) for the latter and (possibly) relevant for the former. Energy saving has been a frequent moral imperative, quite irrespective of the actual price of energy.

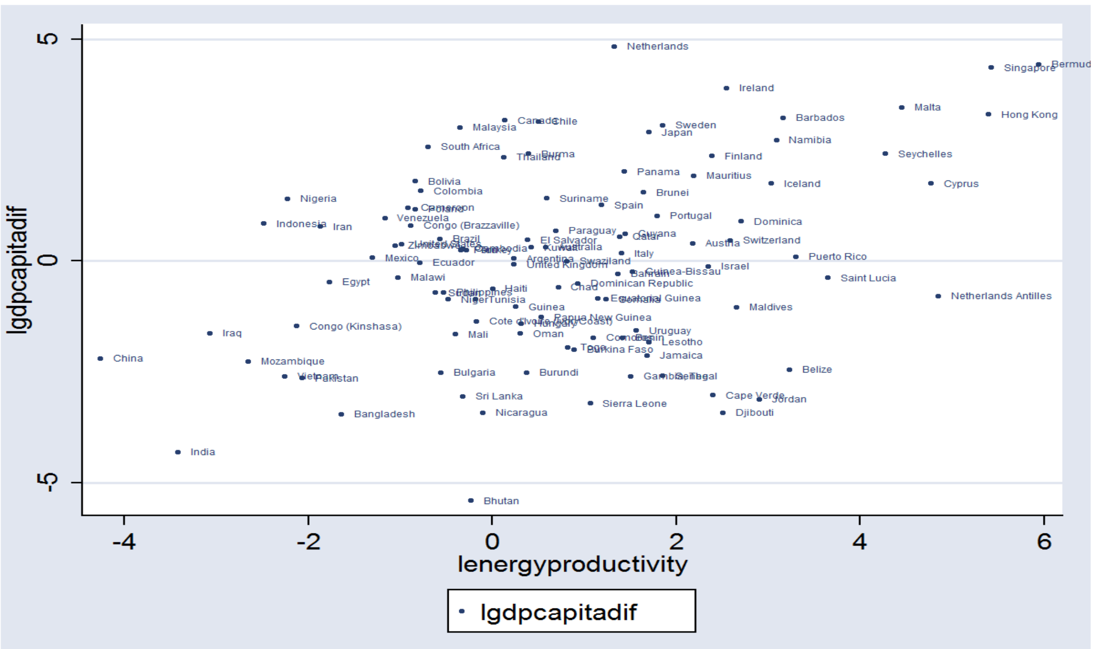
On the next scatter log of growth of real GDP capita is on Y axis and on X axis log of energy production. On a scale from 0 to 8(it’s a log) United States are the biggest producer of energy in the world. Netherlands has biggest growth of real GDP per capita from 1980 to 2002.



On the next graph log of energy consumption and log of growth of GDP per capita are scattered and the results show that Qatar has highest consumption of energy in the world. Qatar has low level of growth from 1980 to 2002 but spends a lot of energy this means that growth is not necessarily positively correlated with spending of energy resources.



About the productivity in energy production sector next scatters shows that countries with higher average growth of GDP per capita have higher productivity ,Singapore, Bermuda, and Hong Kong, have highest productivities in energy sector also are highest growing economies from 1980 to 2002.



A note on sustainable growth

On the next Table it is given part of a strategy for the energy consumption nowadays choices are given in the red column these are non-ecological choices while their environment friendly alternatives are given in the green column[2].

coal	solar, wind and wave power
natural gas	biodiesel (especially from algae)
nuclear power	hydrogen storage of electrical energy (including fuel cells)
wood	increased efficiency
bio-ethanol	‘electranet’ with smart technology to manage electricity use
biodiesel (using arable land or food crops)	reduced distribution distances
tidal power (when damaging estuaries)	
hydrogen produced from fossil fuels	

“In some cases, the surprise element is only a matter of timing: an energy transition, for example is inevitable; the only questions are when and how abruptly or smoothly such a transition occurs. An energy transition from one type of fuel (fossil fuels) to another (alternative) is an event that historically has only happened once a century at most with momentous consequences.”

US National Intelligence Council 2008[3]

This quotation from US National Intelligence Council shows that the transition on one type of fuel to environmentally good alternative is not an easy process, this notion is historically confirmed.

[2] Wakeford, J., (2007), Peak Oil and South Africa: Impacts and Mitigation, Association for the Study of Peak Oil & Gas – South Africa

[3] LLOYD’S 360 RISK INSIGHT , WHITE PAPER ON SUSTAINABLE ENERGY SECURITY

Data and methodology

In this paper data were gathered from International energy annual [4].This sample of data covers period from 1980 to 2002. Data covers 220 countries and regions.

Definitions of our variables are given in the next table

pop	World Population, 1980-2002 (Millions)
gdp	World Gross Domestic Product at Market Exchange Rates, 1980-2002 (Billions of 1995U.S.Dollars)
gdpcap	World Per Capita Gross Domestic Product at Market Exchange Rates, 1980-2002 (Thousand 1995 U.S.Dollars)
encap	World Per Capita Total Primary Energy Consumption,1980-2002 (Million Btu)
enprod	World Total Primary Energy Production (Quadrillion Btu), 1980-2002 (Quadrillion (10 15) Btu)

Standard OLS technique will be applied to the data. This is because panel methods were not available since, some countries have missing data and STATA would not run regressions with insufficient observations. The model is log-log, this enables us to estimate the elasticities. Data were compiled and afterwards aggregated. About the log-log model:
Consider the following model, known as the **exponential regression model** :

$$Y_i = \beta_1 X_i^{\beta_2} e^{u_i}$$

Alternatively this expression becomes :

$$\ln Y = \alpha + \beta_2 \ln X_i + u_i$$

Ln is natural logarithm with base e=2,718

In practice one may use common logarithms, that is, log to the base 10. The relationship between the natural log and common log is: ln*e* *X* = 2.3026 log10 *X*. By convention, ln means natural logarithm, and log means logarithm to the base 10; hence there is no need to write the

[4] **http://www.eia.doe.gov/emeu/international/other.html#IntlGDP**

subscripts *e* and 10 explicitly.

One attractive feature of the log-log model, which has made it popular in applied work, is that the slope coefficient $\beta 2$ measures the **elasticity** of *Y* with respect to *X*, that is, the percentage change in *Y* for a given (small) percentage change in *X*.

The elasticity coefficient, in calculus notation, is defined as

$$(dY/Y)/(dX/X) = [(dY/dX)(X/Y)].$$

We can readily see that β_2 is in fact the elasticity coefficient.

$$d(\ln X)/dX = 1/X \text{ or } d(\ln X) = dX/X,$$

that is, for infinitesimally small changes (note the differential operator *d*) the change in ln *X* is equal to the relative or proportional change in *X*. In practice, though, if the change in *X* is small, this relationship can be written as: change in ln *X* = relative change in *X*, where = **.**means approximately. Thus, for small changes:

$(\ln X_t - \ln X_{t-1}) = (X_t - X_{t-1})/X_{t-1}$ = relative change in X

(1) **absolute change,** (2) **relative** or **proportional change,** and (3) **percentage change,** or **percent growth rate.** Thus, $(X_t - X_{t-1})$ represents absolute change,

(2) $(X_t - X_t{-1})/X_{t-1} = (X_t/X_{t-1} - 1)$ is relative or proportional change and

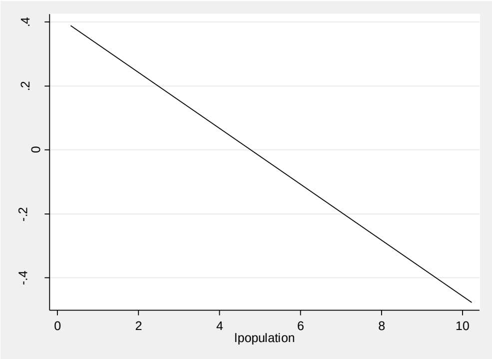
(3) $[(X_t - X_{t-1})/X_{t-1}]100$ is the percentage change, or the growth rate. X_t and X_{t-1} are, respectively, the current and previous values of the variable *X*.

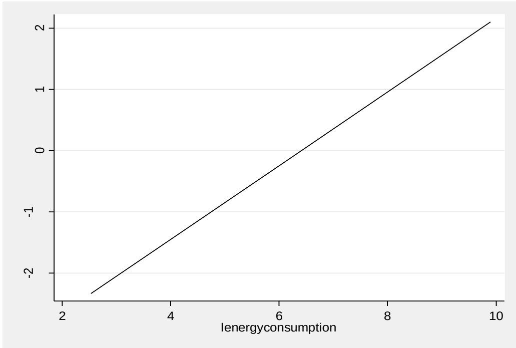
Interpretation of B_1 in log-log model is:

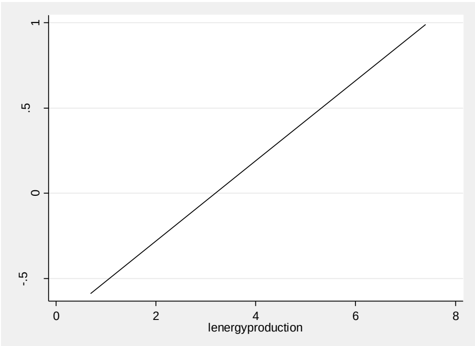
$$\%\Delta y = \beta_1 \%\Delta x$$

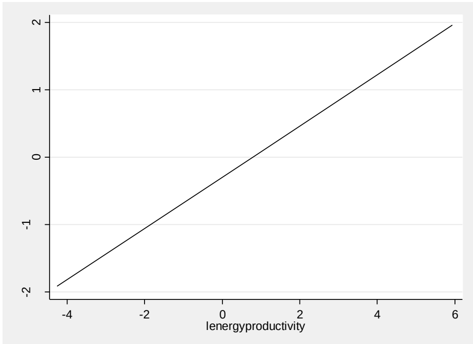
OLS estimation

OLS technique is best known among researchers, we explained earlier why we don't use panel estimators instead we will run OLS only. This estimation gives BLUE (best linear unbiased estimators).









With the command twoway lfit we can see the trend lines with respect to lgdpcapitadif (log of growth of real gdp percapita, first difference of gdp per capita). We can see that energy production and energyconsumption along with energyproductivity variable are positively trended with log of growth of real GDP per capita. Population is negatively trended with logarithm of growth of real GDP per capita.

Descriptive statistics

Descriptive statistics of the model is presented in the next table.

Variable	Obs	Mean	Std. Dev.	Min	Max
lgdpcapita~f	107	-.0182755	2.077313	-5.407699	4.836458
lenergycon~n	184	6.489993	1.736774	2.533697	10.30097
lenergypro~n	192	2.727752	1.735636	.6931472	7.399549
lpopulation	188	4.11219	2.561367	-3.036554	10.22373
lenergypro~y	153	.7332956	1.918405	-4.260581	5.938327

Here lgdpcapita~f is log of first difference(growth) of real GDP per capita, lenergycon~n is log of energy consumption, lenergypro~n is log of energy production, lpopulation is log of population, lenergypro~y is log of energy productivity, i.e ratio of output divided by energy total production.

Correlation matrix

Even correlation matrix shows that correlation between log of population and log of first difference real GDP per capita is negative. Log of energy productivity is high negatively correlated with log of population, and also negative correlated with log of energy production. Here we have 106 observations.

(obs=106)

	lgdpca~f	lpopul~n	le~ption	le~ction	lenerg~y
lgdpcapita~f	1.0000				
lpopulation	-0.0783	1.0000			
lenergycon~n	0.5142	-0.0990	1.0000		
lenergypro~n	0.2197	0.6908	0.4419	1.0000	
lenergypro~y	0.3466	-0.7345	0.3406	-0.6268	1.0000

Correlations move from small to medium which means that autocorrelation is not a problem in our data. Next table confirms this fact.

Variable	VIF	1/VIF
lenergypro~n	3.94	0.253493
lpopulation	3.87	0.258447
lenergycon~n	1.91	0.524375
Mean VIF	3.24	

The only variable that has high VIF is log of energy productivity; this is because this variable is derived from log of energy production variable.

Dependent variable : Log of real gdp per capita growth	OLS ESTIMATES		
Variables	Variables definitions	Coefficients	p-value
lenergycon~n	log of energy consumption	-0.57	0.011
lenergypro~n	log of energy production	1.51	0.000
lpopulation	Log of population	-0.098	0.448
lenergypro~y	Log of energy productivity	1.32	0.000
_cons	Constant	-1.65	0.081
Ramsey RESET test	**Ho: model has no omitted variables**		0.1734
F(4, 101) = 22.38			0.0000

From this table we can interpret the elasticities , i.e. if energy consumption increases by 1% GDP per capita growth will decline by 0,57%, if energy production will rise by 1% growth will rise by 1,51%, if population rise by 1% growth will decline by 0,098%, although this coefficient is statistically here below significance. If productivity in energy sector rise by 1% growth will rise by 1,32%. Ramsey reset test implies that functional form of the model is correctly specified, F-test shows that there is 0% probability of type I error if we reject the null hypothesis of joint insignificance of the variables. [5]

[5] See Appendix 1 OLS estimation of the model.

Appendix 1 OLS estimation of the model

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      Source |       SS       df       MS              Number of obs =     106
-------------+------------------------------           F(  4,   101) =   22.38
       Model |  211.370338     4  52.8425844           Prob > F      =  0.0000
    Residual |  238.443728   101  2.36082899           R-squared     =  0.4699
-------------+------------------------------           Adj R-squared =  0.4489
       Total |  449.814066   105  4.28394349           Root MSE      =  1.5365

------------------------------------------------------------------------------
lgdpcapita~f |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lenergycon~n |   -.563877   .2181807    -2.58   0.011    -.9966888   -.1310652
lenergypro~n |   1.511669   .2874716     5.26   0.000      .941403    2.081936
 lpopulation |  -.0989483     .12976    -0.76   0.448    -.3563573    .1584607
lenergypro~y |   1.319955   .2116355     6.24   0.000     .9001269    1.739783
       _cons |  -1.654565   .9374573    -1.76   0.081    -3.514228    .2050983
------------------------------------------------------------------------------
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```
. estat ovtest

Ramsey RESET test using powers of the fitted values of lgdpcapitadif
       Ho:  model has no omitted variables
                  F(3, 98) =      1.69
                  Prob > F =      0.1734
```

References

1. Wakeford, J., (2007), Peak Oil and South Africa: Impacts and Mitigation, Association for the Study of Peak Oil & Gas – South Africa

2. LLOYD'S 360 RISK INSIGHT , WHITE PAPER ON SUSTAINABLE ENERGY SECURITY

3. European Commission: "Green Paper towards a European strategy for the security of energy supply".

4. U.S. Energy Information Administration, Independent Statistics& Analysis, http://www.eia.gov/emeu/international/other.html#IntlGDP

5. International Energy Agency, http://www.iea.org/stats/index.asp