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NATIONAL ENERGY EFFICIENCY

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Abstract

This paper employs cross country regression analysis to try to pinpoint a few factors that may be of relevance for national energy efficiency so that more effective national energy efficiency policy can be undertaken, and, to test to see whether or not the presupposition commonly held by many policy makers, that improvements in national energy efficiency lead to reductions in the intensity of country energy use , can be empirically verified. With regard to the determinants of national energy efficiency, the paper exams three variables. They are the share of agriculture to GDP, the ratio of energy usage to energy production, and the size of the government relative to the economy. The findings of the paper suggest, first, that each of these three variables seem to be important for national economic efficiency, and, second, that raising national energy efficiency does indeed appear to lower the intensity of national energy usage.

Keywords: Energy efficiency, national energy policy, determinants of national energy efficiency, intensity of energy use, energy production, level of economic development, government size

INTRODUCTION

The purpose of this paper is first, to try to empirically identify a few of the potential determinants of national energy efficiency across countries, and second, to investigate whether improvements in national energy efficiency reduce the intensity of energy usage. If some of the sources of energy efficiency can be discovered, it places politicians, policy makers, and intellectuals in a better position to more effectively devise and implement policies to enhance energy efficiency. If increased energy efficiency is associated with reduced energy use, then improvements in national energy efficiency are valuable not just in and of their selves, but also because of their favorable impact on energy use.

Reducing energy usage is important for a number of reasons. First, the struggle to control important nonrenewable sources of energy, such as coal and oil, that will eventually but most certainly disappear, is a source of intense world rivalry and conflict. Lessening the demand for energy dampens this unwanted international friction. Second, the use of energy in the production and consumption of goods is a major cause of environmental problems. By reducing their energy use, countries can lower the environmental deterioration associated with energy usage. Third, smaller energy use lowers the degree of national energy dependence. Merely due to large energy imports, a lot of nations are forced to run substantial trade deficits.

Although there are likely to be many other factors, here, three factors are considered to be of consequence in determining differences in the level of overall national economic efficiency between countries. The first is the level of economic development. Quite naturally, higher levels of economic development are predicted to be positively associated with national economic efficiency. More developed countries have greater human capital, more scientists and technicians, higher quality infrastructure, and necessary wealth and financial means to readily incorporate energy savings into production and consumption processes.

The second factor is national relative scarcity of energy in terms of the national demand for energy relative to production. Greater national energy usage relative to national production makes energy within a nation more scarce. As individuals respond rationality to circumstances, It is predicted that greater national energy scarcity causes greater search and implementation of energy saving techniques leading to greater national energy efficiency.

The third factor is the size of the government relative to the economy. It is anticipated that bigger government leads to a reduction in national energy efficiency. The assumption is that the private sector, which is subject to competition and runs under the profit motive, is, in general, in most endeavors, more efficient than the public sector. As a greater government share in the economy necessarily means a smaller private share in the economy, a higher government share in economic activity is predicted to lessen national energy efficiency. An additional reason is that, a lot of the time, government focus is on equity and political issues with economic efficiency only a secondary concern.

The investigation of the paper is divided into five sections. The first section reviews some of the basic literature on national economic efficiency. The second section provides a simple theoretical framework for looking at potential determinants of national energy efficiency, and for testing whether national energy efficiency is relevant for energy usage. The next section details the variables used in the empirical analysis. The paper's core comes in fourth section. It shows the results of cross country regressions of national energy efficiency on three selected

explanatory variables, and of the regressions of the intensity of energy use on energy efficiency. The fifth and last section concludes by looking at some of the policy implications.

PREVIOUS LITERATURE ON ENERGY EFFICIENCY

Using panel tobit regression analysis, Pan, Zhang, and Zhang, look at the determinants of energy efficiency in Chinese industry using a panel of twenty eight Chinese provinces for the time period 2000 to 2006 (Pan, Zhang, and Zhang 2013). They employ a measure of energy efficiency, which they develop using data envelopment analysis, that incorporates the negative environmental externality of the volume of industrial waste gas that is generated in energy use in industrial production. They consider four potential determinants of energy efficiency, the extent of market orientation in the province, GDP per capita in the province, per capita investment in research and development in industry in the province, and the percentage of coal consumed as fuel in the province. In general, their results suggest that marketization, per capita GDP, and the percentage of research and development investment are directly related to energy efficiency, while the percentage of coal consumption is negatively related to energy efficiency.

Metcalf investigates potential drivers of energy efficiency in the U.S. using cross state data from 1970 to 2001 (Metcalf 2008). He considers a number of potential drivers of energy efficiency including energy prices, per capita income, climate, population growth, the capital to labor ratio, and the ratio of investment to the capital stock. Metcalf performs regressions not just utilizing the total state consumption to state personal income as the sole dependent variable , but also the two main components from decomposition analysis , the component attributable to shifts in usage or activity and the component due to changes in efficiency. One of his main conclusions is that higher per capita income and higher prices lead to greater energy efficiency.

Costa-Campi, Garcia-Quevedo, and Segarra do a study of the determinants of energy efficiency looking at firm level data (Costa-Campi, Garcia-Quevedo, and Segarra 2014). They run probit regressions on a sample consisting of 5721 Spanish manufacturing firms that innovated in either products or processes from the Community Innovation Survey covering the period 2008-2011. They find that the importance of energy efficiency of Spanish innovating firms depends significantly on the size of a firm, the level of a firm's investment, its percentage of exports to total sales, but does not depend on a firm's investment in research and development, or on the public funding obtained by a firm for research and development activities.

Greater market orientation may be a favorable force for improving energy efficiency in a national economy. Fan, Liao, and Wei, by comparing the Chinese economy's energy own price

elasticity and various elasticity of substitutions between energy and non-energy factors in a period prior to the Chinese acceleration in market oriented economic reforms , 1979-1992, and a period after the reforms, 1993 -2003, find evidence that greater marketization contributes to enhancement in energy efficiency (Fan, Liao, and Wei 2006).

Kaufmann's econometric analysis looks at data for the US to consider whether some non-price factors may be relevant for energy efficiency (Kaufmann 2004). He finds that the composition of the fuel mix used to generate the energy supply, and the percentage of household energy expenditure to GDP, are important for energy efficiency.

Given the sectorial shift from the manufacturing to the service sector commonly associated with higher levels of economic development, energy efficiency in the service sector is, in all likelihood , going to assume a more prominent role in total energy efficiency with the passage of time. Mulder, de Groot, and Pfeiffer address energy efficiency in the service sector (Mulder, de Groot, and Pfeiffer 2014). They look at trends , undertake a decomposition analysis, and perform panel regression analysis on a unique data set consisting of twenty three service sectors and subsectors in eighteen countries from 1980 through 1985. They find strong evidence for convergence, with higher growth rates in energy productivity in sectors with lower initial energy productivity. They also find that that climate, in terms of number of heating and cooling days, typically has an impact on energy productivity in the various service sectors, that information and communication technology is statistically relevant for energy productivity in a few service sectors, and, that energy prices surprisingly do not generally appear to be of consequence for energy productivity in the service sectors.

Using a panel consisting of cross section and time series data to try to uncover potential sources of energy efficiency, Ines and Martinez, specify and then estimate a CES style production function energy efficiency equations for the food industry in two countries, Germany and Colombia (Ines and Martinez 2010). They find that energy prices and capital inputs are statistically relevant for enhancing energy efficiency in Germany, but not in Columbia, and that, in Colombia, the size of enterprise and labor input are statistically important for energy efficiency .

Energy efficiency policy in actual practice is also discussed in the literature. Zhou, Levine, and Price outline the Chinese energy efficiency policy undertaken in 2006 that was designed to stem the tremendous increase in energy to GDP in China during the years 2002 through 2005 (Zhou, Levine, and Price 2009). Some of the features of the program include a sizable government fund for energy efficient investments, incentives for energy efficient improvements, and increased monitoring and enforcement of energy efficiency compliance.

While most people are interested in augmenting national energy efficiency merely on the basis of its intrinsic worth, there is some controversy in the literature whether or not increases in

national energy efficiency bring about reduced energy consumption thereby diminishing environmental problems. Herring maintains that the rebound effect of higher energy efficiency, the notion that increased energy efficiency causes the price of energy to fall resulting in increased energy consumption, overwhelms any possible reduction in energy consumption due to increased energy efficiency (Herring 2006).He feels the stress on energy efficiency as a solution to environmental problems, although it may be politically convenient, is misplaced, and that any real solution to environmental difficulties needs to address ways of limiting or reducing energy consumption.

THE THEORETICAL FRAMEWORK

The theoretical organizing framework for discussing national economic efficiency is composed of just two equations in functional form. The equations with their hypothesized partial derivatives are as follows.

1. $E = f(U, S, G)$ $\delta E/\delta U < 0$, $\delta E/\delta S > 0$, $\delta E/\delta G < 0$
2. $I = g(E, Y)$ $\delta I/\delta E < 0$, $\delta I/\delta Y > 0$

In the equations, E is national energy efficiency, U is the extent of underdevelopment, S is the scarcity of energy in terms of energy demand relative to productive availability, G is the government share in the economy, I, the intensity of energy usage per person, and Y is GDP or income per person.

The first equation is a national energy efficiency equation. The left hand side of this equation is a measure of overall national energy efficiency while the right hand side consists of three potential explanatory factors, underdevelopment, energy use relative to production, and the size of government.

The partial derivative of national energy efficiency on the extent of underdevelopment is hypothesized to be negative. The lack of development is almost certain to be a hindrance to efficient energy usage. Less developed countries lack the technical skill, the infrastructure, and the capital needed for efficient use of energy.

National energy efficiency is theoretically predicted to be positively related to the second national energy determining factor, energy scarcity in terms of energy use relative to production. The relative scarcity or abundance of a product always affects behavior. The lack of availability of any product relative to its usage, and energy is no exception, is apt to lead to economizing on the use of the product and the pursuit of ways for getting more out of any given unit of the product, while, on the other hand, the relative abundance of a product relative to demand is likely to cause more of a devil may care profligate use of a product.

The third and last explanatory variable is the size of the government relative to the economy. It is theoretically anticipated that national economic efficiency will be negatively related to the share of the government in the economy. Unlike the private sector, the government is not subject to the fierce forces of competition that necessitate continual cost cutting and efficiency measures for survival, but, rather, the government is often subject to political pressures that run counter to its efficient operation such as the maintenance of a large featherbedding bureaucracy.

The second equation in theoretical model is the intensity of energy use equation. The first argument in this equation is energy efficiency itself. It is theoretically speculated that intensity of energy use is indirectly related to national economic energy efficiency. The reason is that improvement in energy efficiency allow nations to produce the same level of output (or even more) with less energy than they used before.

The second argument in the energy intensive use equation is income per capita. the partial derivative of intensity of energy usage with regard to income per capita is anticipated to be positive. Energy is presumed to be a normal good so that improvement in the standard of living leads to greater energy use.

In sum, the intensity of energy usage is hypothesized to depend on energy efficiency and on GDP per capita. Energy use per person is theorized to be negatively related to national energy efficiency but positively related to income per person.

Overall, if the little two equation model has validity, if it is true that improvement in energy efficiency lowers national energy usage, then controlling the determinants of energy efficiency to increase energy efficiency is a valuable policy option for reducing the intensity of energy usage with all its associated negative consequences.

THE VARIABLES

All of the variables are annual variables for the year 2010. National economic efficiency is measured by GDP per energy use (purchasing power parity dollars per kg of oil equivalent). The degree of underdevelopment is quantified by using the percentage of agriculture to GDP. The scarcity of energy, of demand relative to availability, is proxied by using the ratio of energy use (kt of oil equivalent) to energy production (kt of oil equivalent). The size of the government relative to the economy is captured by employing the percentage of government consumption to GDP. The intensity of energy use per person is computed by dividing energy use (kt of oil equivalent) by the population. Finally, country income per person is measured by using GDP per capita. The data on all of the variables comes from the World Development Indicators of the World Bank (World Bank 2014).

EMPIRICAL RESULTS

Cross Country Regressions of Energy Efficiency on Potential Energy Efficiency Determinants

Table I shows the results of cross country regressions of overall national energy efficiency on the measure of the level of economic underdevelopment, the percentage of agricultural production to GDP (AGRSHARE), on an index of energy domestic availability relative to demand, the ratio of energy use to energy production (USETOPROD), and on the share of the government in the economy (GOVTSHARE). The table contains three equations. The first shows the findings from regressing national energy efficiency using the agricultural share as the sole explanatory variable. The second adds energy usage to production as an additional explanatory variable. The third is the regression of national energy efficiency on all three independent variables, agricultural share (AGRSHARE), energy usage to production (USETOPROD), and the share of the government in the economy (GOVTSHARE).

Table I: Cross Country Regressions of National Energy Efficiency on Agricultural Share (Agrshare), Energy Usage to Production (Usetoprod), Energy Usage Per Person (Useperperson) and Government Share (Govtshare)

	(1)	(2)	(3)
CONSTANT	10.43 (22.21) *	9.99 (21.69) *	13.60 (11.05) *
AGRSHARE	-.1632 (-4.96) *	-.1453 (-4.60) *	-.2018 (-5.88) *
USETOPROD		.0323 (3.73) *	.0293 (3.58) *
GOVTSHARE			-.1843 (-3.06) *
RSQ	.177	.268	.342
N	116	116	114

The table is organized in the following way. The first column lists the explanatory variables. The three remaining columns show the findings, one regression per column, of three separate regression runs. The regressions are numbered in the first row. The body of the table contains the estimated coefficients and their individual t-statistics. The top element for a given variable row and for a given equation column is the estimated coefficient for that variable in that equation. The individual t-statistic is right below the estimated coefficient in parenthesis. Variables that are significant at the one percent level of significance or better in an equation are

marked with an asterisk under t-statistic. The second to last row shows the R-squared values and the last row the sample size, the number of countries entering a regression equation .

The estimated coefficient on percentage share of agriculture to GDP is negative and is significant at the one percent level or better in every one of the three equations. As agricultural share is a gauge of the level of underdevelopment, the negative estimated coefficient implies, just as theoretically envisioned, that greater levels of economic underdevelopment reduce national energy efficiency while greater levels of economic development enhance overall national economic efficiency.

The regression findings also lend support to the contention that greater energy usage relative to energy production results in greater national energy efficiency. In the two equations that it appears, equations (2) & (3), the ratio of energy usage to energy production (USETOPROD) is positive and significant at the one percent level of significance.

Lastly, the empirical evidence in table I indicates, in line with theoretical expectations, that bigger government size relative to the economy (smaller private sector size) has a negative impact on national economic efficiency. The percentage share of the government to GDP (GOVTSHARE) is negative and significant at the one percent level significance in the single equation that it enters, equation (3).

When used in combination (Equation 3), the three variables explain over thirty four percent of the cross country variation in national energy efficiency in a sample of one hundred and fourteen countries.

What about the consequences of national energy efficiency? Does increased national energy efficiency reduce the intensity of energy use? Table II provides the results of regressions of the intensity of energy use on energy efficiency (ENERGYEFFICIENCY), and of the intensity of energy use on energy efficiency (ENERGYEFFICEINCY) in combination with income per capita (GDPPC).

Table Ii: Regressions of Energy Use Per Person on National Energy Efficiency

	(1)	(2)
CONSTANT	.0042 (6.45) *	.0025 (7.54) *
ENERGYEFFICIENCY	-.00018 (-2.66) *	-.00029 (-8.24) *
GDPPC		.00000013 (19.90) *
RSQ	.052	.789
N	131	131

The regression findings lend support to the contention that greater national energy efficiency diminishes the intensity of energy use. The coefficient on national energy efficiency is negative and significant at the one percent level of significance whether used alone as an explanatory variable in the first equation of table II or when adjusting for income in the second equation. National energy efficiency and per capita GDP when used in combination in the second equation explain over seventy eight percent of the cross country variation in national energy use per person.

CONCLUSION

Modern economies run on energy. Most of the energy of the world is provided by the use of non-renewable sources that are rapidly depleting and quickly becoming more scarce. In such a world, the need for sustaining high levels of energy efficiency and for improving energy efficiency is more and more paramount.

The cross country empirical analysis of the paper identifies three factors that matter for overall national energy efficiency. They are the level of economic development, energy usage relative to production, and the government economic share.

Policy wise, these findings provide an initial starting place for considering some possible inroads for improving economic efficiency.

First, promoting economic development around the world is favorable for energy efficiency. Developing countries, that are highly agricultural and who have made little headway in making the modernizing transition from agriculture to industry, waste a lot of energy per unit of output. With the increased energy efficiency that comes with greater economic development, developing countries can achieve the same level of output and income than before with less energy use, or, more importantly, achieve a higher level output and income using no more energy than before.

Second, higher energy usage relative to energy production in a national economy appears to make a nation more energy scarcity conscious resulting in greater national economizing on energy. Thus, In terms of policy, in countries in which the opposite is true, that is, in countries in which energy production to energy usage is relatively high, it would be favorable for national energy efficiency for these countries to try to pursue policies that make it artificially appear not to be the case, as, for instance, by taking such actions as taxing energy usage in consumption and in production resulting in higher energy prices.

Third, either the size of the government needs to be reduced for improvement in national energy efficiency, so that greater benefits from the more energy efficient private sector are captured, or policies must be devised to make the government itself more efficient and more

energy efficient conscious. As energy efficiency goes hand in hand with output efficiency, reducing corruption, and assuring that the government hires highly qualified and education personnel, that is, hires the best and the brightest, is likely to be favorable for increased government energy efficiency. The government tendency to be grandiose, based on egotistical or legitimizing reasons , must be kept in check. Government allocating scarce resources to impressive but massively energy using projects, buildings and structures, some of which are merely for housing questionable bureaucratic activities, needs to be avoided.

Finally, in terms of future research, more studies need to be undertaken focusing on politically viable and acceptable ways for countries to achieve greater energy efficiency. Further empirical analysis looking for variables potentially important for national energy efficiency ought to be pursued. New creative effective energy efficiency policies have to be developed, promoted, and implemented. Potential alternative paths that countries may take to achieve greater energy efficiency need to be identified, better understood, and clearly delineated.

REFERENCES

Costa-Campi, Maria Teresa, Jose Garcia-Quevedo, and Agusti Segarra. 2014. "Energy Efficiency Determinants: An Empirical Analysis for Spanish Innovative Firms." Working Paper, IEB 2014/4, http://www.ieb.ub.edu/phocadownload/documentostrabajo/doc2014-10.pdf, June 10, 2014.

Fan, Ying, Hua Liao, and Yi-Ming Wei. 2007. "Can Market Oriented Economic Reforms Contribute to Energy Efficiency Improvement? Evidence from China." *Energy Policy*. 35, pp. 2287-2295.

Herring, Horace. 2006. "Energy Efficiency-A Critical view." *Energy*. 31, pp.10-20.

Ines, Clara and Pardo Martinez. 2010. "Analysis of Energy Efficiency Development in the German and Colombian Food Industries." *International Journal of Energy Sector Management*. 4:1, pp.113-136.

Kaufmann, Robert K. 2004. "The Mechanisms for Autonomous Energy Efficiency Increases: A Cointegration Analysis of the US Energy/GDP Ratio." *The Energy Journal*, 25:1, pp. 63-86.

Metcalf, Gilbert E. 2008. "An Empirical Analysis of Energy Intensity and its Determinants at the State Level." 2008. *Energy Journal*. 29:3, pp. 1-26.

Mulder, Peter, Henri L.F. de Groot, and Birte Pfeiffer. 2014. "Dynamics and Determinants of Energy Intensity in the Service Sector: A Cross-Country Analysis, 1980-2005." *Ecological Economics*, 100,pp. 1-15.

Pan, Huifeng, Haiyun Zhang, and Xulu Zhang. 2013. "China's Provincial Industrial Energy Efficiency and its Determinants." *Mathematical and Computer Modelling*, 58, pp. 1032-1039.

World Bank. 2011. World Development Indicators, http://databank.worldbank.org/data/views/variableSelection/selectvariables.aspx?source=world-development-indicators, May 20, 2014.

Zhou, Nan, Mark D. Levine, and Lynn Price. 2010. "Overview of current Energy-Efficiency Policies in China." *Energy Policy*. 38, pp.6439-6452.