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An Exploratory Study of Competitiveness on Energy Consumption based on National Panel Data

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Abstract

This paper combines the results of a panel dataset with 57 national competitiveness factors to explain the effect on their energy consumption from 1997 to 2013. Results from the national panel data model confirm that most of the top perceived competitiveness factors have statistically significant effects on GDP per unit of energy use. According to different country population sizes and development levels, such effects suggest that appropriate policy measures to improve the efficiency of policy approaches may vary depending on the preferred definition of competitiveness. The competitiveness factors *Fiscal Policy* and *Education* are found to be among the most influential factors for China.

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Keyworks: National competitiveness; Energy consumption; Panel data; GDP per unit of energy use

1. Introduction

National competitiveness is an important research topic that continues to attract the attention of researchers. This factor profoundly affects the future development of a country by representing its operation efficiency and core competitiveness. The Global Competitiveness Report [1] of the World Economic Forum defines competitiveness as the set of institutions, policies, and factors that determine the level of productivity of a country,

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and considers national competitiveness as an important determinant for the wellbeing of states in an international trade environment. In 2015, IMD World Competitiveness Center, the publisher of the World Competitiveness Yearbook (WCY), adopts a particular definition of competitiveness that "analyzes how nations and enterprises manage the totality of their competencies to achieve prosperity or profit" [2]. This interpretation is supplemented by an academic definition that defines competitiveness as "A field of Economic knowledge, which analyses the facts and policies that shape the ability of a nation to create and maintain an environment that sustains more value creation for its enterprises and more prosperity for its people". Bris and Caballero [3] proposed a new conceptualization of competitiveness to increase the scope and depth of their study on what makes a country successful in the world economy. IMD World Competitiveness Online provides comparable data series for over 20 years. The Overall Competitiveness Scoreboard is based on four factors, namely, economic performance, government efficiency, business efficiency, and infrastructure. Each of these factors is divided into five sub-factors that highlight every facet of the analyzed areas. Altogether, WCY features 20 such sub-factors and comprise more than 300 criteria. These 20 sub-factors are the core and focus of our research.

Energy efficiency boosts economic growth by reducing energy consumption and achieving sustainable development. Energy consumption, especially energy saving and efficient energy consumption, has also attracted wide research attention.

Based on the current status quo of the main countries in the world, we aim to answer the following questions:

1) What is/are the most essential core competitiveness factor(s) on energy consumption?
2) What are the differences that arise from the variances in population size or national development levels?

With reference to the panel data from WCY, the core competitiveness factors on energy consumption are identified using econometric models. The differences between countries are explored through comparative analysis. The analysis results have theoretical and practical significance in the government governance and public policy-making fields, especially for China.

The rest of this paper proceeds as follows. Section 2 briefly reviews the literature on competitiveness and energy consumption. Section 3 presents the hypotheses and methodology. Section 4 shows the results of the econometric model and further comparative analysis. Section 5 concludes the paper and discusses future research.

2. Literature review

Energy demand and consumption inevitably increase along with economic growth [4]. Many researchers have examined this issue in different countries or regions, including developed [5] and developing countries [6] [7]. The World Bank [8] revealed that the world energy use (kg of oil equivalent per capita) obviously increased by 5.87% from 1792.6 in 2006 to 1897.9 in 2012, thereby leading to massive environmental pollution and greenhouse gas emissions. Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport [8]. Constructing effective approaches for sustainable development and assessing their effectiveness can be of great value to the future of energy policy making and to each country that faces similar challenges. To gain a positive role in reducing global emissions to pace with economic growth, numerous countries have implemented a series of policies or long-term plans. For instance, through its 2008 Climate Change Act [9], the United Kingdom is the first country to set legally binding "carbon budgets" that aim to cut its carbon emissions by 34% in 2020 by investing in energy efficiency and clean energy technologies. The Chinese government also issued the "13th Five-Year Plan" draft outline, which aimed to achieve more than 15% cumulative reduction ratio of GDP per unit of energy use. Energy consumption in China has witnessed explosive growth along with urbanization [10]. Moreover, the rapid economic growth of the country over the past few decades has been accompanied by huge increases in energy demand [11].

National competitiveness is important for any economy that depends on international trade to balance its import of energy and raw materials. The factors of national competeveness and energy consumption, such as urbanization [10], international trade [12], development policies [13], and human development [14], have close relationships. Continuous observations of these factors actually make it possible to analyze them as panel data, which has already drawn attentions from researchers. For example, Lee and Chang [5] applied a new panel data stationarity testing procedure that employed the generalized method of moment techniques to reinvestigate the dynamic interactions between energy consumption per capita and real GDP per capita in 22 developed and 18 developing countries. Dedeoglu and Piskin [15] examined the relationship between energy consumption and GDP per capita through a dynamic panel study. Following this research stream, our study aims to identify the relationship between energy consumption efficiency and national competitiveness using global panel data from 1997 to 2013.

3. Hypothesis and Methodology

3.1. Research Objectives and Hypotheses

Studies on national competitiveness are mostly qualitatively descriptive. We attempt to develop a quantitative approach that can help academics analyze national competitiveness and energy consumption using the econometrically modeled determinants of national competitiveness, and then connect this approach with energy consumption efficiency. GDP per unit of energy use can be viewed as the standard indicator of national energy consumption, represented by the PPP or GDP per kilogram of oil [16].

Our research objectives and hypotheses are proposed as follows. First, we study whether the factors of national competitiveness may affect GDP per unit of energy use and then identify the key competitiveness factors using an econometric model and a panel dataset. Second, we explore the potential moderators or boundary conditions of the main effects of countries, including their (a) population size and (b) development level.

Hypothesis 1 (*H1*): National competitiveness factors are significantly associated with GDP per unit of energy use, and some key factors are determined by using the econometric model and panel data.

Hypothesis 2 (*H2*): The population size of different countries serves as a condition of their main effects. The competitiveness factors on GDP per unit of energy use differ between smaller and larger populations.

Hypothesis 3 (*H3*): The development level of different countries serves as a condition of their main effects. The competitiveness factors on GDP per unit of energy use differ between developing and developed countries.

3.2. Methodology

Data and variables We select the GDP per unit of energy use from the World Bank database as the dependent variable and 20 sub-factors in WCY as the independent variables (Table 1). As pooled time series and cross-sectional data, the panel dataset covers 57 countries (*Appendix A*) (N=57) and 20 competitiveness factors (K=20) in the cross section and, meanwhile, covers the years 1997 to 2013 (*year*=17) in the longitudinal section. Although the panel data have missing values that may lead to imbalance, 90% of the data still comprise complete information. Therefore, we use these data to construct further analysis. Theoretically, the proposed approach shall outperform single cross-sectional data modeling, since panel data analysis also obtains dynamic information from the longitudinal section.

On the basis of population size, 57 countries and regions were divided into 8 large-population countries (> 100 million) and 49 small-population countries (< 100 million). According to the classification standard of the United Nations, 57 of these countries were developed, while the other 25 were developing.

Models Based on the redundant fixed effects-likelihood ratio, the probabilities of cross-sections F and *Chi-square* are less than 0.001, which indicates that the pooled model is invalid. Compared with the fixed-effects regression model (FEM) and random-effects regression model (REM), the correlated random effects–Hausman test rejects the null hypothesis (p value < 0.01) likely due to the correlation between individual effects and regression variables. Considering the effects of independent variables as fixed effects is a relatively reasonable option because the individuals or members in the sample are not randomly selected.

Following models were constructed with the linear model: $y_{it} = \alpha_0 + \alpha_i + \boldsymbol{X}_{it}\boldsymbol{\beta} + u_{it}$, i =1, 2,…57, and t =1, 2,…17, where y_{it} is the dependent variable that is observed for individual i at time t, α_0 is the population-average intercept, α_i is a random intercept term indicating unobserved time-invariant individual effects, $\boldsymbol{X}_{it}$ is the time-variant $1\times k$ independent vector, $\boldsymbol{\beta}$ refers to the fixed effects, and u_{it} is the error term.

Table 1. Test of national competitiveness on GDP per unit of energy use based on panel dataset

National Competitiveness Factors	**Model 1 Overall, *N*= 57**	**Model 2 Pop. > 100 M., *N* =8**	**Model 3 Pop. < 100 M., *N* =49**	**Model 4 Developed, *N* =32**	**Model 5 Developing, *N* =25**
X_1: Domestic Economy	/	/	/	-0.0610** (0.0179)	0.0236* (0.0114)
X_2: International Trade	/	/	/	/	/
X_3: International Investment	0.0448** (0.0096)	/	0.0477** (0.0107)	0.0487** (0.0108)	/
X_4: Employment	/	/	/	/	/
X_5: Prices	/	0.0228* (0.0096)	/	-0.0326** (0.0116)	0.0209** (0.0079)
X_6: Public Finance	/	/	/	-0.0545** (0.0129)	/
X_7: Fiscal Policy	-0.0451** (0.0133)	-0.0566** (0.0166)	-0.0429* (0.0176)	/	-0.0651** (0.0158)
X_8: Institutional Framework	/	0.0724** (0.0178)	/	/	0.0659** (0.0147)
X_9: Business Legislation	/	/	-0.0334* (0.0159)	/	-0.0555** (0.0153)
X_{10}: Societal Framework	/	/	/	/	/
X_{11}: Productivity and Efficiency	/	/	/	0.0742** (0.0169)	/
X_{12}: Labor Market	/	0.0630** (0.0185)	-0.0500** (0.0179)	-0.0602** (0.0211)	0.0655** (0.0157)
X_{13}: Finance	/	/	/	/	0.0723** (0.0192)
X_{14}: Management Practices	/	0.0351** (0.0119)	/	/	0.0257* (0.0110)
X_{15}: Attitudes and Values	/	/	0.0227* (0.0111)	/	/
X_{16}: Basic Infrastructure	/	/	/	-0.0594* (0.0230)	0.0684** (0.0216)
X_{17}: Technological Infrastructure	0.0328* (0.0159)	-0.0556** (0.0187)	0.0765** (0.0208)	0.0762** (0.0241)	/
X_{18}: Scientific Infrastructure	0.0302* (0.0153)	0.0357* (0.0163)	0.0490* (0.0202)	0.1280** (0.0209)	-0.1228** (0.0203)
X_{19}: Health and Environment	0.0860** (0.0179)	/	0.0824** (0.0202)	0.0822** (0.0240)	/
X_{20}: Education	/	-0.0500** (0.0139)	/	/	-0.0349** (0.0126)
Adjusted R-squared	0.8036	0.8893	0.7996	0.8229	0.8865

** p value<0.05, ** p value<0.01.*

4. Results

Model 1 With the panel data of 57 countries and regions, the econometric model is as follow (Table 1):

$$y_{it} = –0.0199+\hat{\alpha}_i+ 0.0448\, X_3 – –0.0451\, X_7 + 0.0328\, X_{17} +0.0302\, X_{18} + 0.0860\, X_{19}, \quad (1)$$

where

y: GDP per unit of energy use — X_3: *International investment*
X_7: *Fiscal policy* — X_{17}: *Technological infrastructure*
X_{18}: *Scientific infrastructure* — X_{19}: *Health and environment*
i =1, 2,…57 and t =1, 2,…17 years

$\hat{\alpha}_i$ shows the variant intercept differences of GDP per unit of energy use in 57 countries and regions. Table 2 lists the 12 countries and regions with the highest and lowest $\hat{\alpha}_i$. The identified differences in the individual-different GDP per unit of energy use on Table 2 likely were attributed to unique regional characteristics, including national policies, basic conditions, etc. Among these countries and regions, Iceland and the USA have the lowest $\hat{\alpha}_i$, indicating that they have the best basic conditions of energy efficiency, ceteris paribus. By contrast, Hong Kong and Peru have the highest $\hat{\alpha}_i$, indicating that they have limited conditions of energy efficiency, ceteris paribus. Although China mainland has huge energy consumption, Table 2 shows that it remains in the lead of the lowest ranking.

Table 2. $\hat{\alpha}i$ in main countries and regions (the highest and lowest 12)

Lowest ranking countries & regions			Highest ranking countries & regions		
1.	Iceland	-6.35	1.	Hong Kong	9.93
2.	USA	-6.23	2.	Peru	8.92
3.	Canada	-4.57	3.	Colombia	6.91
4.	Finland	-4.54	4.	Philippines	4.32
5.	Sweden	-3.69	5.	Indonesia	3.91
6.	Belgium	-3.45	6.	Ireland	3.48
7.	Ukraine	-3.25	7.	Switzerland	3.02
8.	France	-2.99	8.	Brazil	2.87
9.	Russia	-2.98	9.	Croatia	2.62
10.	Australia	-2.49	10.	Turkey	2.53
11.	China Mainland	-2.33	11.	Mexico	2.51
12.	Czech Republic	-2.30	12.	Singapore	2.22

The analysis of competitiveness factors reveals that the competitiveness of *international investment, fiscal policy*, *technological infrastructure*, *scientific infrastructure*, and *health and environment* are significantly associated with GDP per unit of energy use. Only the high level of *fiscal policy* may reduce energy use. Therefore, H_1 cannot be rejected.

Models 2 and 3 According to population size, countries and regions in the panel dataset were divided into the larger-population group (>100 million) and the smaller-population group (<100 million). The panel dataset was accordingly split into two datasets, so as Models 2 and 3 were constructed respectively. Table 1 presents the results of both models. In both smaller- and larger-population groups, some competitiveness factors have significant effects on GDP per unit of energy use with different extents.

Models 4 and 5 In terms of development levels, countries and regions in the panel dataset were divided into the developed and the developing. The panel dataset was accordingly split into two datasets, so as Models 4 and 5 were constructed respectively. Table 1 shows the results of both models. In both developed and developing countries and regions, some competitiveness factors have significant effects on GDP per unit of energy use with different extents.

An exploration of the path for China China Mainland, included in the developing countries, is with a huge population. The results of Panel Models 2 and 5 indicate that the GDP per unit of energy use can be reduced by improving *fiscal policy* and *education. Fiscal policy* comprises 13 indicators, including inferring tax, revenues, and social security contribution (*Appendix B*). In comparison, *education* comprises 18 indicators, because adequate and accessible educational resources can help develop a knowledge-driven economy and improve energy efficiency.

5. Conclusion and Future Research

The theoretical relationship between competitiveness and energy consumption reveals that some competitiveness factors from WCY can significantly affect the GDP per unit of energy use of a country. Competitiveness can be controlled to enhance energy efficiency. The actual situation, population size, and development level of countries can also affect some competitiveness factors.

García [17] described the recent economic transformation of China and its relationship with energy consumption, and further analyzed the relationship between economic growth and Chinese energy production and consumption in the medium and long term. We discuss some aspects for improvement and the new directions and initiatives that China has adopted to address new issues in its energy development. Apart from the current situation in China, *fiscal policy* and *education* are the most effective paths for improving competitiveness and reducing energy consumption.

The following directions beyond the scope of this study, in terms of research limitation and fields, can be pursued. First, the theoretical relationship between competitiveness and energy consumption must be investigated further. Second, the endogenous problems between competitiveness factors and GDP per unit of energy use must be solved. Third, to evaluate the effectiveness of the proposed competitiveness factors, future research must evaluate the core competitiveness sub-indicators and the driving factors for national governance and development. These studies are expected to uncover the principal mechanism and route for improving national competitiveness and development level. Fourth, using competitiveness theory and the core driving factors, future research can evaluate and estimate the future development of Chinese competitiveness and analyze the accompanying risks.

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Appendix

Appendix A: National Classification (N=57)

- Big population (> 100 million) and Developed countries (or regions) (*N*=2): Japan, USA.
- Big population (> 100 million) and Developing countries (or regions) (*N*=6): Brazil, China Mainland, India, Indonesia, Mexico, and Russia.
- Small population (< 100 million) and Developed countries (or regions) (*N*=30): Australia, Austria, Belgium, Canada, China Hong Kong, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and UK.
- Small population (< 100 million) and Developing countries (or regions) (*N*=19): Bulgaria, Chile, Colombia, Croatia, Jordan, Kazakhstan, Lithuania, Malaysia, Peru, Philippines, Poland, Qatar, Romania, South Africa, Thailand, Turkey, UAE, Ukraine, and Venezuela.

Appendix B: The Indicators of Fiscal Policy and Education

Fiscal Policy with 13 indicators		
1)	Collected total tax revenues (%)	Percentage of GDP
2)	Collected personal income tax (%)	On profits, income and capital gains, as a percentage of GDP
3)	Collected corporate taxes (%)	On profits, income and capital gains, as a percentage of GDP
4)	Collected indirect tax revenues (%)	Taxes on goods and services as a percentage of GDP
5)	Collected capital and property taxes (%)	Percentage of GDP
6)	Collected social security contribution (%)	Compulsory contribution of employees and employers as a percentage of GDP
7)	Effective personal income tax rate	Percentage of an income equal to GDP per capita
8)	Corporate tax rate on profit	Maximum tax rate, calculated on profit before tax
9)	Consumption tax rate	Standard rate of VAT/GST
10)	Employee's social security contribution rate	Compulsory contribution as a percentage of an income equal to GDP per capita
11)	Employer's social security contribution rate	Compulsory contribution as a percentage of an income equal to GDP per capita
12)	Real personal taxes	Real personal taxes do not discourage people from working or seeking advancement
13)	Real corporate taxes	Real corporate taxes do not discourage entrepreneurial activity
Education with 18 indicators		
1)	Total public expenditure on education (%)	Percentage of GDP
2)	Total public expenditure on education per capita	US$ per capita
3)	Public expenditure on education per pupil	Percentage of GDP per capita
4)	Pupil-teacher ratio (primary education)	Ratio of students to teaching staff
5)	Pupil-teacher ratio (secondary education)	Ratio of students to teaching staff
6)	Secondary school enrollment (%)	Percentage of relevant age group receiving full-time education
7)	Higher education achievement (%)	Percentage of population that has attained at least tertiary education for persons 25-34
8)	Women with advanced degrees (%)	Percentage of graduates with bachelor and master degrees who are women

9)	Student mobility inbound	Foreign tertiary-level students per 1000 inhabitants
10)	Student mobility outbound	National tertiary-level students studying abroad per 1000 inhabitants
11)	Educational assessment - PISA	PISA survey of 15-year olds
12)	English proficiency - TOEFL	TOEFL scores
13)	Educational system	The educational system meets the needs of a competitive economy
14)	Science in schools	Science in schools is sufficiently emphasized
15)	University education	University education meets the needs of a competitive economy
16)	Management education	Management education meets the needs of the business community
17)	Illiteracy (%)	Adult (over 15 years) illiteracy rate as a percentage of population
18)	Language skills	Language skills are meeting the needs of enterprises