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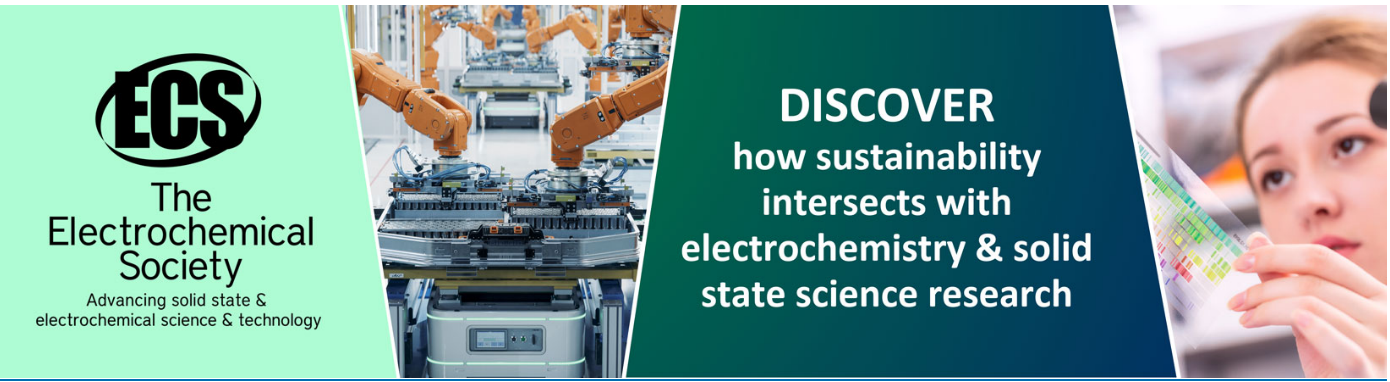

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Retesting the existence, relativity and convergence of energy curse: An empirical test based on the provincial panel data analysis in China

X Qin[1], Y S Xu[1], Q Lu[2] and X L Wang[2, 3]

[1]Faculty of Management and Economics, Dalian University of Technology, Dalian 116023, China
[2]School of Economics and Management, University of Science & Technology Beijing, Beijing 100083, China

E-mail: wangxiaoling@ustb.edu.cn

Abstract. An index, Resource Curse Intensity (RCI), is proposed to evaluate the degree of deviation between energy endowment and economic growth by taking national economic conditions into account for the energy system. The RCI is intended to provide a quantitative measure of what is regarded as the "resource curse", namely, the negative impact of natural resources wealth crowding out productive activities. Based on panel data from 30 provinces/cities from 2001 to 2010, empirical analysis is carried out with the convergence method from neoclassical economics to shed light on the temporal-spatial distribution, evolutionary trends, and convergent determinants of China's RCI for energy. The findings of the study indicate that the index has become significant in China since 2009; compared to other factors, technological progress poses notable positive effect while energy structure, openness Level, and administrative have weak influence on the curse convergence; an inverse correlation shows up between the industrial structure and convergence effect; moreover, club convergence is found in the eastern and central regions but western region in mainland China.

1. Introduction

The traditional recognition regarding the positive relation between natural resources endowment and eco-nomic growth has been challenged by the "resources curse" proposition [1,2]. It has been argued that natural resources exert a crowding-out effect on production, as many studies indicate that resource-poor areas always have higher economic performance than resource-rich regions [3]. Resources on a large scale may become as a "curse" instead of a "blessing" in some instances. This topic then has become popular with the publication of the Natural Resource Abundance and Economic Growth was published [4]. Several additional studies have indicated negative responses between resources endowment and economic growth in various regions around the world [5,6].

As one of the emerging economics and resources production and consumption giants, China has been suffering from the unbalanced resources distribution and a geographical mismatch between energy supply and de-mand, contributing to the possibility of regional resources curse. However, the debate regarding the existence of regional energy curse has not reached a consensus due to the prior contradictory conclusions generated from different analytical perspectives, research subjects, and selected indicators [7-9].

Moreover, further discussions demonstrate that natural resources may exert the crowding-out and/or softening effects on economic development to various extents through institutional factor, educational level, capital investment, openness level, and political intervention [10-19].

Given the fact that there is no universal definition of resources curse yet, nor the evaluation framework, in study we initiate and construct an index, RCI, by taking into the following points: the Heckscher-Ohlin's re-source endowment theory is based on relative advantages of a region, indicating that the degree of “rich/abundant” or “poor/barren” is also relative instead of absolute concept during various development stages and in various areas. Additionally, we need to identify the most suitable and reliable way to measure a subject’s function due to its distinct nature as bananas and oil obviously poses different effects on economic growth.

In this study, we analyze the relationship between regional energy resources and economic growth to test and evaluate the relative degree of energy curse. The study is taken from a dynamic and relative perspective in the context of China’s national economy. We start with the regional relative curse intensity (RCI) by measuring the degree of deviation between energy supply capacity and rate of economic growth. The convergence testing is conducted before macro-economic and managerial factors to study the convergent conditions and determinants under the framework of neoclassic growth theory.

2. Material and methods

In an attempt to reflect a complete and dynamic scenario of China’s situation, this study adopts 300 observations from a longitudinal dataset for 30 provinces/cites spanning from 2001 to 2010 to conduct a multi-level convergence testing and analysis.

2.1. Relative resource curse intensity (RCI)

In order to reflect the relative differential among 30 jurisdictions, the study introduces a relative energy curse intensity index through the lens of deviation degree between regional energy self-sufficient capacity and economic growth rate. Relative Resource Curse Intensity (RCI) is constructed as the ratio of energy abundance index (EAI) and yearly real GDP growth rate. The formula for Relative Resource Curse Intensity is RCI=EAI/ΔGDP.

How to measure the resource endowment or abundance effectively has been one of difficulties in the academia. Indicators, such as the ratio of resource exports or primary commodity exports to GDP, the proportion of employment in the primary products, the quantity of cultivated land per capita, energy reserves [20], and the resource rent ratio of GDP, have been proposed by researchers. However, given the constraints in data source and differentiations in research purpose, there is neither an available universal evaluating framework nor an established model for the evaluation.

Referencing the existing indicators as well as taking various types of energy into account, this study interprets the energy abundance concept into regional energy self-sufficiency that is calculated as:

$$ERI = \sum_{i=1}^{30} \rho_i \phi_i / E_i \,(i = 1, 2, ...30) \tag{1}$$

where, ρ_i denotes the physical quantity of different types of primary energy, ϕ_i stands for conversion coefficients according to the national bureau of statistics, $\rho_i \phi_i$ equals regional indigenous production (metric tons of standard coal equivalent, tce), and E_i represents total energy consumption by region. Meanwhile, regional actual GDP growth rates are estimated by using 2000 as the base year.

2.2. Corresponding macro factors

The formation, transmission, and evolution of energy curse are closely related to regional macro environments and their capability for a comprehensive exploitation of the energy resource. Key macro influencing fac-tors are further identified and analyzed for conditional convergence testing.

Energy consumption structure: In terms of energy endowment, China has adequate supplies of coal, but re-quires imports of gas and oil. Proved and remaining recoverable reserves for conventional primary resources, coal, oil, natural gas, and hydro accounts for 73.2%, 1.3%, 1.3%, and 24.2% respectively. Coal currently comprises 70% of the total primary consumption of the country's energy mix. Accordingly, we focus on the proportion of coal consumption to represent the variations of energy use as embodied in the energy consumption structure.

Computational formula: ES= coal consumption/ primary energy consumption

Where, conversion coefficient of raw coal to standard coal is 0.714
Industrial Structure: Along with rapid urbanization, industrialization, and global trade, energy intense industries, especially the secondary industries, have seen significant expansion. These industries consume a large amount of primary energy (about 70% of total primary energy consumption). Thus the secondary industry plays an important role in energy management and, consequently, we explicitly indicate it as one of observations of this study. Industrial structure is depicted by the ratio of secondary added value to GDP.

Computational formula: IS= secondary added value/GDP

Level of openness: There is a close relation between the level of openness and the growth of China's role in global trade, both of which have been verified as positive factors for regional technological advance and eco-nomic growth. Nevertheless, there is not a clear consensus on whether the growth of global trade would lead to higher efficiency of resources usage, especially when the imbalance of trade shows up. Recognizing constraints of data source, the index of international trade is used as a proxy to demonstrate the level of openness.

Computational formula: OL= total volume of import and export trade/GDP

Technological Progress: Measure of technological advances has been one of the puzzles for scholars and the indicator reveals a wide variation from different perspectives. In this study, we use the Innovation Index that summarizes patents per capita. In addition, by following the view that the Technological Innovation Capability is the key factor in technology development from UNDP, we use only the authorized invention patents that are included, while the other two, the appearance design and the utility model, are excluded. Technological progress is depicted by per capita of invention patent authorization number.

Computational formula: TL= invention patent authorization number/ census registered population

Administrative interventions: The way that macro factors influence the energy efficiency is always in con-cert with the regional background such as the social setting, political context, and the market environment. During this special period in which transition is happening from planned economy to market economy, provinces (cities) have gained more flexibility regarding resource administration. Generally, government exerts its intervention in terms of policy enactment and enforcement including fiscal and monetary policies. In view of the fact that fiscal policy are made by central government and the financial policy is more flexible to local government, we use the ratio of local government fiscal expenditure to GDP to represent the degree of administrative interventions. Administrative interventions are depicted by ratio of fiscal expenditure to GDP.

Computational formula: AI= fiscal expenditure value/GDP

China statistical yearbooks (from 2002 to 2012), namely, China energy statistical yearbook, statistical yearbook of China population, science and technology of China statistical yearbook, and exchange of the people's bank of China annual report are identified as the data source. Additionally, the missing energy data for Ningxia and Hainan in 2002 are supplemented by referencing The Ningxia statistics yearbook 2003 and the Hainan statistics yearbook 2003.

On the basis of above collected and initially processed data, further convergence testing and dynamic analysis are conducted in the following parts.

3. Results

3.1. Spatial-temporal evolution of the relative energy curse intensity

According to the formula of relative energy curse index, corresponding values for the 30 jurisdictions during 2001 to 2010 are calculated and visualized on the following map (figure 1).

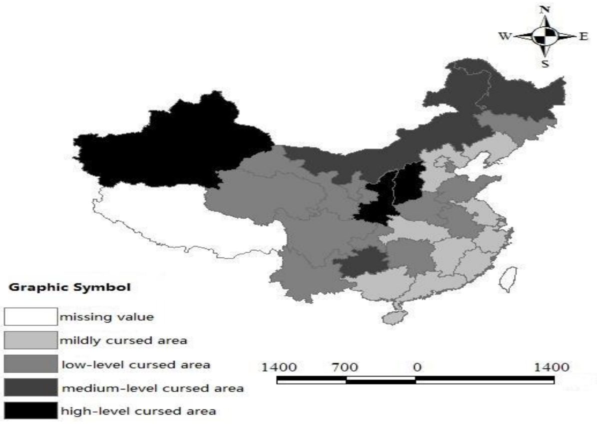

Figure 1. Spatial-temporal distribution of regional relative energy intensity curse (RCI).

The map provides the spatial-temporal distribution of the regional relative energy curse intensity in China. During the last ten years, the energy-constrained eastern areas represented by Shanghai, Zhejiang, Fujian, and Hainan gained high economic growth rates with low energy self-sufficiency levels and fell into the low-RCI category with values between 0.123 and 1.489; correspondingly, big energy net exporters, including Shanxi and Heilongjiang from central area and Shananxi, Neimengu, and Xinjiang from western area, gained high economic performance at the expense of substantial energy consumption and dependence. The RCI values (13.293-26.462) for such regions are grouped as high energy curse category; additionally, other jurisdictions with the yearly RCI values between 4.071-6.205, such as Tianjin, Shandong, Sichuan, and Chongqing, managed to keep synchronous development between energy self-sufficient and economic growth.

The aforementioned relationships indicate that the energy-endowed regions did not put their advantages to good use nor transitioned to benign economic development patterns, thereby implying the existence of the re-source endowment curse. We note that the negative relationship between energy abundant and economic growth is relative (i.e., not absolute).

3.2. Convergence analysis

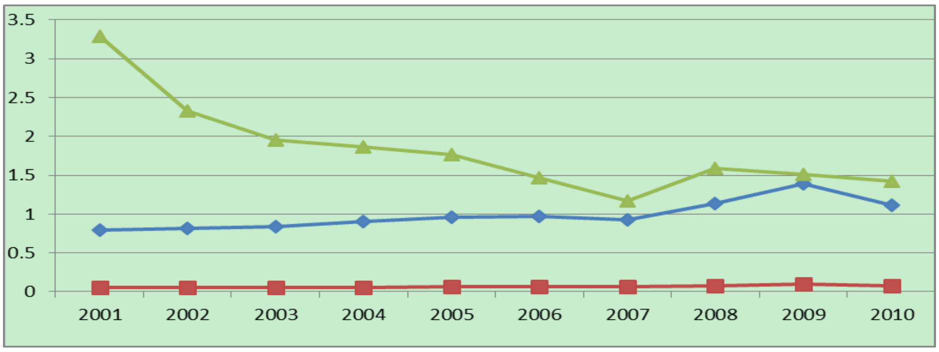

Figure 2. Coefficient of variation, HHI index, the interquartile range of RCI.

3.2.1. The σ- convergence testing. In an effort to test the convergence of RCI to a greater extent, indicators of coefficient of variation, HHI index, and interquartile range are firstly employed to conduct σ-convergence (figure 2).

The results of coefficient of variation, HHI index, and interquartile range show the similar trend with the standard deviation: a divergence appeared during 2007 to 2009, whereas the convergence made a strong come-back after 2009, indicating that the energy curse gap between jurisdictions tends to narrow over time and is like to converge to a relative stable level in the future.

3.2.2. The absolute β- convergence testing. The absolute β-convergence is tested in addition to the σ-convergent model based on the following formula:

$$\ln(y_{i,t+1}/y_{i,t})/T = \alpha + \beta \ln(y_{i,t}) + \varepsilon_{i,t} \tag{2}$$

Where, $\ln(y_{i,t+1}/y_{i,t})$ denotes the RCI for region i during t to t+T, α is constant intercept item, β is the coefficient and λ means the convergent speed, represents the initial economic level for region, $\varepsilon_{i,t}$ is the error term. Therefore, the absolute convergence happens if $\beta < 0$. An individual fixed effects test is chosen in line with the Hausman test and F-statistics.

Table 1. The absolute convergence result of RCI.

variables	coefficient	standard error	T statistic	Prob.	R^2
β	-0.400111[a]	0.051596	-7.754659	0.0000	0.447196
α	0.466522[a]	0.067328	6.929127	0.0000	

[a] p≤0.01

As can be seen from table 1, the absolute convergent coefficient β= -0.400111<0, and all variables are significant on the 1% significance level with an acceptable model fit. In this context, the provinces with high RCI were experiencing an accelerating convergence to catch up with those have low RCI over time, which is in line with the above σ convergent outcome.

3.2.3. The club convergence testing. Along with the national gradient development strategy, national statistic standards, and main relevant re-search, this study groups the 30 provinces (cities) into three groups: the eastern, central, and western region. Whereby, the eastern region includes 11 provinces (cities), i.e., Beijing municipality, Tianjin municipality, Hebei province, Shangdong province, Liaoning province, Shanghai municipality, Jiangsu province, Zhejiang province, Fujian province, Guangdong province, and Hainan province; the central region covers 9 provinces (cities), i.e., Shanxi province, Jilin province, Heilongjiang province, Henan province, Hunan province, Hubei province, Anhui province, and Jiangxi province; and the western region encompasses 11 provinces (cities), i.e., Neimenggu Autonomous Region, Shananxi province, Sichuan province, Chongqing municipality, Guizhou province, Guangxi Autonomous Region, Yunan province, Xizang province, Gansu province, Ningxia Autonomous Region, Qinghai province, and Xinjiang Autonomous Region. By introducing a dummy variable D_ij, the study constructs the following formula to test the club convergence:

$$\ln(y_{i,t+1}/y_{i,t})/T = \alpha + \beta \ln(y_{i,t}) + D_{ij} + \varepsilon_{i,t} \tag{3}$$

Where, i denotes the initial energy endowment for a province (city); j=1, 2 represent the eastern and central regions, respectively; D_ij=1 when a province (city) belongs to region j, otherwise D_ij=0. The model estimation is conducted before the dummy variables' coefficients are tested to observe the existence of club convergence (table 2).

In the above model with acceptable explanatory power, the initial energy curse is negative and all dummy variables except D2, indicating that the convergent phenomenon is strong in eastern and central regions but is not significant in western region. To make a further observation regarding the convergent feature within regions, the study goes on to test the absolute β convergence for the eastern, central, and western regions (table 3).

Table 2. The club convergence result of RCI.

variables	coefficient	standard error	T statistic	Prob.	R2
β	-0.375694[a]	0.066843	-5.62055	0.0000	0.393417
D1	-0.63209[a]	0.197899	-3.194005	0.0016	
D2	0.111975	0.145689	0.76859	0.4428	
α	0.625731[a]	0.161287	3.879618	0.0001	

[a] p≤0.01

Table 3. The club convergence result of RCI.

variables	coefficient	standard error	T statistic	Prob.	R2
β 1	-0.018053[a]	0.003434	-5.256642	0.0000	0.714449
α 1	-0.079887[a]	0.004133	-19.32721	0.0000	
β 2	-0.497189[a]	0.043538	-11.41958	0.0000	0.65800
α 2	0.845071[a]	0.078933	10.70614	0.0000	
β 3	0.020787[b]	0.00965	2.154083	0.0339	0.726512
α 3	-0.051657[a]	0.016625	-3.107248	0.0025	

[a] p≤0.01
[b] p≤ 0.05

As can be seen from table 3, all the coefficients are significant at the 1% -5% significant levels, and there-fore gain a favorable explanatory power. From the convergent coefficients, the inter-convergence appeared in both eastern and central regions, and the central region gained the highest convergent speed among others; conversely, no convergence but a slight divergence showed up in the western region. The evidence manifests that the RCI tends to be stable in eastern region, to be weaken in the central region, and to be deteriorate in the western region where the relation between economic development and resources exploitation is disharmony.

3.2.4. The conditional β convergence testing. A conditional β convergence formula is contrasted according to the research purpose:

$$\ln(y_{i,t+1}/y_{i,t})/T = \alpha + \beta \ln(y_{i,t}) + \sum_{j=1}^{n} \gamma_j x_{i,t}^j + \varepsilon_{i,t} \quad (4)$$

Where, γj is the coefficient of control variable xi,t and εi,t is the error terms. Given the concept of conditional β convergence, whether the cap between lagged and advanced regions can be narrowed or not after adding certain control variables can be observed. The conditional β convergence thus tends to bring out a more systematic and comprehensive explanation for an observed subject than the absolute β convergence.

Result of conditional β convergence is indicated in table 4.

With an acceptable explanatory level of model (R2=0.422828), all variables are statistically significant. The coefficients show that: the technological level has strong positive effect on regional RCI's convergence to narrow the gap between provinces (cities); the administrative level, level of openness, and energy consumption structure exert slight positive effect on regional RCI's convergence; yet an increase in the proportion of secondary industry will widen the regional gap and lead to a deteriorate scenario.

Table 4. The club convergence result of RCI.

variables	coefficient	standard error	T statistic	Prob.
β	-0.398002[a]	0.037045	-10.74388	0.0000
IS	0.006716 [a]	0.002101	3.195911	0.0016
ES	-0.00225[c]	0.001151	-1.955295	0.0517
OP	-0.00199[b]	0.000831	-2.395435	0.0174
TL	-0.121251[a]	0.026845	-4.516679	0.0000
AI	-0.008908[a]	0.002547	-3.497034	0.0006
α	0.553831[a]	0.160921	3.441639	0.0007

[a] $p \leq 0.01$
[b] $p \leq 0.05$
[c] $p \leq 0.10$

4. Discussion

As can be seen from the empirical tests, the phenomenon of energy curse did happen in China as the regions endowed with fossil fuels had much higher RCI values than the areas with less endowment. In addition, RCI tends to be stable in eastern region, to be weaken in the central region, and to be deteriorate in the western region. This scenario is formed due to the following reasons. The main conventional resource endowment in China (coal, oil, and gas) is imbalanced distributed and carries on a “rich in north and west, poor in south and east”, pointing to the phenomenon of regional energy curse. Also, western areas were still struggling with the balance of eco-nomic growth and recourse conservation.

Nevertheless, the curse effect was decreased overtime among the regions and the jurisdictions. Various con-vergence tests have supported this conclusion, including the α- and β-convergence tests. The outcome of the conditional β-convergence test reveal the reasons that explains the situation. Along with the scaled exploitation of renewables, exploration of unconventional energies in the eastern region and the improvement in energy utilization, the energy supply gap among jurisdictions is narrowing. Furthermore, with the function of technology accumulation, diffusion, and penetration coming into play, the difference between regional RCI has also de-creased over time.

5. Conclusions

In an effort to accelerate the convergent effect for RCI, help the western region to get rid of a vicious circle between economic growth and energy consumption, avoid the appearance and worsen of “Matthew effect” (or accumulated advantage) where "the rich get richer and the poor get poorer", reach the sympathetic scenario for energy utilization and economic development, achieve the intra- and inter-generational equity towards energy resources possession, and steer the sustainable development of the energy-economic system, the following suggestions are proposed:

5.1. Enhance the utilization efficiency of coal

Although the development of unconventional and renewable energies has played an important role in adjusting and optimizing the energy mix, such effect is unlikely to reach a considerable degree given the technological constrains, especially for scaled renewables development. Considering the existing resources endowment as well as most new energy forms are on trial and immature, fossil fuel represented by coal is undoubtedly going to dominant China’s energy supply. Consequently, improvement in coal utilization especially for the especially for the western provinces (cites) remains the core consideration to harmonize the economic benefit and resources conservation. Furthermore, coal is the most abundant, distributed, and low-cost energy in China, and thus gains the highest optimal potential compared with other energies.

In view of the distribution and nature of coal, it should be explored and exploited in the following ways: steer the coal-electricity integration to optimize coal’s efficiency according to its low energy grade; facilitate the development of filling mining and clean coal technology, including coal gasification, processing, conversion technologies, integrated gasification combined cycle and super criticality technologies, and large CFB advanced power generation technology, to improve coal's recovery and utilization rate; and boost the marketization of the price of coal by breaking the electric market monopoly, correcting the flaws in coal price design and reducing the excessive administrative oversight.

5.2. Focus on escalation of industrial structure
Increase of the tertiary industrial ratio will facilitate the expansion of a service economy. Upgrading the share of "soft elements" including information, service, technique, and knowledge in the secondary manufacturing sector is also important to this point. In so doing, the secondary industry will tend to transit from an energy-intensive scenario to a greener regime. In such a development, the country's industrial specialization would gain more momentum to move to the high-end of world industry chain.

5.3. Prompt technical innovation in energy sector
Among others, technology has the most significant effect in accelerating the regional RCI convergence. Accordingly, several aspects should be paid attention to. First, make the focus of innovation clear. Select and combine various types of technologies (e.g., labor intensive, capital intensive, resource intensive, and skill intensive, and knowledge intensive technology) in line with local conditions to facilitate inter- and intra- club convergence; Second, direction of innovation should be readjusted. It is urgent to reduce imitation and tracking, and to promote in independent innovation; Third, institutional arrangements should also be revisited. Spillover effect and expansion of clean technology would be accelerated in so doing. As such, scale effect, agglomeration effect, and multiplier effect would be multiplied to facilitate the application as well as allocation of energy technology; Last but not least, leverage the best available technology (BAT) and encourage reverse innovation. Make full use of the best available technologies (BAT) that fit its development background to lower the cost and gain good outcomes; alternatively, incentives should be provided by the government to encourage reverse innovation to set up China's own energy core technological system that supports and fosters the transition of its energy system.

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