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The dynamic relationship between energy consumption and economic growth in China

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ABSTRACT

Economic growth of is mainly associated with technical changes as well as energy consumption of a nation. The causality between energy consumption and economic growth has created much more attention in the literature. With advanced technology and automated comfort life, the requirement of energy demand has been increasing rapidly. The goal of this study is to examine the causal relationship between energy consumption and economic growth in China over the period of 1980 – 2013. As a first step, stationary properties of the selected variables were tested using unit root test statistics. Next, the Johansen co-integration with Vector error correction model (VECM) was applied to examine the dynamic links between among the variables.

The result confirmed a long run bidirectional causal relation running between energy consumption and economic growth. Furthermore, results make a significant contribution to policy makers to open up a new direction to the development of energy sector in China.

KEYWORDS
Economic Growth; Energy Consumption and Vector error correction model

1. Introduction

The relationship between energy consumption (EC) and economic growth has impacted directly both individual's standards of living and industrial enhancements. Day by day, the energy demand of the world has been growing rapidly proportional to the modern technology with automated comfortable life. As a result, miscellaneous types of studies have been carried out in the literature to investigate the dynamical directions between economic growth and EC under four categories. They are unidirectional causality, inverse relations, bidirectional causality, and no causality relation between EC and economic growth (Jayathileke and Rathnayaka, 2013).

Among the Asia-Pacific region, China has achieved rapid economic growth with remarkable economic success after the new economic reform initiated by Deng Xiaoping in 1978 (Chan, 2007). As a result, Chinese economy has been accompanied by significant structural changes and entered the heavy industrial stage after 1984. Currently, China has become the highest energy producer in the world, overtaking the United States, accounting for 46% of global coal production and 49% of global coal consumption. Furthermore, 71% of the total energy demand in China is supplied by coal, which is followed by crude oil (19%), hydroelectricity (6%), natural gas (3%), nuclear energy (1%), and renewable and other sources (0.2%). As a result, by the end of 2012, they have emerged as the world's largest electricity consumer (4,693,000,000 MWh/

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year), with a total energy use of 89 quadrillions British thermal units (see Chan, 2007; Jayathileke and Rathnayaka, 2013).

As a subset of this literature, very few studies have focused on finding the causality relations between EC and economic growth in China. Therefore, for the first time in the literature, the current study focuses on examining the relations of over the 34-year period of 1980–2014 based on some significant questions: does a long-term causal relation exist between EC and economic growth in China? How do they affect each other in the short-term as well as in long-term period of time?

The vector error correction model (VECM) is a part of an error correction model (ECM), which can be used to capture the linear interdependencies among multiple time series models, especially in econometric time series approaches. The main objective of this current study is to understand the relations between EC and economic growth in China. The rest of the paper is organized as follows. Section 2 provides a brief overview of the existing solutions with their associated pros and cons. The empirical model with this article's proposed work is constructed in Section 3. Section 4 provides the estimation results with discussion and Section 5 ends up with conclusion, policy issues, and future work.

2. Methodology

2.1 *Unit root and co-integration test*

A time series X is said to Granger-cause Y, meaning that only those X values provide statistically significant information about future values of Y. But it does not mean that Y values have a significant effect on X. Therefore, the Granger Causality test can be used to determine the variational effect from one time series to another (Granger, 2004).

The economic data are often seasonal and highly fluctuate over time. Theoretically, if a series is distributed with nonconstant mean and co-variance over time, such a series is said to be nonstationary (Johensen 1991). As a result, it is significant to test the stationary and nonstationary conditions before using them for further analysis. Three statistical methods are mainly used in statistics. They are the Augmented Dickey Fuller (ADF) test, the Phillips–Perron (PP) test, and the Im-Pesaran and Shin W (IPSW) test (Rathnayaka et al., 2013).

$$\Delta y_t = \delta + \lambda t + \beta y_{t-1} + \sum_{i=1}^{P-1} \alpha_i \Delta y_{t-i} + \varepsilon_t \tag{1}$$

Where y_t is the variable that is to be tested whether the unit root exists or not and p, λ, and t represent the lag length of the auto-regressive process, the coefficient on a time trend, and time trend variables respectively.

Incorporating all these co-integrated properties with the Johansen test, the VECM is introduced to test the Granger causation of the series in at least one direction. In this study, Johansen co-integration with VECM will be adopted to examine the dynamic links between the per capita GDP and the EC in China. As an initial and essential requirement, VECM necessitates the time series to be co-integrated with the same order. If the series is nonstationary, need to make difference d times until it will become under the stationary. The VECM for real gross domestic product (GDP) per capita, total EC, and total population (POP) can be implicated by equations as follows:

$$\Delta y_t = \delta + \sum_{i=1}^{n} \beta_{ia} \Delta y_{t-1} + \sum_{i=1}^{n} \alpha_{ib} \Delta x_{t-1} + \sum_{i=1}^{n} \phi_{ic} \Delta z_{t-1} + \lambda_1 \, ECT_{t-1} + e_{1t} \tag{2}$$

$$\Delta x_t = \delta + \sum_{i=1}^{n} \beta_{id} \Delta y_{t-1} + \sum_{i=1}^{n} \alpha_{ie} \Delta x_{t-1} + \sum_{i=1}^{n} \phi_{if} \Delta z_{t-1} + \lambda_2 \, ECT_{t-1} + e_{2t} \tag{3}$$

$$\Delta z_t = \delta + \sum_{i=1}^{n} \beta_{ig} \Delta y_{t-1} + \sum_{i=1}^{n} \alpha_{ih} \Delta x_{t-1} + \sum_{i=1}^{n} \phi_{ij} \Delta z_{t-1} + \lambda_3 ECT_{t-1} + e_{3t} \tag{4}$$

In Eqs. (2), (3), and (4), the serially uncorrelated error term e_{it}normally distributes and has wide noise. Moreover, the coefficient λ_i of the ECT_{t-1}represents the error correction term, indicating the deviation of the dependent variables with respect to the long-run equilibrium between two variables (Granger, 2004).

3. Empirical results and discussion

3.1 *Data and estimation procedures*

This study is carried out on secondary data of GDP per capita and total EC (kg oil equivalent), which were obtained from annual reports in Chinese Statistical year book 2013, World Bank data base systems, world development indicators (WDIs), and other relevant sources between 1980 and 2014.

As a necessary and sufficient condition, ADF and PP tests are employed to find the unit root conditions. The reported results in Table 1 suggest that GDP and EC series are nonstationary at the levels and stationary only at first differences ($I(1)$) under the 0.05 level of significance. Furthermore, PP test results confirmed that all the selected variables can be categorized under the $I(1)$ process.

Based on the results in Table 1, as a next step the Johansen rank with trace and maximum Eigenvalue test statistics can be proposed to detect co-integration (Johansen, 1991; Davidson et al. 1978). The estimated co-integration results reported in Table 2 indicate two co-integration equations at the 0.05 level of significance; in other words, there is a significant long-run relationship between GDP per capita and total EC in China. In the next stage, maximum likelihood method based on VECM is set up for investigating the long-run as well as the short-run causality relations between dependent and independent variables. Theoretically, when the variables are co-integrated in the same order, VECM can be run to determine the causality between dependent and independent variables.

According to the VECM methodology, as an initial step, the endogenous variables converted into the first difference and regressed on a one-period lag of the co-integration equation. Table 3 shows the estimation result based on VECM. The coefficient on the error correction terms in the co-integration equation indicates that there is a significant bidirectional relation between GDP and EC in the long run.

As a next step, system equations have been generated based on the target model, which represents the dependent variable (D(GDP)). From the results in Table 4, the error correction term of VECM becomes stationary ($0.0113 < 0.05$) with a negative sign coefficient (−0.59733). This implies that GDP has a 59.73% speed adjustment of coverage of long-run causality on EC. Additionally, the VECM model statistics such as $R^2 = 59.296\%$and F-statistic (4.295) results confirmed the significant bidirectional long-run causality between economic growth and EC in China during the period 1980–2014.

Table 1. Unit root test results.

	ADF		PP	
Variables	Individual Intercept and Trend	Individual Intercept	Individual Intercept and Trend	Individual Intercept
GDP	0.0321	0.0024	0.1674	0.0800
ΔGDP	0.0001	0.0000	0.0001	0.0001
EC	0.0689	0.0656	0.0699	0.0658
ΔEC	0.0000	0.0000	0.0000	0.0000

Notes: All the tests assume asymptotic normality. AIC is used to select the lag length and Barlett kernel is used as the spectral estimation.

Table 2. Johansen co-integration rank test.

	Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	Critical Value	Prob.**
Trace	None*	0.419014	21.53364	15.4947	0.0054
	At most 1*	0.202307	6.328864	3.84146	0.0119
Maximum Eigenvalue	None*	0.419014	15.2047	14.2646	0.0354
	At most 1*	0.202307	6.32886	3.84146	0.0119

Notes: Trace test indicates two co-integrating eqn(s) at the 0.05 level.
*denotes rejection of the hypothesis at the 0.05 level, and critical values based on **MacKinnon–Haug–Michelis (1999) *p*-values.

Table 3. VECM estimation.

Co-integrating Equations	Co-integrating Equation (1)	
GDP	1.000	
EC	−23.00 (21.83) [−1.053]	
C	−9.07096	
Error Correction:	D(GDP)	D(EC)
Coint. Eq1	−0.636 [−2.86]	−0.002 [−0.462]
D(GDP(−1))	0.446 [2.54]	−0.0003 [−0.102]
D(GDP(−2))	−0.137 [−0.69]	0.003 [0.984]
D(EC(−1))	−11.58 [−1.07]	−0.365 [−1.697]
D(EC(−2))	−12.15 [−1.16]	−0.251 [−1.210]
C	−0.148 [−0.37]	0.002 [0.300]

Note: Standard errors in () and *t*-statistics in [].

Table 4. VECM estimation results.

	Coefficient	Std. Error	*t*-Statistic	Prob.
C(1)	−0.59733	0.216098	−2.764166	0.0113
C(2)	0.441766	0.174419	2.532787	0.019
C(3)	−0.17042	0.191866	−0.888224	0.384
C(4)	−10.62469	10.63987	−0.998574	0.3289
C(5)	−12.47678	10.31666	−1.209382	0.2394
C(6)	−0.210337	0.387188	−0.543242	0.5924

Note: Least squares method, D(GDPA) = C(1)*(GDPA(−1) − 23.0001876849*EUR(−1) − 9.0709592858) + C(2)*D(GDPA(−1)) + C(3)*D(GDPA(−2)) + C(4)*D(EUR(−1)) + C(5)*D(EUR(−2)) + C(6).

In the final phase, the robustness of the model specifications or the model efficiency is evaluated based on three criterion measures, namely the residual test of Jarque Bera test statistic to inspect the normality, the heteroskedasticity test for ARCH effect evaluation, and the Portmanteau auto-correction test with the Breusch–Godfrey Serial Correlation LM test to test the serial correlations. Moreover, the Portmanteau auto-correction test, the Ljung-Box-Q statistics and the Breusch–Godfrey Serial Correlation LM test are equal to 26.95, 34.23, and 0.5248 (>0.05), respectively, and suggest that there is no serial correlation up to lag 2–20.

4. Conclusions and policy recommendations

The empirical results suggested that Chinese economy has become more energy efficient after the economic liberalization began in 1978. By the end of 2010, China became the world's biggest energy producer in recoverable reserves of 176.8, 21.2, and 14.3 billion tons of coal, crude oil, and nonconventional oil, respectively (Wang et al., 2012). Day by day, the Chinese EC rate has been increasing rapidly, especially the quantity of EC in the urban regions has been increasing rapidly compared with rural areas (Chan, 2007; Wang et al., 2012). If this situation continues to the next decades, it will result in energy distortions in the future. As a result, China has taken some necessary actions to address the rapidly increasing energy demands in the last two decades, especially the Three

Gorges project was completed in 2008, which is the world's largest and most notorious hydropower plant currently (Yuan et al., 2010; Zhang, 2012).

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