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Coal consumption and industrial production nexus in USA: Cointegration with two unknown structural breaks and causality approaches

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ABSTRACT

The paper investigates the causality relationships among industrial production index, coal consumption and employment in industrial sector for the period of 1973:1–2011:10 in USA. After noticing that there are breaks in the regression model, the Hatemi-J test for cointegration is employed to the cases that take into account two possible regime shifts. It is concluded that there is a long run relationship between industrial production and industrial coal consumption with the breaks at 1983:4 and 1998:4. We found a negative relationship between coal consumption and industrial production for the period of 1973:1–1983:4 and positive relationship for 1983:5–1998:4 period. For the last period that covers 1983:5–2011:10, the cointegration relationship turned to negative. In addition, the results show that causal relationship between coal consumption and industrial production changes over time.

Contents

1. Introduction

Over the past three decades the relationship between energy consumption and economic growth has been a major issue of debate among economists and policy makers. Although coal is the major element for the industrial revolution in the world, the environmental consequences of the sustained use of coal has drawn into question of long-term viability of coal in light of the emergence of cleaner and alternative energy sources [1]. Countries that benefited from their coal reserves in the 19th century are now industrialized countries. Coal keeps its major role because it has high density, low cost and ease of combustion but its use produces several types of emissions that adversely affect the environment. Coal consumption accounted for 37% of the total US emissions of carbon dioxide released into the Earth's atmosphere in 2010 [2].

The entry into force of the Kyoto Protocol to the United Nations Framework Convention on Climate Change has focused the political divide between the coalition of industrialized countries that support the Kyoto treaty and design to implement rigid climate policies, and the few industrialized countries that are unwilling to do so [3]. The Kyoto Protocol requires participating countries to reduce their carbon-dioxide emissions collectively to an annual average of about five percent below their 1990 level over the 2008–2012 period. Coal consumption patterns, especially in USA, will certainly be affected since the United States is home to the largest recoverable reserves of coal in the world. Will coal consumption in reduction cause economic shocks, if there is a causal relationship between coal consumption and economic

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growth? The causal relationship between economic growth and energy consumption has been studied in a large number of empirical studies. However, the results of these studies are mixed due to methodological differences and the time period chosen (see Ozturk [4]).

It is widely believed that discovery of peat lead to industrial revolution. But damages of fossil energy kinds on environment are not denied. So human being search alternative energy researches instead of fossil energies. But there are needs for benefit-cost analysis and this reveals some questions. That is both benefits and cost of coal consumption and alternative energy kinds should be well documented. In addition, coal is the largest source of electricity in the world. However, as renewable energy consumption increase in total consumption, they will tend to be more common than fossil fuels for electricity generation because of reducing CO2 emissions into the atmosphere and combating global climate change. Therefore, this paper examines coal consumption and GDP linkage.

If one looks at the studies between coal consumption and economic growth linkage, this question is answered by four different hypotheses: ***The growth hypothesis*** states to a situation in which coal consumption plays an important role in the economic growth process directly and/or as a complement to capital and labor. The growth hypothesis is supported, if uni-directional causality is found from coal consumption to economic growth. In this case, energy conservation policies aimed at decreasing coal consumption will have negative effects on economic growth. This view is also confirmed by Wolde-Rufael [5] for India and Japan. ***The conservation hypothesis*** signifies that economic growth is the dynamic which causes the consumption of energy sources. According to the conservation hypothesis there is a uni-directional causality running from economic growth to coal consumption. In this state, energy conservation policies which may prevent energy consumption will not have negative impact on economic growth which is confirmed by Jin-ke et al. [6] for China and Japan; Yang [7] for Taiwan; Jin-ke et al. [8] for Japan and China; Wolde-Rufael [5] for China and Korea. ***The feedback hypothesis*** implies a mutual relationship between coal consumption and economic growth. The feedback hypothesis is supported if there is bi-directional causality between coal consumption and economic growth. This hypothesis is checked by Yoo [9] for Korea; Li and Leung [10] for China Coastal and Central regions; Wolde-Rafael [5] for South Africa and USA; Apergis and Payne [1,11] for 20 OECD and 15 emerging countries. ***The neutrality hypothesis*** indicates that energy consumption does not affect economic growth. The absence of causality between energy consumption and economic growth provides evidence for the validity of the neutrality hypothesis. In this case, energy conservation policies devoted to reducing energy consumption will not impact economic growth which is confirmed by Jin-ke et al. [6] for India, South Africa and South Korea; Jin-ke et al. [8] for India and South Africa.

Although all of these studies contribute to investigating the relationship between coal consumption and industrial production, these analyses were introduced based on the assumption that the cointegrating vector remained the same during the period of study. However, there are many reasons to expect that the long-run relationship between the underlying variables might change such as shifts in the cointegrating vector can occur as a result of policy and regime changes and organizational or institutional evolution [12]. This can be an important issue if there are structural shifts in one or more of the energy consumption and industrial production series, since the existence of a structural break may disguise the true nature of any potential relationships among energy consumption, industrial production, capital and labor. The current paper builds on Hatemi-J [12] test for cointegration to the cases that take into account two possible regime shifts. In this test, the timing of each shift is unknown a priori and it is determined endogenously. The distributions of the tests are non-standard and generating new critical values via simulation methods. The size and power properties of these test statistics are estimated through Monte Carlo simulations, which demonstrate the tests have small size distortions and very good power properties.

The paper examines the causality relationships among industrial production index, coal consumption and employment in industrial sector for the period of 1973:1–2011:10 in USA. The paper is organized as follows: in Section 2, we describe model and data, in Section 3, we examine the links between coal consumption and industrial production, and give possible explanations for the econometric results that this research provides. We present the conclusions of our study and discuss policy implications in Section 4.

2. Model and data

In order to take into account the effect of two structural breaks on the parameters, we estimate the following regression model:

$$\ln \mathrm{IPI} = \alpha_0 + \alpha_1 D_{1t} + \alpha_2 D_{2t} + \beta_0 \ln \mathrm{CC}_t + \beta_1 D_{1t} \ln \mathrm{CC}_t + \beta_2 D_{2t} \ln \mathrm{CC}_t + \varphi_0 \ln \mathrm{L}_t + \varphi_1 D_{1t} \ln \mathrm{L}_t + \varphi_2 D_{2t} \ln \mathrm{L}_t + e_t \quad (1)$$

where IPI, CC and L are industrial production index, coal consumption by industrial sector and employment in industrial sector, respectively. All variables were indexed as base year 2005 and monthly data used. Coal consumption by industrial sector measured as thousand tons and obtained from Monthly Energy Review which was provided by US Energy Information Administration. Industrial coal consumption was seasonally adjusted using X12. Seasonally adjusted industrial production index and seasonally adjusted industrial employment are taken from OECD database. A monthly data set is used for the period of 1973:1–2011:10 for USA.

D_{1t} and D_{2t} are binary variables defined as

$$D_{1t} = \begin{cases} 0 \text{ if } t \le T_1 \\ 1 \text{ if } t > T_1 \end{cases} \text{ and } D_{2t} = \begin{cases} 0 \text{ if } t \le T_2 \\ 1 \text{ if } t > T_2 \end{cases}$$

where T is sample size. T_1 denotes the period before the first break and T_2 denotes the period before the second break.

3. Methodology and results

In this study, the method which was used to estimate cointegration test with two breaks consists of three steps. First step is to test the unit roots. Finding breaks in the model is the second step. Finally the cointegration test is carried out.

Before testing for cointegration, all of the variables in the model should meet the condition of $I(1)$. For this purpose, Kwiatkowski et al. [KPSS, [13]] and Lee and Strazicich [14] unit root tests with two endogenous structural breaks were used. The findings indicated that each variable is integrated to the first order.

In the second step, breaks in the multiple linear regression models were analyzed as suggested by Bai and Perron [15,16] who concentrate on the multiple linear regression system

$$Y = X\beta + \overline{Z}\delta + u \quad (2)$$

where $Y = (y_1,\ldots,y_T)'$, $X = (x_1,\ldots,x_T)'$, $U = (u_1,\ldots,u_T)'$, $\delta = (\delta_1',\delta_2',\ldots\delta_{m+1}')'$ and $\overline{Z}$ is the matrix that diagonally partitions Z at $(T_1,\ldots,T_m)$. Estimation method of the model relies on the least squares principle. To detect breaks in regression model, Bai and