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Breaks, Trends, and Unit Roots in Energy Prices: A New View from a Long-run Perspective

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1. Introduction

Berck and Roberts (1996) explore the trend properties of eleven non-renewable natural resources prices. They predict rising price trends using a trend-stationary model, but only find weak evidence for the increasing prices when a difference-stationary model is used.

Ahrens and Sharma (1997) analyze the prices of eleven resource commodities and find that five of them exhibit stochastic trends, while the others are stationary around a deterministic trend.

Lee et al. (2006) find evidence against the unit root hypothesis, and demonstrate that natural resource prices appear to be stationary around deterministic trends with structural breaks.

Ghoshray and Johnson (2010) perform unit root tests allowing for structural breaks on energy resource prices. They find evidence of stationarity, and argue that the spurious unit roots in previous literature might be induced by breaks in trend.

Many studies are conducted on examining the trend properties of resource prices, but the results are controversial.

Despite extensive studies on the trend properties of energy resources, there still exist critical limitations in testing for unit roots and estimating stochastic trends.

Perron (1989) show that a shift in the trend function might bias the sum of autoregressive coefficients towards unit.

Lee and Strazicich (2004, 2003) then develop minimum LM unit root tests with one or two breaks.

Kim and Perron (2009) extend Perron's (1989, 1990) work to the case of one break with an unknown break date.

Carrion-i-Silvestre et al. (2009) improve the previous procedure to allow for an arbitrary number of breaks with unknown break dates under both the null and alternative hypotheses.

This paper investigates the trend properties in the annually price series for coal, natural gas, and petroleum over the period 1880 to 2012. We examine the presence of breaks in trend using a sequential procedure proposed by Kejriwal and Perron (2010).

For prices with at least one breaks, we employ the procedure of Carrion-i-Silvestre et al. (2009) to allow for an arbitrary number of breaks with unknown break dates under both the null and alternative hypotheses. We further investigate their trend properties by estimating deterministic trend with an integrated or stationary noise component, using the Perron and Yabu (2009) trend estimate.

2 Method

2.1 Estimating deterministic trend with an integrated or stationary noise component

We use the following data generating process(Perron and Yabu ,2009; Estrada and Perron ,2012):

$$y_{\mathrm{t}} = x_{\mathrm{t}}' \Psi + u_{\mathrm{t}} \qquad (1)$$

$$u_{\mathrm{t}} = \alpha u_{\mathrm{t-1}} + e_{\mathrm{t}} \qquad (2)$$

$$x_t = (1, t)' \quad , \Psi = (\mu, \beta)' , \quad |\alpha| \leq 1$$

The estimating procedure is as follows:

1.Run the OLS regression on (1) to obtain the residuals $\widehat{u}_t$;

2.Estimate (2) using $\widehat{u}_t$ to obtain $\widehat{\alpha}$;

3.Use $\widehat{\alpha}$ to get the Roy and Fuller (2001) biased corrected estimate $\widehat{\alpha}_M$;

4. Apply the truncation

$$\widehat{\alpha}_{MS} = \begin{cases} \widehat{\alpha}_M & if \;\; |\widehat{\alpha}_M - 1| > T^{-0.5} \\ 1 & if \;\; |\widehat{\alpha}_M - 1| \leq T^{-0.5} \end{cases};$$

5. Run the GLS regression using $\widehat{\alpha}_{MS}$ to obtain the estimates of the trend coefficients and variance of residuals.

2.2 A sequential procedure to determine the number of breaks in trend with an integrated or stationary noise component

using the procedure proposed by Perron and Yabu (2009), as well as Kejriwal and Perron (2010),

1. For any given break date, follow the procedure 1-5 in section 2.1 and construct the standard Wald-statistic W;

2. Since the break date is assumed to be unknown, we repeated the above step for all the permissible break dates, in order to construct the *exp* function of the Wald test: $ExpW = log\left[T^{-1}\sum_{\Lambda} exp\left(\frac{1}{2}W(\lambda)\right)\right]$

where $\Lambda = \{\lambda; \epsilon \leq \lambda \leq 1 - \epsilon\}$ for some $\epsilon > 0$. In line with the literature, we set $\epsilon = 0.15$.

Conditional on the presence of k breaks , we perform the test on $k+1$ segments defined by the break date.

$$ExpW(k+1|k) = \max_{1\leq i\leq k+1}\{ExpW^i\}$$

where $ExpW^i$ is the Perron-Yabu test in segment i.

2.3 Unit root tests with multiple breaks on unknown break dates under both the null and alternative hypotheses

The model is specified with

$x_t = (1, t, DU_{1t}, DT_{1t}, \dots, DU_{mt}, DT_{mt})'$ and

$\Psi = (\mu_0, \beta_{10}, \beta_{11}, \dots, \beta_{m0}, \beta_{m1})$.

Here,$DU_{it} = I(t > T_i)$, $DT_{it} = I(t > T_i)(t - T_i)$ $(i = 1,2,\dots,m)$ with break date $T_i = [\lambda_i T]$ for some $\lambda_i \in (0,1)$ $(i = 1,2,\dots,m)$, where $[\cdot]$ denotes the largest integer that is not more than $\lambda_i T$ and $I(\cdot)$ is the indicator function. The hypothesis to test is $\alpha = 1$.

we apply the Ng-Perron unit root test (the no break M-test) to the natural gas price, and use the test proposed by Carrion-i-Silvestre et al. (2009) (the M-test) for coal and petroleum.

The feasible point optimal statistic:

$$P_T^{gls}(\tilde{\lambda}) = \frac{S(\alpha(\tilde{\lambda}), \tilde{\lambda}) - \alpha(\tilde{\lambda}) S(1, \tilde{\lambda})}{s^2(\tilde{\lambda})}$$

The M-class of test is given by

- $MZ_{\alpha}^{gls}(\tilde{\lambda}) = \left(T^{-1}\hat{y}_T^2 - s^2(\tilde{\lambda})\right)\left(2T^{-2}\sum_{t=2}^{T}\hat{y}_{t-1}^2\right)^{-1}$

$$MSB_{\alpha}^{gls}(\tilde{\lambda}) = \left(T^{-2}\sum_{t=2}^{T}\hat{y}_{t-1}^{2}\right)^{1/2} \Big/ s^{2}(\tilde{\lambda})$$

$$MZ_t^{gls}(\tilde{\lambda})$$
$$= \left(T^{-1}\hat{y}_T^2 - s^2\left(\tilde{\lambda}\right)\right)\left(4s^2(\tilde{\lambda})T^{-2}\sum_{t=2}^{T}\hat{y}_{t-1}^2\right)^{-1/2}$$

$$MP_T^{gls}(\tilde{\lambda}) =$$
$$\left[c^2(\tilde{\lambda})T^{-2}\sum_{t=2}^{T}\hat{y}_{t-1}^2 + \left(1 - c(\tilde{\lambda})\right)T^{-1}\hat{y}_T^2\right]/s^2(\tilde{\lambda})$$

3. Data and Empirical Results

Table 1: Descriptive statistics for energy prices

Series	Period	# Obs.	Mean	Std. dev.	Min.	Max.	Skewness
Coal	1880-2012	133	10.4475	13.8641	0.80	60.88	1.7570
Natural gas	1919-2012	94	121.2443	179.6444	4.5	804.2454	1.9010
Petroleum	1900-2012	113	10.6970	17.4199	0.61	82.7824	2.5200

Table 2: Results for Kejriwal-Perron break test

	ExpW(1|0)	ExpW(2|1)	ExpW(3|2)	ExpW(4|3)	ExpW(5|4)
Series: Coal price					
Test	13.4484***	19.3670***	7.8606***	6.2183***	1.3154
Break Date	1973	1998	1943	1924	--
Series: Natural gas price					
Test	2.0983	--	--	--	--
Break Date	--	--	--	--	--
Series: Petroleum price					
Test	3.0525*	3.6053**	2.6713*	0.1572	--
Break Date	1998	1979	1927	--	--

Notes. *, **, and *** indicate that the statistic is significant at the 10%, 5%, and 1% levels, respectively.

Table 3: Results for Ng-Perron and Carrion- unit root tests

Model	pt	Mpt	Mza	Mzt	MSB
Carrion-i-Silvestre et al. test					
Coal (4 breaks)	25.5017***	23.8266***	-14.9981	-2.7369	0.1825***
Petroleum (3 breaks)	13.2184***	12.1397***	-19.3298	-3.1043*	0.1606**
Ng-Perron test					
Natural gas (0 break)	15.4580***	14.4580***	-1.4986	-0.7739	0.5165***

Notes. *, **, and *** indicate that the statistic is significant at the 10%, 5%, and 1% levels, respectively.

Table 4: Results for Perron-Yabu trend estimate

	μ	β	K (MAIC)
Series: Coal price			
1880-2012	-3.1494***	0.0053	1
	(0.0927)	(0.0080)	
1880-1923	-3.1487***	0.0046	2
	(0.0771)	(0.0116)	
1924-1942	-3.1538***	0.0066	1
	(0.0723)	(0.0166)	
1943-1972	-2.9635***	0.0056	1
	(0.0896)	(0.0164)	
1973-1997	-2.7382***	-0.0093	1
	(0.1229)	(0.0246)	
1998-2012	-3.0061***	0.0348*	1
	(0.0734)	(0.0183)	

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Series: Natural gas price

1919-2012	-1.8407***	0.0096	11
	(0.1299)	(0.0134)	

Series: Petroleum price			
1900-2012	-3.0527***	0.0078	1
	(0.1949)	(0.0183)	
1900-1926	-3.0336***	-0.0113	1
	(0.2046)	(0.0394)	
1927-1978	-3.7498***	0.0099**	1
	(0.1181)	(0.0044)	
1979-1997	-2.8210***	-0.0271	2
	(0.2306)	(0.0529)	
1998-2012	-3.8177***	0.1095*	1
	(0.2206)	(0.0570)	

Notes. *, **, and *** indicate that the statistic is significant at the 10%, 5%, and 1% levels, respectively.

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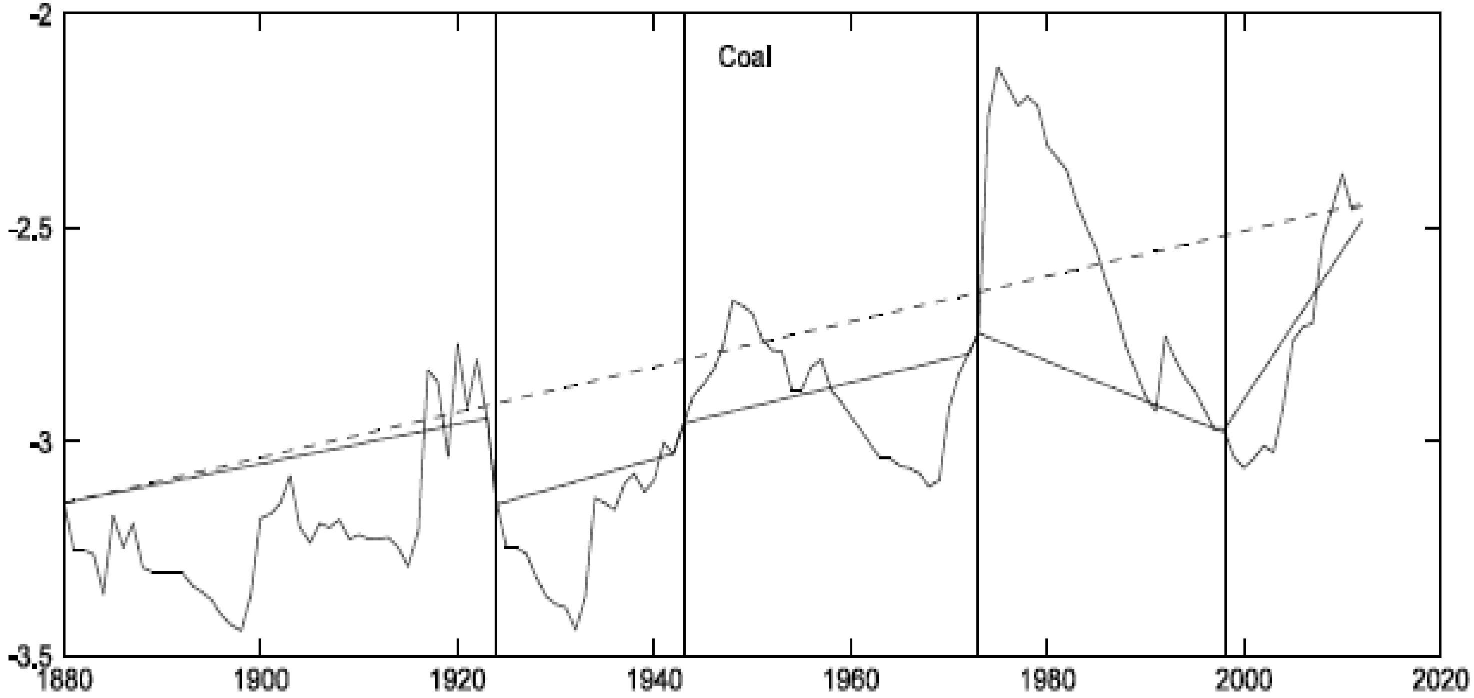
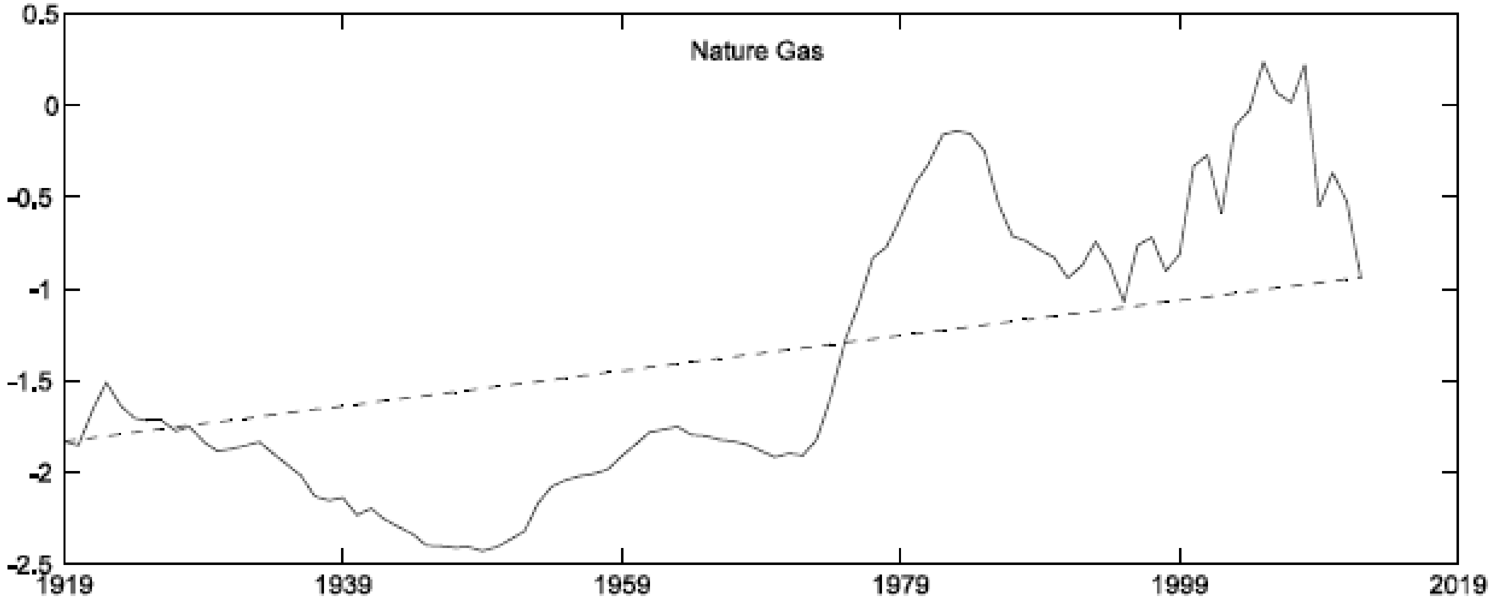
Fig.1(a).



Time series plot of coal price with 4 breaks

Fig.1(b).



). Time series plot of natural gas price without breaks

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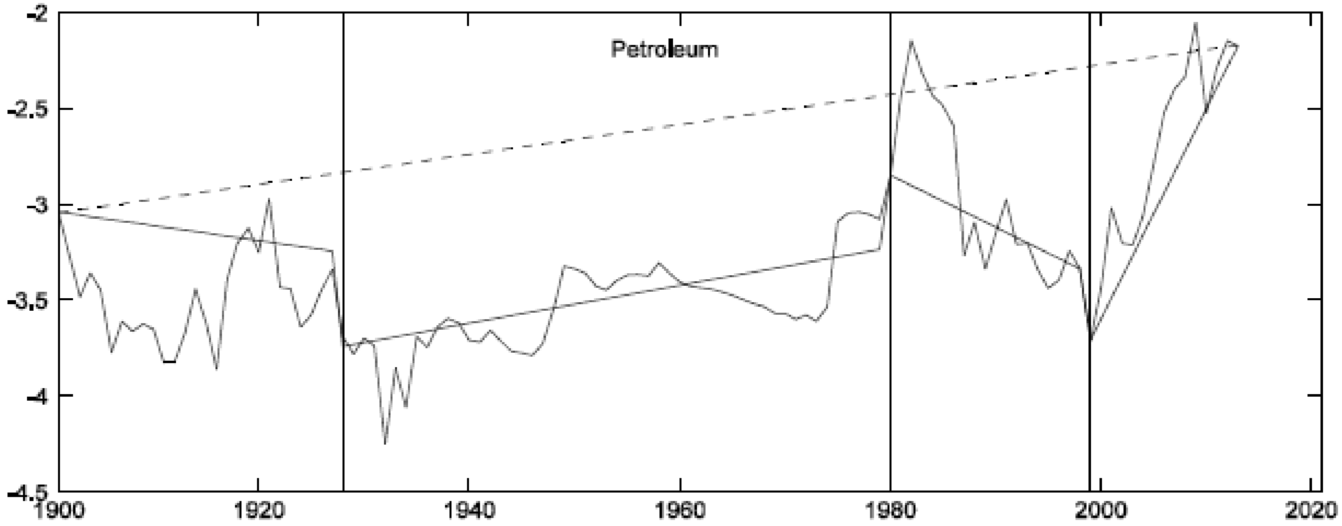
Fig.1(c).



Time series plot of petroleum price with 3 breaks

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4. Conclusions

This paper applies a new set of robust econometric methods to examine the trend properties in the prices of coal, natural gas, and petroleum over 1880-2012. We initially test for number and time of breaks in trend using Kejriwal and Perron's (2010) sequential procedure. we conduct the unit root test proposed by Carrion-i-Silvestre et al. (2009), allowing for multiple breaks in both the null and alternative hypotheses; for natural gas, we use the Ng-Perron test with no breaks.

we conclude that the price series are trend stationary without significant rising deterministic trend; structural breaks exist in the prices for coal and petroleum while not for natural gas. Our results further support the findings in previous studies (e.g., Berck and Roberts, 1996; Lee, et al., 2006; Ghoshray and Johnson, 2010) in the sense that we find evidence against unit roots and rising deterministic trend.

Q&A

Thank You！