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Testing for the purchasing power parity in energy prices in mainland China

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Abstract:
Fan and Wei (2006) investigate the spatial integration of gasoline and diesel in Mainland China. This study empirically tests for the emergence of a market driven energy sector in China by conducting an analysis of cointegration of energy price series for four major fuels and by identifying regional and periodical price cointegration. This study makes contributions to the literature on China's energy economy, by empirically testing for energy price co-integration using a new, high frequency, dataset that consists of the market prices of four energy types from 35 major cities from 1995 to 2005. The results show that gasoline and diesel show more evidence of cointegration (energy market integration and the Law of One Price) than those of caol and electricity. At this stage, it is potentially interesting to ask why? There may be many answers to this, but the following may be important:

- Gasoline and diesel are more homogeneous energy products than coal and electricity. In this case, it is expected that the former price series are more likely more cointegrated than the latter.
- The intensity and time of reforms are different over the two groups of energy sources. According to our review of the energy policy reform in China, the prices of petroleum products and coal were deregulated earlier than that of electricity.
- The price reforms were almost simultaneous for gasoline and diesel while they were not synchronous for coal and electricity. Typically, price deregulation was earlier for the coal industry than for the electricity industry. One might expect that the non synchronous price reforms in the coal industry and electricity industry would not likely lead to observed cointegration and probably contributed to the later emergence of cointegration of the price series of coal and electricity in China.
- Coal and electricity are categorized in the same energy group in this study, but most electricity is generated from coal.
- Substitutability is significantly different between gasoline and diesel and coal and electricity though they are both substitutable. Gasoline and diesel may be easily substitutable while coal and electricity may be complements.
- Differences in price deregulation over energy types are closely related to their effects on the national economic growth and consumer consequences. Typically, changes in electricity price appear more related to the cost of living than input costs. Hence, electricity price deregulation was deferred in China. Correspondingly, price reforms for other commodities closely related to electricity production might be also delayed or overdue. This is particularly true for reform of coal prices where most of it is used to generate electricity.

Keywords: *China; energy prices; cointegration; convergence; Law of One Price*

1. INTRODUCTION

Fan and Wei (2006) investigate the spatial integration of gasoline and diesel. To expand this literature, Ma, Oxley and Gibson (2008) study the integration of coal and electricity prices across cities using a higher frequency price data. However, this is only one of two aspects of a market economy another is whether there is cointegration among various fuel price series – this is the basis of the research reported here.

Poncet (2003 and 2005) investigates interprovincial trade barriers. Because of apparent differences in price regulations and administrations, energy prices vary considerably across energy sectors. The trade barriers may be even larger across energy sectors than across regions in China. Whether different energy regulations have led to a multi energy economies is worthy of investigation.

This study empirically tests for the emergence of a market driven energy sector in China by conducting an analysis of cointegration of energy price series for four major fuels and by identifying regional and periodical price cointegration. This study makes contributions to the literature on China's energy economy, by empirically testing for energy price co-integration using a new, high frequency, dataset that consists of the market prices of four energy types from 35 major cities from 1995 to 2005.

The rest of the study is organized as follows. Section 2 presents the energy price data used in the study. Section 3 presents an overview of the methods used and Section 4 presents the Results. Section 5 Concludes

2. DATA

The most comprehensive price data for China are from the China Price Information Network managed by the Price Monitoring Center (PMC) within the State Development and Reform Commission (SDRC). There are 5000 monitoring sites over 150 medium and large cities and over 280 counties across the country. The energy price data used here are from PMC and are a panel data set of 10-day spot prices for four major fuels in 31 Chinese medium and large cities.[1] The data are collected on the 5th, 15th and 25th of each month from local markets by governmental agencies in 31 Chinese medium and large cities across the whole country.[2]

Unlike other commodity price data, these fuel price data have no missing observations during the study period as fuels are extensively used in all cities. We choose four major fuel products: coal, electricity, gasoline and diesel. These panel data are truly nationally representative because they cover the main fuel components, all provincial capital cities of mainland China, and the period covered is 01/1995 to 12/2005. This is to be contrasted with most other empirical studies, such as Cecchetti, Mark and Sonora (2002), which use a price of lower frequency (such as annual) data. The 10-day frequency of our price data also corresponds well to the time needed for domestic price arbitrage as a lower frequency (monthly) price data are not as useful when we wish to test for price convergence with any degree of precision (Taylor, 2001). Furthermore, monthly spot prices are not as rich a data source as 10-day spot prices, particularly if one wants to measure the half-life of subsequent adjustment (Bachmeier and Griffin, 2006).

3. METHODS

3.1 Univariate unit root tests

A common approach used to investigate market integration is to apply unit root tests to examine whether price differentials are stationary (see for example, Bernard and Durlauf, 1996; Greasley and Oxley, 1997). Rejection of the unit root hypothesis implies that the time series of relative prices are stationary, such that relative prices will converge in the long run. Otherwise, if the tests fail to reject the null hypothesis, the relative price series will follow a random walk (Fan and Wei, 2006).

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[1] The cities are Beijing, Tianjin, Shijiazhuang, Taiyuan, Huhehaote, Shenyang, Changchun, Harbin, Shanghai, Nanjing, Hangzhou, Hefei, Fuzhou, Nanchang, Jinan, Zhengzhou, Wuhan, Changsha, Guangzhou, Nanning, Haikou, Chongqing, Chengdu, Guiyang, Kunming, Lhasa, Xian, Lanzhou, Xining, Yinchuan, Urumqi. They include four municipalities and all the capital cities for the 31 provinces and autonomous regions in mainland China.

[2] The price data are collected to provide price information to the central and local governments for macroeconomic management. According to state law, the local price bureaus in 31 major cities are obligated to report price information for a specified list of products to the Price Information Center The fuel price information is collected three times a month, on the 5th, the 15th and the 25th day of the month. The fuel names are uniform across all cities, and all prices must be market prices.

The first stage of the time series based tests of price convergence utilises some form of unit root test. In our particular example we are interested in testing for integration of the relevant energy market across the major Chinese cities, by testing for price convergence. Tests that suggest the relative price series [$p_{ijt} = \ln(g_{ij,t} / g_{j.t})$] are stationary will provide some evidence of convergence, either absolute or relative. All the ADF specifications used here include an intercept term to capture city-specific fixed effects and a time trend. Such intercept effects may cover, for instance, city-specific transportation, income levels, and local non-traded costs. The inclusion of the intercept term is also used to test whether prices converge to absolute price parity (zero mean) or relative price parity (nonzero mean) (Fan and Wei, 2006).

It is convenient to use group average as a benchmark (g_{jt}) in order to generate relative price series and conduct the ADF unit root tests. Theoretically, it is possible that all of the ADF unit root tests will reject the null hypothesis no matter which city is chosen as a benchmark (g_{jt}) if the energy market is completely integrated. However, there may be apparent differences across energy products in the degree of market integration.

Therefore, we firstly conduct the ADF unit root tests using group average as a benchmark to see how many tests reject the null. If the ADF unit root tests show almost all of them reject the unit root hypothesis for some energy products, it may not be necessary to further conduct the ADF unit root tests of relative price series on city-by-city basis.

3.2 Panel unit root and cointegration tests

It is now well know that the original unit root tests often suffer from low power when applied to series of only moderate length, and it has been proposed that pooling the data across individual members of a panel helps increase power. Panel cointegration techniques are intended to allow researchers to selectively pool information regarding common long-run relationship from across the panel while allowing the associated short-run dynamics and fixed effects to be heterogeneous across different members of the panel (Banerjee, 1999; Maddala and Wu, 1999). Given the properties of our data, we utilize both panel unit root tests and panel cointegration test techniques. Three kinds of panel unit root tests, Levine et al. (2002, thereafter LLC), Im et al. (2003, thereafter IPS) and Hadri (2000), are used in this study. Each has different assumptions, constraints and statistical power. LLC propose an ADF test with a panel setting that restricts parameters γ_i by keeping them identical across cross -sections (in our case cities) as follow:

$$\Delta y_{it} = \alpha_i + \gamma_i y_{it-1} + \sum_{j=1}^{k} \alpha_j \Delta y_{it-j} + e_{it} \qquad (1)$$

Where $t = 1,2,\cdots,T$ refers to the time periods and $i = 1,2,\cdots,N$ refers the numbers of the panel. The null hypothesis of LLC test is that $\gamma_i = \gamma = 0$ for all *i* indicating that the panel data are non-stationary while the alternative hypothesis is $\gamma_1 = \gamma_2 = \cdots = \gamma < 0$. IPS (2003) relax this assumption of LLC by allowing γ to vary across units (cities) under the alternative hypothesis. The null hypothesis of the IPS test is that $\gamma_i = 0$ for all *i*, while the alternative hypothesis is $\gamma_i < 0$ for all *i*. This IPS test uses the mean-group approach and obtains the average of t_y to compute their $\tilde{Z}$ statistic. The statistic $\tilde{Z}$ converges to a Normal distribution, and we can compute the significance level in a simple way. By contrast, Hadri (2000) argues that the nh should be reversed to be a stationary hypothesis in order to increase the power of the test. His Lagrange Multiplier (LM) statistics is computed with consistent estimates of the long-run variance of disturbance terms. In many circumstances it is hard to judge which panel unit root tests is best as most of time we do not know the properties of the price series. Thus, to obtain more robust results, this study uses six panel unit root tests to determine whether the panel dataset is stationary. In addition, three other panel unit root tests: Breitung, Fisher ADF, and Fisher PP are considered. The null hypothesis for LLC and Breitung is a common unit root process; for IPS, Fisher ADF and Fisher PP individual unit root processes are assumed and for Hadri stationarity is the null. Using these panel unit root tests, we proceed to test for cointegration in the data.

Using the heterogeneous panel cointegration test developed by Pedroni (1999) allows for cross-sectional interdependence with different individual effects. There are two types of residual-based tests (Pedroni, 1999). The first type is distributed as being standard Normal asymptotically and is based on pooling the residuals of the regression for the within-group. It includes the panel υ -statistic, panel ρ -statistic, panel PP-statistic (or t -statistic, non-parametric) and the panel ADF-statistic (or t -statistic, parametric). The second type is also distributed as standard Normal asymptotically, but is based on pooling the residuals for the between-group. It includes the group ρ-statistic, group PP-statistic (or t-statistic, non-parametric) and the group ADF-statistic (or t-statistic, parametric). Details of the various tests can be found in Pedroni (1999), where critical values can also be found, and will not be covered here due to space constraints. It is easy to form a conclusion if all seven tests reject the null of no cointegration. It is, unfortunately, not always the case that all of them reject the null hypothesis simultaneously. If the panel is fairly large so that size distortion is less of an issue, the panel υ-statistic tends to have the best power relative to the other statistics and can be most useful when the alternative is potentially very close to the null.

4. RESULTS

Due to space limitations we will report detailed results only for national level panel-based unit root tests and panel-based cointegration.

Univariate unit root tests of price convergence for the whole sample period and for two sub-periods (1995-1999 and 2000-2005) for 35 provincial capital city markets using the group averages of all 35 markets as a benchmark show that there are five instances of convergence for coal, two for electricity, 13 for gasoline and 14 suggest convergence for diesel. The general results suggest that there are fewer instances of convergence for coal and electricity than for gasoline and diesel. From these simple tests we cannot conclude that China's energy markets are integrated.

Using the same procedure, we next conduct panel unit root tests to ascertain whether there is a national integrated energy market in China. Panel unit root tests for the relative price series for 35 city markets based on the group average as benchmark are presented as Table 1, which displays three periods and five types of tests for all four types of energy. Several points can be made based on the panel unit root test results from Table 1.

Table 1. Panel unit root tests of relative price data for all 35 city markets

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-2005:								
LLC	4.97	0.99	0.62	0.73	-3.45	**0.00**	-4.74	**0.00**
Breitung	-1.79	**0.04**	-4.73	**0.00**	-6.72	**0.00**	-9.86	**0.00**
IPS	-2.26	**0.01**	-0.29	0.39	-8.69	**0.00**	-8.83	**0.00**
Fisher ADF	100.61	**0.01**	61.42	0.76	226.67	**0.00**	221.77	**0.00**
Fisher PP	302.93	**0.00**	951.95	**0.00**	1728.9	**0.00**	1403.0	**0.00**
2000-2005:								
LLC	-1.41	**0.08**	5.22	0.99	-2.65	**0.00**	-2.89	**0.00**
Breitung	-2.57	**0.01**	-3.93	**0.00**	-5.05	**0.00**	-4.72	**0.00**
IPS	-2.01	**0.02**	-2.24	**0.01**	-11.40	**0.00**	-10.05	**0.00**
Fisher ADF	103.76	**0.01**	82.31	0.15	343.16	**0.00**	249.23	**0.00**
Fisher PP	160.99	**0.00**	2123.1	**0.00**	1950.4	**0.00**	1292.7	**0.00**
1995-1999:								
LLC	9.05	0.99	2.97	0.99	3.94	0.99	4.32	0.99
Breitung	-2.90	**0.00**	-3.66	**0.00**	-0.12	0.45	-0.83	0.20
IPS	-0.38	0.35	-0.13	0.45	-4.26	**0.00**	-2.48	**0.01**
Fisher ADF	78.21	0.23	64.03	0.68	148.33	**0.00**	106.62	**0.00**
Fisher PP	306.25	**0.00**	407.42	**0.00**	792.52	**0.00**	602.41	**0.00**

Note: Null hypothesis is common unit root for LLC and Breitung tests, and individual unit root for IPS. Fisher ADF and Fisher PP tests. Exogenous variables include Individual effect and individual linear trend.

Firstly, it should be noted that most of the LLC panel unit root tests fail to reject the null hypothesis, which might be due to the assumption of a common unit root process. Secondly, most of the remaining panel unit root tests reject the null hypothesis of a unit root, which suggests that energy prices are convergent as a whole. Thirdly, there are more tests that reject the null in the second subsample period than in the first, suggesting that it is more likely that relative energy prices are convergent in the second subsample period than in the first. Finally, fewer panel unit root tests reject the null for coal and electricity than for gasoline and diesel, suggesting that gasoline and diesel are more likely to be market-oriented than coal and electricity.

Given the potential for different pricing periods and reform effects, in the subsequent analysis we test for the existence of inter-fuel price cointegration first for the whole period and then for sub-periods whose dates are informed by institutional and historical changes. The tests also consider national and regional level markets.

If all tests reject or all tests do not reject, the conclusion is clear, however, as is common when using such a battery of tests, the results are potentially ambiguous and care must be exercised in choosing which results to emphasize and why. As discussed in Pedroni (2004), in terms of monthly data, with fewer than 20 years of data it may be possible to distinguish even the most extreme cases from the null of no cointegration when the data are pooled across members of panels with these dimensions. This condition has been met in our case since we have 36 observations each year or 3 observations each month. Furthermore, if the panel is fairly large so that size distortion is less of an issue, the panel υ-statistic tends to have the best power relative to the other statistics. In very small panels, however, if the group-rho statistic rejects the null of no cointegration, we can be relatively confident of the conclusion as it is slightly undersized and empirically the most conservative of the tests. The other statistics tend to lie somewhere in between these two extremes and have minor comparative advantages over different ranges of the sample size. The panel-υ statistic is the strongest panel cointegration test and therefore the next discussions will be focused on this test.

Table 2. Panel cointegration tests for all 35 markets (p values)

Test statistics	**All four fuels**		
	1997-2005	**1997-1999**	**2000-05**
No deterministic trend:			
Panel ν -statistic	**0.399**	**0.305**	**0.386**
Panel ρ -statistic	0.000	0.000	0.000
Panel t -statistic [a]	0.000	0.000	0.000
Panel t -statistic [b]	0.394	0.204	0.005
Group ρ -statistic	0.000	0.001	0.000
Group t -statistic [a]	0.000	0.001	0.000
Group t -statistic [b]	0.344	0.258	0.051
Deterministic intercept and trend:			
Panel ν -statistic	**0.004**	**0.374**	**0.057**
Panel ρ -statistic	0.000	0.000	0.127
Panel t -statistic [a]	0.000	0.000	0.036
Panel t -statistic [b]	0.047	0.000	0.139
Group ρ -statistic	0.000	0.000	0.011
Group t -statistic [a]	0.000	0.000	0.008
Group t -statistic [b]	0.008	0.000	0.398

Table 2 and 3 present the national panel cointegration tests for the inter-fuels of all four fuels (Table 2), electricity and coal, and diesel and gasoline (Table 3) for the full period (1997-2005) and two sub-periods (1997-1999 and 2000-2005).

For the full sample period the national panel cointegration tests suggest that all four price series move together in the long-run given the assumption of no deterministic trend (Table 2). *A priori*, however, we would find this result unlikely since we know that for some years and some fuels energy prices were independently controlled and their time series paths appear to vary. If we consider the three sub-period tests, most of the panel υ-statistic tests do not reject the null of no cointegration. The lack of cointegration for all fuels at the national level is also as we might expect as coal and electricity appear to move, over time, differently to gasoline and diesel prices. Such an expectation is supported in the results. However, it is clear that that all four fuel prices are more cointegrated in the second sub-period than in the first sub-period since one of panel υ-statistic tests rejects the null hypothesis in the second sub-period.

For coal and electricity, the national panel cointegration tests provide some weak evidence of cointegration for the full sample period. However, these weak results are not supported when we consider the two sub-periods where the results suggest that the coal and electricity price series did not move together in a long-run during 1997-1999, while the coal and electricity price series may have moved together during 2000-2005. These results are consistent with our previous observations.

The national panel cointegration tests show a different scenario for gasoline and diesel price series. The national panel cointegration tests suggest that gasoline and diesel price series have moved together in a long-run during both for the full sample period and the two sub-periods.

Table 3. Panel cointegration tests for all 35 markets (p values)

Test statistics	**Electricity and coal**			**Diesel and gasoline**		
	1997-2005	**1997-1999**	**2000-2005**	**1997-2005**	**1997-1999**	**2000-2005**
No deterministic trend:						
Panel v -statistic	**0.229**	**0.345**	**0.075**	**0.000**	**0.000**	**0.000**
Panel ρ -statistic	0.000	0.000	0.000	0.000	0.000	0.000
Panel t -statistic [a]	0.000	0.002	0.000	0.000	0.000	0.000
Panel t -statistic [b]	0.001	0.260	0.011	0.000	0.000	0.000
Group ρ -statistic	0.000	0.000	0.000	0.000	0.000	0.000
Group t -statistic [a]	0.000	0.001	0.000	0.000	0.000	0.000
Group t -statistic [b]	0.000	0.240	0.000	0.000	0.000	0.000
Deterministic intercept and trend:						
Panel v -statistic	**0.014**	**0.393**	**0.100**	**0.000**	**0.000**	**0.000**
Panel ρ -statistic	0.000	0.000	0.279	0.000	0.000	0.000
Panel t -statistic [a]	0.000	0.000	0.182	0.000	0.000	0.000
Panel t -statistic [b]	0.090	0.000	0.385	0.000	0.000	0.000
Group ρ -statistic	0.000	0.000	0.079	0.000	0.000	0.000
Group t -statistic [a]	0.000	0.000	0.227	0.000	0.000	0.000
Group t -statistic [b]	0.011	0.000	0.240	0.000	0.000	0.000

Note: Statistics are asymptotically distributed as normal. The statistic ratio test is right-sided, while the others are left-sided. Null hypothesis is no cointegration among the fuel prices and no exogenous variables are included in test equation. Pedroni panel cointegration test is based Engle-Granger. Pedroni (1999) shows that the panel-ADF and group-ADF statistics have better small sample properties than the other statistics, and hence they are more reliable. [a] Non-parametric and [b] parametric.

5. CONCLUSIONS

At this stage, it is potentially interesting to ask why the price series of gasoline and diesel show more evidence of cointegration than those of coal and electricity, both statistically and economically. There may be many answers to this, but the following may be important:

- Gasoline and diesel are more homogeneous energy products than coal and electricity. In this case, it is expected that the former price series are more likely more cointegrated than the latter.

- The intensity and time of reforms are different over the two groups of energy sources. According to our review of the energy policy reform in China, the prices of petroleum products and coal were deregulated earlier than that of electricity.

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- Coal and electricity are categorized in the same energy group in this study, but most electricity is generated from coal.

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