Energy Market Integration in China: Evidence from Panel Unit Root and Panel Cointegration Tests

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Abstract: The paper tests for energy price co-movement in China over the past decade as part of a strategy to identify the existence of a national energy market. Test results suggest that not all energy commodities are spatially homogenous in prices and the processes of energy price cointegration are different over time and over fuel sources, demonstrating China's gradual, spatially partial and idiosyncratic energy reform process. Coal and electricity price series have co-moved since 2000, while the national panel cointegration test statistics suggest that gasoline and diesel price series have co-moved since 1997. Regional panel tests also show that there are apparent differences in the emergence of energy price co-movement. This may mean that regional energy markets have emerged in China. One of the important lessons of the research is that an energy market has, to some extent, already emerged in China and, as a consequence, energy prices are much less distorted than previously. If correct, this fact is of major, global, significance both in terms of future environmental effects and future trade and investment negotiations as China is seen internationally as a 'market driven economy'.

Key words: China; Energy; Cointegration
JEL classifications: D24, O33, Q41

1. Introduction

Deregulation of energy markets typically allows them to respond more freely to energy supply and demand conditions. As a consequence, more competitive and interrelated market environments are starting to appear (Park et al., 2006, 2008), with the expectation that price determination is more likely to be in the hands of the market participants rather than those of the regulators (Mjelde and Bessler, 2009). A market determined price mechanism allows participants to more quickly respond to changes in energy prices and allows more efficient allocation of resources. In the electricity market for example, electricity spot markets may respond to price changes in fuel source markets, while fuel source prices can in turn respond to changes in electricity prices (Asche et al., 2006). Given the nature and use of the different fuel sources, one would further expect fuel source prices to be at least weakly integrated (Bachmeier and Griffin, 2006). This relationship is also reflected in the fact that one energy source may be the input factor of other energy sources, implying that there exists an input-output relationship between energy.. This is particular true in China where approximate 75% of total coal is used to generate electricity (CESY, 2008).

Establishing whether fuel markets are econometrically ‘cointegrated’ is potentially important for economists and researchers as the results of such estimation and testing can inform a range of analytical and policy issues. As Mjelde and Bessler (2009) highlight, at least three efficiencies lead to energy source prices being related: time (dynamic), space (location) and form (transformations). Since energy sources are used as factor inputs, their substitution possibilities can be dependent upon the cointegration relationship between fuel markets and their energy consumption behaviors. In particular, it is naive to study the relationships (substitution and complementarities) between fuel sources without a clear understanding of the actual energy market conditions. If markets are spatially heterogeneous and the Law of One Price is found not to hold, econometric studies that measure inter-fuel substitution possibilities are purely academic. Similarly, attempts to forecast energy usage and substitution possibilities would surely be erroneous if fuel prices are exogenously and regionally determined by regulators. Therefore, the degree of price transmission from input factor to output products is dependent upon how energy source markets are well such markets are integrated as demonstrated by spatial fuel price homogeneity.

China has undertaken a series of significant policy reforms to its energy industries and markets over the last two decades, including regulatory decentralization and pricing deregulation (for details see Ma 2009). However, the timing and intensity of policy reforms across energy sectors has varied considerably for example, China's coal and electricity sectors have experienced unbalanced developments in terms of regulatory decentralization and pricing deregulation (Wang, 2007). One of the main reasons why energy sources are not as substitutable as technically feasible may be because energy markets are not completely free of regulatory influence or lack transmission capacity (Asche et al., 2006). As a consequence, therefore is would be fundamentally important to understand whether China's energy reforms have brought with them more competitive and interrelated energy market environments. This study will help answer this question and the results will have important implications for further energy policy reforms in China.

Given its importance, the market integration of energy fuel source markets has been extensively and empirically investigated in many countries for example, the U.S. integration of electricity markets and their major fuel source markets has been extensively studied (see Panagiotidis and Rutledge 2007 and Bachmeier and Griffin 2006 for a brief literature review). Honarvar (2009) investigated the asymmetry in retail gasoline and crude oil price movements in the United States. Oil and gas market cointegration in the UK has also been examined (see Mjelde and Bessler 2009 for a brief literature review). However, given China's economic size and significant effect of energy consumption on the world energy markets, to our knowledge, no study has examined interdependencies between China's major energy fuel source markets.

In this study we investigate empirically the emergence of an integrated energy market in China by conducting an analysis of the existence of cointegration between energy price series for four major fuels. The study makes two major contributions to the literature on China's energy economy. Firstly, we test for the existence of an integrated national energy market in China for the major energy source markets and secondly, we test for energy price cointegration using a new, high frequency, dataset that consists of spot prices of four major energy sources from 35 major cities from January 1995 to December 2005.

The analysis commences with the presentation of some high-level descriptive statistics which are used to highlight the various development stages of an energy economy since China adopted a gradualism reform strategy. It is useful to demonstrate how energy reforms affect the integration of energy source markets over regional and temporal subsets of the data. This is especially useful in China where national energy policies are typically operated as regional energy and development policies due to the regionally unbalanced distribution of energy reserves. Consequently, the process of energy market liberalization could differ over regions and time.

The rest of study is organized as follows. Section 2 presents the energy price data to be utilized in the study. Section 3 reviews China's energy reforms over time and industries to show their potential effects on the cointegration of China's energy source markets. This helps motivate and identify the various stages or sub-periods of the transitional energy economy in China discussed in Section 4. Section 5 considers statistically the relations between fuel prices over time and reform stages by providing various figures that show the relation between fuel prices and the effects of energy economic reforms on the development of energy source markets. Section 6 presents panel unit root and cointegration results for fuel prices co-movement so as to provide primary evidence for the emergence of energy market integration in China. Section 7 summarizes the main findings and provides some policy implications to conclude the study.

2. Data

The most comprehensive price data for China are available 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 located in 150 medium and large cities and over 280 counties spread over the country. The price database covers consumer goods, various fuels, production factors, cash crops, food grains, medicines, vehicles, real estate, and many other items for a total of several thousand commodities.

The energy price data used here are from the 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 all over the 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. Four major fuel products are used in the research: coal, electricity, gasoline and diesel. These panel

[1] The cities are Beijing, Tianjin, Shijiazhuang, Taiyuan, Hohhot, 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, and 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 price information must be collected from fixed local markets. 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.

data are truly nationally representative as they cover the main fuel components, all provincial capital cities of mainland China, and the period used is 01/1995 to 12/2005. This is to be contrasted with most other empirical studies, for example Robinson (2007) and Cecchetti et al. (2002), where they use data of lower frequency (annual). The 10-day frequency of the price data used here corresponds well to the time needed for domestic price arbitrage. Lower frequency (monthly) price data are much less likely to be useful when testing for price convergence with any degree of precision (Taylor, 2001).

The quality of Chinese data is often criticised as reporting in China is often affected by political factors (Rawski, 2001). However, we believe that the data for specific product prices collected by local government agencies under strict government mandates are unlikely to be subject to such manipulation. Central government requires the collection of prices for specific products at fixed dates and locations and these price data are also available to the public so that local officials would find it hard to report false data. Unlike macro-economic data (such as GDP growth and employment rates), these micro data could hardly serve as indicators when assessing the performance of local officials and hence local officials have less incentive to falsify them.

3. Energy price reforms in China

Although it has lagged somewhat behind the general national economic reform, reform of the energy sector is an integral part of the overall economic reform package in China,. China's energy prices were 'irrational' and caused enormous macroeconomic and microeconomic distortions in the energy sector and throughout the economy (Fesharaki et al., 1994). In this section we review China's major energy price reforms and their corresponding effects on the time path of energy prices.

3.1 Features of the energy reforms

As early as the1980s, China introduced several measures to rationalize oil, coal, gas and electricity prices, however, many of the most important energy reforms were launched in the early 1990s. A complete market-oriented energy economy has, however, not yet been created and many energy policy reforms are still under way. The slow pace of transition to a complete market-oriented energy economy reflects the most important facet of reform in China, that of “gradualism”. In the early years of gradual reform there were few adjustment costs (Lau et al., 2000) and thus strategy appears to have worked well and has been generally accepted (Young, 2000).

Until the reforms of the late 1970s, energy prices were fully state-controlled in China. During the early 1980s, China adopted a ‘dual track’ system of energy pricing policy, i.e., ‘in-plan’ prices and ‘out-plan’ prices. This energy pricing system remained in place until 1993. ‘In-plan’ energy prices were normally lower than market prices, while ‘out-plan’ energy prices were typically market prices. However, in-plan energy prices were not always fixed. Most in-plan prices dramatically increased as energy price reform proceeded after 1994 (Wu and Li, 1995), and were gradually replaced by market-mediated prices. This prepared the sector for government initiated market-oriented energy price reform, which is described below.

3.2 Evolution of energy pricing policies

3.2.1 Coal price reforms

The market-oriented energy price reform varied in time and in intensity across energy type. The ‘dual track’ pricing system for coal was introduced in 1985. Under this policy, central government-owned mines had to fulfill an output quota at low price for allocation to those important state-owned downstream industries such as electricity, steel, metallurgy, engineering, chemicals and transportation. The local government-owned mines and town-village-owned mines had also to fulfill quota. Coal within quotas was referred to as ‘in-plan’ and production beyond the quota obligation was referred to as ‘out-plan’ and could be priced up to 100% higher than within quotas (Cheng, 1998).

As more and more coal was sold on the free market, the deliberate low price of ‘in-plan’ coal was difficult to sustain. Moreover, the price scheme introduced in 1985 allowed upstream and downstream industries to adjust their out prices in relation to the fluctuation of input costs (Wang, 1995). Consequently, coal prices were gradually freed-up and by 1996 price regulation on coal was completely abolished (Hang and Tu, 2007).

One downstream industry, however, which could not afford to operate with market priced coal was power generation since electricity tariffs remained tightly controlled. Consequently, some coal enterprises refused to sell coal to power plants and a new policy was established in 1996 with the price of coal sold to power plants again guided by central government and announced at the end of every year. This policy could not be implemented perfectly as coal producers used various reasons to avoid fulfilling their contracts (Wang, 2007). Consequently, the electricity industry could not always obtain its coal under guided prices, with led to frequent power blackouts.

Bargaining between the two parties became even more intense after 2002 when the system of government-guided price of coal was disbanded, however, electricity tariffs remained regulated. This meant that coal producers were allowed to determine the price of coal as they wished. As a result, only 90 mmt was contracted in 2002, which was less than 37% of the total demand for coal by power generators (Wang, 2007). Faced with serious power shortages, in April 2003 the NDRC gave an order such that the coal price to generators was to be set as the midpoint between the requirements of the two parties. In 2004, the government introduced a new coal pricing policy called the ‘co-movement’ of prices of both coal and electricity. The co-movement was not a free market adjustment, but regulated and determined periodically by the SDRC to avoid extreme price fluctuation.

Adjustments would only be made if coal price fluctuations exceeded 5%, otherwise, the change would be accumulated to the next adjustment period (Ma and He, 2008).

Coupled with a strong demand for coal, coal prices increased considerably after 2002 due to the intense bargaining between coal producers and power plants (Figure 1). For example, coal-based electricity generation was 13276 million KWh in 2002 and 23696 million KWh in 2006, with a 15.6% of growth rate annually. Correspondingly, the coal price increased from around ¥260 per ton at the end of 2001 to nearly ¥300 per ton at the end of 2003 and ¥410 per ton by the end of 2005.

The China Taiyuan Coal Trade Exchange was established on 18 June 2007 (TCTE, 2007), to replace the coal ordering meetings between coal producers and power producers. Since its creation more freedom has been given to coal suppliers and consumers, suggesting that the toughest reform issue in China's energy industry has been resolved. This new price-setting system should make the price of coal more market-oriented.

3.2.2 Petroleum price reforms

Petroleum price regulation has experienced four stages. Pre-1981, petroleum prices were fully state-controlled. From 1981 to 1994, a 'dual track' pricing system was adopted, while from 1994 to 1998 petroleum prices were market meditated. Post 1998, domestic petroleum prices have been set in accordance with the international market price (Hang and Tu, 2007). Meanwhile, central government sets the regional prices of refined oil products according to the Singaporean oil market and as a result, the 1998 reform resulted in domestic petroleum prices closely tracking international prices (Wu, 2003).

3.2.3 Electricity price reforms

Electricity pricing reform has been complicated and costly in China, as it affects millions of households. As a consequence, the Chinese government has been very cautious in reforming the electricity industry. As in other countries, electricity prices are not completely deregulated in China, however, the government has made significant progress including increasing electricity prices to 'realistic' market levels.

In 1985, electricity tariffs were raised throughout the country. For the first time, local producers were allowed to raise tariffs to cover the rising costs of coal and transportation (Hang and Tu, 2007). The State Council also encouraged investment in the power industry and introduced multi-tiers of electricity tariffs. In 1987, the government issued a new policy of *Fuel and Transportation Add-up*. It was used as an adjustable surcharge on catalog prices based on fluctuations in coal and transportation costs. This price adjustment procedure was administered and assessed annually by the SDRC.

In 1991, a 'high-in' and 'high-out' policy was introduced, allowing electricity tariffs to fluctuate according to coal and other factor costs. In 1993, a 'new plant-new price' policy was implemented, which allowed all power plants built after 1992 to sell power to provincial power companies at debt repayment prices in order to provide sufficient revenue for the repayment of loan capital with interest. In the 1990s, a range of surcharges, such as the '*Power Construction Fund*', '*Three Gorge Construction Fund*', were imposed (Ma and He, 2008). With these new policies, electricity tariffs have risen rapidly (Lam, 2004), however, the new policies also resulted in a complicated price structure, with highly regulatory, supervisory and transaction costs.

To simplify the control of priced, a scheme, 'operation-period price' and 'yardstick price', was adopted in 1997. The price under this scheme is based on an average social generation cost and a unified internal rate of return on capital over the remaining operation period. For present plants, this is indeed an operation-period price while for new plants the scheme actually specifies a unified yardstick price. This price reform led to steady rise of electricity prices except in 1997 when prices were turbulent (Panel A of

Figure 1) for example, the electricity price jumped from ¥350 per KWh in early 1997 to ¥437 per KWh in early 1999 and to almost ¥510 per KWh in early 2002.

Other, new policies were introduced post 2002. ‘Operation-period price’ and ‘yardstick price’ are still used in regions where competitive regional wholesale markets were not established after 2002. For regions where competitive wholesale transactions have been introduced, the price consists of two components: ‘capacity price’ which is determined by the government according to the average cost of all generation units in the market, and ‘volume price’ which is determined competitively in the market. This new policy continued with electricity price increases to nearly ¥580 per KWh in 2005.

4. Reconciling reforms and changes in energy prices

The market-oriented energy price reforms varied in time and in intensity across energy type. Consequently, it is unlikely that various energy prices are fully cointegrated over the full study period. It is also unlikely that energy prices were well cointegrated during the periods of heavy government regulation given that energy price cointegration results from arbitrage and other market forces. As reforms varied in pace and intensity across fuels, it may not be expected that prices will be fully cointegrated during the transition period to full market pricing. However, post 2002, when market-oriented pricing was in place, there is the potential for fully integrated, market- and arbitrage-driven energy prices. These sub-sample period expectations, however, are all testable and will be considered below. The sensitively to possible sub-periods is also important for statistical reasons, as time series based order of integration and cointegration tests are biased towards the non rejection of a unit root when there are structural breaks in the data (Nelson and Plosser, 1982; Perron, 1989; Enders, 1995).

Identifying the presence and timing of structural breaks is therefore necessary before conducting statistical tests on the fuel price series (Zou and Chau, 2006). Our expectation is that the fuel price reforms should be embodied in the changing patterns of fuel prices, so we use the timing of these reforms to focus attention in the search for structural breaks. Figure 1 illustrates how prices changed over the period 01/1995-12/2005 for the four major fuels in China. As can be seen from Figure 1 energy prices changed little (except for coal) as a consequence of being highly regulated in the first two years. Although the 'dual track' pricing was abandoned for petroleum in May 1994, other regulations limited price changes until June 1998 whent China's domestic oil prices were set by the SDRC in accordance with the global oil price (Hang and Tu, 2007; Wu, 2003). In contrast, coal prices rose after deregulation in 1994. Such experiences would suggest, a priori, that energy prices were cointegrated in the early years as fuel prices were relatively independently regulated by different government bodies, and thus they were not necessarily closely correlated with during this highly regulated period.

China's energy prices fluctuated considerably in 1997 and 1998 and might be regarded as a transition period. During this period, it seems that each fuel price varied widely, for example, coal prices jumped ¥26 per ton from ¥234 in 12/1996 to ¥260 in 01/1997; diesel prices jumped ¥450 per ton from ¥2243 in 12/1996 to ¥2693 in 01/1997; gasoline prices jumped ¥284 per ton from ¥2585 in 12/1996 to ¥2869 in 01/1997. Electricity prices jumped from ¥355 per thousand KWh in 12/1996 to ¥381 in 07/1997, continuing to ¥518 in 01/1998, rising by ¥163 per thousand KWh within one year. For electricity and gasoline, their prices varied wildly between 1997 and 1998, but eventually seemed to regress to something approximating a trend. During this stage, coal prices remained 'flat' for a long period (until 01/2002), to be followed by a sudden jump in 12/1996. The reason for the jump is not because coal prices once again became regulated, but because coal supply exceeded demand and the government had to close small coal mines to reduce coal output (Wang, 2007). The erratic electricity price changes might have been caused by the introduction of a new electricity price scheme in 1997 (called operation-period price and yardstick price), but this is only one possibility.

Post 1999, China's energy economy could be treated as being in a new regime period, during which it seems prices changed smoothly. Reconciling fuel price reforms with the features illustrated in Figure 1, from 1999 to early 2002 could be regarded as the early period of the new regime. This period began with the June 1998 complete petroleum price deregulation and the emergence of two major petroleum companies that have been competing in the retail market since June 1998 (Wu, 2003).

A further phase of the new regime commenced in 2002 with many key market reforms taking place after 2002 for example, in 2002 the system of government-guided prices for coal used in power plants was abandoned (Wang, 2007). Also in 2003, the State Power Corporation, a monopoly in the electricity sector, was dismantled and competition introduced by diversifying generation entities (Ma and He, 2008).

5. Inter-fuel price trends

In this section, we use the new price data to firstly sketch a descriptive picture of China's energy market cointegration. Firstly, we plot the price data and examine to what extent various fuel prices appear to move together in the same geographical region or market. Sub-periods will be distinguished and determined by the historical events discussed above. The analysis will be undertaken at national, regional and city levels for two sub-periods of transition (1997-1998) and the new regime (post 1999). Particular attention will be paid to the price co-movements of coal-electricity and gasoline-diesel as these two pairs of fuel price series are most likely to be cointegrated.

5.1 National level

Panel A (Figure 1) shows the price co-movement of coal and electricity for the three sub-periods. It can be seen that the electricity price jumps to a higher level from 1997 to 1998, from approximately ¥360 per thousand KWh in 1997 to ¥475 per thousand KWh in 1998, while the price of coal remained virtually unchanged for the whole transition period. Government control played a more important role in price formation during this transition period. By contrast, the third sub-period shows a market-oriented period where electricity prices have increased, particularly after 2004 while coal prices began to increase, particularly post 2004. It seems from casual observation that convergence of coal and electricity prices emerged after 2002, however, this requires robust statistical testing to corroborate the ocular 'test'.

Turning to gasoline and diesel, during the transitional period (01/1997-12/1998), the prices of gasoline and diesel were low and their trends flat and parallel (Panel B of Figure 1). Recall that during this period, 1994 to 1998, retail price levels were much lower than international market prices.[3] Petroleum prices have been set according to the international market since 1999, and this can be seen especially since 2002 when petroleum prices were set according to the international oil market.

5.2 Regional level

As discussed previously, each region might have its own energy regulation policy because of unbalanced economic growth and unbalanced energy reserves across regions. Under such circumstances, even if fuel prices are cointegrated at the national levels, it doesn't necessarily mean that they are cointegrated in each region. To observe price trends of pairs of fuels for each region and compare whether there are any differences in these price trends of pairs of fuels during the whole study period (01/1995-12/2005), we present Figures 2-8. According to these figures, all regional price trends of pairs of coal and electricity are generally similar to that at the national level. Secondly, some variations are still evident in price trends of pairs of fuels. The most obvious example is

[3] There are likely two reasons for the low prices of petroleum products. The first is low domestic production cost of petroleum products. The second is low quality of both domestically processed and imported petroleum products.

that the price trends of pairs of gasoline and diesel are more likely cointegrated than those of coal and electricity for each region. Thirdly, the price trends of coal and electricity are more likely to be cointegrated as the energy policy reforms proceed. The most likely period of cointegration for price trends of pairs of coal and electricity occurs post 2003 where coal prices show a strong rising trend, approaching the electricity price trend. Fourthly, the price trends of pairs of gasoline and diesel are more similar at the national level than the price trends of pairs of coal and electricity. This is because the prices of petroleum products are more likely homogeneous all over the country than coal and electricity prices. Fifthly, the price trends of pairs of gasoline and diesel look homogeneously cointegrated during the whole study period for all regions. However, similar to the national level results, the price trends of pairs of gasoline and diesel seemingly appear to diverge post 2002 for all regions.

Having visually compared the variations over regions, we can tentatively propose that:

Firstly, the prices trends of pairs of coal and electricity demonstrate the least evidence of the emergence of an energy market in Region Two (Figure 3) and in Region Three (Figure 4), for example, during the transition period, electricity prices remain flat, jump to a new level and remain flat until 2000, and the jump and remain flat again until 2003 in Region Two (including Beijing, Shanghai and Tianjin). Correspondingly, however, during the transition period, coal prices remained flat, decline to a new level in 1998 and decline three times until mid-2000, after which they begin to slowly increase until early 2003, after which they increase rapidly until mid-2004 in Region Two (Figure 3). This probably reflected political considerations relating to stability as this region comprised Beijing, Shanghai and Tianjin.

Secondly, having compared the trends of pairs of electricity and coal prices, we see that electricity prices adjusted more frequently and more sensitively to demand than coal prices in Region Five (Figure 6, including Fuzhou, Changsha, Nanning and Haikou). This pattern can also be seen in Region One (Figure 2, including Shijiazhuang, Taiyuan, Hefei, Jinan and Zhengzhou) and probably Region Six (Figure 7, including Chongqing, Chengdu, Xi'an, Lanzhou, Guiyang and Kunming).

Thirdly, although the price trends of pairs of gasoline and diesel have shown a consistent co-movement for most regions since the transitional period (01/1997, see Panel B of Figures 2-8), Region Two (including Beijing, Shanghai and Tianjin) seemingly demonstrate apparent price regulation in the trends of pairs of gasoline and diesel during the late 1998 to the late 1999 (Panel B of Figure 3).

5.3 City level

Whether inter-fuel price trends at city level are similar to those at the national and regional levels requires examination as aggregation might obscure the real relations between pairs of fuel prices at the city level. To save space, only 14 provincial capital cities are selected: Harbin, Beijing, Shijiazhuang, Taiyuan, Jinan, Zhengzhou, Wuhan, Nanjing, Shanghai, Hangzhou, Guangzhou, Xi'an, Chengdu, and Urumqi. These cities are evenly located across the country, and are either important energy production bases or important economic growth zone or both. The GDP in the 14 provinces of the sample cities accounts for approximately 70% of the national GDP in 2006. Therefore, these 14 provincial capital city markets are representative of national level energy reforms.

Price trends for pairs of fuel sources are presented in order from the northeast (Harbin) to South (Guangzhou) and to West (Xinjiang) and Southwest (Chengdu) as Appendix Figures 1-14. The price trends of pairs of coal-electricity and gasoline-diesel at the city level are basically similar to those at both the national and regional aggregate levels.

The potential emergence of energy price cointegration appeared one year later at the city level than discussed above. This may be explained by data aggregation-related issues. As observed at both the national and regional aggregate levels, the new regime of energy economic development appeared to begin in early 1999. However, the city level price data show that the new regime of energy economy emerged mid or late 1999 for example, in Beijing (Panel B of Appendix Figure 2), Jinan (Panel B of Appendix Figure 5), Zhengzhou (Panel B of Appendix Figure 6), Wuhan (Panel B of Appendix Figure 7) and Nanjing (Panel B of Appendix Figure 8), gasoline and diesel prices displayed rising and changing trends in late 1999.

The emergence of a cointegrated energy market for coal and electricity seems later than for petroleum products. It appears that coal and electricity prices show a cointegrated relationship for most of the cities post 2002. The prices of coal and electricity have also changed more frequently. Therefore, we can tentatively conclude that the real emergence of coal and electricity cointegration was post 2002.

Finally, a strange phenomenon can be found between the price trends of coal and electricity for most provincial city markets during the transition and new regime periods, which seems to vary across city markets. In particular, electricity prices increase while coal price decline, for example, during the early 1998 to the late 2001, electricity prices increased twice, while coal prices correspondingly dropped twice in Harbin (Panel A of Appendix Figure 1). During the 2000, electricity prices jumped dramatically, while coal prices declined slightly in Beijing (Panel A of Appendix Figure 2). The reasons for this are unclear, but large surpluses of coal production may be one of the most important factors that significantly depressed the coal price during this period (Wang, 2007).

In summary, the following primary contenders for the emergence of energy price cointegration in China to be statistically tested in the next section are: firstly, the emergence of energy price cointegraton across homogeneous pairs of fuels is apparent though the intensities of energy price cointegration vary across homogeneous pairs of fuels. Secondly, the descriptive illustrations of fuel price trends indicate that the same co-movement of prices occurs in the case of different petroleum products in the whole study period (01/01/1995-31/12/2005). When reconciling energy price reforms and price co-movement trends, however, we may conclude that it is most likely that only since 2000 have we seen the emergence of energy price cointegration across petroleum products. The emergence of energy price cointegration appears to occur one year later using city level regional or national aggregate level. This is likely due to price level aggregations issues. Thirdly, the descriptive figures of fuel price trends seem to demonstrate that the same co-movement of prices has most likely occurred in the case of pairs of coal and electricity since 2003 when the prices of coal and electricity began to increase and change significantly for most city-level markets. Similarly, the emergence of energy price cointegration appears to be several years using city level rather than observed either regional or national aggregate level data. As can be seen, the emergence of energy price cointegration seems to be three years earlier for gasoline and diesel than for coal and electricity. The price reforms in the gasoline and diesel markets are earlier and complete compared to those for coal and electricity markets. In the next section, we statistically test for the existence of energy price cointegration and consider whether these tentative conclusions and puzzling timing results are robustly supported.

6. Testing for energy price cointegration

Given the potential for different pricing periods and reform effects, identified in the previous section, here we test for the existence of energy price cointegration firstly for the whole period first and then for relevant sub-periods. The tests also consider national, regional and city level effects.

6.1 Methods

It is well know that the original unit root tests suffer from low power when applied to series of only moderate length and when utilised on series with structural breaks. 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 to test for homogeneity in fuel prices across time and space.

As is now standard practice, before testing for cointegration we conduct panel unit root test to consider the order of integration and common unit root properties of the data. Three kinds of panel unit root tests, Levine et al. (2002, thereafter LLC), Im et al. (2003, thereafter IPS) and Hadri (2000), are provided 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:

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

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 $\gamma_1 = \gamma_2 = \cdots = \gamma < 0$. This test is based on the statistics, $t_y = \hat{\gamma} / s.e.(\hat{\gamma})$. The IPS (2003) relaxes 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 the following statistic:

(2) $\tilde{Z} = \sqrt{N}(\bar{t} - E(\bar{t})) / \sqrt{\text{var}(\bar{t})}$

where $\bar{t} = (1/N)\sum_{i=1}^{N} t_{y_i} E(\bar{t})$ and $Var(\bar{t})$ represent the mean and variance of each t_y, respectively. The statistic term $\tilde{Z}$ converges to a Normal distribution, and we can compute the significance level in a simple way. By contrast, Hadri (2000) argues that the null hypothesis should be reversed to be a stationary hypothesis in order to increase the power of the test. His Lagrange Multiplier (LM) statistics is given by the follow expression:

(3) $LM = \frac{1}{N}\sum_{i=1}^{N}(\frac{T^{-2}\sum_{t=1}^{T}\sum_{j=1}^{t}\hat{\varepsilon}_{ij}}{\hat{\sigma}_{\varepsilon}^{2}})$

Where $\hat{\sigma}_{\varepsilon}^{2}$ is the consistent Newey-West (1987, 1994) estimate of the long-run variance of the disturbance terms (ε_{ij}).

It is hard to judge which panel unit root tests is optimal as we do not know the actual properties of the price series. Some authors prefer some types, while others prefer other tests for example, Hlouskova and Wagner (2006) found that the Breitung (2000) panel unit root test generally had the highest power and smallest size distortions of any of the so-called first generation panel unit root tests and therefore Narayan and Smyth (2007) employed this test in their paper. However, this test assumes a common unit root process, which may not reflect reality, especially for this empirical study, which covers 35 city markets located in 31 provinces in China. Thus, to obtain more robust results, this study presents all six panel unit root tests to determine whether the panel dataset is stationary. In addition to the tests outlined above, three other panel unit root tests are used; Breitung;

Fisher ADF; and Fisher PP. The null hypothesis for LLC and Breitung is of a common unit root process; for IPS, Fisher ADF and Fisher PP the n.h. is of an individual unit root process and for Hadri the n.h. is stationarity. In this study, all six panel unit root tests are implemented to determine whether the panel dataset is stationary. Conclusions may (and do) vary in the main because the assumptions of the tests may be invalid. We will attempt to explain inconsistencies as and when they arise.

Using these panel unit root test results, we proceed to test for cointegration in the data using the heterogeneous panel cointegration test developed by Pedroni (1999) which allows for cross-sectional interdependence with different individual effects. If the panel data follow an I(1) series, the Pedroni (1999 and 2004) panel cointegration model is applied to test whether a cointegrating relationship exists. Pedroni (1999) suggests the following time series panel expression:

(4) $y_{it} = \alpha_{it} + \gamma_{it} t + X_i \beta_i + e_{it}$

Where y_{it} and X_{it} are the observable variables with dimension of $(N \times T) \times 1$ and $(N \times T) \times m$, respectively. He develops the asymptotic and finite-sample properties of the test statistics to examine the null hypothesis of non-cointegration in a panel. The tests allow for heterogeneity among individual member of panel in both the long-run cointegration vectors and in the dynamics (Lee and Chang, 2008), for there is no reason to believe that all parameters are the same across cities.

Pedroni (1999) suggests two types of residual-based tests for cointegration. As for the first type, is distributed as standard Normal asymptotically and is based on pooling the residuals of the regression for the within-group. Specifically, 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.

Specifically, it includes the group ρ -statistic, group PP-statistic (or t -statistic, non-parametric) and the group ADF-statistic (or t -statistic, parametric). The heterogeneous panel cointegration statistics, equations 5-8, and the heterogeneous group-mean panel cointegration statistics, equations 9-11, are presented as follows, respectively:

(5) Panel υ -statistic: $Z_{\hat{\upsilon}} = (\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{e}_{it-1}^{2})$

(6) Panel ρ -statistic: $Z_{\hat{\rho}} = (\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{e}_{it-1}^{2})^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_{i})$

(7) Panel t -statistic (non-parametric): $Z_{t} = (\hat{\sigma}^{2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{e}_{it-1}^{2})^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_{i})$

(8) Panel t -statistic (parametric): $Z_{t}^{*} = (\hat{s}^{*2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{e}^{*2}{}_{it-1})^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{e}^{*}{}_{it-1}\Delta\hat{e}^{*}{}_{it}$

(9) Group ρ -statistic: $\widetilde{Z}_{\hat{\rho}} = \sum_{i=1}^{N}(\sum_{t=1}^{T}\hat{e}_{it-1}^{2})^{-1}\sum_{t=1}^{T}(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_{i})$

(10) Group t -statistic (non-parametric): $\widetilde{Z}_{t} = \sum_{i=1}^{N}(\hat{\sigma}_{i}^{2}\sum_{t=1}^{T}\hat{e}_{it-1}^{2})^{-1/2}\sum_{t=1}^{T}(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_{i})$

(11) Group t -statistic (parametric): $\widetilde{Z}_{t}^{*} = \sum_{i=1}^{N}(\sum_{t=1}^{T}\hat{s}_{i}^{2}\hat{e}_{it-1}^{*2})^{-1/2}\sum_{t=1}^{T}(\hat{e}_{it-1}^{*}\Delta\hat{e}_{it}^{*})$

Where $\hat{e}_{it}$ is the estimated residual from equation (4) above and $\hat{L}_{11i}^{-2}$ is the estimated long-run covariance matrix for $\hat{e}_{it}$. Similarly, $\hat{\sigma}_{i}^{2}$ and $\hat{s}_{i}^{2}$ ($\hat{s}_{i}^{*2}$) are, respectively, the long-run and contemporaneous variances for individual *i*. The other terms are defined in Pedroni (1999) with the appropriate lag length determined by the Newey-West method. All seven tests are distributed as standard Normal asymptotically. This requires the standardization based on the moments of the underlying Brownian motion function. The panel υ -statistic is one-sided test where large positive values reject the null of no cointegration. The remaining statistics diverge to negative infinitely, which means that large negative values reject the null. The critical values are also tabulated in Pedroni (1999).

The statistics refereed to above are based on estimators that simply average the individually estimated coefficients for each member, and each of these tests is able to accommodate individual specific short-run dynamics, individual specific fixed effects and deterministic trends, as well as individual specific slope coefficients (Pedroni, 2004). The number of observations available during testing is greatly increased in a panel framework and this can substantially increase the power of the cointegration tests (Rapach and Wohar, 2004).

6.2 Empirical results

The methodology of the testing process implemented here is that if the 'Law of One Price' (market integration) holds for individual series, one would expect to find that pairwise (and multi-) comparisons of the same form of energy, spatially, should show that price differences are stationary (cointegrated). If the price of gasoline is the same (statistically) in Beijing and Shanghai, then the (gasoline) market is integrated, etc. Repeating this across all pairs of cities and for all cities together, local, regional and national energy market integration can be assessed. Repeat this for different fuels and different locations and the simple ocular 'tests' discussed above can be vigorously and rigorously tested using modern time series methods.

Based on the approach outlined above, we first conduct panel unit root tests for both the national panel and regional panels by making assumptions on the exogenous variables included in the test equation (1) to ascertain their order of integration. One exogenous variable is an individual effect and other is the individual effect and individual linear trend. The panel unit root tests on the raw price series are presented as Table 1 for all 35 city markets and Table 2 for the panels of regions 1-7.[4] We pay specific attention to

[4] To save space, Table 2 only lists the IPS panel unit root test results. For other panel unit root test results refers to Appendix Table 9-1 to appendix Table 9-7.

two sub-periods 01/1995-12/1999 and 01/2000-12/2005. The results show consistent evidence in favour of an order of integration of 1 or I (1).

Using the panel unit root tests, we proceed to test these energy price series for cointegration in order to determine whether there is a long-run relationship exists among them, ie., providing evidence of energy market integration. We utilise all seven panel cointegration statistics discussed above (equations 5-11) for specific price series and specific time periods of interest.

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. In this study, we choose the panel-υ statistic as the most panel cointegration test of first choice.

The panel-υ cointegration statistics are presented as Table 3 for the national panel. Other panel cointegration test results are presented as Appendix Table 9-15 in Ma 2009. 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 intercept and trend (Table 3, column 1). *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 two sub-period tests, most of the panel υ-statistic tests do not reject the null of no cointegration except for the sub-periods of 01/2000-12/2005 when we assume a deterministic intercept and trend. 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.

Secondly, for coal and electricity, the national panel cointegration tests provide some weak evidence of cointegration for the full sample period (Table 3, column 2). 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 the sub-period of 01/1997-12/1999, while the coal and electricity price series may have moved together during the sub-period of 01/2000-12/2005. These results are consistent with our previous tentative conclusions.

Thirdly, 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 the full sample period and the two sub-periods (Table 3, column 3).

Based upon similar analysis, the panel-υ cointegration statistics in Table 4 (other panel cointegration statistics refer to Appendix Tables 9-16 to 9-21 of Ma 2009), we can make the follow conclusions for the regional-based panel cointegration tests:

Firstly, all the regional panel tests accept the null of no cointegration for coal, electricity, gasoline and diesel prices, which suggests that no one region identifies cointegration of all four fuels in the long-run (Table, columns 2 and 4). Though some statistical tests reject the null, it is less likely that the coal and electricity price series and gasoline diesel price series move together during the transitional energy economy. Moreover, the strongest panel-υ statistic tends not to reject the null hypothesis of no cointegration for either the full or sub-periods results as a whole.

Secondly, half of the regional panel tests do not reject the null hypothesis of no cointegration for coal and electricity prices during both sub-periods (Table 4, columns 6 and 8). Although most of the previous results display some cointegration for coal and electricity prices after 2000, the regional panel statistical tests do not confirm these results. However, there seem to be two exceptions; Regions 1 and 6 for the sub-period 01/2000-12/2005 under both assumptions, for which the strongest panel υ-statistics tend to reject the null hypothesis of no cointegration; Region 5 for the sub-period 01/2000-12/2005 under the assumptions of no deterministic trend, for which the strongest panel υ-statistic tends to reject the null hypothesis of no cointegration. It may appear strange to find the majority of tests do not reject the null hypothesis of no cointegration for coal and electricity prices during the earlier period (01/1997-12/1999), but not during the latest period (01/2000-12/2005). However, this was a period of state controlled prices where some common movements would be expected. One might therefore expect this regulated link to disappear as a consequence of the gradualist reforms.

Thirdly, all regional panel tests reject the null hypothesis of no cointegration for gasoline and diesel prices during the latest sub-period of 01/2000-12/2005 (Table 4, columns 10 and 12), which suggests that gasoline and diesel prices move together in the long-run after 2000 in all regions. However, the regional panel tests for the 01/1997-12/1999 sub-period (equivalent to the period of transition) suggest that gasoline and diesel prices move together in a long-run in some regions. For example, four regional panel tests reject the null hypothesis of no cointegration for gasoline and diesel prices in Regions 1, 2, 4 and 5, while three regional panel tests do not reject the null hypothesis of no cointegration for gasoline and diesel prices in Regions 3, 6 and 7 given the assumption of no deterministic trend. There are several points to be drawn here. Firstly, geographically, gasoline and diesel prices appear to move together even during the transition period for those regions located in the center, east and south, but not for those regions located in the remote areas, such as northeast, west, and southwest. Secondly, regional petroleum products markets are evident in China. Thirdly, gasoline and diesel prices have moved together since 1997 in relatively developed areas which are circled by Shijiazhuang, Taiyuan, Xi'an, Wuhan, Changsha, and east coastal areas.

Although there are some studies on the emergence of China's commodity markets (e.g., Huang and Rozelle, 2006; Fan and Wei, 2006), there are few studies on the emergence of cointegration of China's fuel commodity markets, especially for panel cointegration tests. Therefore, it is difficult for us to compare our finding with others.

At this stage, it is potentially interesting to ask why the price series of gasoline and diesel are more cointegrated than those of coal and electricity, both statistically and economically. There may be many answers to this, but the following may be the most 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 cointegrated than the latter.
- The intensity and time of reforms are different over the two groups of energy sources. According 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 they are a homogeneous commodity although most electricity is generated from coal. Especially, most of electricity is generated from coal in China.
- Substitutability is significantly different between gasoline-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. Therefore, 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.
- Successful coal price reform could be the most crucial factor that contributes to the unobserved cointegration of the price series of coal and electricity. As reviewed previously, coal users (major power plants) used to pay a low price to coal producers. However, after a series of reforms, coal price need to be decided on the negotiation tables. As a result, the coal users had begun to pay higher price

to coal producers. Figure 1 clearly displays that coal price has sharply increased approximately since the late 2003.

- The Law of One Price assumes transport and transactions costs are low(zero). Transporting gasoline and diesel is relatively cheap compared with the shipping of lower value coal and high transport infrastructure, electricity. Therefore, the Law of One Price assumptions may be less likely to hold for coal and electricity, than gasoline and diesel.

7. Conclusions and implications

In this paper, we have shown, in a number of ways, the emergence of price series co-movement in energy markets in China during the past decade. The panel cointegration test results are mostly consistent with our simple graphical observations and our anecdotal understanding of China's energy economy. Several points have been emphasized:

The panel cointegration tests did not reject the null hypothesis of no cointegration for four energy price series during the whole period. This means that the emergence of four major fuel price series co-movement has not occurred in China. However, the panel cointegration tests results vary over sub-periods and pairs of fuels. This suggests that not all energy commodities are homogenous in price and the processes of energy price cointegration are also different over time and over pairs of fuel sources, demonstrating China's gradual, spatially partial, and distinguished energy reform process.

The national panel cointegration test statistics show that coal and electricity price series have co-moved since 2000, while the national panel cointegration test statistics demonstrate that gasoline and diesel price series have co-moved since 1997.

These results are not surprising, in fact, energy source markets may be weakly linked and it is consistent with existing literature on energy market integration. There is a common belief that gasoline prices respond more quickly to crude oil price increases than decreases. Some economists and politicians believe that asymmetry in oil and gasoline price movements is the outcome of a non-competitive gasoline market requiring that governments take policy action to address ‘unfair pricing’ (see Honarvar 2009 for a short review). Borenstein et al. (1997) argue whether gasoline prices respond symmetrically to crude oil price changes. Reilly and Witt (1998) test the hypothesis of a symmetric response by petrol retailers to crude price rises and falls. Galeotti et al. (2003) examine the asymmetries in the transmission of shocks to crude oil prices onto the retail price of gasoline and make an international comparison on European gasoline markets using updated data. Bachmeier and Griffin (2003) find new evidence on asymmetric gasoline price responses. Micola (2007) even found a weak link between two markets in the European countries.

Regional panel tests also show that there are apparent differences in the emergence of energy price co-movement across regions, for example, in some regions coal and electricity prices were cointegrated even during the transitional period, while in some regions gasoline and diesel prices were not cointegrated during the same period, although in most they were. This may mean that regional energy markets have emerged in China.

Some of these results may not surprise Chinese-based energy market specialists although the non-Chinese literature does not seem to be aware of such behaviour. This is important to know when considering and negotiating global energy and environmental policies. During the 1990s, China’s leaders were taking a cautious, gradual approach to reformation of its energy market. Our results show that despite the gradualist strategy, the operation of markets during this time has led to the emergence of energy commodity market cointegration, which have been steadily strengthened in the new millennium in China.

The power of markets to continue to integrate perhaps more than anything shows the power of China's gradual method of transition in its energy economic reform. China's market reform has really been one of entry-driven competition (Huang and Rozelle, 2006). In the case of China, entry has come from both the dismantled state-owned energy enterprises and the emergence of many small energy companies. In doing so, China enfranchised both domestic and overseas companies to be involved in energy exploration, production and distribution.

One of the real lessons of our work is that both China's leaders and domestic and foreign profit-seekers and other observers should now see that China's energy market has already emerged and energy prices are much less distorted than previously. This fact will become of significance in future international trade and investment talks as China attempts to be declared a 'market economy'. The rising coal price in the coal industry will however, have an important effect on the electricity industry, regionally and nationally.

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

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-1999:								
Level:								
LLC	7.62	0.995	1.48	0.931	4.38	1.000	4.81	0.998
Breitung	-2.10	0.078	-3.69	0.000	3.73	1.000	1.23	0.891
IPS	0.85	0.803	-1.51	0.085	-3.54	0.000	-0.99	0.160
1^{st} difference:								
LLC	-100.69	0.000	-128.57	0.000	-122.34	0.000	-120.97	0.000
Breitung	-47.04	0.000	-76.67	0.000	-22.64	0.000	-27.22	0.000
IPS	-77.04	0.000	-96.73	0.000	-97.01	0.000	-99.99	0.000
2000-2005:								
Level:								
LLC	-0.64	0.260	4.83	1.000	4.67	0.998	2.60	0.995
Breitung	0.14	0.557	-3.12	0.001	-1.95	0.026	-4.59	0.000
IPS	1.10	0.865	-3.48	0.000	2.13	0.983	-1.51	0.066
1^{st} difference:								
LLC	-83.52	0.000	-189.13	0.000	-169.78	0.000	-104.97	0.000
Breitung	-12.19	0.000	-43.87	0.000	-44.11	0.000	-30.64	0.000
IPS	-52.22	0.000	-143.93	0.000	-136.05	0.000	-71.64	0.000

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

Table 2. Panel IPS unit root tests by region

Region	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-1999:								
Level:								
Region 1	-0.096	0.462	0.180	0.571	-0.827	0.204	-0.541	0.294
Region 2	0.159	0.563	-3.179	0.001	-1.567	0.059	-0.692	0.245
Region 3	-1.288	0.099	0.378	0.647	-0.349	0.364	0.110	0.544
Region 4	0.591	0.723	0.359	0.640	-0.065	0.474	-1.095	0.137
Region 5	1.440	0.925	-0.674	0.250	-0.206	0.418	0.311	0.622
Region 6	1.504	0.934	0.000	0.500	-1.650	0.050	-1.561	0.059
Region 7	-0.032	0.487	-1.614	0.053	-2.675	0.004	0.404	0.657
1^{st} difference:								
Region 1	-32.377	0.000	-35.582	0.000	-46.096	0.000	-46.359	0.000
Region 2	-27.021	0.000	-24.563	0.000	-23.672	0.000	-34.060	0.000
Region 3	-25.832	0.000	-41.809	0.000	-35.920	0.000	-33.966	0.000
Region 4	-26.828	0.000	-33.615	0.000	-25.809	0.000	-23.907	0.000
Region 5	-41.207	0.000	-34.930	0.000	-53.412	0.000	-46.703	0.000
Region 6	-29.829	0.000	-46.278	0.000	-40.829	0.000	-34.495	0.000
Region 7	-22.296	0.000	-25.151	0.000	-39.325	0.000	-38.724	0.000
2000-2005:								
Level:								
Region 1	0.780	0.782	-1.686	0.046	0.960	0.830	-1.410	0.080
Region 2	-0.588	0.278	-0.642	0.261	0.419	0.663	-0.940	0.174
Region 3	0.270	0.606	-0.689	0.246	0.463	0.678	-0.201	0.421
Region 4	1.440	0.925	-1.878	0.030	1.039	0.851	-0.333	0.370
Region 5	0.218	0.586	-1.467	0.071	1.018	0.846	-1.113	0.133
Region 6	0.218	0.586	-1.467	0.071	1.018	0.846	-1.113	0.133
Region 7	0.355	0.639	-0.827	0.204	0.843	0.800	-0.279	0.390
1^{st} difference:								
Region 1	-21.984	0.000	-58.244	0.000	-25.270	0.000	-16.060	0.000
Region 2	-29.053	0.000	-36.946	0.000	-38.906	0.000	-18.610	0.000
Region 3	-18.835	0.000	-51.588	0.000	-43.730	0.000	-23.817	0.000
Region 4	-5.715	0.000	-43.418	0.000	-46.242	0.000	-29.265	0.000
Region 5	-19.282	0.000	-23.324	0.000	-17.490	0.000	-15.468	0.000
Region 6	-21.488	0.000	-60.580	0.000	-60.054	0.000	-26.389	0.000
Region 7	-30.121	0.000	-61.789	0.000	-49.882	0.000	-17.769	0.000

Note: Null hypothesis is individual unit root. Group is used as a benchmark. Individual effect and linear trend are included. Regional classification is referred to Table 1-2 of Chapter One.

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

Test statistics	All four fuels 1997-2005	1997-1999	2000-2005	Electricity and coal 1997-2005	1997-1999	2000-2005	Diesel and gasoline 1997-2005	1997-1999	2000-2005
No deterministic trend:									
Panel v -statistic	**0.399**	**0.305**	**0.386**	**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	0.000	0.000	0.000
Panel t -statistic [a]	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000
Panel t -statistic [b]	0.394	0.204	0.005	0.001	0.260	0.011	0.000	0.000	0.000
Group ρ -statistic	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Group t -statistic [a]	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Group t -statistic [b]	0.344	0.258	0.051	0.000	0.240	0.000	0.000	0.000	0.000
Deterministic intercept and trend:									
Panel v -statistic	**0.004**	**0.374**	**0.057**	**0.014**	**0.393**	**0.100**	**0.000**	**0.000**	**0.000**
Panel ρ -statistic	0.000	0.000	0.127	0.000	0.000	0.279	0.000	0.000	0.000
Panel t -statistic [a]	0.000	0.000	0.036	0.000	0.000	0.182	0.000	0.000	0.000
Panel t -statistic [b]	0.047	0.000	0.139	0.090	0.000	0.385	0.000	0.000	0.000
Group ρ -statistic	0.000	0.000	0.011	0.000	0.000	0.079	0.000	0.000	0.000
Group t -statistic [a]	0.000	0.000	0.008	0.000	0.000	0.227	0.000	0.000	0.000
Group t -statistic [b]	0.008	0.000	0.398	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.

Table 4. Panel ν -statistic cointegration tests by Region

Region	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Region 1	0.481	0.355	0.458	0.359	0.863	0.275	2.028	**0.051**	3.344	**0.002**	12.178	**0.000**
Region 2	2.360	**0.025**	1.315	0.168	1.959	**0.059**	0.348	0.376	3.959	**0.000**	11.675	**0.000**
Region 3	-0.457	0.359	0.600	0.333	-0.811	0.287	0.945	0.255	-0.202	0.391	6.815	**0.000**
Region 4	0.799	0.290	1.990	**0.055**	2.537	**0.016**	1.209	0.192	3.985	**0.000**	9.478	**0.000**
Region 5	-0.221	0.389	5.762	**0.000**	2.316	**0.027**	2.444	**0.020**	4.862	**0.000**	14.336	**0.000**
Region 6	1.638	0.104	9.793	**0.000**	5.247	**0.000**	2.545	**0.016**	1.496	0.130	13.313	**0.000**
Region 7	2.698	**0.011**	2.889	**0.006**	4.374	**0.000**	0.927	0.260	1.298	0.172	8.249	**0.000**
Deterministic intercept and trend:												
Region 1	0.527	0.347	1.191	0.196	1.008	0.240	2.262	**0.031**	1.611	0.109	7.511	**0.000**
Region 2	1.141	0.208	1.027	0.236	0.003	0.399	-0.490	0.354	1.764	**0.084**	7.702	**0.000**
Region 3	-1.518	0.126	0.297	0.382	-2.201	**0.035**	0.679	0.317	-0.797	0.290	4.370	**0.000**
Region 4	0.587	0.336	1.592	0.112	1.782	0.082	0.026	0.399	1.739	**0.088**	5.773	**0.000**
Region 5	-1.235	0.186	5.241	**0.000**	0.293	0.382	0.346	0.376	2.290	**0.029**	9.333	**0.000**
Region 6	1.038	0.233	9.169	**0.000**	3.747	**0.000**	1.855	**0.071**	0.207	0.391	8.693	**0.000**
Region 7	1.487	0.132	2.103	**0.044**	1.933	**0.062**	-0.319	0.379	0.276	0.384	5.711	**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. Regional classification is referred to Table 1-2 of Chapter One.

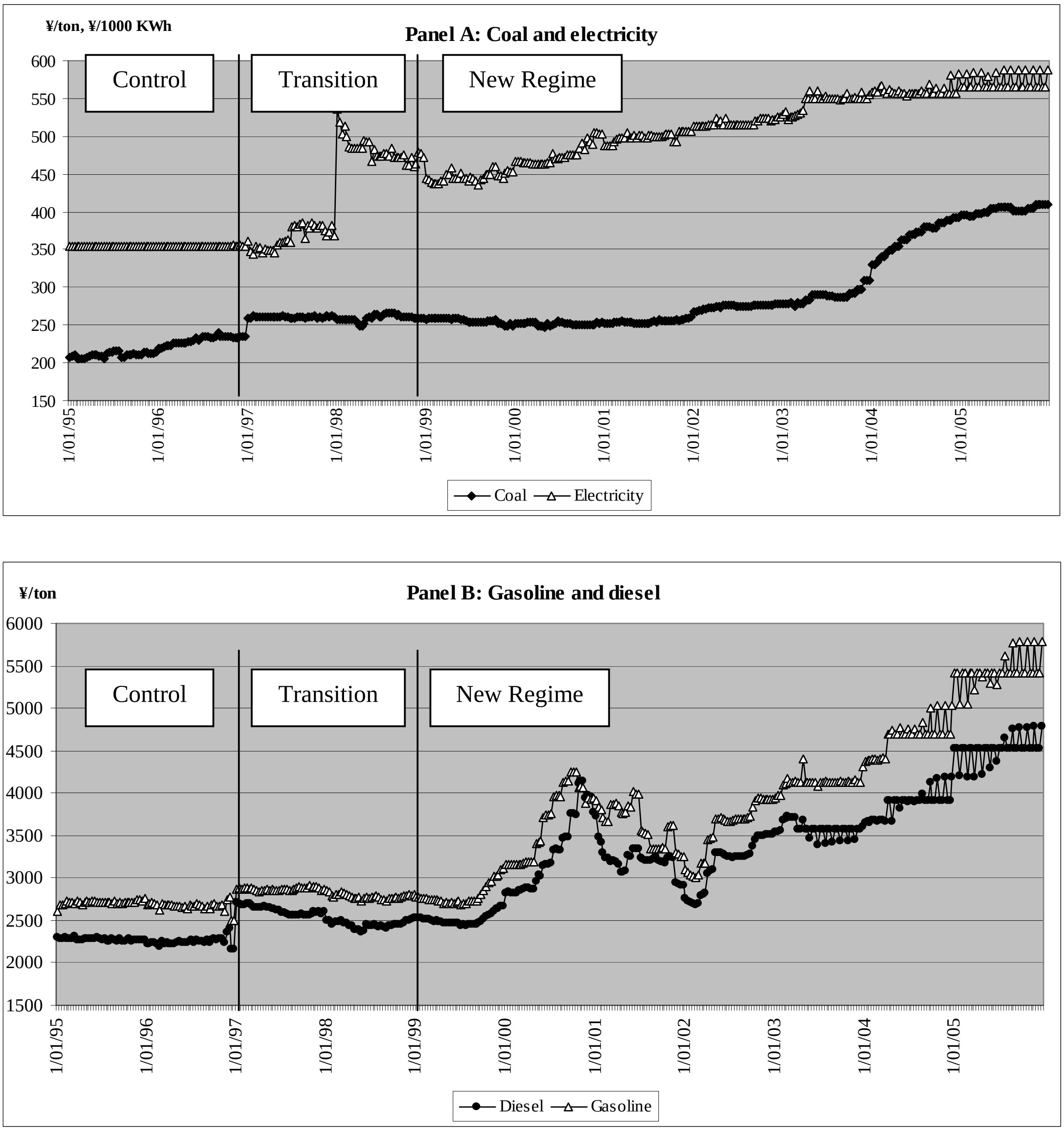


Figure 1. Price trends for pairs of coal-electricity and gasoline-diesel at the national level

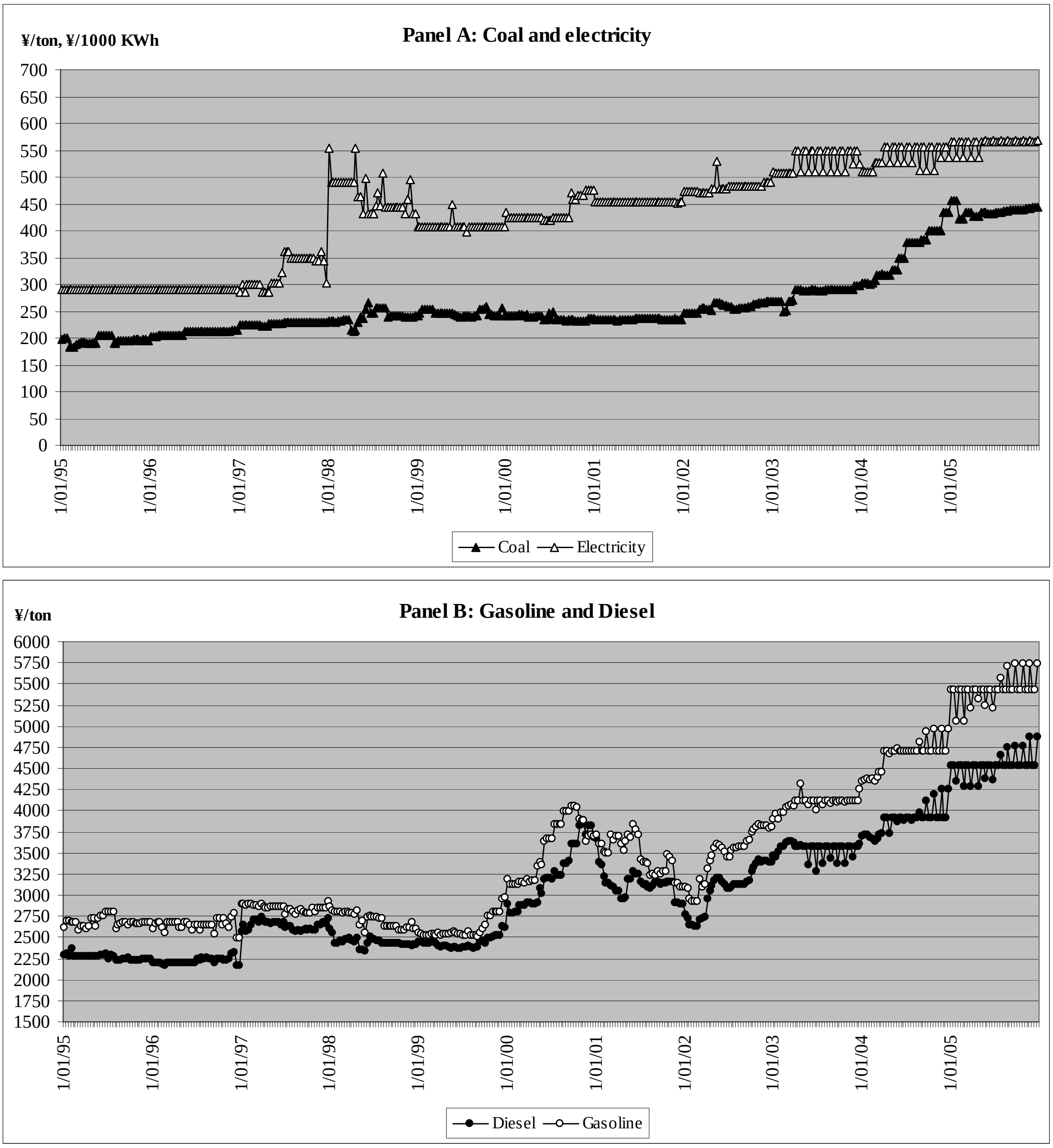


Figure 2. Price trends for pairs of coal-electricity and gasoline-diesel for Region 1
Note: Region 1 includes Shijiazhuang, Taiyuan, Hefei, Jinan and Zhengzhou.

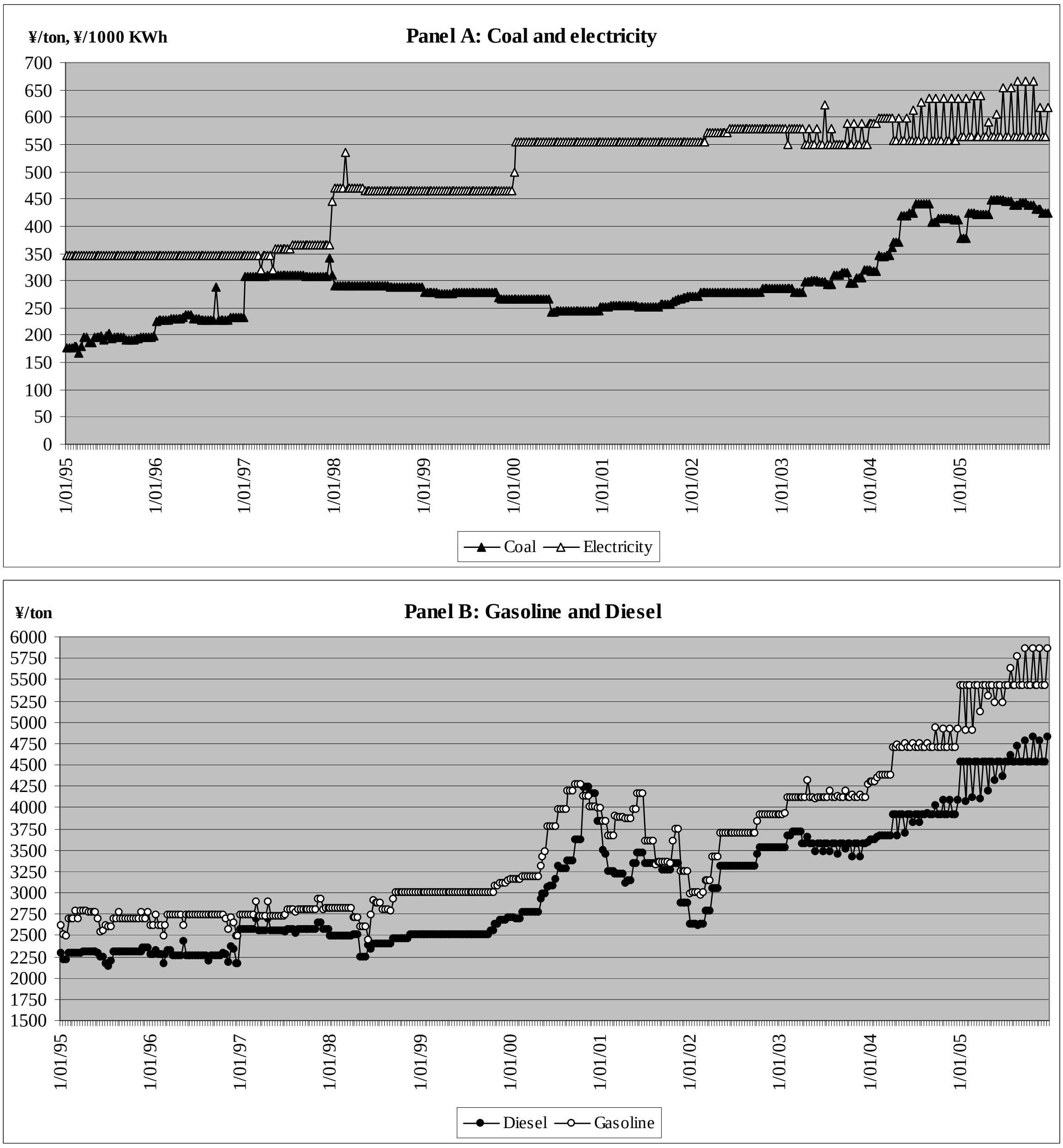


Figure 3. Price trends for pairs of coal-electricity and gasoline-diesel for Region 2
Note: Region 2 includes Beijing, Tianjin and Shanghai.

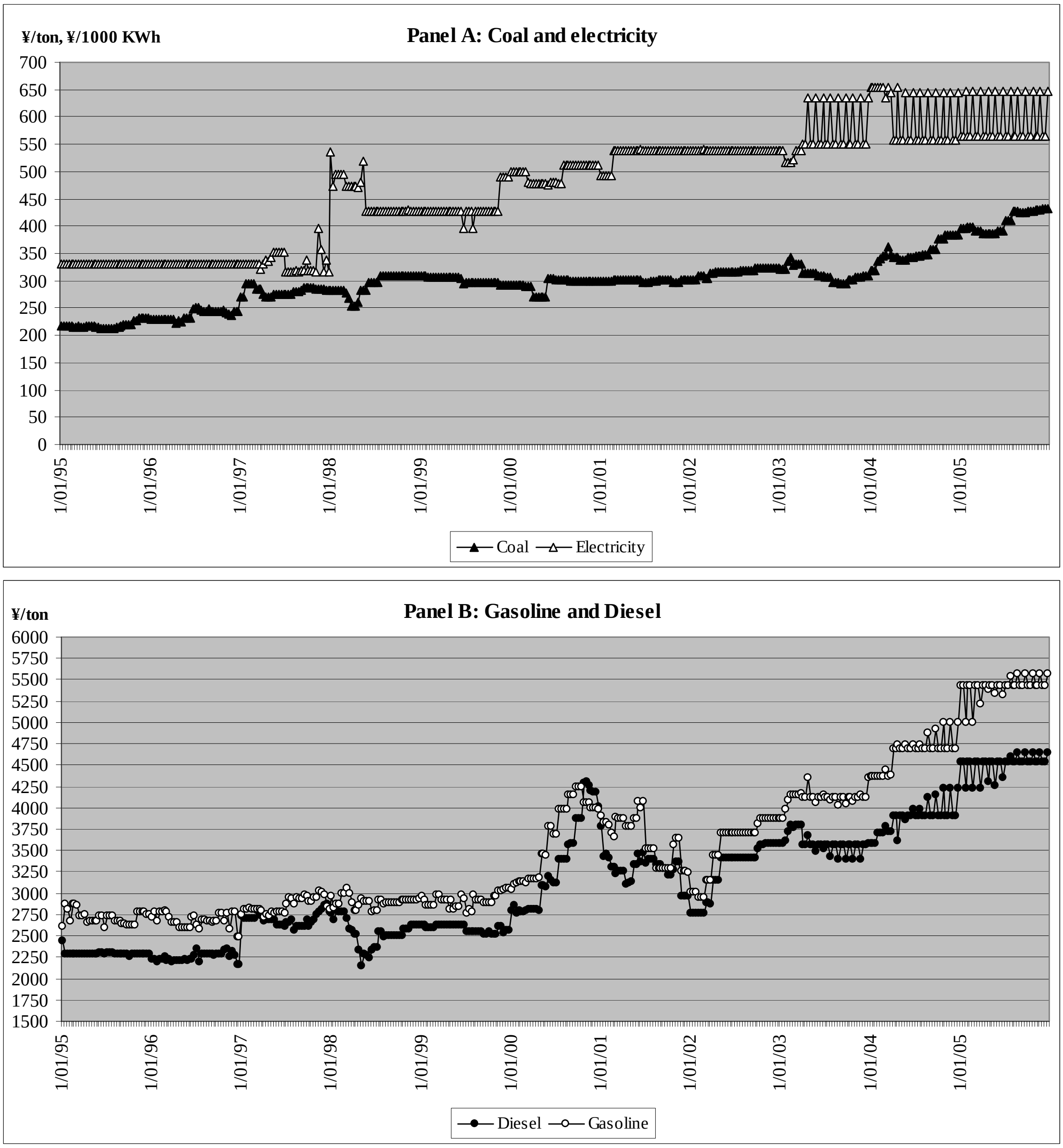


Figure 4. Price trends for pairs of coal-electricity and gasoline-diesel for Region 3
Note: Region 3 includes Shenyang, Changchun and Harbin.

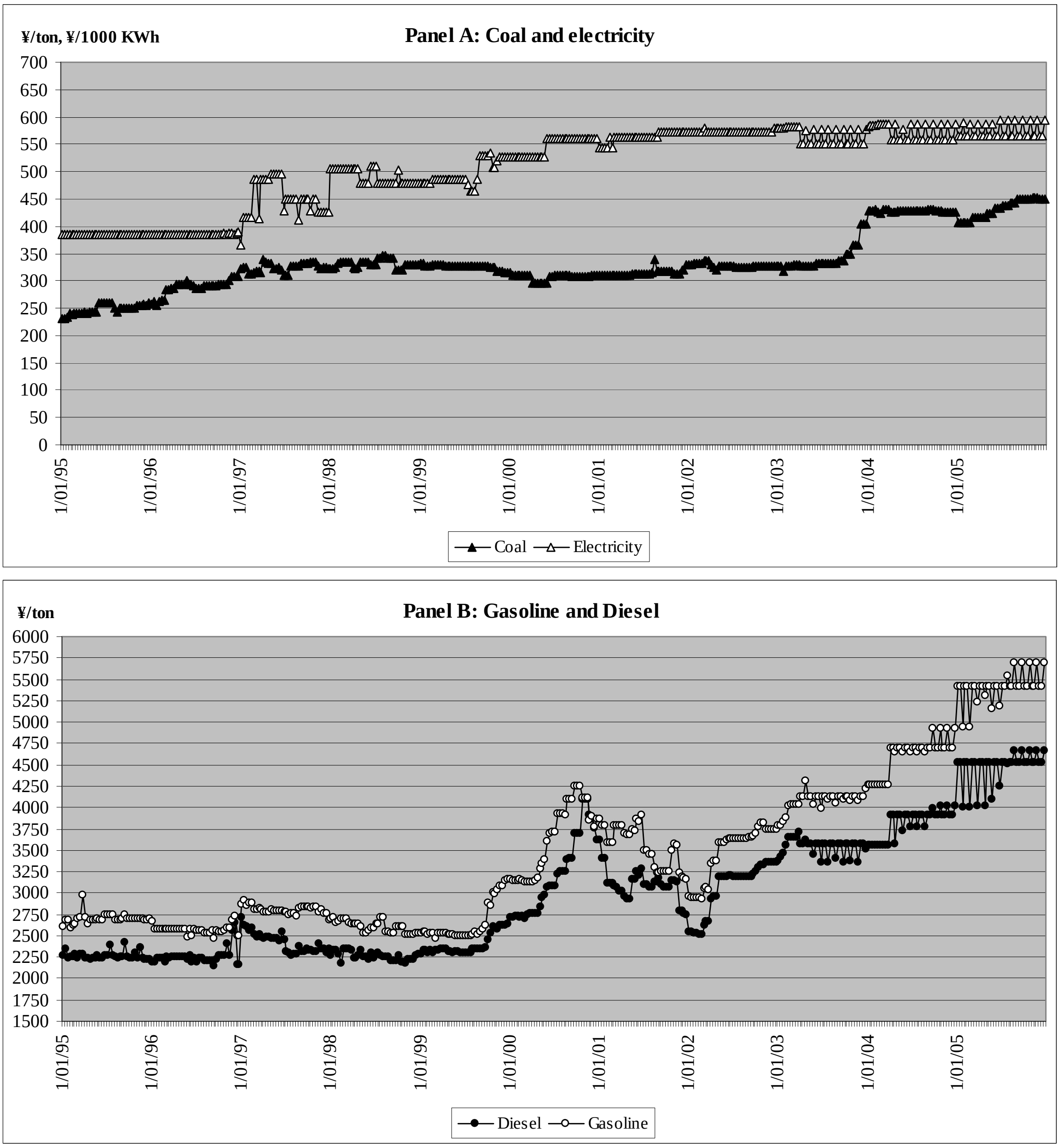


Figure 5. Price trends for pairs of coal-electricity and gasoline-diesel for Region 4
Note: Region 4 includes Nanjing, Hangzhou, Nanchang and Wuhan.

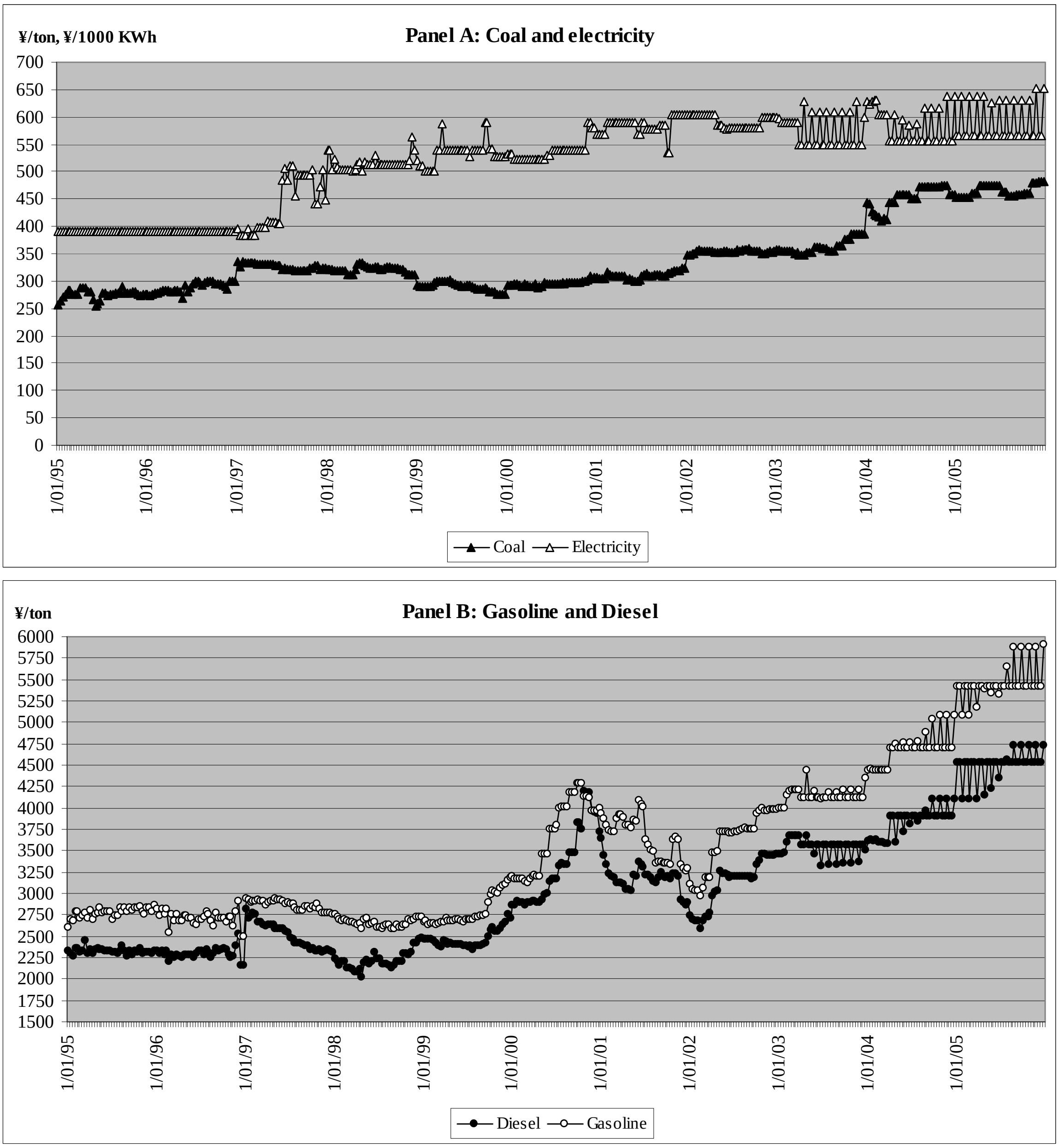
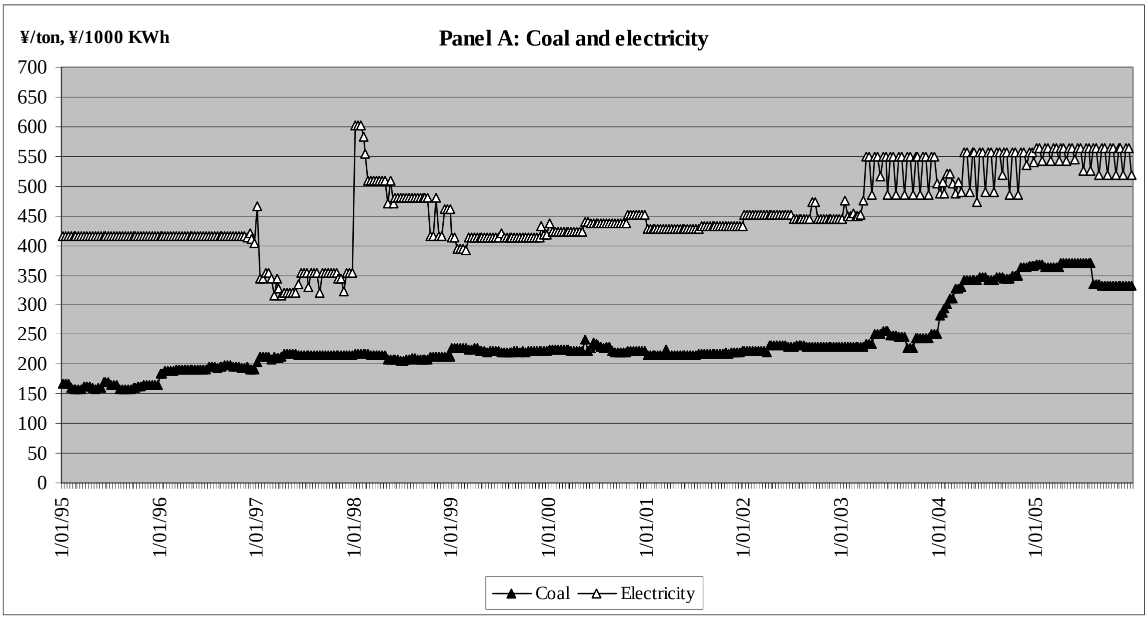


Figure 6. Price trends for pairs of coal-electricity and gasoline-diesel for Region 5
Note: Region 5 includes Fuzhou, Changsha, Guangzhou, Nanning and Haikou.



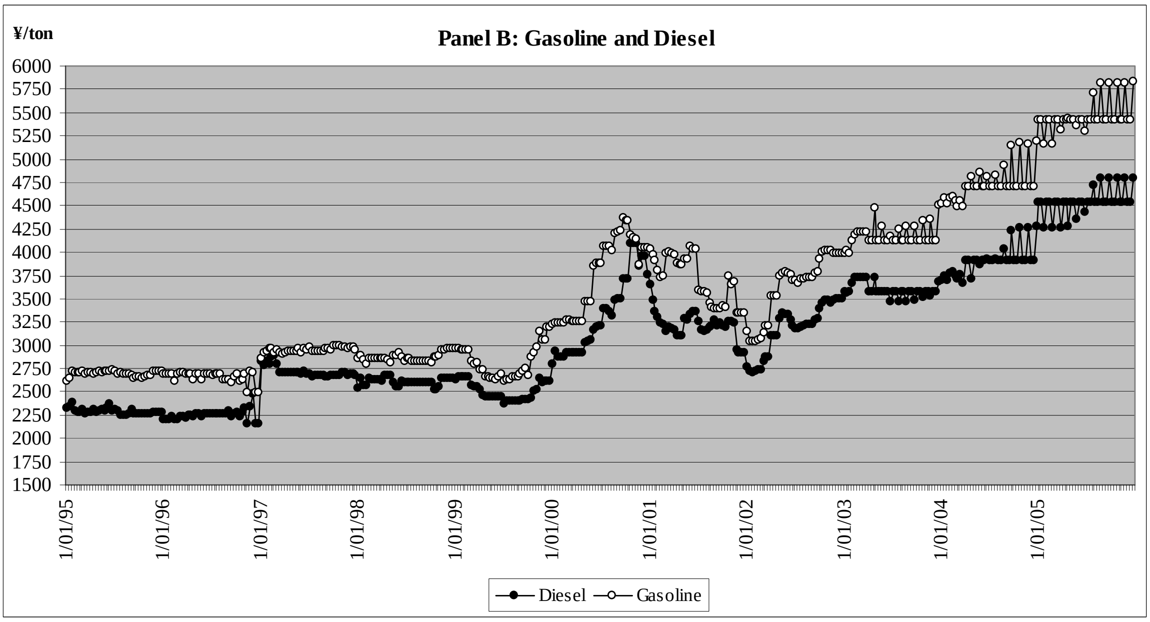


Figure 7. Price trends for pairs of coal-electricity and gasoline-diesel for Region 6
Note: Region 6 includes Chongqing, Chengdu, Xi'an, Lanzhou, Guiyang and Kunming.

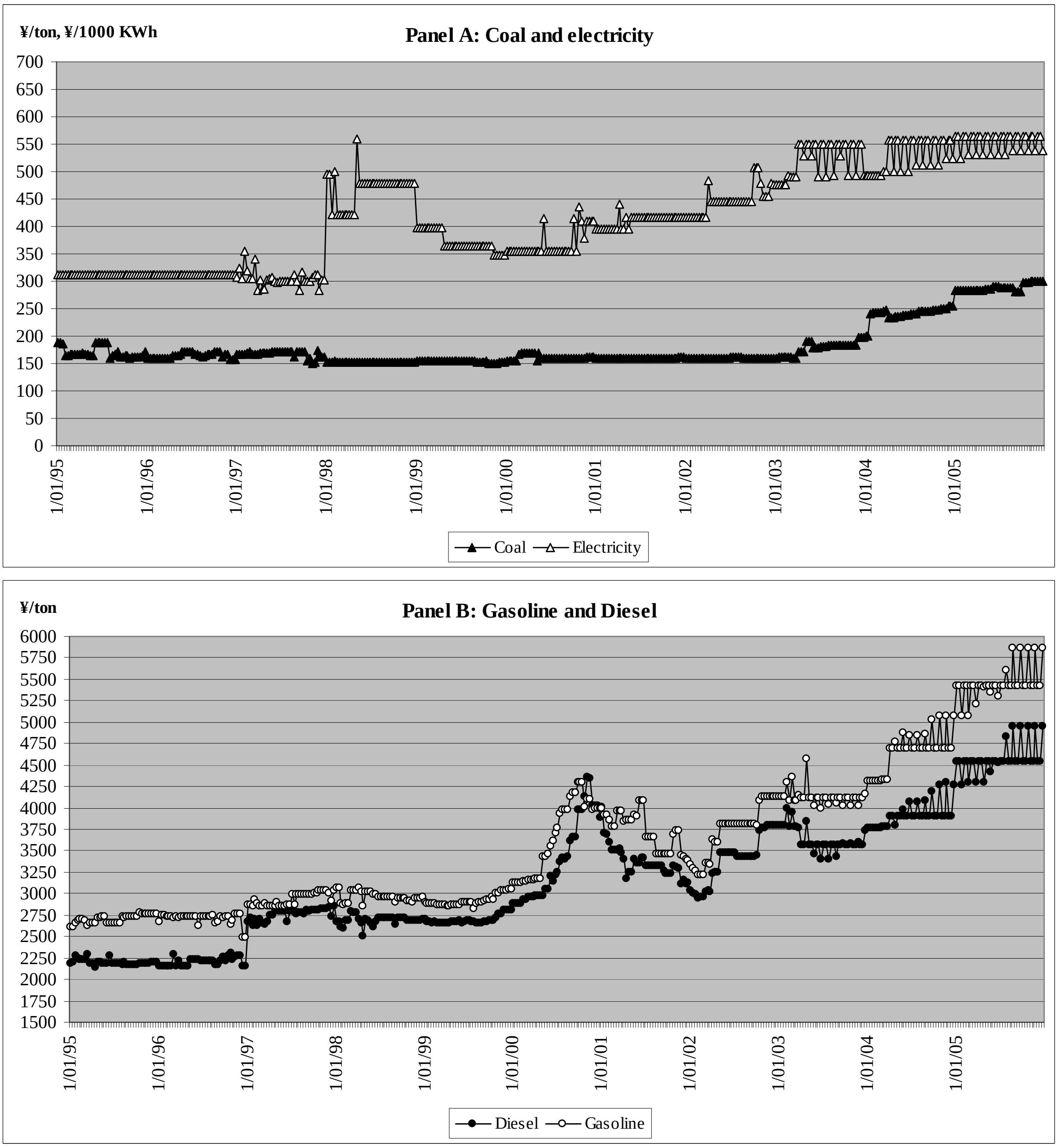


Figure 8. Price trends for pairs of coal-electricity and gasoline-diesel for Region 7.
Note: Region 7 includes Hohhot, Lhasa (data unavailable), Xining, Yinchuan and Urumqi.

Appendix Table 1. Panel cointegration tests for Region 1

Test statistics	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Panel v -statistic	0.481	0.355	0.458	0.359	0.863	0.275	2.028	0.051	3.344	0.002	12.178	0.000
Panel ρ -statistic	-4.136	0.000	-14.397	0.000	-6.805	0.000	-22.843	0.000	-7.266	0.000	-29.404	0.000
Panel t -statistic [a]	-4.447	0.000	-9.651	0.000	-5.601	0.000	-10.712	0.000	-4.677	0.000	-12.419	0.000
Panel t -statistic [b]	-3.491	0.001	-0.615	0.330	-4.534	0.000	-3.461	0.001	-1.649	0.102	-7.220	0.000
Group ρ -statistic	-8.586	0.000	-43.841	0.000	-13.614	0.000	-60.942	0.000	-6.687	0.000	-28.646	0.000
Group t -statistic [a]	-7.073	0.000	-20.582	0.000	-8.111	0.000	-20.765	0.000	-5.064	0.000	-14.211	0.000
Group t -statistic [b]	-4.349	0.000	-1.404	0.149	-5.381	0.000	-3.162	0.003	-1.579	0.115	-8.835	0.000
Deterministic intercept and trend:												
Panel v -statistic	0.527	0.347	1.191	0.196	1.008	0.240	2.262	0.031	1.611	0.109	7.511	0.000
Panel ρ -statistic	-5.823	0.000	-30.359	0.000	-8.838	0.000	-41.491	0.000	-7.153	0.000	-26.520	0.000
Panel t -statistic [a]	-7.140	0.000	-17.665	0.000	-8.457	0.000	-18.288	0.000	-5.071	0.000	-13.806	0.000
Panel t -statistic [b]	-4.873	0.000	-1.999	0.054	-6.654	0.000	-3.615	0.001	0.405	0.368	-7.658	0.000
Group ρ -statistic	-7.594	0.000	-43.474	0.000	-10.619	0.000	-56.449	0.000	-6.258	0.000	-24.222	0.000
Group t -statistic [a]	-7.768	0.000	-24.060	0.000	-8.993	0.000	-25.424	0.000	-4.888	0.000	-14.474	0.000
Group t -statistic [b]	-3.642	0.001	-1.577	0.115	-5.161	0.000	-3.022	0.004	0.274	0.384	-8.917	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 Engle-Granger based. 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. Region 1 includes Shijiazhuang, Hohhot, Taiyuan, Hefei, Jinan and Zhengzhou.

[a] Non-parametric and [b] parametric.

Appendix Table 2. Panel cointegration tests for Region 2

Test	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
Statistics	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Stat.	Prob.	Stat.	Stat.	Prob.	Stat.	Stat.	Prob.	Stat.
No deterministic trend:												
Panel ν -statistic	2.360	0.025	1.315	0.168	1.959	0.059	0.348	0.376	3.959	0.000	11.675	0.000
Panel ρ -statistic	-5.755	0.000	-44.359	0.000	-9.215	0.000	-62.009	0.000	-8.020	0.000	-12.521	0.000
Panel t -statistic [a]	-5.397	0.000	-17.704	0.000	-5.911	0.000	-17.552	0.000	-5.378	0.000	-5.914	0.000
Panel t -statistic [b]	-5.289	0.000	0.070	0.398	-5.375	0.000	-1.178	0.199	-4.499	0.000	-5.255	0.000
Group ρ -statistic	-7.428	0.000	-38.117	0.000	-11.105	0.000	-50.422	0.000	-5.837	0.000	-10.505	0.000
Group t -statistic [a]	-6.475	0.000	-16.430	0.000	-7.092	0.000	-16.653	0.000	-4.816	0.000	-6.225	0.000
Group t -statistic [b]	-5.727	0.000	0.502	0.352	-6.248	0.000	-1.484	0.133	-4.084	0.000	-6.077	0.000
Deterministic intercept and trend:												
Panel ν -statistic	1.141	0.208	1.027	0.236	0.003	0.399	-0.490	0.354	1.764	0.084	7.702	0.000
Panel ρ -statistic	-4.564	0.000	-59.578	0.000	-6.323	0.000	-86.919	0.000	-6.171	0.000	-10.069	0.000
Panel t -statistic [a]	-5.272	0.000	-24.959	0.000	-5.589	0.000	-26.408	0.000	-5.662	0.000	-5.909	0.000
Panel t -statistic [b]	-5.393	0.000	-0.647	0.324	-5.215	0.000	-1.218	0.190	-4.720	0.000	-5.171	0.000
Group ρ -statistic	-5.355	0.000	-40.813	0.000	-7.656	0.000	-52.519	0.000	-4.474	0.000	-7.863	0.000
Group t -statistic [a]	-5.229	0.000	-18.928	0.000	-6.002	0.000	-19.938	0.000	-4.891	0.000	-5.697	0.000
Group t -statistic [b]	-4.715	0.000	-0.058	0.398	-5.414	0.000	-1.078	0.223	-3.998	0.000	-5.601	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 Engle-Granger based. 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. Region 2 includes Beijing, Tianjin and Shanghai.

[a] Non-parametric and [b] parametric.

Appendix Table 3. Panel cointegration tests for Region 3

Test Statistics	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Panel v -statistic	-0.457	0.359	0.600	0.333	-0.811	0.287	0.945	0.255	-0.202	0.391	6.815	0.000
Panel ρ -statistic	-16.488	0.000	-41.345	0.000	-33.026	0.000	-56.906	0.000	-7.135	0.000	-20.562	0.000
Panel t -statistic [a]	-14.992	0.000	-16.754	0.000	-16.588	0.000	-16.161	0.000	-5.089	0.000	-9.046	0.000
Panel t -statistic [b]	-14.753	0.000	0.501	0.352	-16.601	0.000	-0.803	0.289	-3.283	0.002	-4.599	0.000
Group ρ -statistic	-17.586	0.000	-46.049	0.000	-18.584	0.000	-49.965	0.000	-4.983	0.000	-16.065	0.000
Group t -statistic [a]	-15.423	0.000	-23.596	0.000	-11.402	0.000	-18.855	0.000	-3.600	0.001	-7.793	0.000
Group t -statistic [b]	-14.475	0.000	0.543	0.344	-10.927	0.000	-0.697	0.313	-2.101	0.044	-4.556	0.000
Deterministic intercept and trend:												
Panel v -statistic	-1.518	0.126	0.297	0.382	-2.201	0.035	0.679	0.317	-0.797	0.290	4.370	0.000
Panel ρ -statistic	-16.281	0.000	-50.789	0.000	-26.755	0.000	-84.717	0.000	-7.645	0.000	-18.436	0.000
Panel t -statistic [a]	-16.191	0.000	-23.129	0.000	-19.019	0.000	-26.667	0.000	-5.842	0.000	-9.914	0.000
Panel t -statistic [b]	-15.630	0.000	-1.279	0.176	-18.860	0.000	-2.038	0.050	-6.067	0.000	-5.406	0.000
Group ρ -statistic	-15.324	0.000	-55.731	0.000	-14.176	0.000	-76.163	0.000	-3.787	0.000	-13.411	0.000
Group t -statistic [a]	-14.660	0.000	-30.864	0.000	-11.468	0.000	-32.532	0.000	-2.828	0.007	-8.069	0.000
Group t -statistic [b]	-11.875	0.000	-1.002	0.241	-10.736	0.000	-1.950	0.060	-2.846	0.007	-4.896	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 Engle-Granger based. 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. Region 3 includes Shenyang, Changchun and Harbin.

[a] Non-parametric and [b] parametric.

Appendix Table 4. Panel cointegration tests for Region 4

Test Statistics	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Panel v -statistic	0.799	0.290	1.990	0.055	2.537	0.016	1.209	0.192	3.985	0.000	9.478	0.000
Panel ρ -statistic	-1.744	0.087	-19.470	0.000	-3.576	0.001	-38.403	0.000	-6.135	0.000	-19.513	0.000
Panel t -statistic [a]	-2.169	0.038	-12.789	0.000	-2.462	0.019	-14.656	0.000	-4.400	0.000	-8.628	0.000
Panel t -statistic [b]	0.390	0.370	-0.369	0.373	-0.641	0.325	-0.433	0.363	-2.376	0.024	-6.192	0.000
Group ρ -statistic	-5.066	0.000	-41.124	0.000	-6.010	0.000	-60.573	0.000	-5.294	0.000	-17.880	0.000
Group t -statistic [a]	-4.877	0.000	-18.645	0.000	-3.984	0.000	-18.894	0.000	-5.134	0.000	-9.616	0.000
Group t -statistic [b]	-2.001	0.054	-2.254	0.032	-0.458	0.359	-1.404	0.149	-1.799	0.079	-7.025	0.000
Deterministic intercept and trend:												
Panel v -statistic	0.587	0.336	1.592	0.112	1.782	0.082	0.026	0.399	1.739	0.088	5.773	0.000
Panel ρ -statistic	-2.505	0.017	-24.083	0.000	-4.885	0.000	-36.963	0.000	-4.689	0.000	-15.321	0.000
Panel t -statistic [a]	-2.849	0.007	-16.567	0.000	-3.793	0.000	-19.007	0.000	-4.132	0.000	-8.654	0.000
Panel t -statistic [b]	0.216	0.390	-0.217	0.390	-1.360	0.158	0.089	0.397	-1.743	0.087	-5.826	0.000
Group ρ -statistic	-5.226	0.000	-36.293	0.000	-6.732	0.000	-50.257	0.000	-3.554	0.001	-13.232	0.000
Group t -statistic [a]	-5.337	0.000	-18.513	0.000	-5.438	0.000	-20.952	0.000	-4.377	0.000	-8.930	0.000
Group t -statistic [b]	-2.082	0.046	-2.035	0.050	-2.572	0.015	-1.733	0.089	-1.029	0.235	-5.974	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 Engle-Granger based. 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. Region 4 includes Nanjing, Hangzhou, Nanchang and Wuhan.

[a] Non-parametric and [b] parametric.

Appendix Table 5. Panel cointegration tests for Region 5

Test Statistics	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Panel v -statistic	-0.221	0.389	5.762	0.000	2.316	0.027	2.444	0.020	4.862	0.000	14.336	0.000
Panel ρ -statistic	-4.809	0.000	-35.637	0.000	-10.998	0.000	-59.609	0.000	-9.078	0.000	-27.199	0.000
Panel t -statistic [a]	-4.709	0.000	-19.297	0.000	-6.744	0.000	-21.366	0.000	-6.422	0.000	-11.736	0.000
Panel t -statistic [b]	-2.163	0.038	-0.190	0.392	-4.769	0.000	-1.407	0.148	-5.614	0.000	-9.361	0.000
Group ρ -statistic	-4.453	0.000	-51.768	0.000	-9.764	0.000	-80.854	0.000	-6.846	0.000	-23.641	0.000
Group t -statistic [a]	-4.939	0.000	-24.526	0.000	-6.950	0.000	-25.875	0.000	-6.812	0.000	-12.146	0.000
Group t -statistic [b]	-3.116	0.003	-1.595	0.112	-5.234	0.000	-1.895	0.066	-5.949	0.000	-10.190	0.000
Deterministic intercept and trend:												
Panel v -statistic	-1.235	0.186	5.241	0.000	0.293	0.382	0.346	0.376	2.290	0.029	9.333	0.000
Panel ρ -statistic	-10.772	0.000	-42.572	0.000	-16.945	0.000	-60.318	0.000	-7.894	0.000	-24.135	0.000
Panel t -statistic [a]	-9.655	0.000	-24.596	0.000	-11.006	0.000	-26.395	0.000	-6.736	0.000	-12.833	0.000
Panel t -statistic [b]	-2.892	0.006	-0.063	0.398	-4.918	0.000	-1.033	0.234	-5.284	0.000	-9.852	0.000
Group ρ -statistic	-6.719	0.000	-48.603	0.000	-10.495	0.000	-63.357	0.000	-7.227	0.000	-20.114	0.000
Group t -statistic [a]	-7.297	0.000	-25.446	0.000	-8.267	0.000	-27.801	0.000	-7.783	0.000	-12.272	0.000
Group t -statistic [b]	-3.737	0.000	-1.363	0.158	-4.917	0.000	-2.201	0.035	-5.809	0.000	-10.196	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 Engle-Granger based. 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. Region 5 includes Fuzhou, Changsha, Guangzhou, Nanning and Haikou.
[a] Non-parametric and [b] parametric.

Appendix Table 6. Panel cointegration tests for Region 6

Test Statistics	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Panel v -statistic	1.638	0.104	9.793	0.000	5.247	0.000	2.545	0.016	1.496	0.130	13.313	0.000
Panel ρ -statistic	-6.536	0.000	-58.409	0.000	-8.991	0.000	-71.483	0.000	-5.277	0.000	-27.416	0.000
Panel t -statistic [a]	-5.571	0.000	-22.598	0.000	-5.961	0.000	-20.364	0.000	-4.446	0.000	-11.663	0.000
Panel t -statistic [b]	0.165	0.394	-1.036	0.233	-0.741	0.303	-0.983	0.246	-2.208	0.035	-6.910	0.000
Group ρ -statistic	-5.139	0.000	-54.933	0.000	-5.973	0.000	-69.385	0.000	-3.615	0.001	-25.591	0.000
Group t -statistic [a]	-4.711	0.000	-24.456	0.000	-4.835	0.000	-21.832	0.000	-3.671	0.001	-13.089	0.000
Group t -statistic [b]	-0.321	0.379	-0.792	0.292	-1.162	0.203	-1.281	0.176	-1.886	0.067	-8.516	0.000
Deterministic intercept and trend:												
Panel v -statistic	1.038	0.233	9.169	0.000	3.747	0.000	1.855	0.071	0.207	0.391	8.693	0.000
Panel ρ -statistic	-7.949	0.000	-61.175	0.000	-10.937	0.000	-100.182	0.000	-6.385	0.000	-25.646	0.000
Panel t -statistic [a]	-7.410	0.000	-26.679	0.000	-8.139	0.000	-30.911	0.000	-5.706	0.000	-13.334	0.000
Panel t -statistic [b]	-4.773	0.000	-0.475	0.356	0.164	0.394	-1.991	0.055	-3.722	0.000	-7.134	0.000
Group ρ -statistic	-5.654	0.000	-52.741	0.000	-6.251	0.000	-76.732	0.000	-4.896	0.000	-22.218	0.000
Group t -statistic [a]	-5.591	0.000	-25.783	0.000	-5.207	0.000	-28.453	0.000	-5.147	0.000	-13.610	0.000
Group t -statistic [b]	-3.112	0.003	0.005	0.399	0.179	0.393	-1.429	0.144	-3.971	0.000	-8.158	0.000

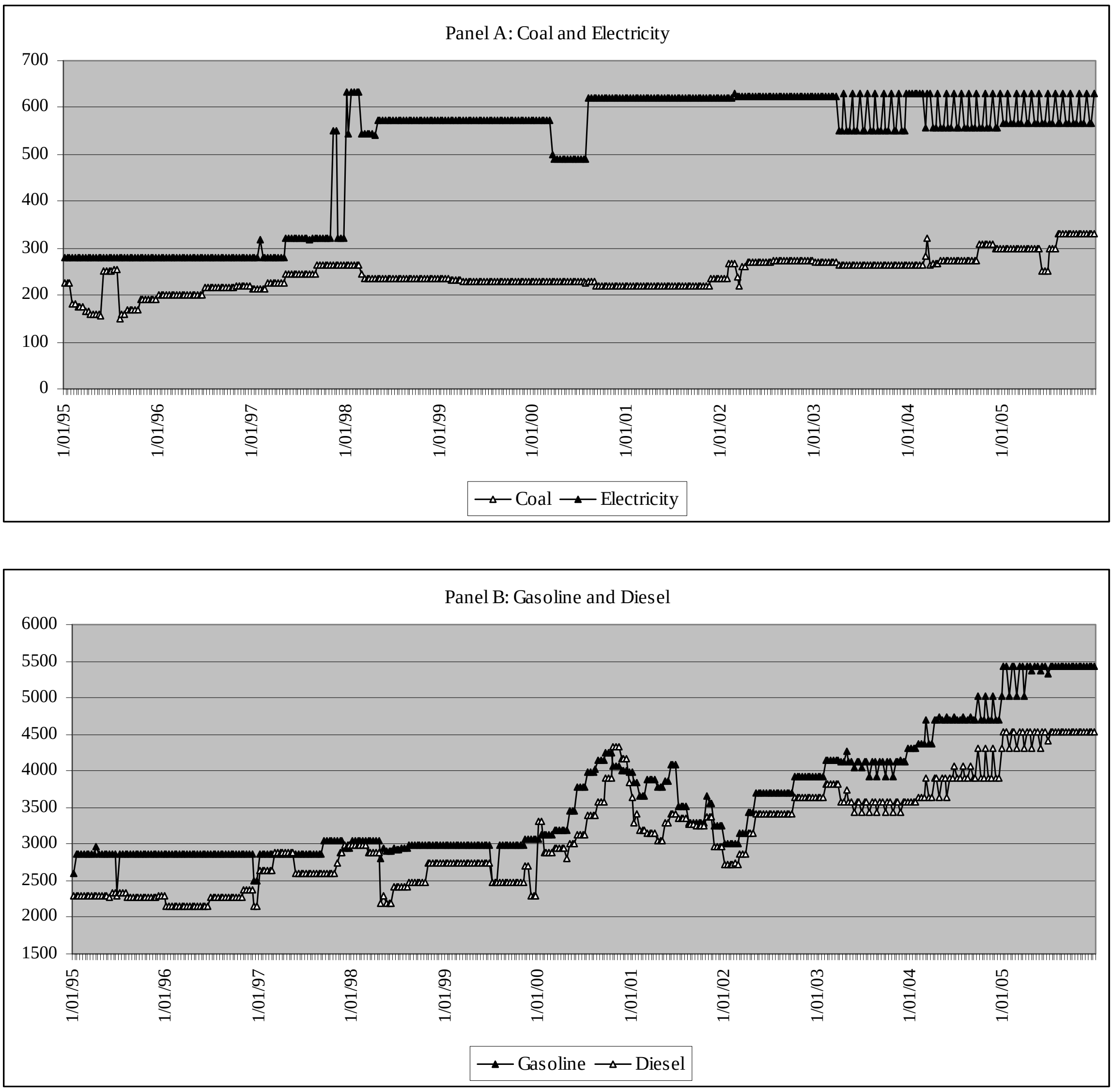
Note: Statistics are asymptotically distributed as normal. The statistic ratio test is right-sided, while the others are left-sided. Null hypothesis is no cointegration among the fuel prices and no exogenous variables are included in test equation. Pedroni panel cointegration test is Engle-Granger based. 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. Region 6 includes Chongqing, Chengdu, Xi'an, Lanzhou, Guiyang and Kunming.

[a] Non-parametric and [b] parametric.

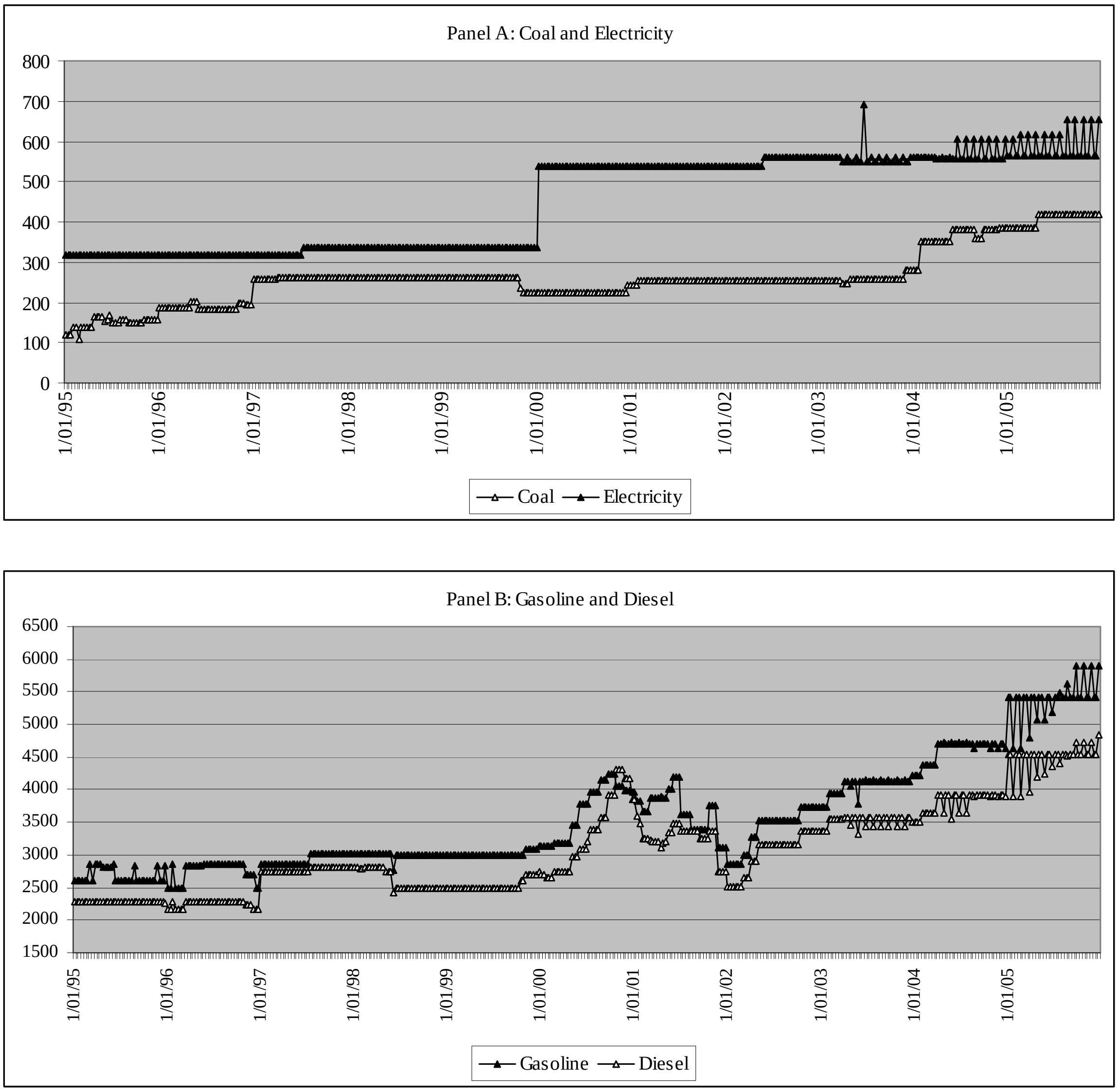
Appendix Table 7. Panel cointegration tests for Region 7

Test Statistics	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Panel v -statistic	2.698	0.011	2.889	0.006	4.374	0.000	0.927	0.260	1.298	0.172	8.249	0.000
Panel ρ -statistic	-2.723	0.010	-36.983	0.000	-5.633	0.000	-61.369	0.000	-11.583	0.000	-11.363	0.000
Panel t -statistic [a]	-2.611	0.013	-17.357	0.000	-3.670	0.001	-18.003	0.000	-6.596	0.000	-5.888	0.000
Panel t -statistic [b]	0.122	0.396	-0.956	0.253	-1.229	0.188	-1.298	0.172	-6.618	0.000	-4.704	0.000
Group ρ -statistic	-3.779	0.000	-54.535	0.000	-6.862	0.000	-70.080	0.000	-8.847	0.000	-10.444	0.000
Group t -statistic [a]	-3.594	0.001	-23.976	0.000	-4.674	0.000	-22.286	0.000	-6.538	0.000	-6.529	0.000
Group t -statistic [b]	0.314	0.380	-0.923	0.261	-1.544	0.121	-0.950	0.254	-7.070	0.000	-5.353	0.000
Deterministic intercept and trend:												
Panel v -statistic	1.487	0.132	2.103	0.044	1.933	0.062	-0.319	0.379	0.276	0.384	5.711	0.000
Panel ρ -statistic	-2.435	0.021	-44.425	0.000	-3.875	0.000	-68.121	0.000	-13.025	0.000	-11.838	0.000
Panel t -statistic [a]	-2.702	0.010	-22.555	0.000	-3.152	0.003	-24.309	0.000	-9.139	0.000	-7.154	0.000
Panel t -statistic [b]	0.794	0.291	-0.359	0.374	-0.090	0.397	-1.125	0.212	-7.207	0.000	-5.639	0.000
Group ρ -statistic	-2.938	0.005	-54.814	0.000	-4.772	0.000	-76.741	0.000	-10.334	0.000	-9.648	0.000
Group t -statistic [a]	-3.282	0.002	-27.972	0.000	-3.847	0.000	-29.049	0.000	-8.640	0.000	-7.031	0.000
Group t -statistic [b]	0.998	0.242	-0.608	0.332	-0.388	0.370	-1.089	0.221	-8.252	0.000	-5.498	0.000

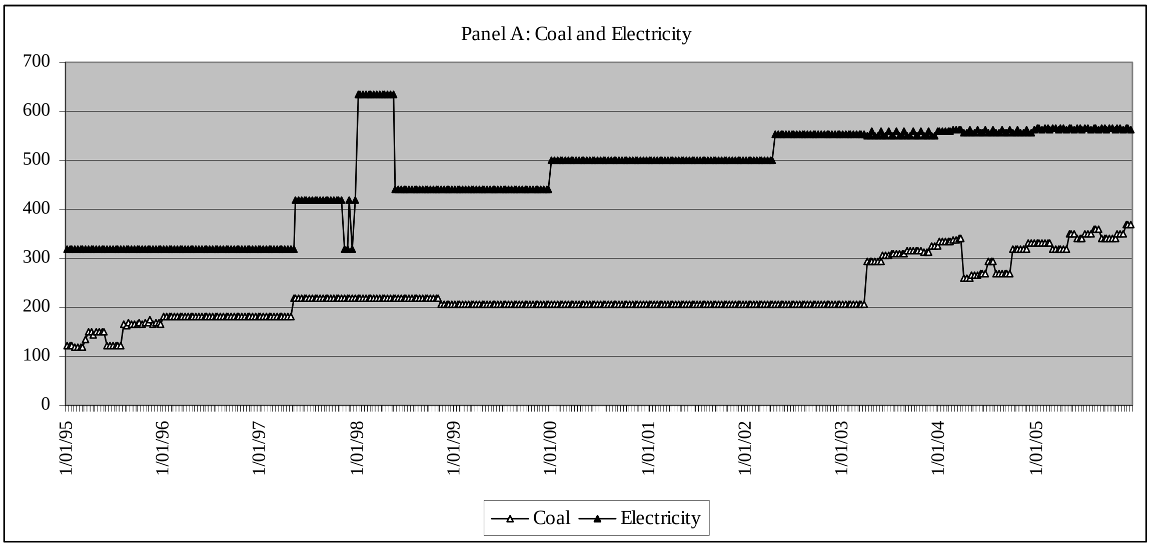
Note: Statistics are asymptotically distributed as normal. The statistic ratio test is right-sided, while the others are left-sided. Null hypothesis is no cointegration among the fuel prices and no exogenous variables are included in test equation. Pedroni panel cointegration test is Engle-Granger based. 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. Region 7 includes Lhasa (data unavailable), Xining, Yinchuan and Urumqi.
[a] Non-parametric and [b] parametric.

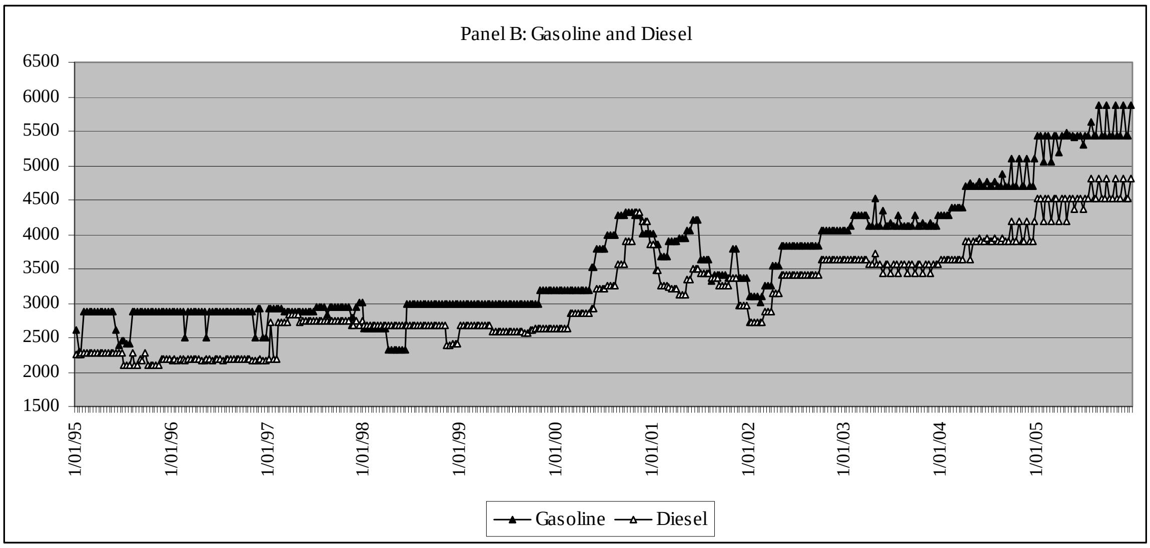


Appendix Figure 1. Price trends for pairs of coal-electricity and gasoline-diesel in Harbin of Heilongjiang province

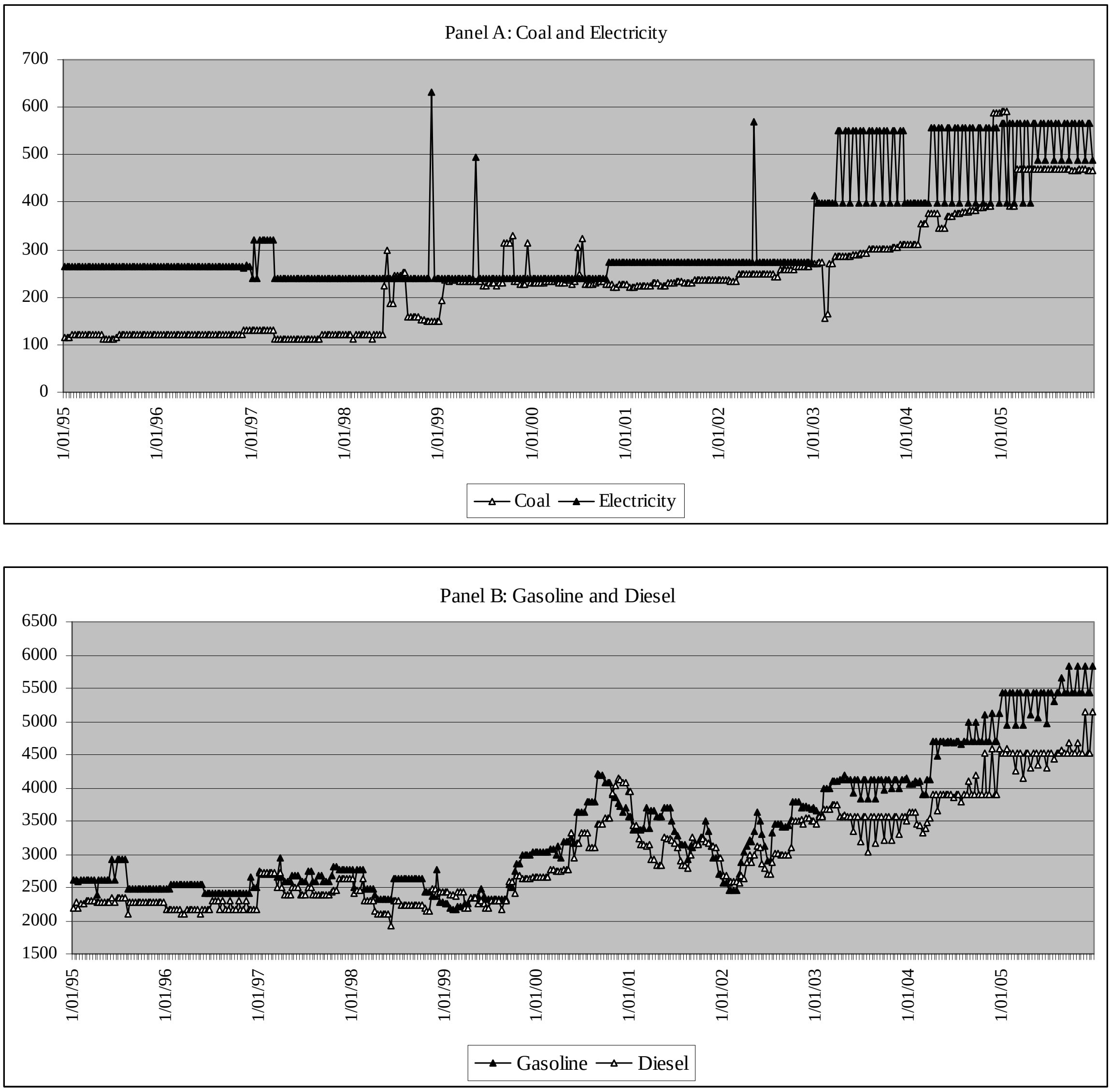


Appendix Figure 2. Price trends for pairs of coal-electricity and gasoline-diesel in Beijing

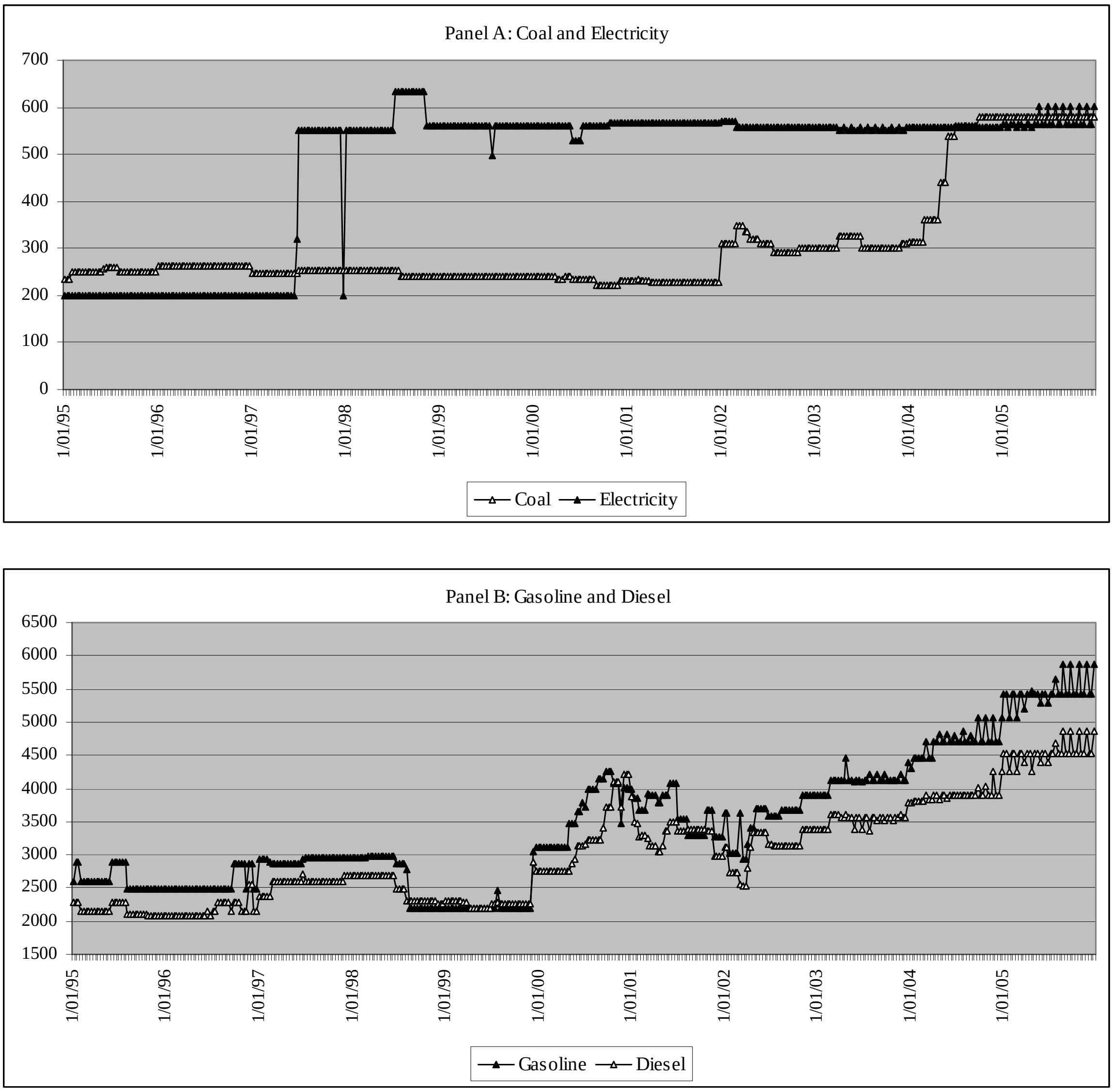




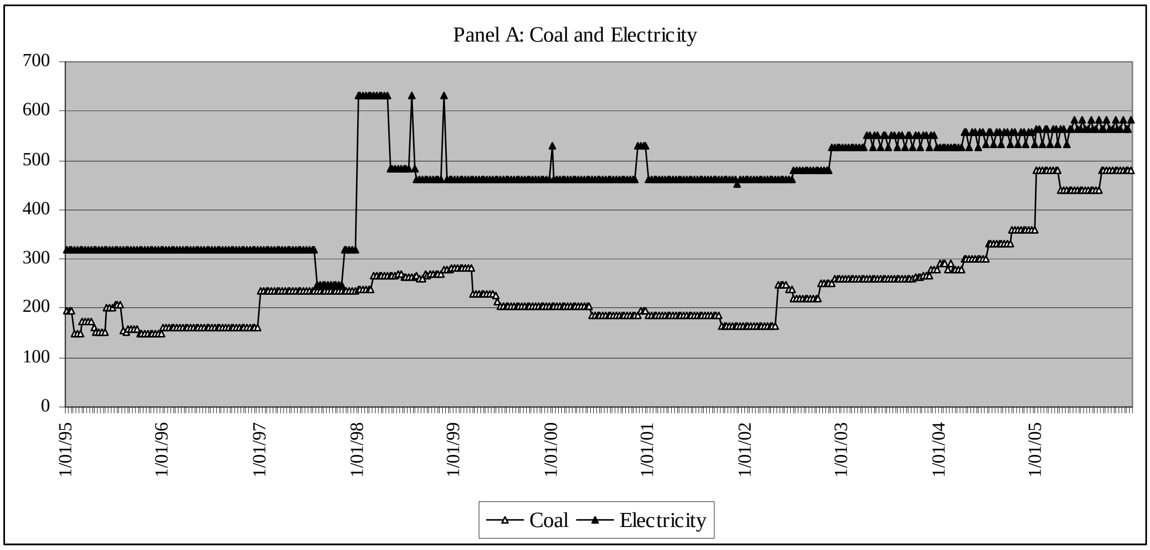
Appendix Figure 3. Price trends for pairs of coal-electricity and gasoline-diesel in Shijiazhuang of Hebei province

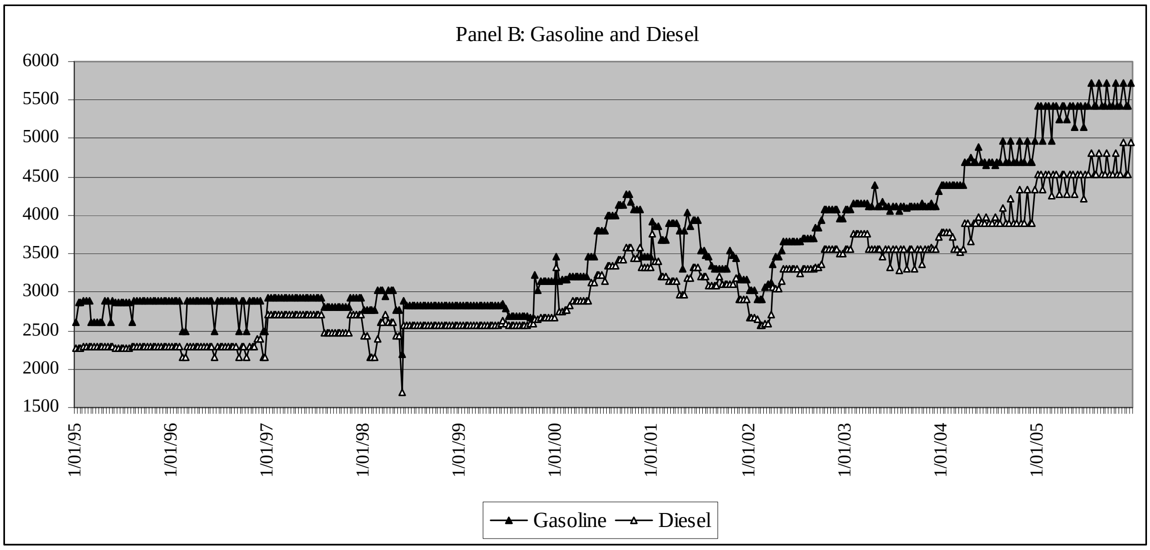


Appendix Figure 4. Price trends for pairs of coal-electricity and gasoline-diesel in Taiyuan of Shanxi province

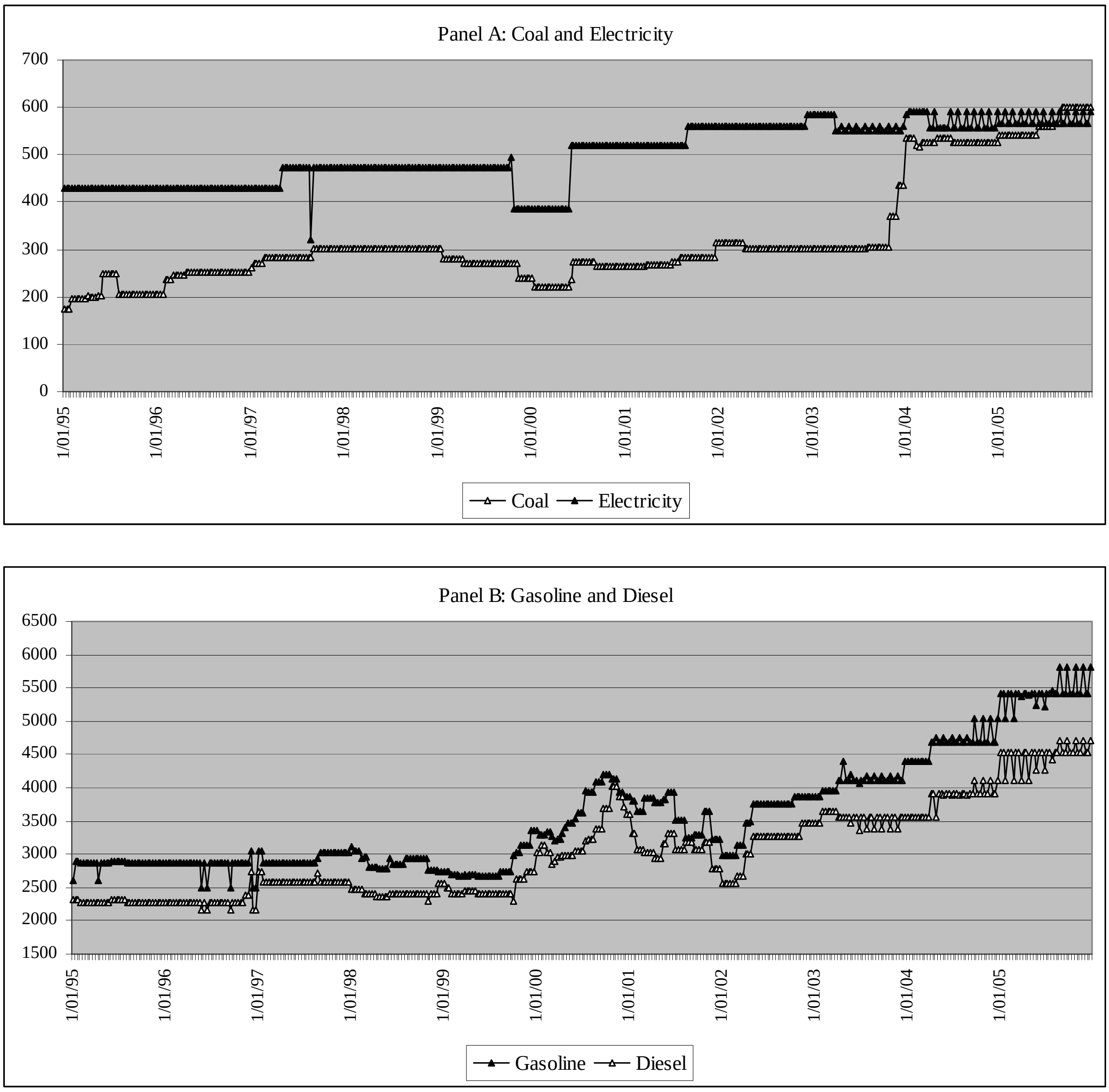


Appendix Figure 5. Price trends for pairs of coal-electricity and gasoline-diesel in Jinan of Shandong province

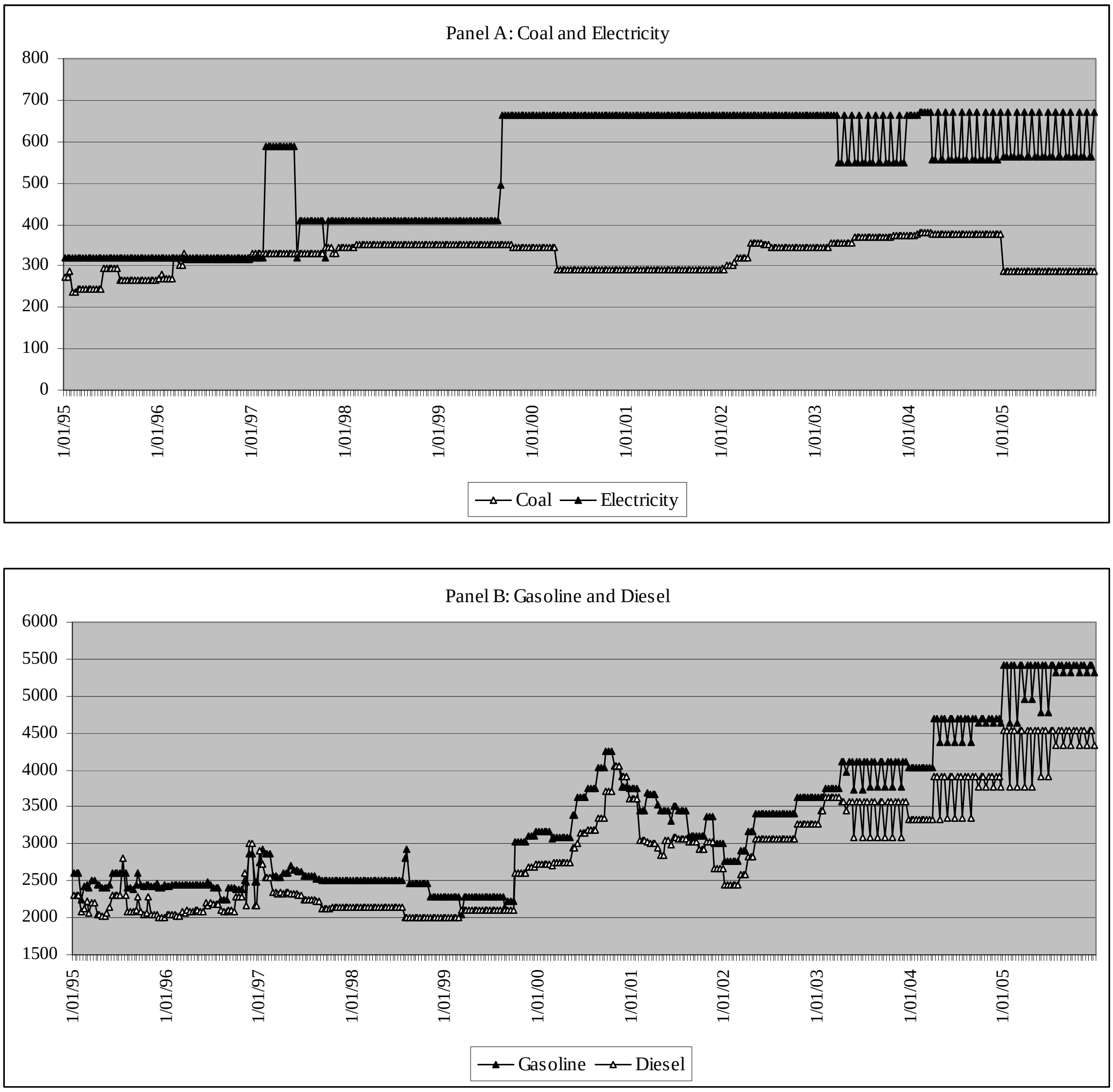




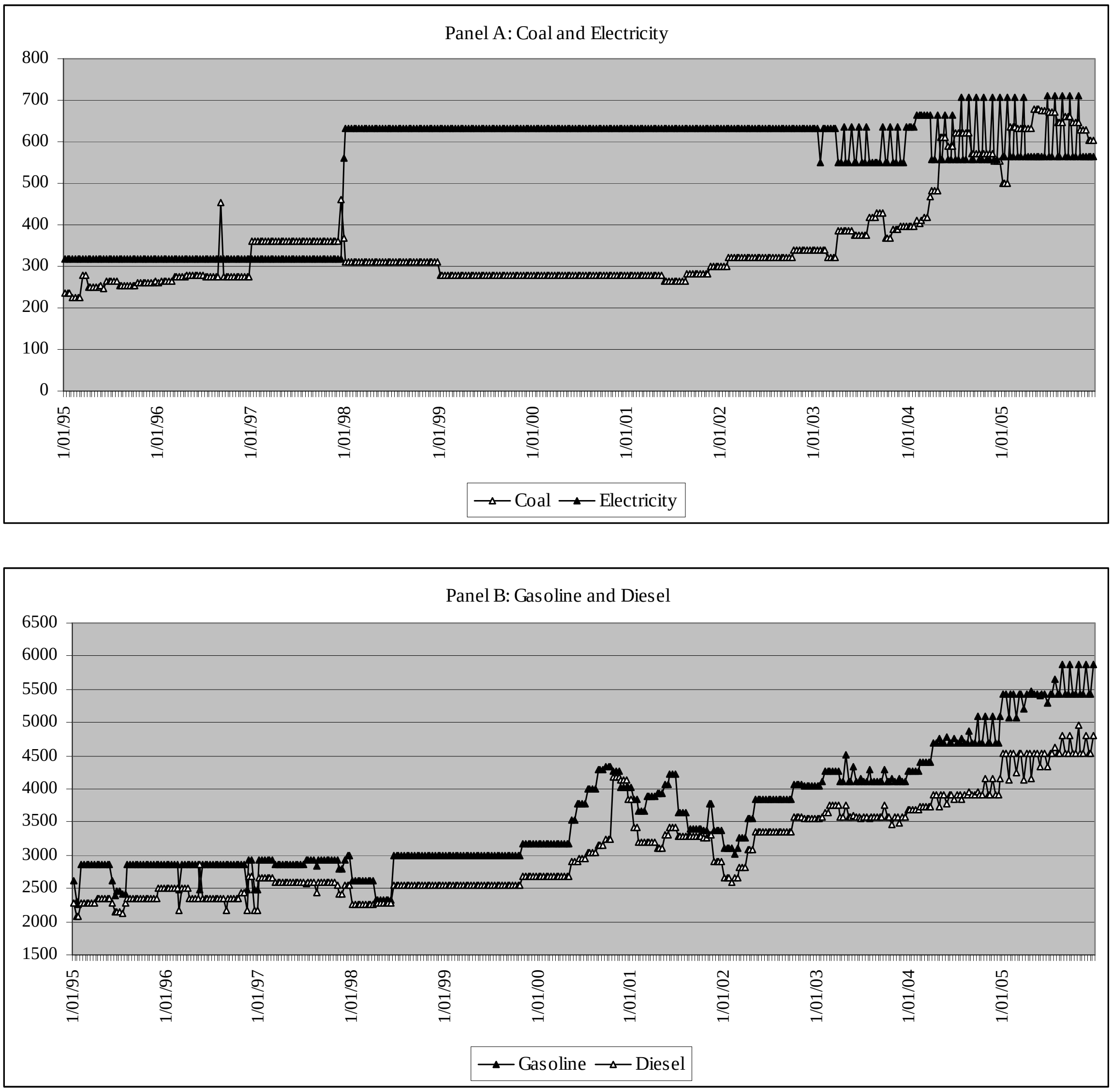
Appendix Figure 6. Price trends for pairs of coal-electricity and gasoline-diesel in Zhengzhou of Henan province



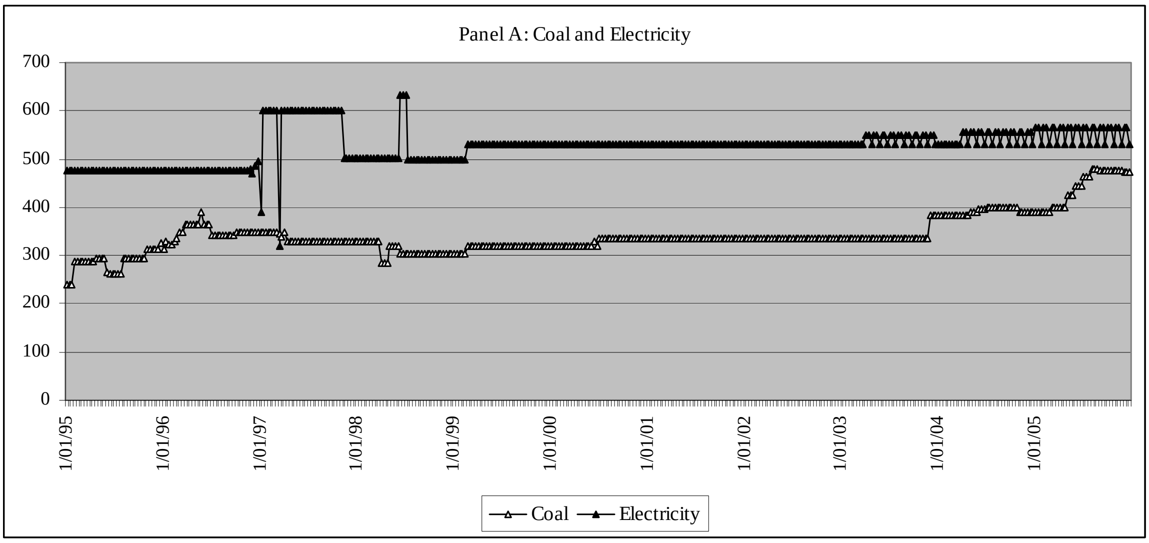
Appendix Figure 7. Price trends for pairs of coal-electricity and gasoline-diesel in Wuhan of Hubei province

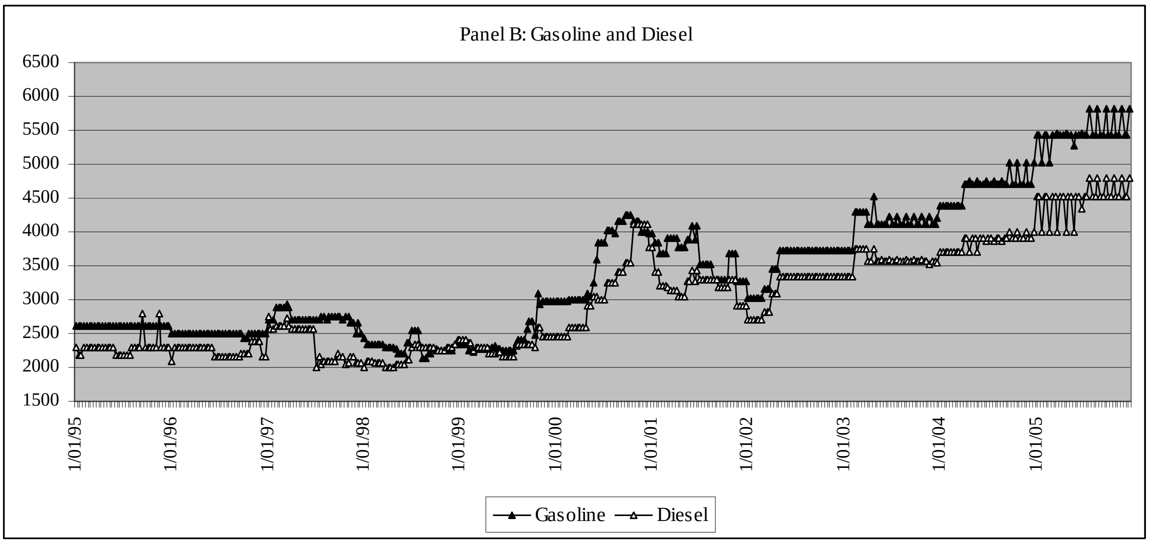


Appendix Figure 8. Price trends for pairs of coal-electricity and gasoline-diesel in Nanjing of Jiangsu province

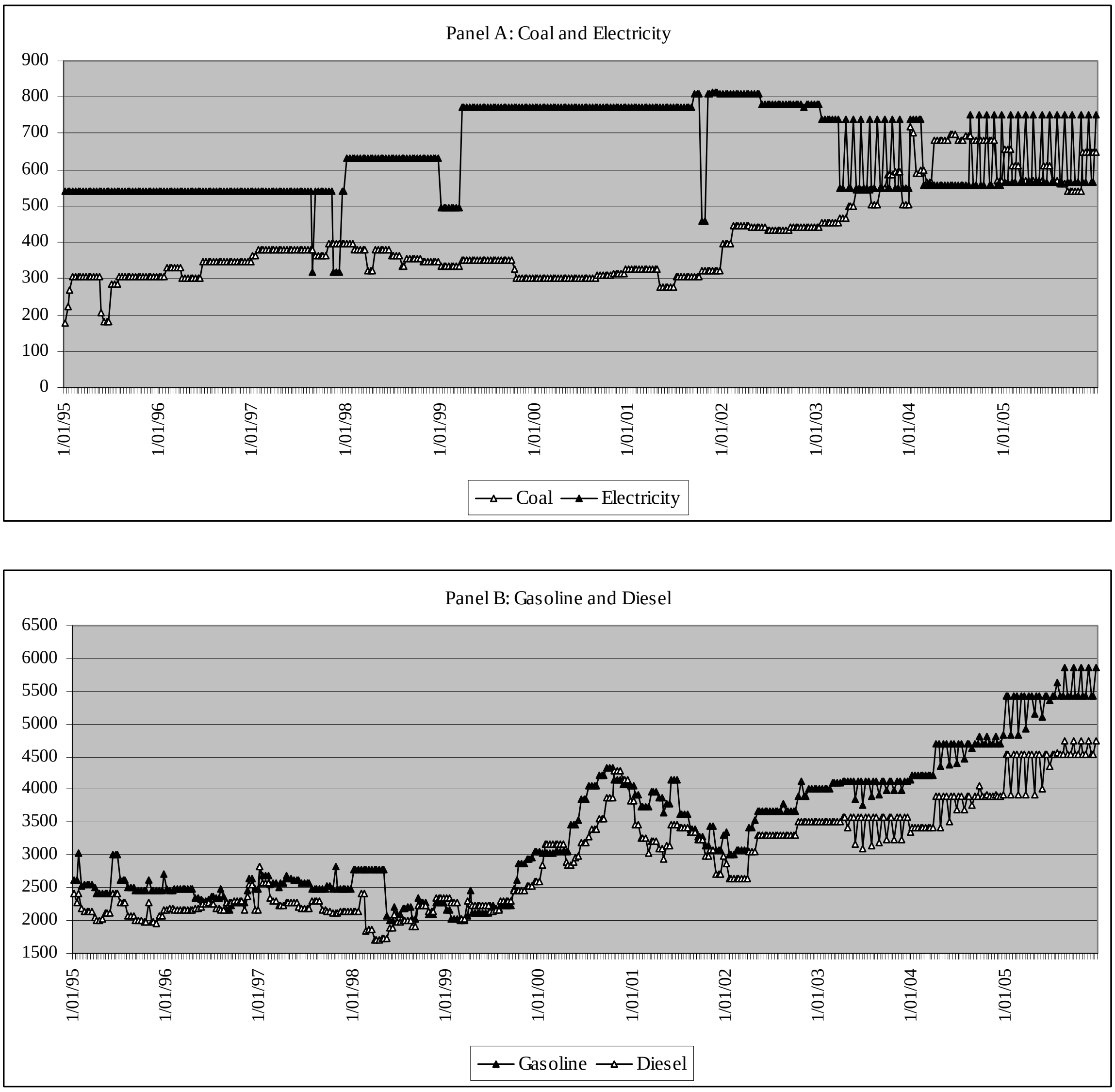


Appendix Figure 9. Price trends for pairs of coal-electricity and gasoline-diesel in Shanghai

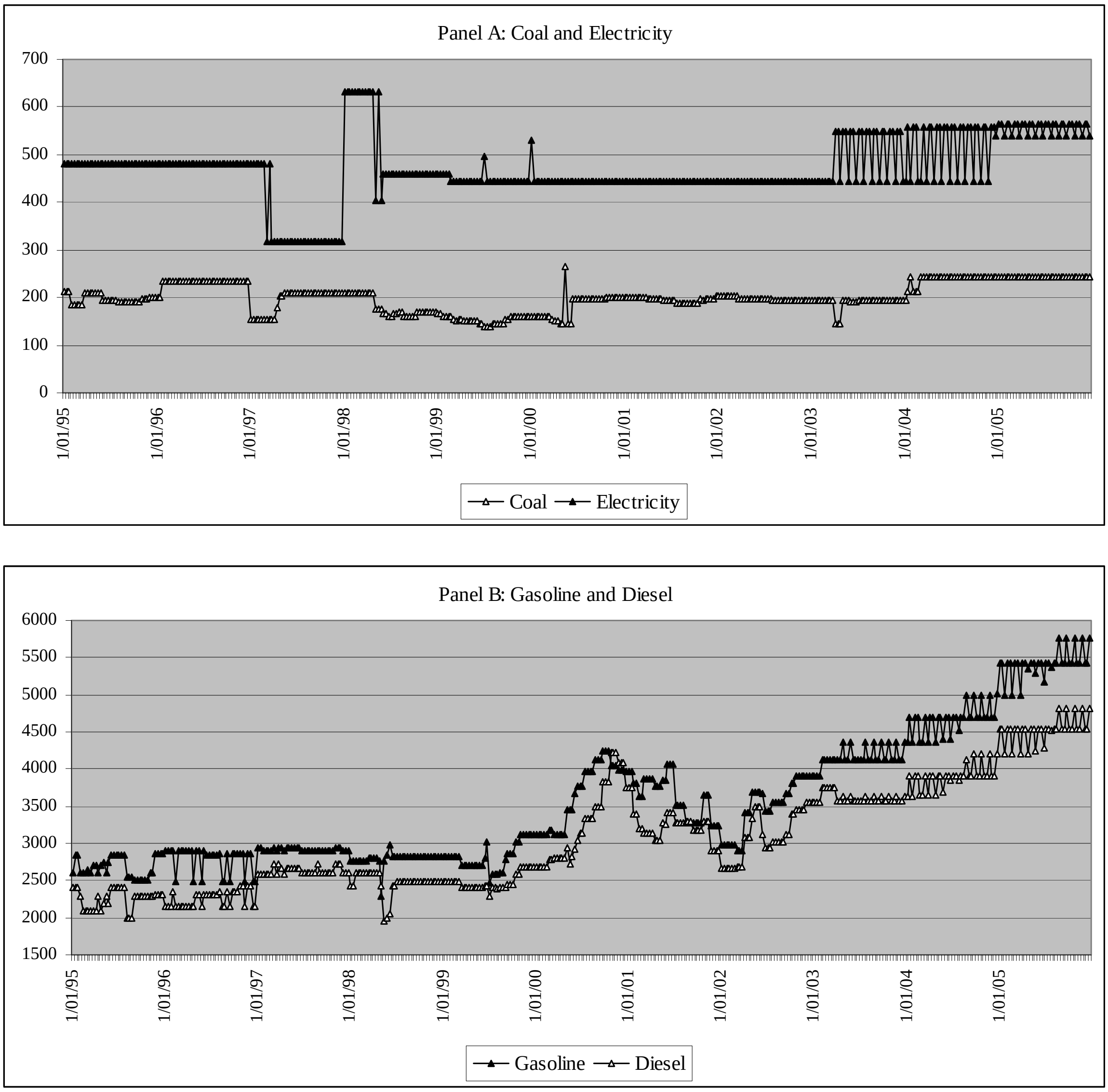




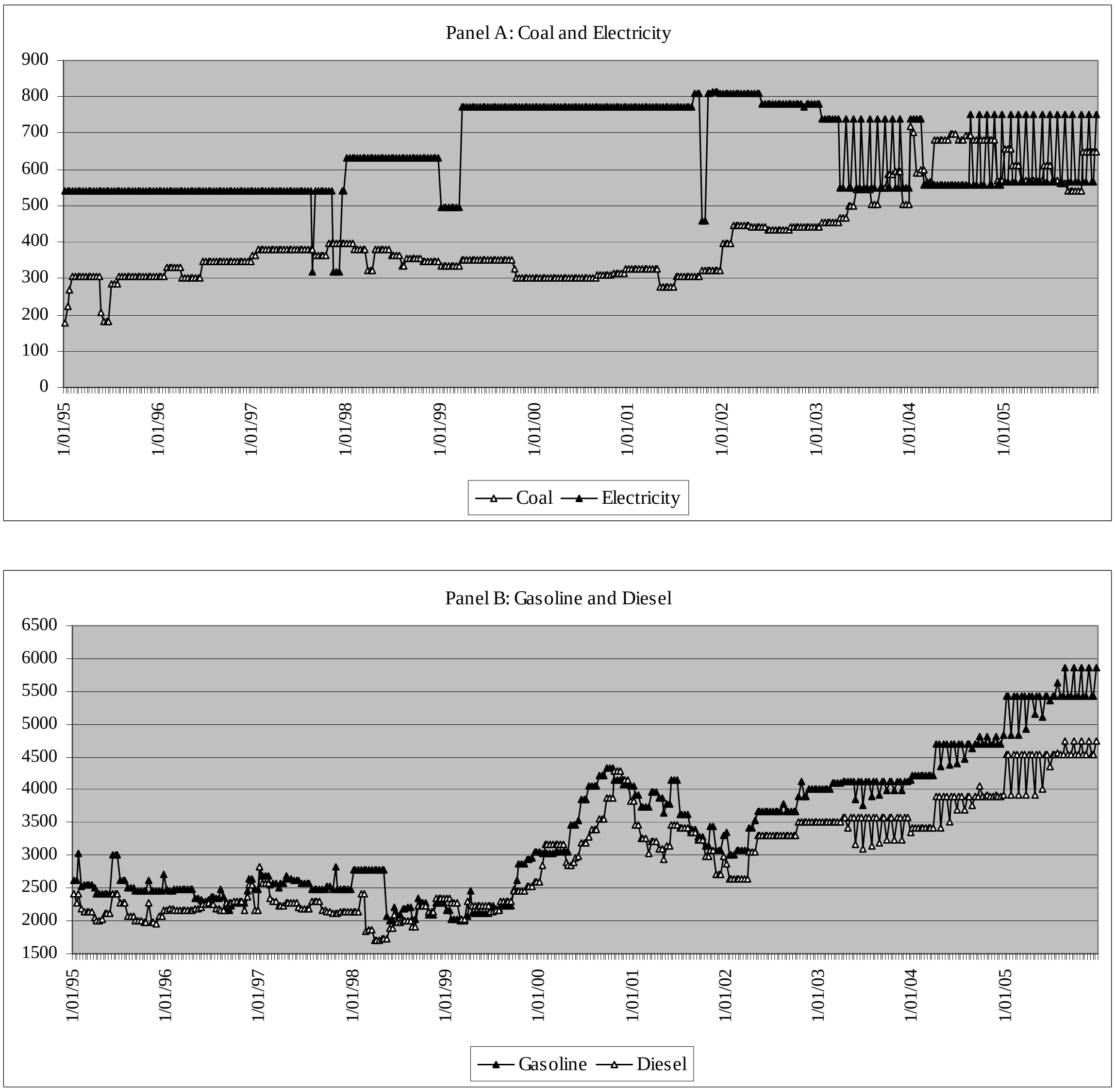
Appendix Figure 10. Price trends for pairs of coal-electricity and gasoline-diesel in Hangzhou of Zhejiang province



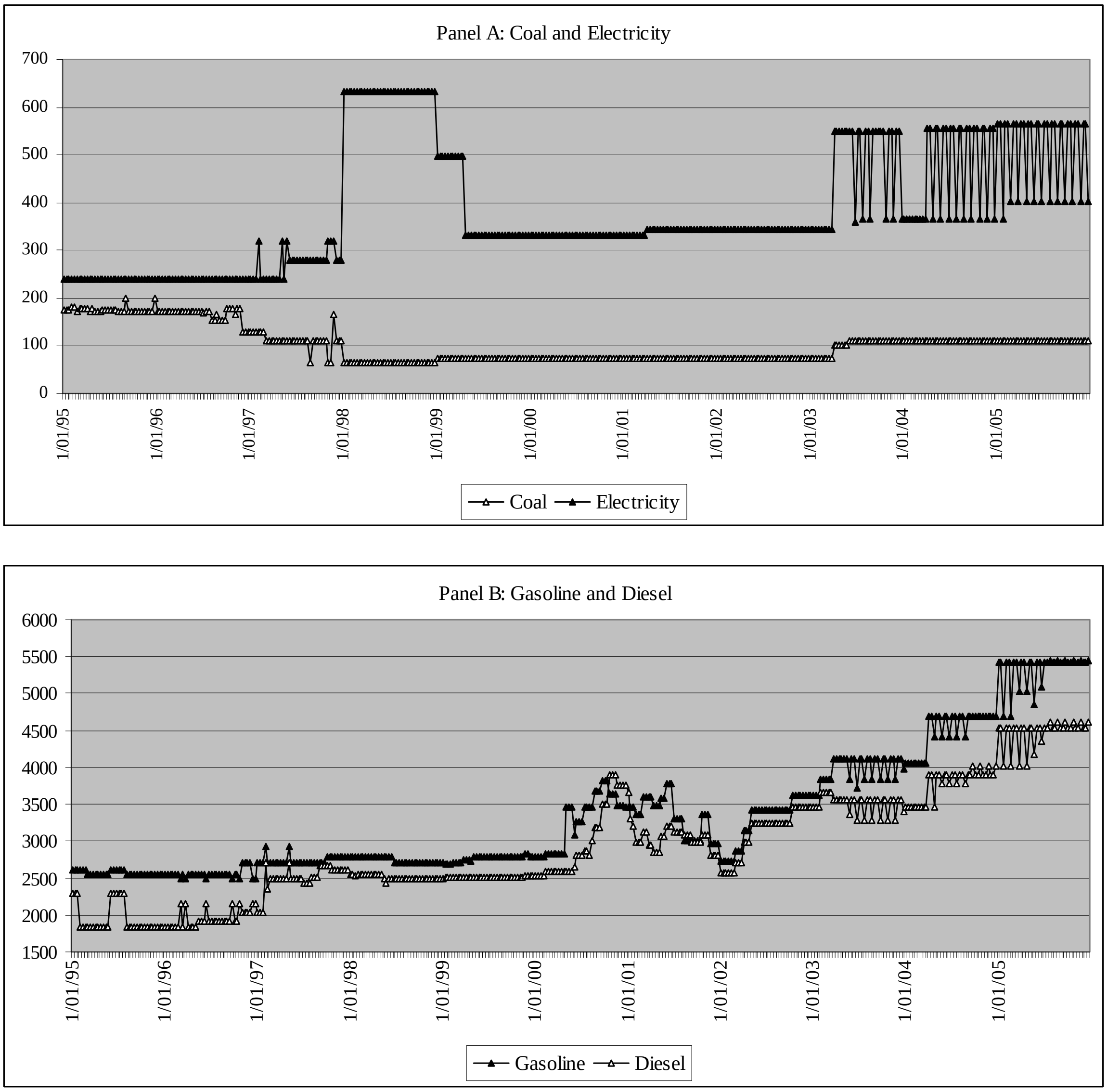
Appendix Figure 11. Price trends for pairs of coal-electricity and gasoline-diesel in Guangzhou of Guangdong province



Appendix Figure 12. Price trends for pairs of coal-electricity and gasoline-diesel in Xi'an of Shaanxi province



Appendix Figure 13. Price trends for pairs of coal-electricity and gasoline-diesel in Chengdu of Sichuan province



Appendix Figure 14. Price trends for pairs of coal-electricity and gasoline-diesel in Urumqi of Xinjiang autonomous region