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The Emergence and Evolution of Regional Convergence Clusters in China's Energy Markets

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Abstract: Employing the new regression tests for *Convergence, Club Convergence and Clustering* proposed by Phillips and Sul (2007), this paper models and analyzes the behavior of China's energy sectors. Energy market 'convergence clusters' are identified using new price data and their regional spatial distributions are mapped for four major fuel types; coal, gasoline, diesel and electricity. It is found that: i) as yet, there are no fully integrated national energy markets in China as more than one convergence cluster is identified for all four fuels; ii) some regional energy markets can be regarded as 'quite mature' as evidenced by the existence of some highly concentrated convergence clusters connected geographically; iii) some regional markets remain in a 'state of transition' as witnessed by convergence clusters that are scattered geographically and growing in membership; vi) it seems that there is more regional-based integration for coal and electricity than for gasoline and diesel as more convergent clusters were identified for coal and electricity than for gasoline and diesel v) Overall, China still appears to be in the process of energy market integration as demonstrated by the number and evolution of convergence clusters over time.

Key words: China; Energy market; Convergence cluster

JEL classifications: D24, O33, Q41

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1. Introduction

China is the world's most populous and largest developing, transition economy, and assessments of its market performance have been mixed. On the one hand, China has been praised for promoting market competition among the state-owned, collective and private sectors (Qian and Xu, 1993). As a result, many authors studying China's market economy have concluded that some of China's markets are integrated. Rozelle et al. (1997), for example, investigate market integration in China's rural sectors in the late 1990s and find evidence in favour of such a transition. Zhou et al. (2000), Park et al. (2002), Huang and Rozelle (2006), and Awokuse (2007) investigate market integration in China's agricultural commodity markets and all found that the grain markets were well integrated. Fan and Wei (2006) also conducted tests for price convergence amongst 96 commodities and concluded that prices had converged to the 'Law of One Price' in China for an overwhelming majority of goods and services. However, some recent articles argue that changing patterns of provincial economic structure suggest that China's markets have become less rather than more nationally integrated during much of the reform period. Some conclude that the effects of reforms have been to create a number of 'regional convergence clubs' rather than one single national market. For example, Weeks and Yao (2003) found that there was system-wide income divergence during the reform period (1978-1997) as witnessed by the fact that the coastal provinces do not share a common initial technology progress rate with the interior provinces. Young (2000) argues that China's economic reform has actually led to the fragmentation of domestic markets. Poncet (2005) measured China's domestic market disintegration and identified its determinants and she concluded that China is a fragmented economy. Demurger et al. (2002) states that this is not surprising given the substantial differences in regional, location-specific advantages and central government preferential policy, which have resulted in economic development disintegration in China. Maasoumi and Wang (2008) also investigate further evidence of regional economic reforms, economic growth and economic development convergence using a metric entropy-based measure. Their results show that there exist many small economic development convergence clubs in both the pre- and post-reform periods for China.

Based on the above discussions, it might be reasonable to expect that China is not yet a completely integrated market economy, and that it is still effectively in a state of transition. The final outcome may be the formation of powerful, geographically disconnected (or partially connected) regional growth zones. However, rejection of convergence for the country as a whole does not imply there is no evidence of convergence within regional subgroups. Examples include the possible existence of convergence clusters around separate points of equilibria or steady state growth paths, as well as cases where there may be both convergence clusters and divergent members in the full panel of regions or sectors. These convergence clubs may be geographically linked, ie., coastal; east-west; north-south, or natural resource based. If there are local equilibria or club convergence clusters, then it is of considerable interest as to where they are, in what sectors and whether they have/are evolving over time. The new testing procedures of Phillips and Sul (2007) enable us to identify the existence of such clusters including their number, composition, membership and evolution.

Though some studies have identified economic convergence clubs for China (e.g., Maasoumi and Wang, 2008), there have been few econometric tests of 'convergence clustering' for important, specific commodity markets. Exceptions include, Ma et al. (2009) and Ma and Oxley (2010) who investigated the convergence of major energy fuel price series using traditional unit root and panel cointegration methods. They found that energy price series are not convergent as a whole and regional energy price series display a differing convergent pattern, implying that there might be some regional energy markets in China.

The study presented here uses the new and more powerful methods of Phillips and Sul (2007) to investigate the existence of regional convergence clubs and crucially the transitional dynamics of their formation. The new econometric tests are applied to China's four major fuel price series, coal, electricity, gasoline and diesel, using a unique, high frequency dataset.

The paper is organized as follows: Section 2 introduces China's major energy reforms to provide the historical background necessary to enable sensible interpretation of the results of the tests. Although econometrically powerful, the testing approach of Phillips and Sul (2007) is atheoretical in that it requires no prior, specific inputs or assumptions on potential, regional, convergence club locations or associations. Section 3 outlines the testing approach and how it is applied to the data, which are also discussed in this section. Section 4 presents the empirical results and discussion. The final section presents some conclusions and possible policy implications.

2. China's major energy sector reforms

China's energy reforms have recently been extensively documented and discussed (see Ma et al. 2009). Here we simply describe some of the major energy reforms in China, which have apparently led to significant changes in behavior to demonstrate the effects of the gradual reform process. Within the period of analysis, there were four major energy reforms of fuel price changes (see Figure 1). These major energy reforms occurred in 1997, 1999, 2002 and 2004, respectively.

Firstly, as more coal entered the 'free' market, the controlled low price of 'in-plan' coal was difficult to sustain. Consequently, coal prices were gradually relaxed and for the first time in 1997—intense bargaining between coal companies and power plants was introduced (Hang and Tu, 2007). This led to a sharp increase in the price of coal from March 1997. Meanwhile, to simplify the control of prices, a new scheme, 'operation-period price' and 'yardstick price', was adopted for electricity pricing in 1997. The price under this scheme was 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 (Ma and He, 2008). This price reform led to a steady increase in the price of electricity post- 1997 when prices also became more volatile (Panel A of Figure 1)

Secondly, domestic petroleum prices have, since 1999, been set in accordance with the international market (Hang and Tu, 2007). 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 increasing substantially (Wu, 2003). As can be observed from Panel B of Figure 1, spot prices of gasoline and diesel increased sharply, from approximately ¥2500/ton in the mid 1999 to over ¥4000/ton in October 2000, and then continuously regressed for one year until the beginning 2002.

Thirdly**,** the system of government-guided price of coal was abandoned while electricity tariffs remained regulated from 2002 (Wang, 2007). As a result, the coal price jumped in 2000 from approximately ¥250/ton to ¥270/ton, while electricity prices maintained at or about their previous trends. As a result, bargaining between the two parties became more intense post-2002. Only 90 million metric tons of coal was contracted in that year, which was less than 37% of the total demand for coal by power generators. Faced with serious power shortages, the National Development and Reform Committee issued an order such that the price of coal to generators was to be set as the midpoint between the requirements of the two parties in 2003 (Wang, 2007). Coincidently, petroleum prices had begun to rise, from ¥3000/ton and ¥2700/ton in early 2002 to ¥5700/ton and ¥4700/ton at the end 2005 for gasoline and diesel, respectively.

Finally, the government introduced a new coal pricing policy called the 'co-movement' of prices of both coal and electricity in 2004 (Ma and He, 2008). The co-movement was not a free market adjustment, but regulated and determined periodically by the State Development and Reform Committee to avoid extreme price fluctuations. Adjustments would only be made if coal price fluctuations exceeded 5%, otherwise, the change would be accumulated to the next adjustment period. However, as can been observed, it seems that this reform might not make the prices of coal and electricity econometrically cointegrated. Panel A of Figure 1 shows that coal prices increased sharply while electricity prices remained almost constant during 2004.

Based upon the brief discussion above, and the details presented as Figure 1, China's energy reforms and energy prices apparently demonstrate a gradual, evolving, process. As a consequence, we might expect to see that, if convergence clustering were to exist, it too would involve a gradual process, which evolves over time and space. For example, it may be expected that there are more convergence clusters being established during the transition period (e.g., 01/1997-12/1998) than during the new regime (01/1999-12/2005) given other factors are held constant (e.g., energy transportation, energy supplying areas). Therefore, to test for energy price convergence cluster formation against various energy reform backgrounds, we will divide the whole study period into four sub-periods (refer to Figure 1); the control period (01/1996-12/1998); the transition period (01/1997-12/1998); the pre new regime (01/1999-12/2001); and the post new regime (01/2002-12/2005).

Finding evidence of regional convergence clusters, i.e., regions where the ‘Law of One Price’ holds for a commodity or group of commodities could occur for one of two reasons. Firstly, the free actions of markets may lead to the removal of arbitrage opportunities as in the traditional convergence story. Clusters may be ‘regional’ rather than a single ‘national’ market where all prices are the same independent of location, because of the real-world existence of significant transactions costs, which the traditional theory of the “Law” assumes are zero. An alternative explanation of regional convergence clusters is that the Central government control of prices process has either explicitly or ‘by accident’ created such price convergence, as a consequence of the control process itself.

3. Method and data

3.1 Method

Phillips and Sul (2007) develop a new and powerful approach for modeling and identifying both the existence of convergence clusters and the economic transition behavior in the presence of common growth characteristics. The approach is a nonlinear factor model with a growth component and a time varying idiosyncratic component that allows for quite general heterogeneity across individuals/regions and over time. The formulation is particularly useful in measuring transition towards a long run growth path or individual transitions over time relative to some common trend, representative, or aggregate variable. The formulation also gives rise to a simple and convenient time series regression test for convergence. This convergence test further provides the basis for a stepwise clustering algorithm that is proposed for finding convergence clusters in panel data setting and for analyzing transition behavior between clusters and over time. The tests have excellent asymptotic properties, including local discriminatory power, and are particularly easy to apply in practice.

The Phillips-Sul procedure proposes that there exists a core subgroup and then follows a four-step approach to try and identify it by: i) last observation ordering, ii) core group formation, iii) sieving individuals for club membership, and iv) a stopping rule. For a detailed explanation, see Phillips and Sul (2007).

This new approach is highly appropriate for investigation of the potential to identify whether China has energy market convergence clubs given the gradual economic reform characteristics discussed in Section 2.

3.2 Data

The dataset comprises a panel of 10-day prices for four energy products in 35 major Chinese cities.[1] The price data are collected by the China Price Monitoring Centre – a division of the State Development and Reform Commission of the People's Republic of China. The data relate to spot prices and are regularly collected on a ten-day interval (the 5th, 15th and 25th of each month) from local markets by local governmental agencies.[2]

[1] These 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, Xi'an, Lanzhou, Xining, Yinchuan, Urumqi, Qingdao, Dalian, Xiamen and Ningbo.

[2] The price data are collected to provide price information to the central and local governments for

Unlike other market price data, the fuel price data have no missing observations during the study period as fuels are extensively used in all cities. We use four major fuel products; coal, electricity, gasoline and diesel. These panel data are truly nationally representative as they cover the main fuel components, all provincial capital cities of mainland China, and the period, January 1995 to December 2005. This is to be contrasted with most other empirical studies, which use a price index of lower frequency (typically annual) data. The 10-day frequency of the data also corresponds well to the time required for domestic price arbitrage as lower frequency (monthly) price data are less likely to show any rapid arbitrage when we wish to test 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 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 for prices could hardly serve as indicators when assessing the performance of local officials and hence local officials have little incentive to falsify them.

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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.

4. Results and analyses

Following Phillips and Sul (2007), we empirically model China's energy markets and analyze the transition behavior by identifying convergence clusters and map their geographic distribution.

4.1 Identifying Convergent clusters

The convergence clusters identified are listed in Tables 1, 2, 3 and 4 for coal, electricity, gasoline and diesel over three major energy reform periods, respectively. The following points can be made identified based on our observations and analyses:

Firstly, there are apparent variations in the numbers of convergence clusters and changes in their composition and membership over the three energy reform periods across the four major fuel price series. For example, it seems that there were more convergence clusters during latest sub-period (2002-2005) for coal and electricity (five clusters each, Tables 1 and 2) than gasoline and diesel (three and two clusters, respectively, Tables 3 and 4). This suggests that gasoline and diesel markets might be more integrated than coal and electricity markets in China. In fact, this finding is consistent with the recent conclusion of Ma et al. 2009. The primary causes here are likely due to the- cost-constraining characteristics of coal transportation and electricity transmission networks.

Secondly, there were fewer convergence clusters during the first (controlled) sub-period (1995-1996) than during the other three sub-periods except for electricity. For example, there were two convergence clusters for coal market during the first sub-period (Table 1), while there was only one cluster for gasoline and diesel markets during the same sub-period (Tables 3 and 4). It should be noted that this situation is probably the result of government energy regulation rather than by the operations of a freer energy market due to liberalization. As can be seen from Figure 1 and previous sections, energy prices were generally regulated by government agencies during this period (1995-1996), potentially creating convergence in prices via central control.

Thirdly, as can be seen from Table 2, there were nine convergence clusters for electricity price series during the first (controlled) sub-period (1995-1966). This is the largest number of separate convergence clusters identified in the analysis and is more than for any other three sub-periods or any other fuel. The reason is unclear, however, it is most likely due to the many new price policies created during the early 1990s. For example, in 1991, a ‘high-in’ and ‘high-out’ policy was introduced; in 1993, a ‘new plant-new price’ policy was implemented; in the 1990s, ‘*Power Construction Fund*’ and ‘*Three Gorge Construction Fund*’ were imposed (Ma and He, 2008). As a result, electricity tariffs have risen rapidly and apparently vary regionally (Lam, 2004). These policies were stopped when a new price scheme (operation-period price and yardstick price) was adopted in 1997.

Fourthly it seems that more separate convergence clusters have appeared as energy reforms have emerged. A typical case may be seen from the results on the coal price series, for example, there were only two convergence clusters during the first (controlled) sub-period (1995-1996), three convergence clusters during the second sub-period (1997-1998), and four convergence clusters during the third sub-period

(1999-2001), while there were five convergence clusters during the latest sub-period (2002-2005), see (Table 1). The same cluster pattern can be found for the electricity price series during the last three sub-periods (Table 2). For the gasoline price series, there were also more convergence clusters during the last two sub-periods (3 each) than during the first two sub-periods (1 and 2, respectively, Table 3). Only for the diesel price series, does it seem that fewer convergence clusters can be isolated for the latest sub-period (2002-2005) than during the middle two sub-periods (4 each, Table 4).

Finally, what do the above results suggest? There are several possible explanations and implications for China and its energy market. On the one hand, one might expect to see fewer separate convergence clusters (but with more members/regions included) as the energy reforms take effect. In particular, a fully integrated 'national' market would include all regions in a 'single' cluster – the nation. However, this extreme case may not be an informed expectation given the size and geographic heterogeneity of the country where there are substantial variations in economic growth, energy reserves and geographical location across regions. Therefore, some convergence clusters are likely expected, but gradually reducing in number, but increasing in membership, over time. If this pattern of gradual reduction in the number of clusters is not identified over time, one might reasonably conclude that China's energy markets are not fully integrated. Geography, distance or effective central government regional price policy variations may dominate the predicted effects of the 'Law of One price'. However, the evidence found here is that there are more convergence clusters identified during the latest sub-period than earlier suggesting that China's energy markets have become somewhat freer of the effects of regulation. This may be particularly true for the coal and electricity markets. For example, during the 1995-1996 period there were more coal mines, both small private and large state-owned, but they were regulated by the government. As a result there might have been less variation in the wholesale price of coal and therefore fewer convergence clusters. However, during the 'new regime' period, as more coal reserves are found and explored and more market deregulation and decentralization, there might emerge more regional-based coal markets, and therefore there might be an increase in the number of coal price convergence clusters identified during this period. Likewise, as more coal-burning power plants and more electricity transmission networks are constructed, there might appear to be more regional-based electricity markets, and therefore more electricity convergence clusters will be identified and measured.

4.2 The dynamics of convergent clusters

As well as identifying the number and coverage of convergence clusters for each of fuel price series over the various sub-periods, we can also observe the dynamics of moving 'in and out' of a particular convergence cluster by each city and over three sub-periods. The following interesting observations can be made:

Firstly, though, in general, there were two convergence clusters during both 1996-1997 and 1997-1998 periods, actually, one of convergent clusters has already covered most of cities for coal (Table 1). For example, about 77% of cities are included in Cluster One during 1995-1996 and about 74% of cities are included in Cluster Two during 1997-1998. This may indicate that convergent clusters almost remain identical between both sub-periods. However, some cities still form a separate small Cluster One: Beijing, Chongqing, Dalian, Chengdu and Xining are staying while Taiyuan and Guiyang are leaving Cluster Two. Only two cities (Yinchuan and Xi'an), off Cluster Two, form Cluster Three.

A similar cluster dynamic can be seen for movements from the second sub-period to the third sub-period. For example, most of the cities stay in Cluster One, while most of cities still remain in Cluster Two. Only a few cities from Cluster Two moved to Cluster One (Hohhot, Changchun, Wuhan, Shijiazhuang, Guangzhou and Haikou) and to Cluster Three (Lanzhou and Urumqi). It will be clearer if we sort Table 1 using column 5.

It seems, however, that convergence clusters demonstrate more of a dynamic during the last two sub-periods. Those that used to belong to Cluster One in the third sub-period form into three different clusters: nearly half of (rows 1-5: Beijing, Taiyuan, Chongqing, Dalian and Hohhot) still stay in Cluster One; three (rows 7-9: Guiyang, Changchun and Wuhan) go to Cluster Two, and three (rows 18-20: Xining, Shijiazhuang and Guangzhou) move to Cluster Three. Similarly, those that used to belong to Cluster Two in the third sub-period are also broken into three convergent clusters: of which 37% (rows 10-16) still stay, 37% (rows 21-27) go to Cluster Three, and 26% (rows 29-33) go to Cluster Four.

Secondly, there appears more dynamic movement for electricity convergence clusters with the majority of cities shifting among the clusters, and as a result, there are rarely cities that stay in successive sub-period clusters. As can be seen from Table 2, for example, only Jinan and Nanchuang successively remain in three same clusters (One and Two, respectively). There are only three cities (Hefei, Shanghai and Changchun) that stay in the same successive luster (One, Two and Three, respectively). Therefore, it seems there are no strict patterns or rules as to how city markets form convergent clusters and how these convergent clusters decompose into new clusters

However, it does seem that there are clearer dynamic convergence patterns that emerge for the second and the third sub-periods if we sort the cities of Table 2 by column 6 first and then columns 5, and 4. For example, some of the cities that used to belong to Cluster One and Three converge to form Cluster One; part of cities that used to belong to Cluster One and Two converge to form Cluster Two; some of the cities that used to belong to Cluster One converge to form Cluster Three; and some of the cities that used to belong to Cluster One, Two and Three converge to form Cluster Three.

Thirdly, the dynamics of gasoline convergent clusters seems to be relatively simple (Table 3). All cities stay in the same convergent cluster under the control sub-period (1995-1996), then with gradual price decentralization, some cities move out and form a new small Cluster Two. By the third stage, most cities are included in Cluster Two and only a few cities comprise Cluster One and Cluster Three. While more cities that used to belong to Cluster Two move to Cluster One and Cluster Three by the last period the majority of cities comprise Cluster Two.

Finally, by the second stage (1997-1998), approximately 40% and 30% of cities form two larger clusters (Cluster One and Cluster Three), respectively, while only a few cities form two smaller clusters (Cluster Two and Cluster Four). By the third stage (1999-2001), most of Cluster Two and a large part of Cluster Three, (plus a few cities from each of Cluster Two and Cluster Four), form a large Cluster Two. A few cities from each of the previous clusters form Cluster Three. By the last period, the memberships of cities that converge to a new Cluster are mixed. The majority of Cluster Two and half of Cluster Three combine into Cluster One, while some of the cities from each of Cluster Two and Cluster Three form Cluster Two.

4.3 The geography of convergent clusters

In the next stage, we consider the geographical distribution of convergence clusters to consider whether the atheortic test results make geographic sense. Theoretically, it might be expected that the patterns of convergence clusters should become gradually more concentrated and connected geographically as the energy reforms take effect. This is a testable hypothesis which we can investigate using the clustering analysis of Phillips and Sul. Figures 2 through to 5 present the geographical characteristics and evolution of convergence clusters over the four sub-periods for coal, electricity, gasoline and diesel, respectively. The Figures are created using the same tests results as those presented as Tables 1-4 and as discussed in the previous section. The following points can be observed from these Figures:

Firstly, there is some evidence showing that new convergence clusters have appeared following the reforms process and were concentrated geographically. For example, Cluster One for coal was scattered across vast areas of China during the third sub-period (1999-2001), covering twelve city markets (Panel C of Figure 2). However, during the latest sub-period (2002-2005) this cluster evolved into Cluster One (in the north, except for Chongqing and Beijing) and Cluster Two (in the south, except for Changchun and Fuzhou), which connected primarily on geographic lines (Panel D of Figure 2).

Secondly, there is apparent evidence showing a trend in convergence clusters becoming more and more concentrated and geographically connected. This seems to follow for all fuels, and is especially evident during the ‘new regime’, for example, Cluster Three for coal was geographically separate during the third sub-period (Panel C of Figure 2), while this cluster was geographically connected during the latest sub-period (Panel D of Figure 2). In addition, electricity Cluster Four was extremely scattered during the third sub-period (Panel C, Figure 3), while it finally evolved during the last sub-period into Cluster Two, which was mainly concentrated around Nanning, Chongqing, Chengdu, Guiyang, Kunming, Lanzhou, Yinchuan and Nanchang and Zhengzhou (Panel D, Figure 3, Table 2).

Thirdly, there is apparent evidence showing that the convergence clusters evolved ‘rationally’, for example, Cluster Two for diesel appeared to be scattered across the country from the far west (Urumqi) to far east (Hangzhou) and from far south (Haikou) to far northeast (Harbin) during the third sub-period (Panel C of Figure 5, Table 4). This may be more evidence of central attempts to control prices than a rational market outcome. However, this cluster evolved to represent groups identified as west to east and concentrated from far east to the center during the latest sub-period (Panel D of Figure 5).

Finally, the same can be observed for Cluster Two during the third sub-period (Panel C of Figure 4) and Cluster Two during the last sub-period (Panel D of Figure 4). This cluster was scattered across almost all the country during the third sub-period (Panel C of Figure 4), while it evolved to remove many of the remote areas, such as Lhasa, Hohhot and Harbin, in the last sub-period (Panel D of Figure 4). The changing composition and configuration of clusters that have evolved over time appears to make sense in that they are what one might expect to see given the geography and population and commerce concentrations that have emerged in China. That there is not one single (national) cluster is evidence of the lack of full market integration, but evidence of a growing number of ‘sensibly located’ regional clusters, could be construed that market integration is ‘in process’.

5. Concluding remarkets

This paper employs the new testing approach of Phillips and Sul (2007) to model and analyze China’s energy sector price transition behavior in the presence of common movement characteristics. Price convergence clusters are identified and presented and analyzed. The spatial distributions of convergence clusters are mapped and discussed over four sub-periods for each of four fuels.

The paper found some evidence showing that a number of regional convergence clusters have appeared for the major energy markets in China as the reforms have been gradually. Some conclusions that can be drawn are:

Firstly, there is no single nationally integrated energy market in China as there exist more than one convergence cluster for all four fuels, especially during the latest sub-period. Secondly, some regional energy markets have become more mature as some convergence clusters have become more highly concentrated and geographically connected. Thirdly, some regional markets still seem to be evolving and developing as the convergence clusters identified remain geographically scattered. Fourthly, it is consistent with the characteristics of the various types of energies tested, that more regional integrated markets exist for coal and electricity than for gasoline and diesel. Fifthly, the dynamics of convergent clusters is different across energy types. As a consequence, convergence clusters for the electricity market are the most dynamic, while those for the gasoline market are the least dynamic. Finally, China is still in the process of energy market integration as evidenced by the continuing evolution of the number, composition and coverage of the various clusters.

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Table 1. Regional **coal** market convergence and clustering analysis results

Cities	Code	Row	1995-1996	1997-1998	1999-2001	2002-2005
Beijing	1	1	1	1	1	1
Taiyuan	4	2	2	1	1	1
Chongqing	22	3	1	1	1	1
Dalian	33	4	1	1	1	1
Hohhot	5	5	1	2	1	1
Yinchuan	30	6	2	3	4	1
Guiyang	24	7	2	1	1	2
Changchun	7	8	1	2	1	2
Wuhan	17	9	1	2	1	2
Chengdu	23	10	1	1	2	2
Shanghai	9	11	1	2	2	2
Hefei	12	12	1	2	2	2
Fuzhou	13	13	1	2	2	2
Jinan	15	14	2	2	2	2
Zhengzhou	16	15	1	2	2	2
Changsha	18	16	2	2	2	2
Kunming	25	17	1	2	4	2
Xining	29	18	1	1	1	3
Shijiazhuang	3	19	1	2	1	3
Guangzhou	19	20	1	2	1	3
Tianjin	2	21	1	2	2	3
Hangzhou	11	22	1	2	2	3
Nanchang	14	23	1	2	2	3
Lhasa	26	24	1	2	2	3
Qingdao	32	25	1	2	2	3
Xiamen	34	26	1	2	2	3
Ningbo	35	27	1	2	2	3
Haikou	21	28	1	2	1	4
Shenyang	6	29	1	2	2	4
Harbin	8	30	1	2	2	4
Nanjing	10	31	1	2	2	4
Nanning	20	32	1	2	2	4
Xi'an	27	33	2	3	2	4
Lanzhou	28	34	2	2	3	5
Urumqi	31	35	2	2	3	5
# of Cluster	-	-	2	3	4	5

Note: The column two (code) is sorted first by column 7 and then columns 6, 5, and 4.

Table 2. Regional **electricity** market convergence and clustering analysis results

Cities	Code	Row	1995-1996	1997-1998	1999-2001	2002-2005
Jinan	15	1	7	1	1	1
Hefei	12	2	4	3	1	1
Taiyuan	4	3	7	2	2	1
Urumqi	31	4	3	1	3	1
Xining	29	5	2	3	5	1
Shenyang	6	6	6	3	5	1
Harbin	8	7	5	1	1	2
Nanning	20	8	8	3	1	2
Shanghai	9	9	6	1	2	2
Nanchang	14	10	6	2	2	2
Chengdu	23	11	7	1	3	2
Beijing	1	12	5	2	3	2
Ningbo	35	13	6	1	4	2
Lanzhou	28	14	5	1	4	2
Chongqing	22	15	6	2	4	2
Kunming	25	16	3	2	4	2
Guiyang	24	17	9	3	4	2
Zhengzhou	16	18	4	3	4	2
Yinchuan	30	19	9	3	5	2
Nanjing	10	20	1	1	1	3
Dalian	33	21	2	2	1	3
Changsha	18	22	8	1	2	3
Xiamen	34	23	7	1	2	3
Haikou	21	24	7	1	2	3
Lhasa	26	25	6	2	2	3
Changchun	7	26	4	1	3	3
Shijiazhuang	3	27	3	1	4	3
Tianjin	2	28	6	2	4	3
Qingdao	32	29	6	2	4	3
Xi'an	27	30	9	3	5	3
Hohhot	5	31	2	1	1	4
Wuhan	17	32	4	2	2	4
Guangzhou	19	33	5	1	3	5
Hangzhou	11	34	1	2	4	5
Fuzhou	13	35	4	2	5	5
# of Cluster	-	-	9	3	5	5

Note: The column two (code) is sorted first by column 7 and then columns 6, 5, and 4.

Table 3. Regional **gasoline** market convergence and clustering analysis results

Cities	Code	Row	1995-1996	1997-1998	1999-2001	2002-2005
Wuhan	17	1	1	1	1	1
Lhasa	26	2	1	1	1	1
Beijing	1	3	1	1	2	1
Hohhot	5	4	1	1	2	1
Chengdu	23	5	1	1	2	1
Guangzhou	19	6	1	2	2	1
Chongqing	22	7	1	1	2	2
Dalian	33	8	1	1	2	2
Yinchuan	30	9	1	1	2	2
Guiyang	24	10	1	1	2	2
Shanghai	9	11	1	1	2	2
Fuzhou	13	12	1	1	2	2
Zhengzhou	16	13	1	1	2	2
Changsha	18	14	1	1	2	2
Kunming	25	15	1	1	2	2
Shijiazhuang	3	16	1	1	2	2
Tianjin	2	17	1	1	2	2
Nanchang	14	18	1	1	2	2
Xiamen	34	19	1	1	2	2
Haikou	21	20	1	1	2	2
Shenyang	6	21	1	1	2	2
Xi'an	27	22	1	1	2	2
Lanzhou	28	23	1	1	2	2
Urumqi	31	24	1	1	2	2
Jinan	15	25	1	2	2	2
Hangzhou	11	26	1	2	2	2
Ningbo	35	27	1	2	2	2
Nanning	20	28	1	2	2	2
Hefei	12	29	1	1	3	2
Taiyuan	4	30	1	2	3	2
Changchun	7	31	1	1	2	3
Xining	29	32	1	1	2	3
Qingdao	32	33	1	1	2	3
Harbin	8	34	1	1	2	3
Nanjing	10	35	1	2	3	3
# of Cluster	-	-	1	2	3	3

Note: The column two (code) is sorted first by column 7 and then columns 6, 5, and 4.

Table 4. Regional **diesel** market convergence and clustering analysis results

Cities	Code	Row	1995-1996	1997-1998	1999-2001	2002-2005
Yinchuan	30	1	1	1	1	1
Lhasa	26	2	1	1	1	1
Shanghai	9	3	1	1	2	1
Changsha	18	4	1	1	2	1
Tianjin	2	5	1	1	2	1
Hangzhou	11	6	1	1	2	1
Ningbo	35	7	1	1	2	1
Haikou	21	8	1	1	2	1
Shenyang	6	9	1	1	2	1
Guiyang	24	10	1	2	2	1
Kunming	25	11	1	2	2	1
Beijing	1	12	1	3	2	1
Xining	29	13	1	3	2	1
Shijiazhuang	3	14	1	3	2	1
Urumqi	31	15	1	3	2	1
Jinan	15	16	1	4	2	1
Taiyuan	4	17	1	1	3	1
Guangzhou	19	18	1	1	3	1
Hohhot	5	19	1	2	3	1
Zhengzhou	16	20	1	2	3	1
Fuzhou	13	21	1	3	3	1
Nanchang	14	22	1	4	3	1
Hefei	12	23	1	2	4	1
Changchun	7	24	1	1	2	2
Harbin	8	25	1	1	2	2
Nanning	20	26	1	1	2	2
Chengdu	23	27	1	3	2	2
Xi'an	27	28	1	3	2	2
Lanzhou	28	29	1	3	2	2
Dalian	33	30	1	4	2	2
Wuhan	17	31	1	2	3	2
Qingdao	32	32	1	3	3	2
Xiamen	34	33	1	3	3	2
Nanjing	10	34	1	4	3	2
Chongqing	22	35	1	3	4	2
# of Cluster		-	1	4	4	2

Note: The column two (code) is sorted first by column 7 and then columns 6, 5, and 4.

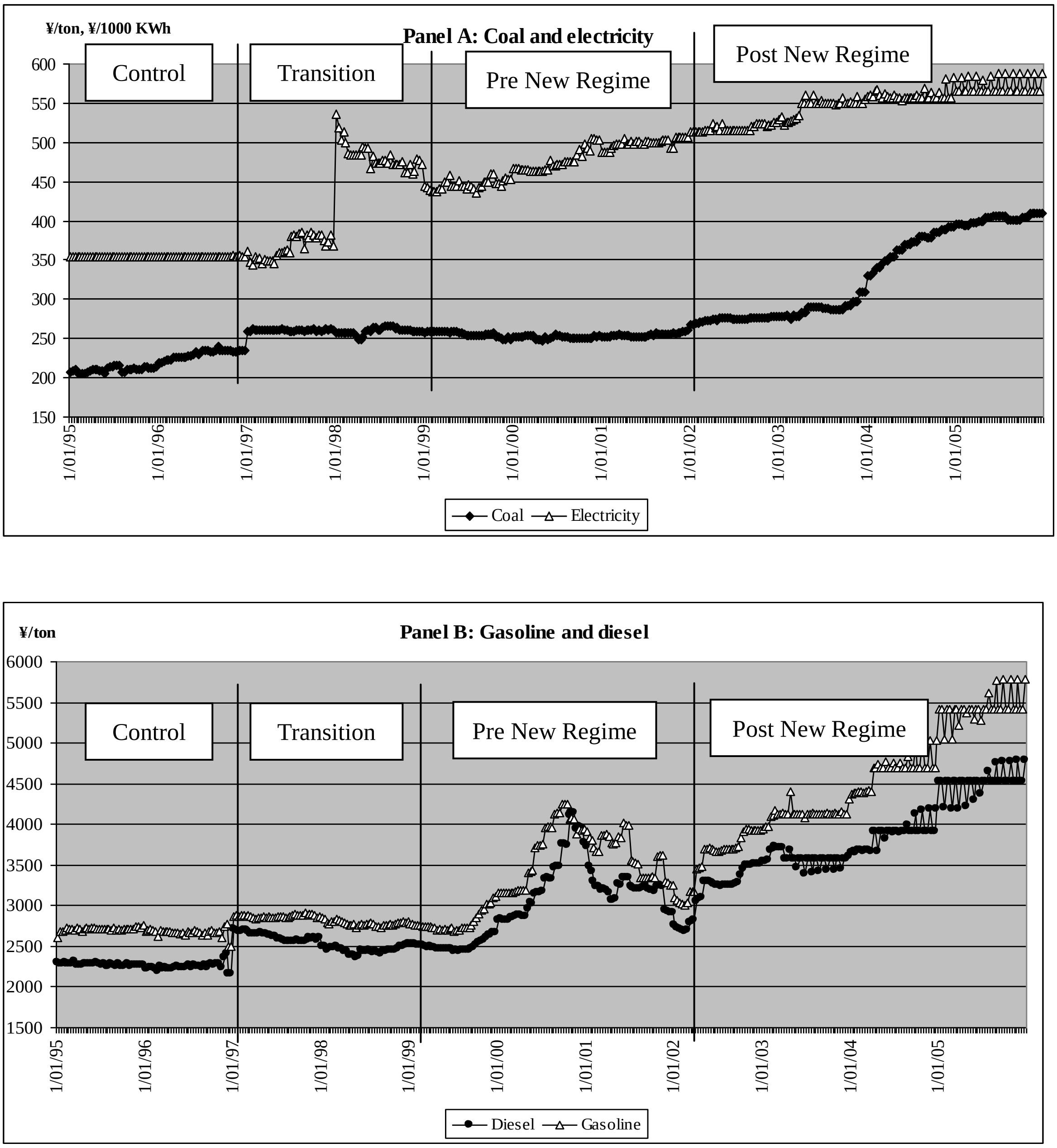
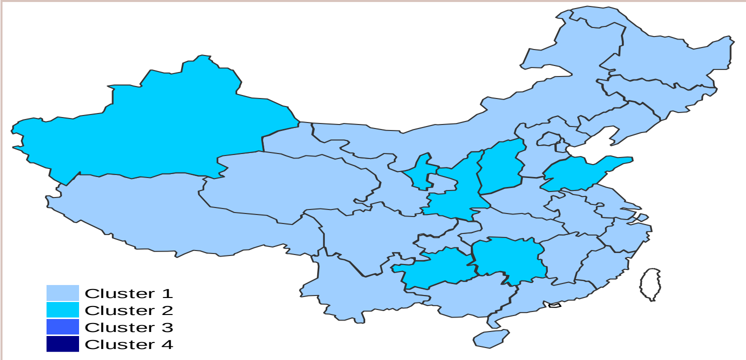
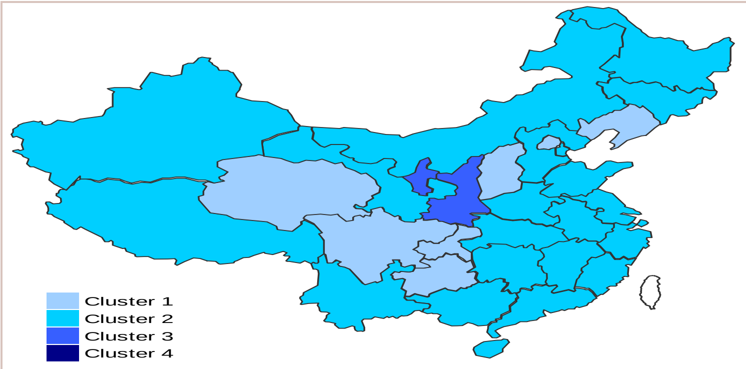


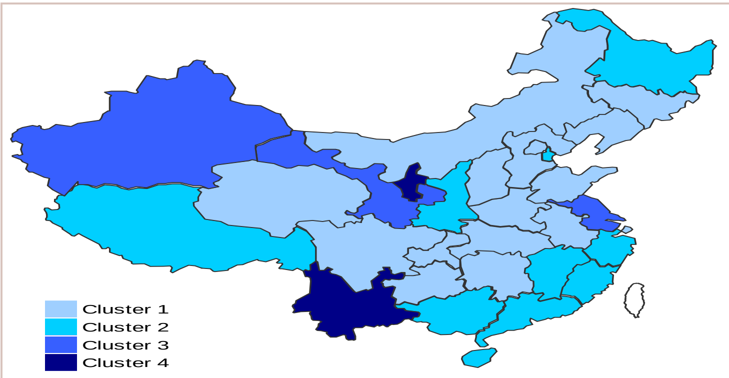
Figure 1. Energy reforms and price changes for pairs of coal-electricity and gasoline-diesel at the national level



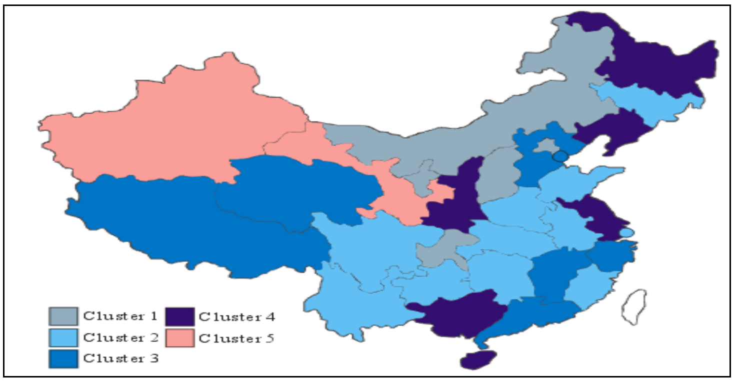
Panel A: 1995-1996



Panel B: 1997-1998

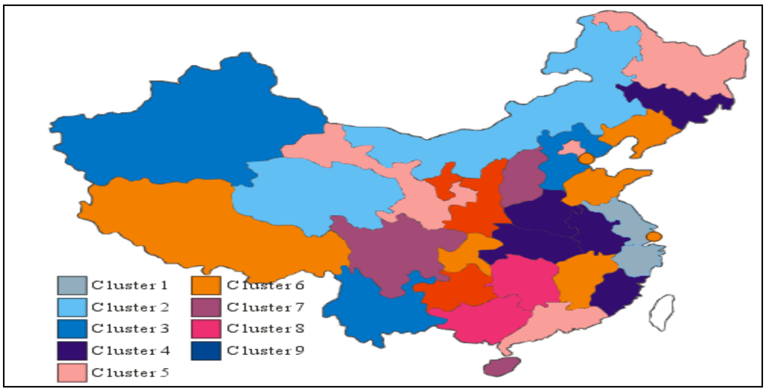


Panel C: 1999-2001

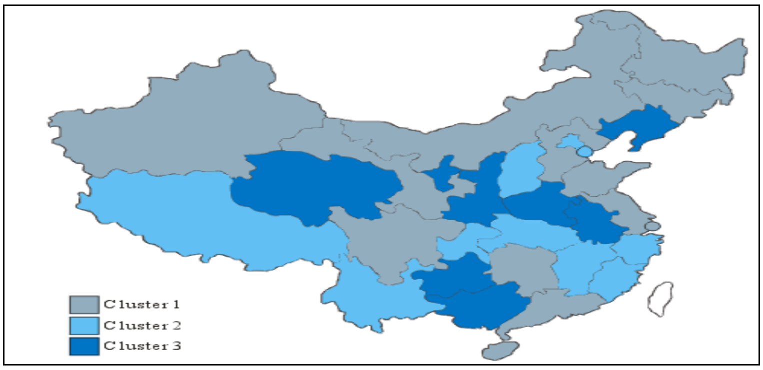


Panel D: 2002-2005

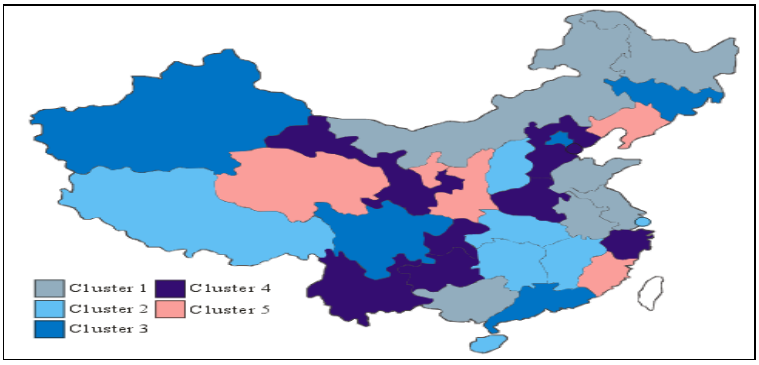
Figure 2: The evolution of coal price convergence clusters over four sub-periods



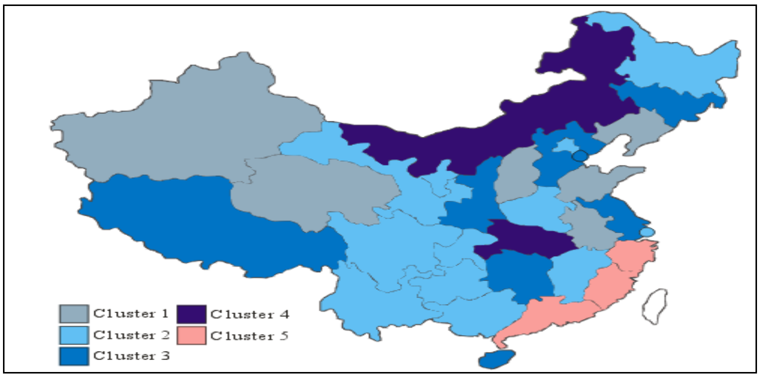
Panel A: 1995-1996



Panel B: 1997-1998



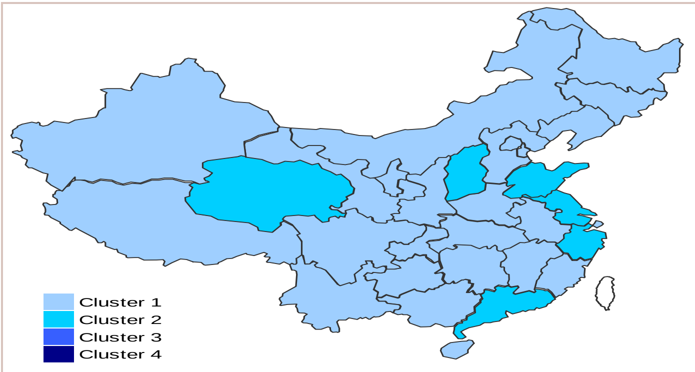
Panel C: 1999-2001



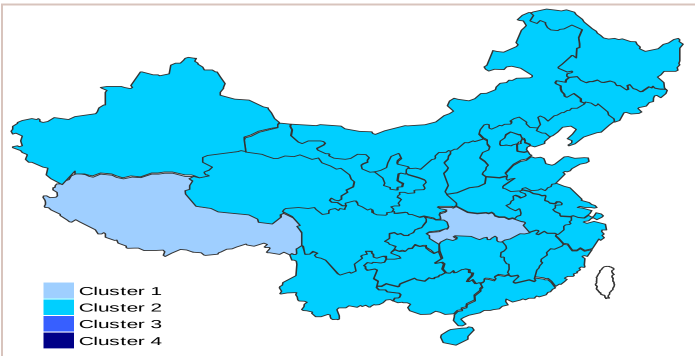
Panel D: 2002-2005

Figure 3: The evolution of electricity price convergence clusters over four sub-periods

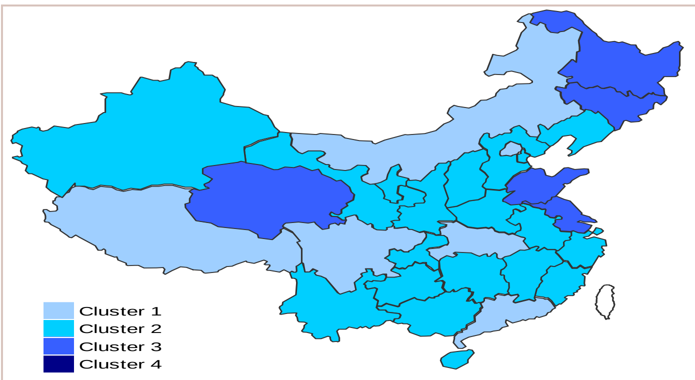
Panel A: 1995-1996



Panel B: 1997-1998



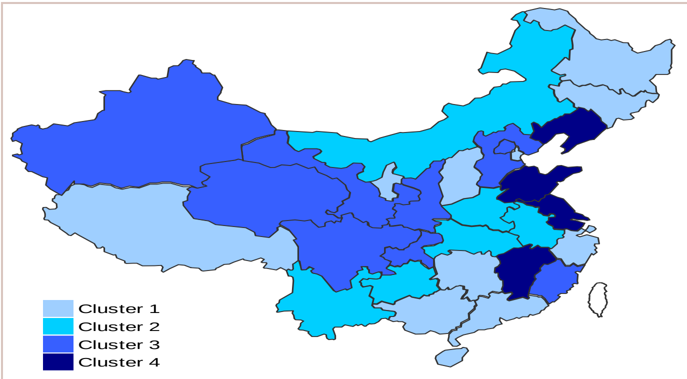
Panel C: 1999-2001



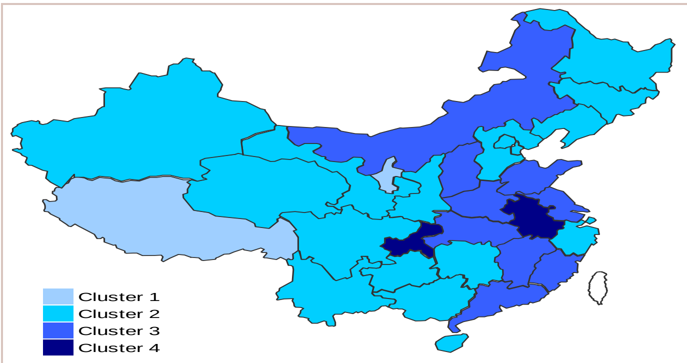
Panel D: 2002-2005

Figure 4: The evolution of gasoline price convergence clusters over four sub-periods

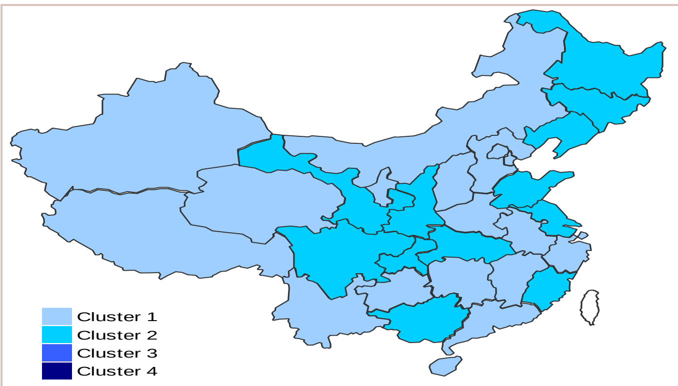
Panel A: 1995-1996



Panel B: 1997-1998



Panel C: 1999-2001



Panel D: 2002-2005

Figure 5**:** The evolution of diesel price convergence clusters over four sub-periods