

China's Energy Economy: Substitution possibilities, market integration and some possible environmental implications

Thursday, 13 August 2009, 12:30pm to 2:00pm
Spectrum Presentation Theatre, BP House, 20 Customhouse Quay, Wellington

Professor Les Oxley, University of Canterbury

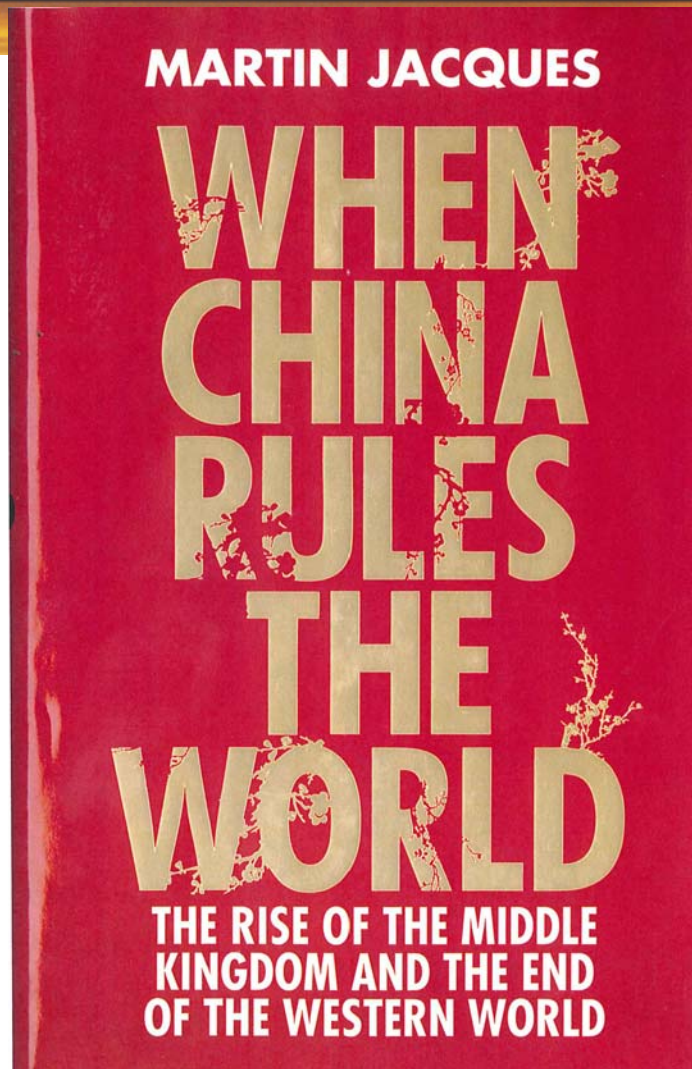
China's Energy Economy

- Joint work with ***Hengyun Ma*** and ***John Gibson***
 - "China's Energy Economy: Technical change, factor demand and interfactor/interfuel substitution," *Energy Economics*, 30, 2167-2183, 2008
 - "Substitution Possibilities and Determinants of Energy Intensity for China," *Energy Policy*, 2009, 37, 5, 1793-1804
 - **"China's Energy Situation in the New Millennium
Renewable and Sustainable Energy Reviews, 2009"**
 - "Gradual Reforms and the Emergence of Energy Markets in China: Evidence from Tests for Convergence of Energy Prices," *Energy Policy*, 2010 (to appear)
 - "A Survey of China's Renewable Energy Economy" *Renewable and Sustainable Energy Reviews (to appear)*
 - "Integration of major fuel source prices in China: Evidence from the time series tests," (typescript)

Motivations #1

- My interests are broad, but main interest relates to determinants of economic growth
 - Why do countries grow at different rates?
- Historical similarities
 - Role of coal in British Industrial Revolution (BIR)
 - Coal big issue in China
 - Urbanisation with industrialisation (BIR)
 - Effects on energy usage – good (urbanisation) and bad (urbanisation)
- Current issues
 - Economic growth v environmental impacts?
 - Importing carbon footprints via trade

Or simply...motivation....#2



China: Some known, knowns

- **Aggregate GDP \$3.31 trillion in 2007**
- **10% pa economic growth rate over two decades**
- **Aggregate primary energy (pe) consumption**
 - **1997=961.4 mill tonnes oil equivalent (mtoe)**
 - **2007=1863.4 mtoe**
 - **OECD average growth of pe = 8.1%**
 - **World average growth of pe = 24.6%**
 - **China average growth of pe = 100%**
- **China second largest energy consumer (after US) in 2008**
- **China has around 100 years of coal reserves**
- **China has a growing urban population -> growing transport congestion**

China: Some less well known knowns

- China's energy efficiency is low
- China's energy intensity is high (though fluctuates)
 - 0.91 toe/\$1000 in 2000 prices in China
 - 0.32 0.91 toe/\$1000 in 2000 prices World
 - 0.19 0.91 toe/\$1000 in 2000 prices OECD
 - China's intensity has fallen, but rising again due to high energy intensity capital usage
- China is probably highest emitter of CO₂

China: Some not so well known knowns

- **60% of Chinese population rural**
 - Biomass is their main fuel source (straw, corn husks dung, fowl waste, wood, biogas) – mostly just burnt -> CO₂
 - 193.8 mt wood; 363.5 mt stalks; 6964.1 mcm biogas; total of 272.8 mt coal equivalent (2004-2008). 75.8% total rural energy consumption, biomass
 - Crop stalks account for 60% of aggregate rural energy consumption
 - China 3rd largest producer of bioethanol, 1.3 mt in 2006
 - Maize (3.4% total prod) and wheat (4.4% of total prod) used for bioethanol
 - Biofuels led to serious grain price increases has made China a net grain importer for first time

China: Some not so well known knowns

- **Renewable energy use (includes biomass)**
 - **2006:** 8% primary energy supply renewable
 - **Hydro:** 1906 kWh in 1995; 4829 kWh in 2007
 - Annual growth of supply 8% pa
 - Contribution to electricity production: 14.7%
 - Actual: Potential = 50% exploited
 - **Nuclear:** 12.8 bill kWh in 1995; 62.9 bill kWh in 2007
 - Annual growth of supply 15% pa
 - Contribution to electricity production: 2%
 - **Total exploitable renewable:**
 - ***Known:*** 7.2 billion tonnes coal equivalent
 - ***Currently: exploited*** 0.1 billion tonnes coal equivalent
 - ***Total (actual) coal stocks: 115 billion tonnes***

China: Some not so well known knowns

Table 8

China's energy production and consumption (million tonne standard coal).

Year	Aggregate Production	Of which (%)			
		Coal	Oil	Natural gas	Others
1985	855.5	72.8	20.9	2.0	4.3
1990	1039.2	74.2	19.0	2.0	4.8
1995	1290.3	75.3	16.6	1.9	6.2
2000	1289.8	72.0	18.1	2.8	7.2
2005	2058.8	76.5	12.6	3.2	7.7
2006	2210.6	76.7	11.9	3.5	7.9
Growth rate annually (%)					
1985–1990	4.0	0.4	–1.9	0.0	2.2
1990–1995	4.4	0.3	–2.7	–1.0	5.3
1995–2000	0.0	–0.9	1.7	8.1	3.0
2000–2005	9.8	1.2	–7.0	2.7	1.4
2005–2006	7.4	0.3	–5.6	9.4	2.6
Year	Consumption	Coal	Oil	Natural gas	Others
1985	766.8	75.8	17.1	2.2	4.9
1990	987.0	76.2	16.6	2.1	5.1
1995	1311.8	74.6	17.5	1.8	6.1
2000	1385.5	67.8	23.2	2.4	6.7
2005	2246.8	69.1	21.0	2.8	7.1
2006	2462.7	69.4	20.4	3.0	7.2
Growth rate annually (%)					
1985–1990	5.2	0.1	–0.6	–0.9	0.8
1990–1995	5.9	–0.4	1.1	–3.0	3.6
1995–2000	1.1	–1.9	5.8	5.9	1.9
2000–2005	10.2	0.4	–2.0	3.1	1.2
2005–2006	9.6	0.4	–2.9	7.1	1.4

Data source: China Statistical Yearbook (1996–2007) [17].

China: Some not so well known knowns

- **Energy transportation is massive and causes significant domestic trade within China**
 - **Inter provincial coal shipments of 2394 mmt**
 - **Or: 1820 bill metric tonnes km**
 - **Or: 75% total rail cargo in 2006**
 - **Or: Average distance of rail transport 760 km**
 - **Coal shipped from East -> West and North -> South**
 - **Inflows 40% (993 mmt) and outflows 60% (1400 mmt)**

China: Some not so well known knowns

Table 2

The volume of interprovincial coal shipment in 2006, million metric tonnes.

Province	Outflow shipment	Inflow shipment	Total shipment	% of total consumption
Beijing	3.9	26.9	30.8	90
Tianjin	0.0	37.8	37.8	87
Hebei	28.9	173.3	202.2	75
Shanxi	431.6	39.5	471.1	153
Inner Mongolia	145.4	17.9	163.3	95
Liaoning	5.4	77.8	83.2	51
Jilin	4.7	51.8	56.4	71
Heilongjiang	35.1	11.5	46.6	50
Shanghai	1.8	53.3	55.0	95
Jiangsu	7.1	158.1	165.2	81
Zhejiang	0.0	112.1	112.1	96
Anhui	30.8	35.5	66.2	70
Fujian	2.1	31.4	33.5	59
Jiangxi	3.0	20.9	23.9	47
Shandong	28.1	187.9	216.0	70
Henan	83.3	49.9	133.2	60
Hubei	0.0	82.9	82.9	80
Hunan	8.3	34.8	43.1	42
Guangdong	0.0	98.1	98.1	85
Guangxi	10.6	36.7	47.3	102
Hainan	0.0	2.4	2.4	68
Chongqing	5.5	3.1	8.6	21
Sichuan	19.2	20.3	39.5	41
Guizhou	29.2	0.0	29.2	28
Yunnan	6.1	8.3	14.4	16
Tibet	-	-	-	-
Shaanxi	80.0	0.0	80.0	104
Gansu	9.1	10.4	19.5	44
Qinghai	0.0	3.8	3.8	38
Ningxia	11.1	14.2	25.3	70
Xinjiang	2.5	0.4	2.9	6

Note: Physical unit. Average distance of rail shipment was 760 km in the last decade.

Data source: China Energy Statistical Yearbook (2007) [13].

The Good.....

- Regulatory systems have changed
- Prices more market orientated with a gradual reforms process
- Some expansion of renewable fuels
- Realization of (politics of) environmental issues
- Some decline (but now increase) in energy intensity

... the not so good

- Continued reliance (for foreseeable future) in use of coal (currently 75% of primary energy) especially to produce electricity
- Importer of oil-based products growing with urbanization and transport needs
- Rural bio-mass and effects on grain prices and imports and environment
- SR inter-fuel substitution possibilities, low

...and the downright ugly

- Coal
 - without technological change
- Biomass
 - without technological change
- Emissions
 - without technological change

The Good.. Some more details

- Institutional changes to remove Government ownership and more direct links to sectors

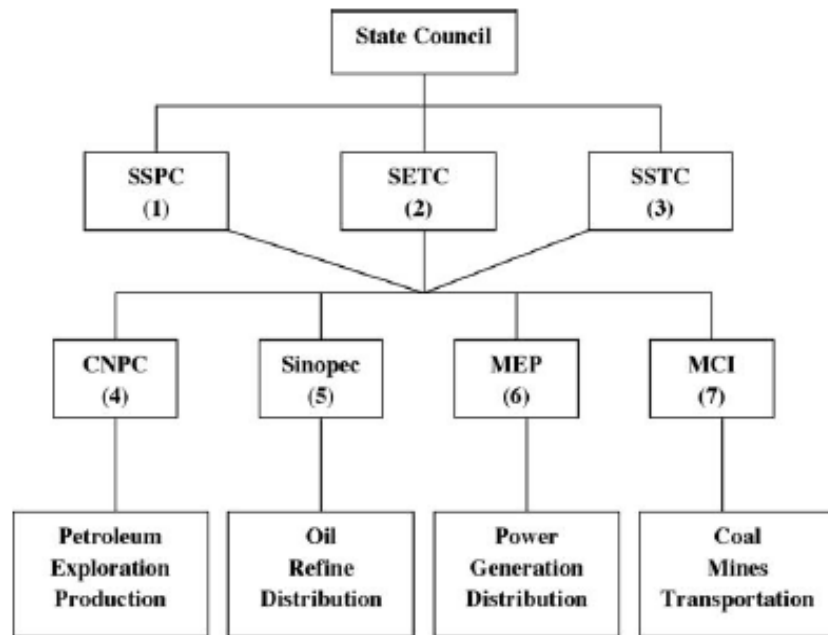


Fig. 4. Old government structure and regulatory system for energy sector setup in 1993. Note: (1) SSPC—State Planning Commission; (2) SETC—State Economic Trade Commission; (3) SSTC—State Science Technology Commission; (4) CNPC—China National Petroleum Corporation; (5) Sinopec—China Petroleum and Chemical Corporation; (6) MEP—Ministry of Electric Power; (7) MCI—Ministry of Coal Industry.

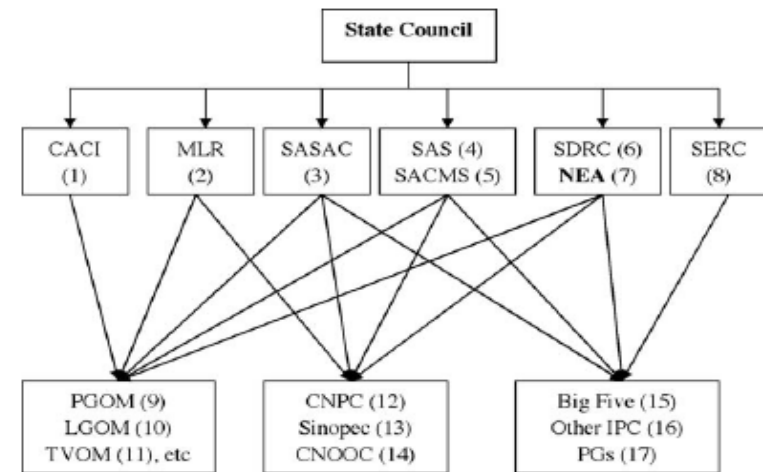


Fig. 5. New government structure and regulatory system for energy sector in 2008. Note: (1) CACI—China Association of Coal Industry. (2) MLR—Ministry of Land and Resources. (3) SASAC—State-owned Assets Supervision and Administration Commission of State Council. (4) SAS—State Administration of Work Safety. (5) SACMS—State Administration of Coal Mine Safety. (6) SDRC—State Development and Reform Commission. (7) NEA—National Energy Administration in SDRC set up at August 8, 2008. (8) SERC—State Electricity Regulatory Commission. (9) PGOM—Provincial government owned mines. (10) LGOM—local government owned mines. (11) TVOM—Township and village owned mine enterprises. (12) CNPC—China National Petroleum Corporation. (13) Sinopec—China Petroleum and Chemical Corporation. (14) CNOOC—China National Offshore Oil Corporation. (15) Big Five—Huaneng Group, Datang Group, Huadian Corporation, Guodian Co. and Power Investment Co. (16) IPP—Independent Power Plant. (17) PGs—Power Grids.

The Good.. Some more details

- Institutional changes to remove Government ownership and more direct links to sectors
- Energy pricing that more directly relates to world prices and incentives

National Aggregate Energy Prices 1995-2006

Table 4
National aggregate energy price 1995–2005.

Year	Coal (¥/tonne)	Electricity (¥/kWh)	Gasoline (¥/tonne)	Diesel (¥/tonne)
1995	214	38	2772	2293
1996	231	38	2773	2306
1997	264	40	2876	2612
1998	260	45	3240	2451
1999	247	46	2870	2530
2000	241	48	3640	3305
2001	240	50	3685	3229
2002	261	51	3571	3177
2003	283	54	4154	3516
2004	366	56	4730	3913
2005	414	58	5455	4501
1995–2005				
%Change	93	54	97	96
%Growth rate	6.8	4.4	7.0	7.0

Data source: calculated by taking the average of 10-day interval spot price time series published by State Development and Reform Committee of China.

Fuel Price Changes (%)

Table 2
 Fuel prices and change (%) from 1995 by provincial capital cities.

Market	Coal (¥/ton)		Electricity (¥/KWh)		Gasoline (¥/ton)		Diesel (¥/ton)	
	2005	Δ%	2005	Δ%	2005	Δ%	2005	Δ%
Beijing	408	172	63	87	5345	88	4373	93
Tianjin	370	114	62	56	5486	96	4533	123
Shijiazhuang	387	165	56	33	5469	101	4533	106
Taiyuan	389	227	45	88	5534	116	4549	109
Hohhot	296	104	52	29	5491	96	4539	98
Shenyang	397	61	61	131	5357	103	4556	99
Changchun	475	147	67	86	5270	87	4323	90
Harbin	321	69	56	100	5107	79	4432	94
Shanghai	632	150	71	27	5544	102	4513	94
Nanjing	634	141	68	15	5292	118	4077	90
Hangzhou	501	75	72	30	5502	108	4430	93
Hefei	559	136	57	81	5333	90	4554	94
Fuzhou	523	87	65	6	5592	83	4435	84
Nanchang	374	58	58	95	5297	82	4489	94
Jinan	552	115	56	182	5395	109	4579	112
Zhengzhou	370	123	50	102	5330	85	4566	99
Wuhan	426	106	57	32	5210	81	4406	93
Changsha	490	87	59	36	5367	92	4411	94
Guangzhou	467	69	72	29	5422	102	4361	106
Nanning	369	41	56	135	5476	84	4517	83
Haikou	370	10	60	22	5779	109	4576	86
Chongqing	537	327	57	92	5666	99	4570	74
Chengdu	358	99	58	123	5631	119	4518	116
Guiyang	313	148	49	-32	5614	92	4606	86
Kunming	411	183	50	61	5682	97	4606	93
Lhasa	370	50	56	88	6410	143	5242	129
Xi'an	245	24	52	9	5390	97	4501	100
Lanzhou	168	-17	48	28	5440	96	4556	98
Xining	241	46	42	190	5099	83	4557	102
Yinchuan	270	132	47	12	5404	93	4504	108
Urumqi	135	-24	48	99	5082	99	4360	138

Data source: calculated by taking the average of 10-day interval spot price time series published by State Development and Reform Committee of China.

Japan coal price v China coal price

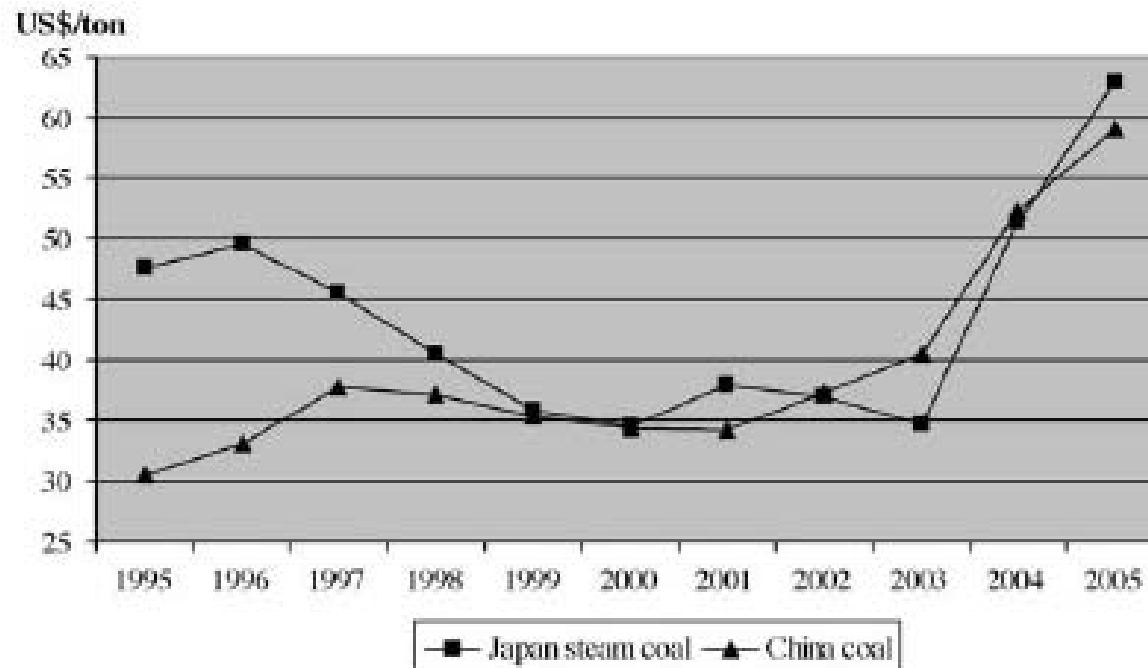


Fig. 8. Japan steam coal import cif price and China's coal spot price 1995-2005.
Note: exchange rate of US\$ to RMB is 7.0. Data source: BP 2008 [15] and National Development and Reform Committee, PRC.

The Good.. Some more details

- Institutional changes to remove Government ownership and more direct links to sectors
- Energy pricing that more directly relates to world prices and incentives
- The maybe not so good – new investment still in coal-based inputs

Newly installed capacity by type

Table 1

Present new installed capacity and its percentage of total capacity (million tonne each year and million kW).

Year	Coal exploitation		Crude oil exploitation		Coal power plant		Hydropower station	
	Capacity	Δ%	Capacity	Δ%	Capacity	Δ%	Capacity	Δ%
1993	42.8	3.7	6.9	4.8	9.4	6.6	4.0	9.4
1994	9.5	0.8	6.2	4.3	8.1	5.2	4.2	8.3
1995	23.3	1.7	7.4	4.9	10.7	6.4	3.7	7.1
1996	16.9	1.2	9.0	5.7	13.6	7.4	3.7	7.1
1997	30.0	2.2	12.5	7.8	10.3	5.3	3.7	6.8
1998	9.7	0.8	8.4	5.2	15.4	7.9	6.2	10.8
1999	23.5	2.2	9.5	5.9	12.8	6.0	9.1	16.0
2000	22.6	1.7	9.2	5.6	13.4	5.8	4.5	7.3
2001	14.9	1.3	15.6	9.5	10.1	4.1	3.4	4.3
2002	34.2	2.5	25.4	15.2	33.2	12.0	5.2	6.5
2003	74.4	4.5	17.2	10.1	21.4	6.5	12.7	16.1
2004	154.4	7.8	24.7	14.0	37.0	9.9	11.1	11.3
2005	183.8	8.3	23.9	13.2	52.8	12.4	12.8	11.6
2006	226.5	9.5	16.0	8.7	80.2	16.2	13.0	10.7
Average								
1990s	22.2	1.8	8.6	5.5	11.5	6.4	4.9	9.4
2000s	101.5	5.1	18.9	10.9	35.4	9.6	9.0	9.7

Note: Coal power capacity was estimated by total coal electricity generation divided by 24 h/day) × 200 (day/year) and hydropower capacity was estimated by total hydroelectricity generation divided by 24 h/day × 150 days/year.

Data source: China Statistical Yearbook (2007) [17].

Shares of Aggregate Consumption by Sector

Table 9
Shares of aggregate energy consumption by sector in China.

Year	Agriculture	Industry	Construction	Transportation	Commerce	Others	Resident
1985	7.7	79.7	1.7	1.5	0.9	3.0	5.4
1990	4.9	68.5	1.2	4.6	1.3	3.5	16.0
1995	4.2	73.3	1.0	4.5	1.5	3.4	12.0
2000	4.4	68.9	1.5	7.3	2.2	4.2	11.5
2004	3.8	70.5	1.6	7.4	2.4	3.9	10.5
2005	3.6	71.0	1.5	7.4	2.2	3.9	10.4
2006	3.4	71.1	1.5	7.5	2.2	3.9	10.3
Growth rate annually (%)							
1985–1990	–8.6	–3.0	–6.7	25.1	7.6	3.1	24.3
1990–1995	–3.0	1.4	–3.6	–0.4	2.9	–0.6	–5.6
1995–2000	0.9	–1.2	8.4	10.2	8.0	4.3	–0.8
2000–2005	–3.9	0.6	0.0	0.3	0.0	–1.5	–2.0
2005–2006	–5.6	0.1	0.0	1.4	0.0	0.0	–1.0

Data source: China Statistical Yearbook (1996–2007) [17].

The not so good.. Some more details

- Interprovincial coal shipments by railways are huge

Domestic railway coal shipments

Table 3

Major domestic railway coal shipment by origins and destinations in 2006.

Origin	Coal shipment (mmt)	Of total outflow (%)	Major destinations (Provinces)
Shanxi	390	90	Hebei, Shandong, Tianjin, Jiangsu, Beijing and Liaoning
Inner Mongolia	120	83	Liaoning, Tianjin, Heilongjiang, Jilin and Hebei
Henan	69	83	Hubei, Jiangsu, Shandong, Jiangxi and Anhui
Shaanxi	66	83	Hubei, Jiangsu, Shandong and Henan
Heilongjiang	34	99	Liaoning and Jilin
Hebei	23	81	Tianjin and Jilin
Shandong	20	74	Jiangsu and Zhejiang
Guizhou	18	64	Guangxi
Anhui	16	55	Jiangsu

Data source: China Transportation Yearbook (2007) [54].

The not so good.. Some more details

- Interprovincial coal shipments by railways are huge
- Energy intensity has declined, but now increasing. Provincial differences vary.

Energy Intensity

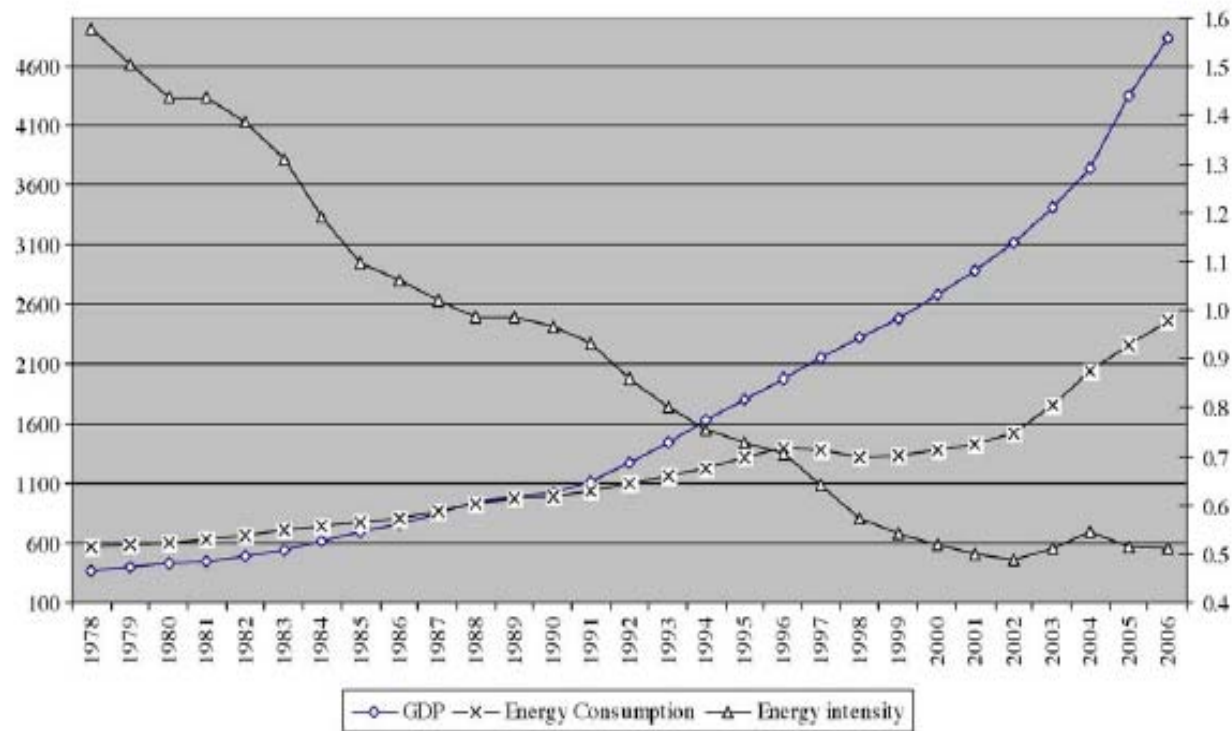


Fig. 9. National GDP (billion, 1978 price), aggregate energy consumption (million tonne standard coal), and aggregate energy intensity (tonne/¥1000). Data source: China Statistical Yearbook [17]. Note: Left-hand y axis is for GDP and energy consumption, and right hand y axis is for aggregate energy intensity.

Changes in National Energy Intensity

Table 6
 The Changes of national energy intensity by sector.

Year	Agriculture	Industry	Construction	Transportation	Commerce
1980	0.44	1.98	0.54	1.41	0.20
1985	0.25	1.62	0.43	1.11	0.11
1990	0.25	1.38	0.29	0.86	0.16
1991	0.25	1.27	0.28	0.81	0.15
1992	0.24	1.12	0.25	0.79	0.15
1993	0.22	1.00	0.20	0.77	0.19
1994	0.22	0.91	0.18	0.72	0.17
1995	0.23	0.87	0.16	0.67	0.17
1996	0.23	0.81	0.16	0.62	0.18
1997	0.23	0.72	0.13	0.71	0.17
1998	0.21	0.63	0.16	0.70	0.17
1999	0.21	0.55	0.13	0.70	0.18
2000	0.20	0.50	0.13	0.70	0.17
2001	0.21	0.44	0.12	0.64	0.17
2002	0.22	0.48	0.13	0.67	0.17
2003	0.21	0.49	0.12	0.72	0.18
2004	0.23	0.53	0.21	0.75	0.20
2005	0.23	0.52	0.19	0.74	0.19
2006	0.23	0.52	0.19	0.76	0.19

Note: Energy intensity (tonne/¥1000) = energy consumption (10k tonne)/GDP (¥100 million in 1978 price).

Data source: China Statistical Yearbook (1996–2007) [17], China Energy Statistical Yearbook (2007) [13].

Energy Intensity by Province

Table 7
 Aggregate energy intensity over Provinces in 1996, 2001 and 2006 and change.

Province	1996	2001	2006	% Change	
				1996–2001	2001–2006
Beijing	0.97	0.66	0.35	–32.0	–46.7
Tianjin	0.97	0.69	0.49	–28.9	–29.4
Hebei	1.11	0.81	0.88	–26.8	7.6
Shanxi	2.26	1.96	1.34	–13.3	–31.6
Inner Mongolia	1.23	1.15	1.10	–6.5	–4.7
Liaoning	1.33	0.93	0.81	–30.2	–12.6
Jilin	1.34	0.83	0.73	–38.1	–12.2
Heilongjiang	1.05	0.74	0.66	–29.5	–10.3
Shanghai	0.71	0.51	0.41	–27.5	–20.7
Jiangsu	0.58	0.41	0.41	–29.7	0.0
Zhejiang	0.50	0.42	0.40	–16.0	–6.5
Anhui	0.83	0.68	0.54	–18.1	–20.0
Fujian	0.40	0.32	0.42	–19.6	30.2
Jiangxi	0.61	0.47	0.47	–23.4	0.5
Shandong	0.66	0.46	0.56	–30.3	21.1
Henan	0.78	0.64	0.61	–17.8	–4.2
Hubei	0.87	0.57	0.67	–34.7	18.2
Hunan	0.89	0.51	0.61	–42.9	21.2
Guangdong	0.51	0.42	0.36	–18.2	–15.0
Guangxi	0.56	0.52	0.54	–6.1	2.9
Hainan	0.38	0.42	0.41	9.3	–2.1
Chongqing	0.00	0.75	0.64	–	–15.4
Sichuan	0.96	0.67	0.68	–30.1	1.6
Guizhou	2.20	1.79	1.45	–18.9	–18.7
Yunnan	0.80	0.74	0.78	–7.9	6.2
Tibet	0.00	0.00	0.00	–	–
Shaanxi	1.29	0.77	0.61	–40.1	–20.3
Gansu	1.69	1.18	0.98	–29.8	–17.1
Qinghai	1.63	1.35	1.40	–17.4	3.5
Ningxia	1.78	0.00	1.86	–100.0	–
Xinjiang	1.52	1.03	0.94	–32.3	–9.1

Note: calculated based on 1978 price, tonne/¥1000.

Data source: China Statistical Yearbook [17] and China Energy Statistical Yearbook [13].

The not so good.. Some more details

- Interprovincial coal shipments by railways are huge
- Energy intensity has declined, but now increasing. Provincial differences vary.
- Energy deficits across provinces

Energy Output and Deficit by Province

Table 3

Energy output and deficit by province (represented by provincial capital city) in 2006.

Market	Raw coal (mmt)		Electricity (billion KWh)		Gasoline (mmt)		Diesel (mmt)	
	Output	Deficit	Output	Deficit	Output	Deficit	Output	Deficit
Beijing	6.5	-24.1	21.5	-40.4	1.73	-1.05	2.05	0.28
Tianjin	-	-38.1	35.9	-8.7	1.30	0.02	3.87	1.40
Shijiazhuang	83.6	-129.9	146.1	-27.4	2.13	-0.51	4.12	-0.72
Taiyuan	581.4	297.9	152.6	42.8	-	-1.13	-	-2.67
Hohhot	297.6	135.7	141.3	52.8	0.61	-1.51	0.54	-4.39
Shenyang	73.7	-68.4	101.5	-21.3	10.32	6.38	19.11	13.23
Changchun	30.0	-45.5	44.3	3.1	1.60	-0.33	3.44	0.40
Harbin	102.8	12.5	64.7	5.0	3.87	0.42	5.77	0.99
Shanghai	-	-51.4	72.1	-26.9	2.48	-0.21	6.39	2.68
Nanjing	30.5	-153.8	253.6	-3.4	2.01	-2.49	7.02	1.15
Hangzhou	0.2	-113.1	176.6	-14.3	2.55	-1.50	7.50	-0.92
Hefei	83.3	-5	73.4	7.2	0.87	-0.11	1.94	-0.46
Fuzhou	19.3	-34.7	90.4	3.7	1.03	-1.05	1.56	-2.24
Nanchang	27.8	-18.1	44.0	-1.3	0.87	0.21	1.79	-1.35
Jinan	140.7	-149.3	231.5	0.3	5.00	-0.41	10.41	-1.80
Zhengzhou	195.3	-14.7	160.1	6.7	1.41	-1.09	2.65	-0.81
Wuhan	11.2	-85.3	130.7	41.2	1.78	-2.43	3.52	-1.45
Changsha	59.5	-34.9	75.5	-1.4	1.24	-1.39	2.19	-1.23
Guangzhou	-	-111.3	246.6	-53.8	4.01	-3.70	9.94	-3.74
Nanning	6.8	-34.9	52.3	-5.6	0.25	-1.59	0.42	-2.92
Haikou	-	-3.3	9.7	-0.1	0.66	0.33	0.95	0.32
Chongqing	39.9	2.6	29.1	-11.4	-	-0.86	-	-1.87
Chengdu	86.0	0.7	122.7	16.8	0.32	-2.37	0.61	-2.94
Guiyang	118.2	18.8	98.6	36.6	-	-0.79	-	-1.70
Kunming	73.4	-1.4	75.4	10.8	-	-1.28	-	-3.32
Lhasa	-	-74	1.5	-	-	-	-	-
Xi'an	182.6	143	58.5	0.4	4.10	1.99	6.05	3.83
Lanzhou	39.5	30.4	53.0	-0.6	2.39	1.51	5.86	4.68
Xining	6.9	-28	28.2	3.6	0.32	0.14	0.48	0.21
Yinchuan	32.7	-11.7	38.8	1.0	0.58	0.39	0.78	0.00
Urumqi	43.2	12.6	35.7	0.1	2.52	1.34	7.59	4.18

Data source: CESY, 2007.

The not so good.. Some more details

- Interprovincial coal shipments by railways are huge
- Energy intensity has declined, but now increasing. Provincial differences vary.
- Energy deficits across provinces
- Energy deficits - international

Exports and Imports of Energy

Table 11
 Export and imports and trade reliance of China's energy, million metric tonnes and %.

Year	Aggregate trade and reliance				Coal trade and reliance				Petroleum trade and reliance			
	Import	Export	Balance	Reliance	Import	Export	Balance	Reliance	Import	Export	Balance	Reliance
1980	2.6	30.6	-28.0	-4.6	2.0	6.3	-4.3	-0.7	0.8	18.1	-17.2	-19.7
1985	3.4	57.7	-54.3	-7.1	2.3	7.8	-5.5	-0.7	0.9	36.3	-35.4	-38.6
1990	13.1	58.8	-45.7	-4.6	2.0	17.3	-15.3	-1.4	7.6	31.1	-23.5	-20.5
1995	54.6	67.8	-13.2	-1.0	1.6	28.6	-27.0	-2.0	36.7	24.5	12.2	7.6
1996	68.4	75.3	-6.9	-0.5	3.2	36.5	-33.3	-2.3	45.4	27.0	18.4	10.6
1997	99.6	76.6	23.0	1.7	2.0	30.7	-28.7	-2.1	67.9	28.2	39.7	20.2
2000	143.3	90.3	53.1	3.8	2.2	55.1	-52.9	-4.0	97.5	21.7	75.8	33.8
2004	265.9	116.5	149.5	7.4	18.6	86.7	-68.1	-3.5	172.9	22.4	150.5	47.5
2005	269.5	114.5	155.1	6.9	26.2	71.7	-45.6	-2.1	171.6	28.9	142.8	43.9
2006	310.6	109.3	201.3	8.2	38.3	63.3	-25.0	-1.0	194.5	26.3	168.3	48.2
Growth rate annually:												
1980-1990	17.6	6.7	-	-	0.0	10.6	-	-	25.2	5.6	-	-
1990-2000	27.0	4.4	-	-	1.0	12.3	-	-	29.1	-3.5	-	-
2000-2006	13.8	3.2	24.9	13.7	61.0	2.3	-11.7	-20.6	12.2	3.3	14.2	6.1
1997-2006	15.6	4.4	27.3	19.3	38.7	8.4	-1.5	-7.7	14.6	0.1	17.4	10.2

Note: Aggregate energy is measured in million tonne standard coal and reliance is the percentage of net import in total domestic consumption.
Data source: China Statistical Yearbooks [17].

What has our research added #1?

- We have provided new results on
 - **Interfactor &**
 - **Interfuel elasticities of substitution &**
 - **Price elasticities of demand**
 - **What determines energy intensity**
- For 4 main fuel supplies
 - Gasoline; diesel; coal and electricity
 - Labour, capital and energy
- Why is this useful?
 - Without these measures cannot inform policy
 - Without these measure cannot model, simulate and forecast the effect of changes in use including emissions etc

What has our research added #2?

- The 'Law of One Price' in energy types across China
- Are energy markets domestically 'well integrated' in terms of energy market prices?
- Why is this important?
 - To policy makers concerned with economic reforms
 - To simulate, forecast and model effects of policy changes

Implied Elasticities of Substitution and Price Elasticities of Demand for Interfactor Substitution

Table 2

Implied elasticities of substitution (σ_{ij}) and price elasticities (η_{ij}) of factor demand for the interfactor substitution for the aggregate economy from Eqs. (7) and (8)

	Elasticities	Standard error
σ_{EE}	-1.7229 **	0.2574
σ_{EK}	0.8034	0.5102
σ_{EL}	0.6130 **	0.1198
σ_{KK}	-3.0342 **	0.9237
σ_{KL}	0.3384	0.2168
σ_{LL}	-0.3646 **	0.0645
η_{EE}	-0.4715 **	0.0704
η_{EK}	0.1109	0.0643
η_{EL}	0.3606 **	0.0615
η_{KE}	0.2199	0.1275
η_{KK}	-0.4189 **	0.1784
η_{KL}	0.1991	0.1177
η_{LE}	0.1678 **	0.0286
η_{LK}	0.0467	0.0276
η_{LL}	-0.2145 **	0.0380

Note: E denotes aggregate energy, K denotes capital and L denotes labor. Elasticities are calculated at the mean of each share. $S_E=0.2727$, $S_K=0.1381$ and $S_L=0.5882$.

** Denotes significant at the 5% level.

Implied Elasticities of Substitution and Price Elasticities of Demand for Interfactor Substitution

The third feature of the results in [Table 2](#) is that the substitution possibilities between energy and labor are almost as large as those for capital and energy, and are more statistically significant, with the Allen partial elasticity of substitution, σ_{EL} of 0.61 and the cross-price elasticities, $\eta_{EL}=0.36$ and $\eta_{LE}=0.17$. Fourth, capital and labor are only slightly substitutable, with $\sigma_{KL}=0.34$ and cross-price elasticities of $\eta_{KL}=0.20$ and $\eta_{LK}=0.05$ (all statistically insignificant). Finally, no complementarity is found among energy, capital and labor in this study. As in [Cho et al. \(2004\)](#), all the cross-price elasticities are less than one, suggesting that the scope for substituting capital and labor for energy in China is somewhat limited.

Implied Elasticities of Substitution and Price Elasticities of Demand for Interfactor Substitution

Table 4

Implied elasticities of substitution (σ_{ij}) and the price elasticities (η_{ij}) of fuel demand for the interfuel substitution of the aggregate economy from Eqs. (7) and (8)

	Elasticities	Standard error		Elasticities	Standard error
σ_{CO-CO}	-3.2666 **	0.7140	η_{CO-CO}	-0.5249 **	0.1147
σ_{CO-GA}	-0.8175	0.5338	η_{CO-GA}	-0.1314 **	0.0632
σ_{CO-EL}	1.4948 **	0.1869	η_{CO-EL}	0.2402 **	0.1088
σ_{CO-DI}	-1.7908 **	0.6043	η_{CO-DI}	-0.2878 **	0.0838
σ_{GA-GA}	-1.8035	1.6485	η_{GA-CO}	-0.0968	0.0858
σ_{GA-EL}	0.5951 **	0.2052	η_{GA-GA}	-0.2137	0.1953
σ_{GA-DI}	-0.0099	1.2603	η_{GA-EL}	0.0705	0.1195
σ_{EL-EL}	-0.6964 **	0.0896	η_{GA-DI}	-0.0012	0.1748
σ_{EL-DI}	0.6826 **	0.2346	η_{EL-CO}	0.8702 **	0.0300
σ_{DI-DI}	-0.7814	1.2348	η_{EL-GA}	0.3464 **	0.0243
			η_{EL-EL}	-0.4054 **	0.0522
			η_{EL-DI}	0.3973 **	0.0326
			η_{DI-CO}	-0.2484 **	0.0971
			η_{DI-GA}	-0.0014	0.1493
			η_{DI-EL}	0.0947	0.1366
			η_{DI-DI}	-0.1084	0.1713

Note: CO, GA, EL and DI denote coal, gasoline, electricity and diesel, respectively; elasticities are calculated at the mean of each share (namely, $S_C=0.1607$, $S_G=0.1185$, $S_E=0.5821$ and $S_D=0.1387$).

** Denotes significant at the 5% level.

Implied Elasticities of Substitution and Price Elasticities of Demand for Interfactor Substitution

Based on the estimated parameters reported in [Table 3](#), and again using Eqs. (7) and (8), the implied elasticities of substitution (σ_{ij}) and price elasticities (η_{ij}) of fuel demand for China are calculated and the results are presented in [Table 4](#). Several important features are apparent in [Table 4](#):

- (i) coal and electricity have substantial substitution possibilities — the estimated $\sigma_{\text{CO-EL}} = 1.49$ (with a standard error of 0.19);¹¹
- (ii) in contrast, coal and diesel appear to be complementary — the estimated $\sigma_{\text{CO-DI}} = -1.79$ (with a standard error of 0.60) while the complementarity between coal and gasoline is smaller and imprecisely estimated ($\sigma_{\text{CO-GA}} = -0.82$ with a standard error of 0.53);
- (iii) gasoline and electricity are slightly significantly substitutable — the estimated $\sigma_{\text{GA-EL}} = 0.60$;
- (iv) likewise, electricity and diesel are slightly significantly substitutable — the estimated $\sigma_{\text{EL-DI}} = 0.68$.

Total Own Cross-Price Elasticities of Fuel Demand for Interfuel Substitution

- (i) The estimated results suggest that some fuel sources are substitutable while others are complementary. For example, coal–gasoline, gasoline–diesel and coal–diesel are all complementary, while electricity–diesel and gasoline–electricity are substitutable;
- (ii) The fuel demands of coal and electricity are more sensitive to their own-price change than of gasoline and diesel. In other words, the former are elastic while the latter are inelastic;
- (iii) Electricity demand is more sensitive to coal-price change than to gasoline- and diesel-price change, $\eta_{EI-CO}^* = 0.597$ and $\eta_{EI-GA}^* = 0.072$ and $\eta_{EL-DI}^* = 0.123$. This finding implies that in

Table 5

Total own- and cross-price elasticities (η_{ij}^*) of fuel demand for the interfuel substitution of the aggregate economy from Eq. (9)

	Elasticities		Elasticities
η_{CO-CO}^*	-0.6007	η_{EL-CO}^*	0.5956
η_{CO-GA}^*	-0.2072	η_{EL-GA}^*	0.0718
η_{CO-EL}^*	0.1644	η_{EL-EL}^*	-0.6800
η_{CO-DI}^*	-0.3635	η_{EL-DI}^*	0.1228
η_{GA-CO}^*	-0.1527	η_{DI-CO}^*	-0.3139
η_{GA-GA}^*	-0.2695	η_{DI-GA}^*	-0.0668
η_{GA-EL}^*	0.0146	η_{DI-EL}^*	0.0293
η_{GA-DI}^*	-0.0571	η_{DI-DI}^*	-0.1738

Note: CO, GA, EL and DI denote coal, gasoline, electricity and diesel, respectively; elasticities are calculated at the mean of each share (namely, $S_C = 0.1607$, $S_G = 0.1185$, $S_E = 0.5821$ and $S_D = 0.1387$).

- the long run, a coal-price change has greater effect on electricity demand rather than a gasoline-price change;
- (iv) Diesel demand is more sensitive to coal-price change than to gasoline-price change, $\eta_{DI-CO}^* = -0.314$ and $\eta_{DI-GA}^* = -0.067$.

Decomposition of the Change in Energy Intensity

Table 6
Decomposition of the change in energy intensity for the aggregate economy^a

Region ^b	$\Delta\hat{e}/\hat{e}$	Budget	Substitution			GDP	Technologies	
			Sum	Energy	Capital			Labor
National	0.0727	-0.1934	0.0043	0.0619	-0.0017	-0.0559	0.0251	0.2368
Region 1	0.0702	-0.2387	0.0363	0.0701	-0.0014	-0.0324	0.0387	0.2340
Region 2	0.0550	-0.1540	-0.0581	0.0641	-0.0010	-0.1212	0.0153	0.2517
Region 3	-0.0429	-0.3589	0.0214	0.0916	-0.0019	-0.0683	0.0647	0.2299
Region 4	0.1336	-0.1123	-0.0099	0.0409	-0.0014	-0.0494	0.0071	0.2487
Region 5	0.0638	-0.2242	0.0195	0.0594	-0.0008	-0.0391	0.0341	0.2343
Region 6	0.1345	-0.1161	0.0069	0.0523	-0.0026	-0.0428	0.0095	0.2342
Region 7	0.0602	-0.1686	-0.0143	0.0656	-0.0027	-0.0771	0.0113	0.2318

^a To make the estimate more stable and reliable, we take three year averages of 1995–1997 and 2002–2004 for the base year and reporting year to calculate the growth rate of energy intensity.

^b Region 1 includes Hebei, Shanxi, Anhui, Shandong and Henan; region 2 includes Beijing, Tianjin, and Shanghai; region 3 includes Liaoning, Jilin and Heilongjiang; region 4 includes Jiangsu, Zhejiang, Jiangxi and Hubei; region 5 includes Fujian, Hunan, Guangdong, Guangxi and Hainan; region 6 includes Chongqing, Sichuan, Shaanxi, Gansu, Guizhou and Yunnan; and region 7 includes Mongolia, Tibet (data unavailable), Qinghai, Ningxia and Xinjiang.

Decomposition of the Change in Energy Intensity

- Aggregate energy intensity increased (nationally) by 7.3% mainly be due to 2 forces:
 - Rising energy prices
 - Technological change effects (adopting energy intensive technologies)
 - Substitution and production effects small and net out
 - +5.6% and -6.2%
 - Budget effects -19.3% -> energy use as prices rise (25% over the period)
 - energy intensive technologies -> +23.7% increase
- Regional effects similar

Energy Market integration: LOOP

- Use time series based tests on (10 day data) on regional/city prices of coal, electricity, gasoline and diesel
- Test for 'convergence' in energy prices
 - Across energy types
 - Spatially
- Based on 'unit root' and cointegration methods
 - If pairs/combinations 'stationary' and/or 'cointegrated' then support for LOOP
 - If pairs/combinations 'non-stationary' and/or 'non-cointegrated' then no support for LOOP

Pedroni (1999) - based tests

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

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

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

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

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

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

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

Energy Market integration: LOOP

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

Test statistics	All four fuels			Electricity and coal			Diesel and gasoline		
	1997-2005	1997-1999	2000-2005	1997-2005	1997-1999	2000-2005	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.

Summary of 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.

Summary of results..

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).

Energy Market integration: LOOP

Table 4. Panel V -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.

Conclusions : Issues and possible Policy Directions

- Unlikely that anything will prevent a significant increase in China's primary energy consumption and electricity generation with consequent effects on emissions.
- China's policy makers therefore have to prioritize, encourage, legislate, support etc a range of options
- Some of these challenges for the future noted next

Challenges and possible solutions

- Some of these are “Motherhood and Apple Pie”, but..
- Need to increase investment in energy industry
 - Economic growth requires energy intensive production
 - Need to reduce energy intensity and increase energy efficiency
 - Enhance technical innovation for demand and supply
 - Balance increase supply plans with conservation
 - Market prices might help

Challenges and possible solutions

- Increase research and production of clean renewables
 - Biomass is renewable, but not clean
 - Biomass has spillover effects on food prices
 - Large potential, but currently dominated by coal
- Transportation of energy and inputs
 - Currently supply of energy distant from demand, except electricity
 - Energy use to supply energy is large
 - Micro-production closer to source
 - Urbanisation will have some positive effects, but negative through traffic congestion

Challenges and possible solutions

- Further Institutional Reform
 - Need to raise energy prices to reflect real costs and priorities
 - Create independent *Ministry of Energy* to formalize commitment to coherent strategy on energy
 - Realize environmental and energy demand/supply related
 - Emissions policy