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INDUSTRIAL ORGANIZATION OF THE CHINESE COAL INDUSTRY

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Tu is an experienced policy advisor and project manager who specializes in operations strategy and policy analysis of the coal, oil, gas, and power sectors and sustainable resource and environmental management. Since early 2000s, Tu has applied a hybrid energy-economy model – CIMS – to China's energy sector and made policy recommendations to address China's GHG emissions, local air pollution, and energy security challenges. From 2007 to 2009, he was entrusted by the Canada School of Public Service to advise the Central Party School in Beijing on environment and sustainable development. In 2009, Tu was appointed by the China Council for International Cooperation on Environment and Development (CCICED) as the lead consultant of the CCICED Task Force on Sustainable Use of Coal in China. He has authored many articles covering China's energy and environmental issues.

Tu holds a master of resource and environmental management degree from Simon Fraser University in Canada and a bachelor of chemical and mechanical engineering degree from Zhejiang University in China.

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Executive Summary

Coal has played a key role in China's rapid economic growth since the Chinese economy was opened to the outside world in 1978. China's annual coal production, at 3.24 billion tonnes (Gt) in 2010, accounted for near half of world total.¹ Nevertheless, the unprecedented exploitation and utilization of coal has also created enormous environmental and social challenges including 1) coal mining waste and land subsidence-related environmental impacts in many areas of the country; 2) severe water shortage at major coal mining regions such as Shanxi, Shaanxi, and Inner Mongolia; 3) mounting safety challenges as more than 250,000 miners² have died in China's numerous coal mine accidents since the inception of the People's Republic of China in 1949; 4) bottlenecks in China's transport infrastructure (especially rail); 5) deteriorating air quality in many urban centers and adjacent regions; and 6) pressure to mitigate greenhouse gas (GHG) emissions, especially after China overtook the United States (US) as the lead in CO₂ emissions in 2006.³

Historically, China has been a net coal exporter because of a large reserve base, low labor costs, attractive export prices, and government tax incentives. In 2003, China's coal exports peaked at 94 million tonnes (Mt) with net coal exports at 83 Mt. In 2009, the prolonged dispute over contract thermal coal prices between China's major coal enterprises and power companies and the geographic proximity between China's coastal provinces and major regional coal export countries turned China into a net coal importer. Given that the volume of the entire world seaborne coal trade is less than one third of China's annual coal production, the shifting of China's coal import/export balance has the potential to significantly disrupt the international coal trade. While China looms over the global coal markets, leaving the international industry guessing how the Chinese import/export patterns will develop, the impacts of the Chinese coal industry on the global coal market are too significant to be overlooked.

To better understand the Chinese coal industry and its role in the global coal trade, the author was entrusted by the Program on Energy and Sustainable Development (PESD) at Stanford University to conduct a research on the industrial organization of the Chinese coal industry that

¹ National Bureau of Statistics and BP. Statistics from industrial sources suggest 3.41 Gt as coal output in 2010.

² Source: Official statistics. Independent sources suggest much higher fatalities; see section "Grey Markets and Coal Statistical Distortion" for detail.

³ The original energy statistics published by the National Bureau of Statistics suggest year 2007 instead.

covers the complete value chain of the Chinese coal industry including coal mining, transport, and end use such as power generation. The objectives of this study are to 1) comprehensively review the Chinese coal value chain and 2) identify problems and policy challenges in the Chinese coal industry.

The Chinese Coal Mining Industry

China's coal resources cover a land area of 600,000 km², encompassing 6 percent of the country's 9.6 million km² area. There are five major coal endowment districts in China: northeast, north China, south China, northwest, and Tibet and Yunnan. The China Geological Survey reported that China's inferred coal resources total 5,555 Gt. More than 90 percent of identified coal reserves in China are in less-developed, arid areas that are environmentally vulnerable (MLR 1999).

Figure 1: Chinese Coal Resource Distribution Map



Source: Ministry of Land and Resources.

As illustrated in Figure 1, 89 percent of China's gross coal resources are located in 12 provinces (or municipalities or autonomous regions) to the west of Daxing'anling-Taihangshan-Xuefengshan serial of mountain ranges; these provinces include Shanxi, Shaanxi, Inner Mongolia, Ningxia, Gansu, Qinghai, Xinjiang, Sichuan, Chongqing, Guizhou, Yunnan, and Tibet. Twenty provinces (or municipalities or autonomous regions) to the east of the above mountain ranges account for only 11 percent of gross coal resources in China. Similarly, 93.6 percent of gross coal reserves are located in 18 provinces to the north of the Kunlunshan-Qinling-Dabieshan serial of mountain ranges; these provinces include Beijing, Tianjin, Hebei, Liaoning, Jilin, Heilongjiang, Shandong, Jiangsu, Anhui, Shanghai, Henan, Shanxi, Shaanxi, Inner-Mongolia, Ningxia, Gansu, Qinghai, and Xinjiang. Only 6.4 percent of gross coal reserves lie in 14 provinces to the south of these mountain ranges. Not surprisingly, the unbalanced resource distribution largely determines the pattern of coal transportation in China, which generally follows routes from the north to the south and from the west to the east (TFSUC 2009).

Table 1: Coal Resources and Reserves in China at the End of 2006 (Gt)

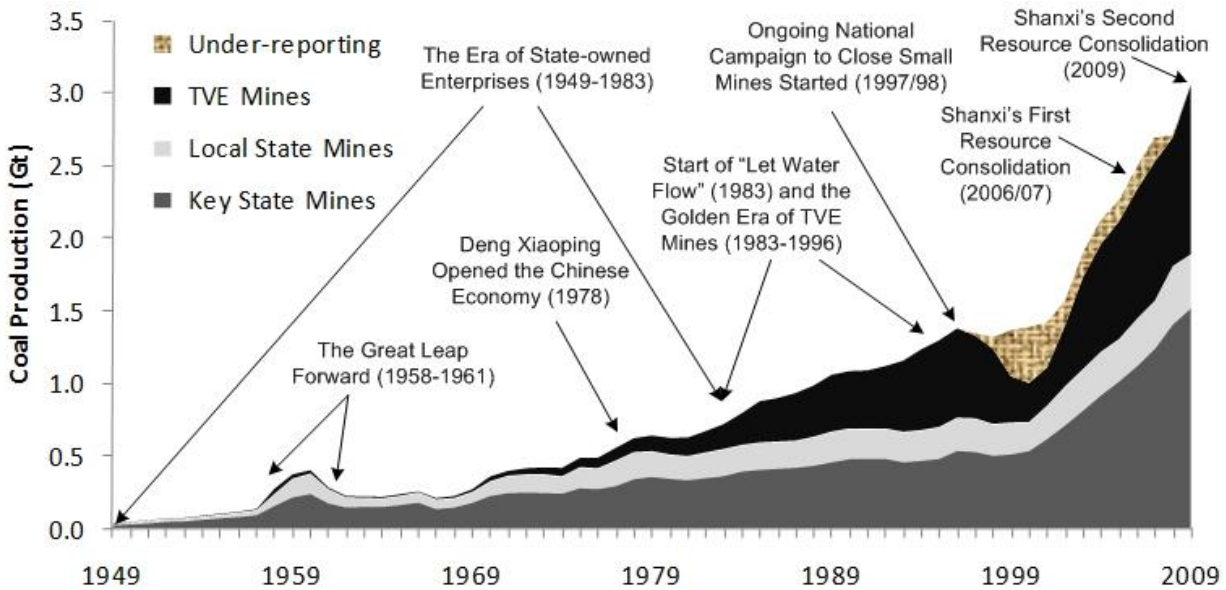
Planning Area (Province/Municipalities/Autonomous Region)	No. of Mining Districts	Proven Reserves	Basic Reserves *	Prognostic Reserves *	Total Reserves *
Jing-Jin-Ji (Beijing, Tianjin, Hebei)	277	2.70	7.69	9.57	17.25
Northeast (Liaoning, Jilin, Heilongjiang)	1,208	5.45	14.45	17.57	32.03
East China (Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong)	1,440	11.01	25.38	31.17	56.54
Central South + Hainan (Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan)	1,576	8.37	15.79	17.12	32.91
Jin-Shang-Meng-Ning (Shanxi, Shaanxi, Inner Mongolia, Ningxia)	1,320	126.51	220.16	532.15	752.31
Southwest (Chongqing, Sichuan, Guizhou, Yunnan)	1,454	18.25	29.04	62.93	91.96
Xin-Gan-Qing + Tibet (Gansu, Qinghai, Xinjiang, Tibet)	690	10.25	20.98	155.80	176.77
Total Coal	7,965	182.54	333.48	826.30	1,159.78
Coking Coal		64.3	124.2	150.3	274.8

*: Resources. Note: Basic reserves are based on relatively extensive geological exploration activities; they are suitable for resource extraction in the near future or longer term. The proven coal reserves are the portion of basic reserves that can be economically recovered in the near future. Prognostic reserves are primarily based on geological inferring and modeling instead of extensive exploration activities. Total Reserves = Basic Reserves + Prognostic Reserves. Source: Huang et al. (2008) and China Coal Transportation and Distribution Association (CCTD).

In 2006, the Ministry of Land and Resources (MLR) reported that China's total coal reserves stood at 1,160 Gt across the country's 7,965 mining districts, comprising 334 Gt of "basic reserves" and 826 Gt of "prognostic reserves." China's "proven reserves" were reported as 183 Gt, which is significantly higher than the similar statistics at 114.5 Gt provided by British Petroleum⁴ (Huang et al. 2008, BP 2010).

⁴ China's coal resource classification is considered to be incompatible with international standards; BP has not updated China's proven coal reserves at 114.5 Gt for many years, which is significantly lower than the similar figure at 182.5 Gt in Table 1.

Figure 2: China's Coal Production by Type of Enterprises, 1949-2009



Note: Underreporting represents coal statistical revisions made by the NBS in 2006 and 2010, which has not been disaggregated by the NBS in terms of type of coal enterprises. Source: Thomson (2003), CCII (various years), SXCOAL and CCTD .

There are three types of coal mines in China.

Key state-owned enterprises (SOE) were once supervised by the former Ministry of Coal Industry (MCI). Nowadays, except for Shenhua Group and China Coal Energy Company, all key state-owned coal enterprises are supervised by provincial governments. This group accounted for half of national coal output in 2009. Coal production and sales of Shenhua Group, the largest state-owned coal mining company in China, reached 328 Mt and 357 Mt in 2009.⁵ In comparison, Peabody Energy Corp., the world's largest private-owned coal mining company, produced only 172 Mt of coal in the same year (Peabody 2009, U.S. EIA 2009). Moreover, Shenhua's fatality rate was 0.027 death/Mt of coal in 2009, significantly lower than national

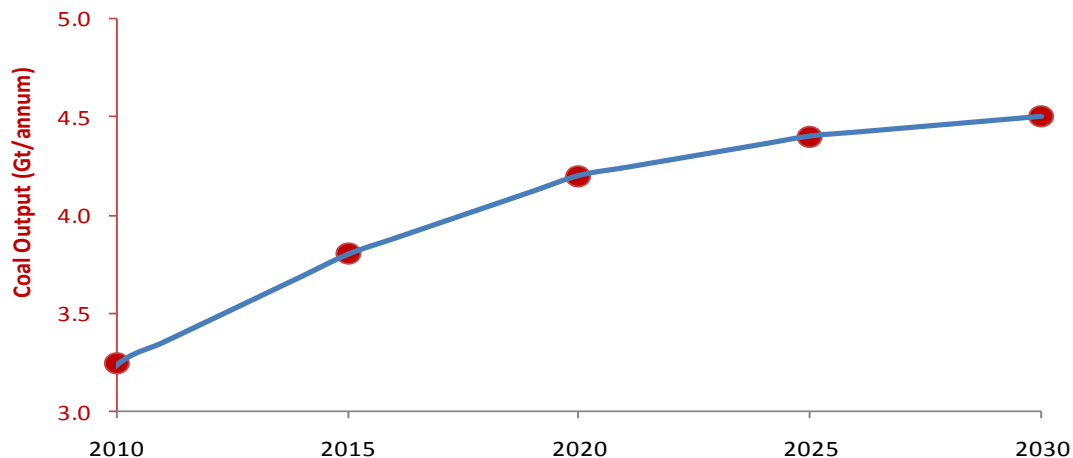
⁵ The difference can be largely explained by coal bought by Shenhua from other producers (e.g., TVE mines) primarily due to the latter's lack of access to rail transport network.

average at 0.86 death/Mt of coal in the same year. Not surprisingly, the Chinese government is trying to promote the Shenhua model.⁶

The numerous Township and Village Enterprises (TVE) in the Chinese coal industry are mines invested and controlled by agricultural collective economic organizations or peasants. They have caused many regulatory challenges such as environmental degradation, tax evasion, and mine accidents. Their number once exceeded 100,000 in 1991. The central government plans to reduce the number of operating TVE mines to 10,000 by 2010. TVE mines accounted for about 38 percent of national coal output in 2009.

Finally, local SOE mines are owned and supervised by the local instead of the central government; their market share shows a declining trend in recent years. In 2009, local SOE mines accounted for only 12 percent of national coal output.

Figure 3: Reference Coal Production Trajectory in China by 2030



Note: Reference coal production forecast in this study is based on expert opinions solicited during the author's interview with Chinese academia and officials between 2009 and 2011, tentative discussion on the 12th FYP of the Chinese coal industry, and the author's own estimation.

⁶ For discussion of Chinese coal sector consolidation policy and the "Shenhua Model", see PESD Stanford's "Remaking the World's Greatest Coal Market: the Quest to Develop Large Coal Power Bases in China", by Rui, Morse, and He.

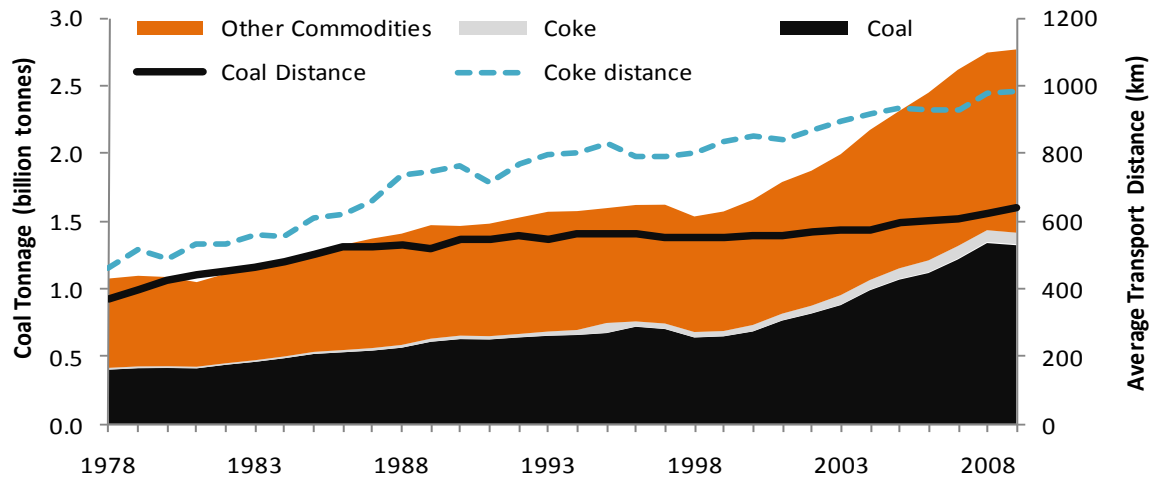
In the late 1990s, Beijing launched a national campaign to close TVE mines (most are private and small). Nevertheless, conflicts of interests between the local and central governments and vested interests of many local officials made Beijing's regulatory effort largely unsuccessful. Coal production underreporting became rampant, and coal statistical distortion was common. For instance, energy planning and forecasting in the 1990s and early 2000s generally shows substantial differences with observed reality in later years.

Figure 3 presents this study's reference trajectory of China's coal production growth by 2030. Though the Chinese government has a very strong political desire to control the national coal output around 3.8 Gt/annum by the end of the 12th Five Year Plan (FYP) period, coal output in China may be significantly higher than the reference trajectory under the following two scenarios: 1) sizable coal grey markets exist in China and the official coal output statistics in recent years have been seriously underreported and 2) the Chinese government's ambitious planning targets are unable to effectively prevent a domestic coal consumption spike (similar to what happened during the 11th FYP period, when the original 2010 coal production control target of 2.6 Gt/annum was later far exceeded by an actual coal output level of 3.24 to 3.41 Gt/annum).

Coal Transport

China's coal reserves and production lie largely in the north, northwest, and southwest parts of the country. In comparison, major coal-consuming centers in the east and south coastal regions have only limited coal endowments especially when compared with their consumption levels. As a result, the long distance between China's coal production regions in the hinterland and consuming centers in the coastal areas make transportation one of the most important issues in the Chinese coal industry.

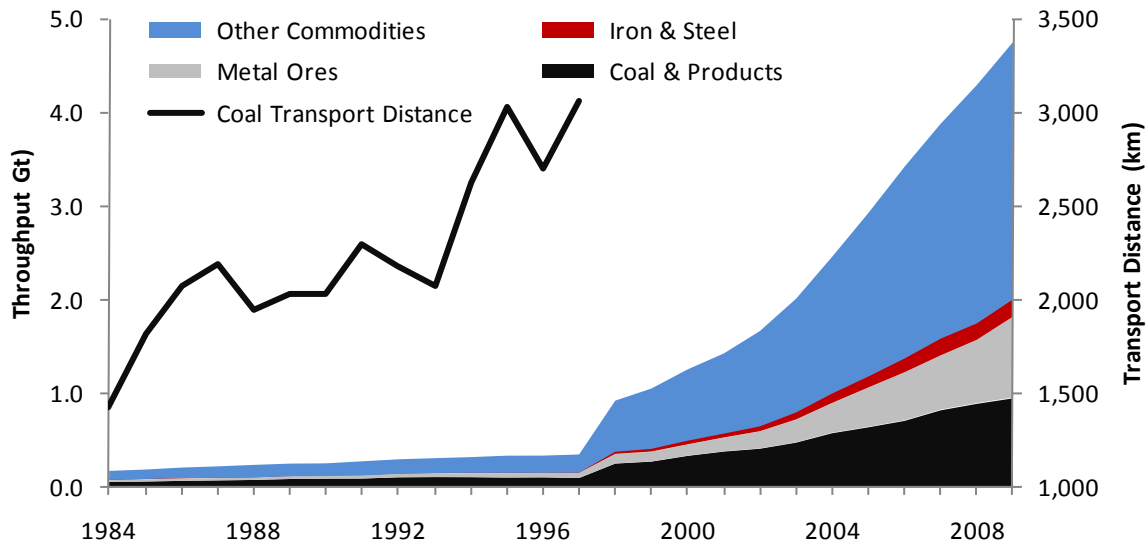
Figure 4: Transportation by China's National Rail Network, 1978-2009



Source: NBS (various years).

Coal transport by rail is so far the most important mode for moving coal within China. The amount of coal and coke transported by rail increased steadily from 417 Mt in 1978 to 1,413 Mt in 2009, a 4.0 percent increase annually during the study period. In comparison, national coal output grew 5.3 percent annually since 1978. The lower growth rate of coal transportation by rail compared with national coal output growth suggests that the bottleneck of railway infrastructure has become an increasingly serious constraint in China's coal value chain. Not surprisingly, the share of national coal output transported by rail has declined continuously from 65 percent in 1978 to 44 percent in 2009. As a result, the lack of access to railway infrastructure has forced the Chinese coal industry increasingly to rely on road transport, which is not only less fuel efficient but also more environmentally polluting and more expensive. To make the matter worse, the average distance of coal and coke transported by rail is increasing, which has made the infrastructure bottleneck issue even more serious in recent years.

Figure 5: China's Coal Transportation by Major Coastal Ports, 1984-2009



Source: NBS (various years-b).

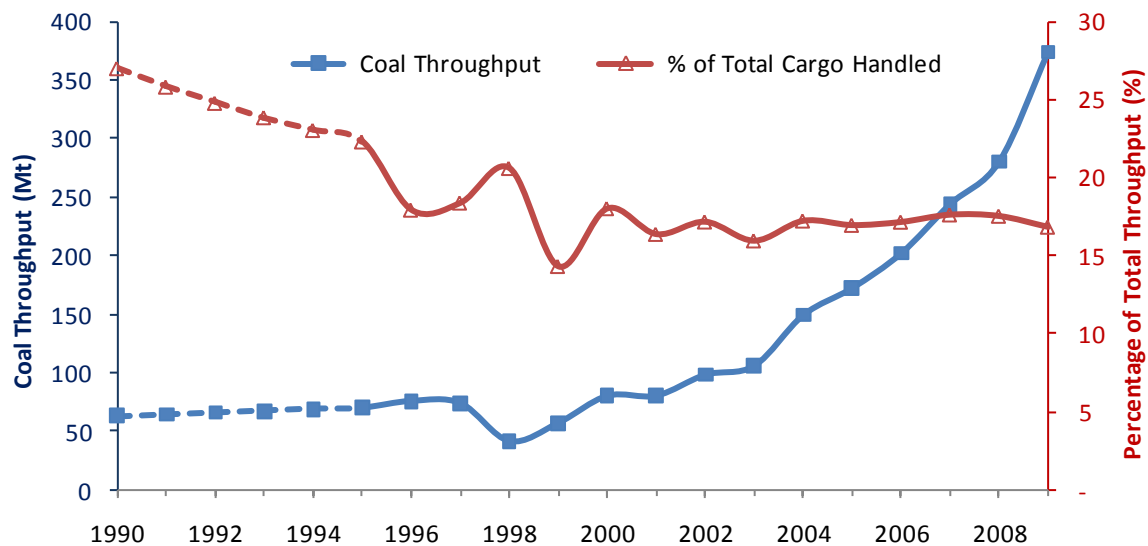
Since the late 1990s, the rapid capacity expansion of major ports across the country made the total cargo throughput (including coal) processed by major coastal ports increase from 347 Mt in 1997 to 4,755 Mt in 2009, the equivalent of 24.4 percent growth annually during the study period. Since 1997, coal and coal products handled by major coastal ports increased from 86 Mt in 1997 to 949 Mt in 2009, the equivalent of a more than 10-fold spike, which is much higher than coal production growth during the same period.

Transportation on the inland waterways is an important element of the domestic coal distribution system, carrying 374 Mt of coal in 2009, accounting for approximately 12 percent of China's coal output in the same year. Currently, coal represents an important share of shipping on the inland waterways, accounting for approximately 17 percent of total cargo tonnage. Inland waterway transport is expected to remain cost competitive to move large quantities of coal along long-distance transport corridors in China, and geographic suitability and availability of port facilities instead (rather than freight costs) are expected to be the primary constraint to sustain growth of inland waterway coal transport in China.

Transporting coal by roadway is only considered to be a supplemental mode to rail and waterway due to the latter two modes' economy of scale. Road is most likely to be used as an intermediate mode along the producer-rail-port-user transport chain. In addition, long-distance trucking of coal is both economically unattractive and environmentally undesirable; road transport is

generally only suitable for short-distance coal delivery within a coal-producing province or between coal-producing and coal-consuming regions that are not far apart. Coal transport distance by truck is normally within the 500 km threshold. Nevertheless, in rare circumstances (e.g., Datong to Qinhuangdao: 638 km), this distance can be significantly longer if a highway connection is available and other modes of transport are capacity constrained.

Figure 6: Coal Handled at Major Chinese Inland Ports, 1990-2009

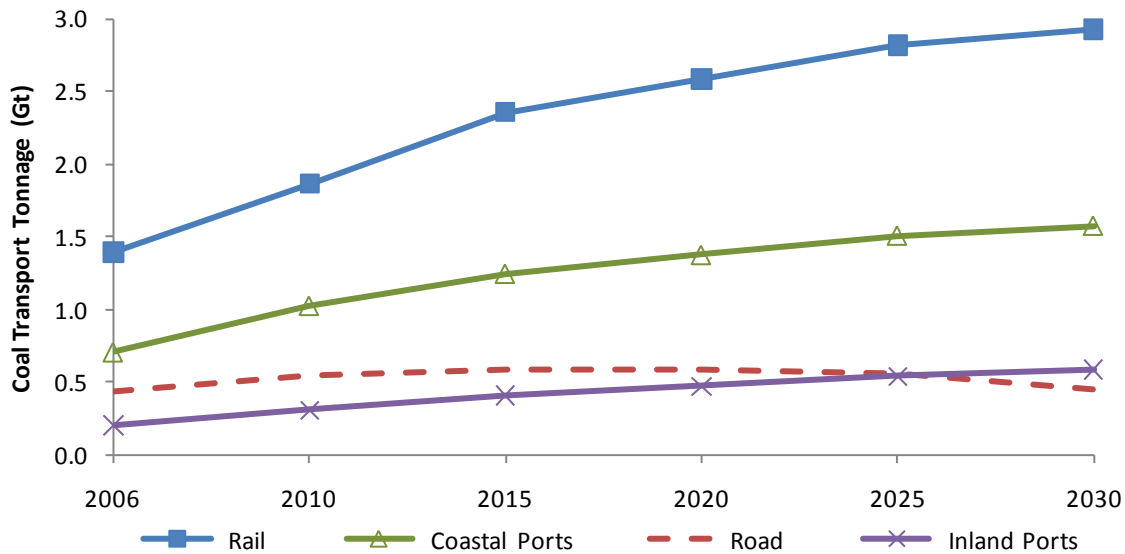


Source: MOTC (various years).

Based on the reference coal production trajectory in this study, Figure 7 presents a forecast of coal transport tonnages by mode in China by 2030. Rail is expected to continuously be the most dominant mode for moving coal from west China to the east and from the north to the south. In 2009, 1.7 Gt⁷ of coal were hauled by rail. Beyond that, coal tonnage by rail is expected to increase by 2.3 percent annually, approaching 3 Gt by 2030. With high fuel costs and increasingly stringent regulatory countermeasures on truck overloading, railways are expected to haul most inter-provincial coal transport tonnages. Except in a few regions, road is only a supplemental coal transport mode.

⁷ This figure includes coal tonnages hauled by local railways and Shenhua.

Figure 7: Scenario of Coal Transport by Mode in China



Note: Only inter-provincial coal transport by road is included. Source: NBS (various years-b), Li (2008), and industrial sources.

In 2009, about 0.5 Gt of coal were hauled by truck. In the future, coal transport tonnage by road is expected gradually decline to the late 2010s tonnage level by 2030. In 2009, coal throughput at major inland ports was 0.4 Gt, which is expected to grow over time, and inland waterway is projected to partially substitute road for inter-provincial coal transport. In 2009, coal throughput at major coastal ports was near 1.0 Gt, which is expected to grow at 2.7 percent annually, reaching 1.8 Gt in 2030. The geographic advantage of northern coal ports—especially the N7 (the seven major Northern ports)—makes them cost competitive, and the integration of rail and coastal marine transport modes is expected to be strengthened over time.

Coal Consumption

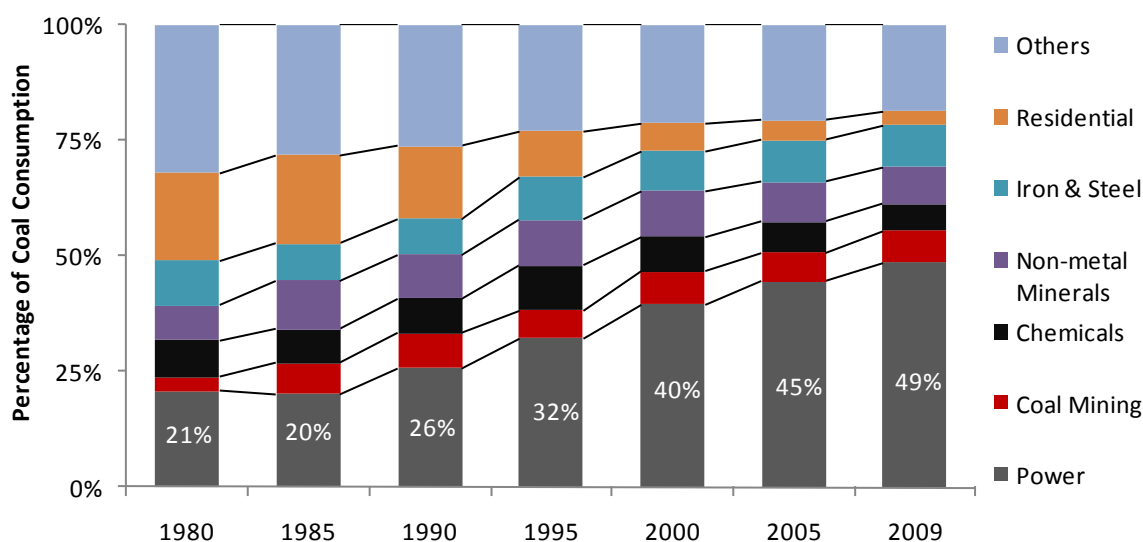
With limited domestic petroleum and natural gas endowments, coal accounted for 96.3 percent of China's primary energy consumption in 1949, 93.9 percent in 1960, 80.9 percent in 1970, 72.2 percent in 1980, 76.2 percent in 1990, 79.2 percent in 2000, and 70.4 percent in 2009 (NBS various years-a).

In 1980, power generation, other transformation industries (e.g., coking, heating, coal washing), industrial end use (e.g., iron and steel), and other end use (e.g., construction, commercial,

residential, transportation, agriculture) accounted for 21 percent, 16 percent, 35 percent, and 26 percent of national coal consumption, respectively.

The electricity industry's share of national coal consumption has increased steadily from 21 percent in 1980 to 49 percent in 2009, and is expected to keep rising in the coming decades. Other transformation industries' share of national coal consumption has increased from 11 percent in 1980 to 20 percent in 2009, which is primarily driven by rising coke and heating demand. The iron and steel industry's share of national coal consumption has been steady at 8 percent to 10 percent since 1980. In comparison, chemicals' share of national coal consumption fluctuated over time and declined moderately from 8.0 percent in 1980 to 5.8 percent in 2009. Further, non-metal minerals' share of national coal consumption also fluctuated over time and increased slightly from 7.5 percent in 1980 to 7.9 percent in 2009 (NBS various years-a).

Figure 8: Coal Consumption by Sector in China



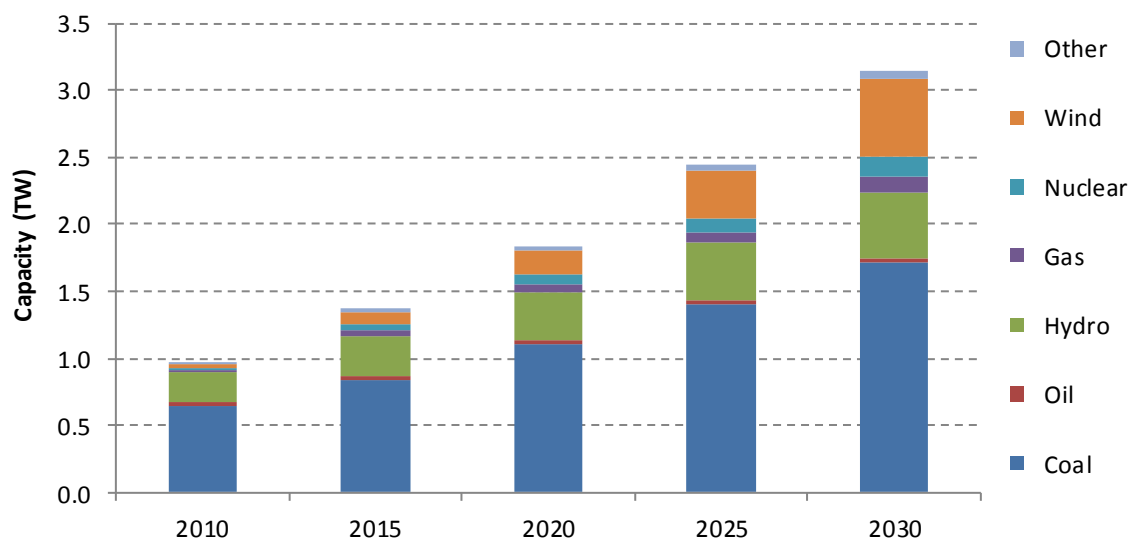
Source: NBS (various years-a) and CNCA (2006).

The residential sector's share of national coal consumption has dropped from 19 percent in 1980 to 3.1 percent in 2009, which was primarily driven by increasingly stringent environmental regulation and rising environmental awareness. Finally, other end user's share of national coal consumption shows a declining trend over time, dropping sharply from 32 percent in 1980 to 19 percent in 2009.

With the large-scale installation of advanced greenfield generation plants and accelerated retirement of small inefficient units, thermal electricity generation efficiency in China has improved significantly in recent years. During the 11th FYP period, the Chinese government's mandate of lowering national energy intensity per unit GDP by 20 percent between 2005 and 2010 has encouraged the installation of supercritical and ultra-supercritical technology in the power sector. Similar policies have been implemented in the 12th FYP that will maintain the incentive to increase coal combustion efficiency in power generation.

In addition, small-scale and inefficient power plants have been shut down by central government policy to comply with energy intensity target set by Beijing. Nevertheless, compared with international best practices, there is still sufficient room for China to further improve the efficiency level of its generation fleet.

Figure 9: Reference Electricity Generation Capacity Mixture in China by 2030



Note: Only grid-connected Greenfield power plants are included in the assessment. Source: 2010 capacity is based on data from the China Electricity Council.

Figure 9 presents this study's reference forecast on the generation capacity mixture in the Chinese electricity industry by 2030. In 2010, installed capacity of the Chinese electricity industry was approaching 1.0 TW. To meet China's surging power demand, installed generation capacity in China is expected to increase at more than 6 percent annually, exceeding 3.1 TW in 2030. Among all the generation technologies, windmills are expected to show the strongest growth at 16 percent annually during the study period. In comparison, installed capacity of coal-

fired units is expected to expand moderately at near 5 percent annually to meet rising domestic demand and build a sufficient reserve margin in the coming decades (though absolute capacity growth will likely be greater than non-coal alternatives).

Despite of the Fukushima Daiichi crisis, the share of nuclear in China's electricity capacity mixture is expected to increase over time due to strong support by the Chinese government. As a result, its share in total installed capacity is expected to increase from about 1 percent in 2010 to near 5 percent in 2030.

Natural gas-fired generation is projected to grow during the study period to 1) alleviate air pollution in the urban centers and 2) meet peak load demand. In comparison, at the beginning of the 11th FYP period, China's installed oil generation capacity at about 27 GW was planned to be gradually phased out due to rising oil prices. Nevertheless, to meet energy intensity targets set by the central government, restricting power supply has become a widespread practice at the local government level. As a result, diesel engines have been installed across the country in recent years. If such practice continues in the future, oil-fired power generation is expected to maintain a marginal but still important role in China.

Coal Pricing and International Coal Trade

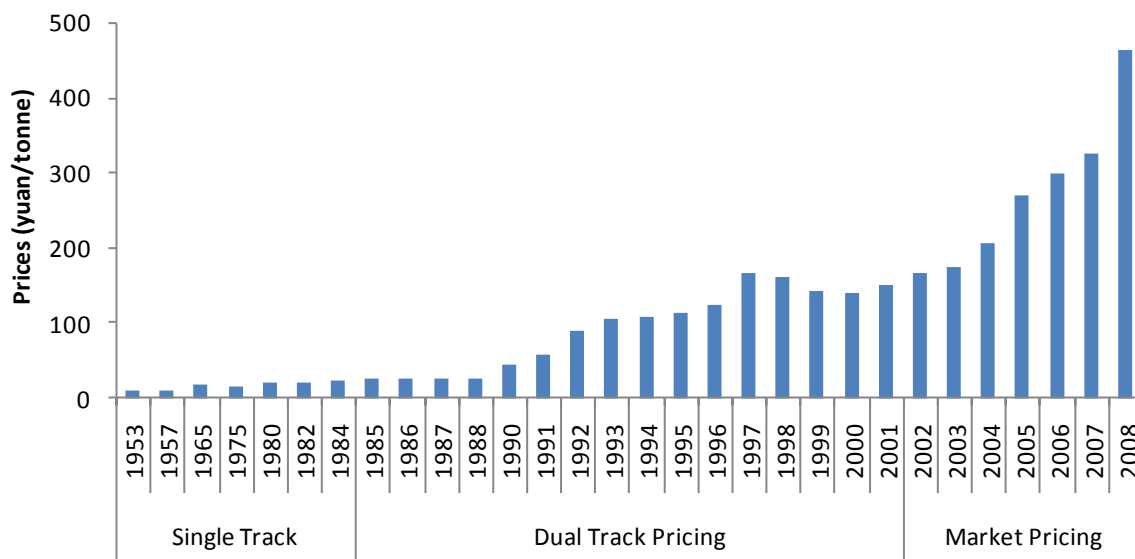
Figure 8 shows that historical coal pricing in China can be categorized as below:

Single-track pricing period (1949 - 1985): at the inception of the PRC, the commodity pricing in China was dominated by the theory promoted by the former Soviet Union. According to this approach, part of value-added income in the heavy industry should be materialized in the light industry or other production sectors, so prices of raw materials including coal were set at arbitrarily low levels. Although coal production costs in China increased over time, coal prices had only been adjusted marginally several times between 1949 and 1984; as a result, the Chinese coal mining industry ran a deficit during most of this period.

Dual-track pricing period (1985 – 2002): To meet the surging coal demand, Beijing actively encouraged the development of small coal mines and deregulated prices for coal produced by TVE mines. In addition, state-owned mines were allowed to sale their above-capacity output at market prices. Since 1993, the Chinese government has gradually deregulated coal retail prices in most sectors. Nevertheless, it still imposed “supervised prices” for thermal coal consumed by power plants between 1994 and 2001.

Market-oriented pricing period (2002 - present): In 2002, the Chinese government abolished the “supervised thermal coal prices” implemented since 1994. To facilitate the thermal coal contract negotiation for use by utilities, the state still issued reference coal prices at the Annual Coal Trade Fair. In 2006, the NDRC finally allowed prices of thermal coal for utility use to be fully subject to market pricing. According to the Guidelines Regarding Improving the Linkage Amongst Coal Production, Transport, and Demand, issued by the NDRC on December 14, 2009, thermal coal contracts for utility uses should be directly and independently negotiated between coal-producing enterprises and power plants without state intervention; this marks the complete deregulation of coal pricing regime at the central government level in China.

Figure 10: Average Mine Mouth Sales Price for Coal Produced by Key SOEs in China

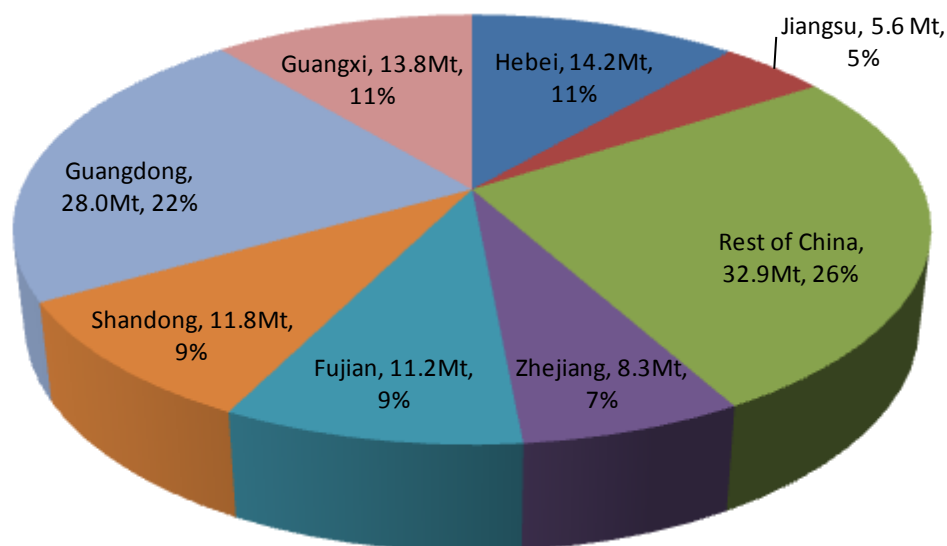


Source: Yang et al. (2009), Wang and Pan (2009), and the Energy Research Institute at NDRC.

Since late 1990s, China’s coal exports increased rapidly and peaked at 94 Mt in 2003 (NBS various years-a). Since then, coal exports have been subject to a mandatory quota system set by the central government and show a continuously declining trend. In comparison, China’s coal imports show an overall upward trend in the past decade, reaching 165 Mt in 2010. According to the IEA, world seaborne hard coal trade volume was 859 Mt in 2009. In comparison, China’s coal production was 3,050 Mt in the same year. Given the enormous size of China’s coal industry compared with the amount of coal traded in the international market, if China takes even a small share of its coal supply from the international market, impacts on the international coal trade can be significant.

While China has long been a net coal exporter, the prolonged dispute on contract thermal coal prices between China's major coal enterprises and power companies and the geographic proximity between China's coastal provinces and major regional coal-exporting countries have finally turned the country as a net coal importer in 2009. The behavior of Chinese coal importers can be explained with their intention to 1) check the bargaining power of major coal enterprises but 2) not seriously disrupt global coal trade. As illustrated in Figure 11, coal importers in China's coastal provinces especially Hebei, Shandong, Fujian, Jiangsu, Zhejiang, Guangdong, and Guangxi are expected to keep importing moderate levels of coal from overseas suppliers in the future, which is expected to stimulate inland waterway transport especially in the Yangtze River Delta and Pearl River Delta regions. Morse and He discuss Chinese import behavior in detail in another PESD study.⁸

Figure 11: China's Coal Imports by Province in 2009



Source: China Customs.

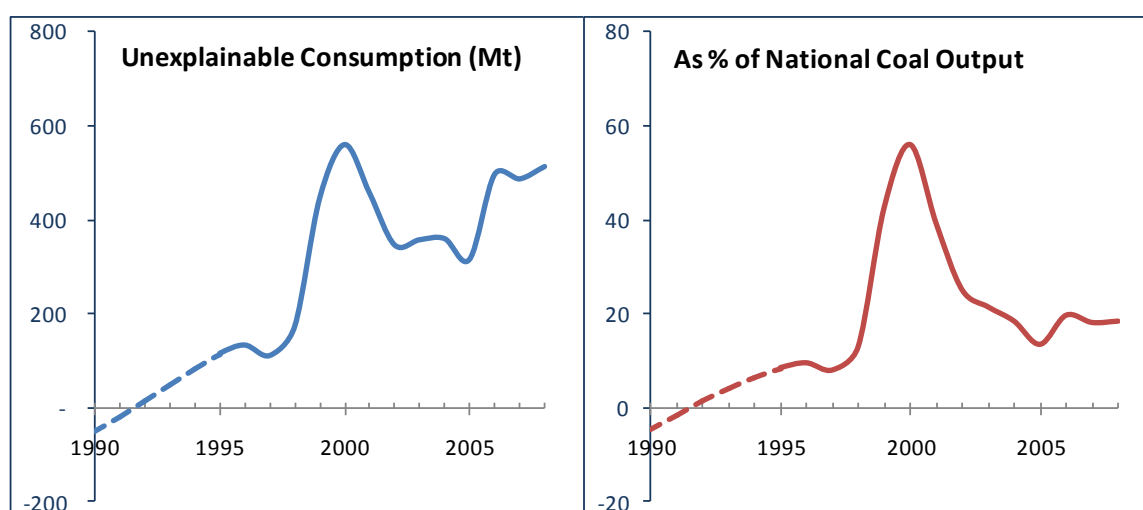
Grey Markets and Coal Statistical Distortion

A grey market is the trade of a commodity through distribution channels that, while legal, are unofficial, unauthorized, or unintended by the original producer. In contrast, a black market is the trade of goods and services that are illegal in themselves and/or distributed through illegal

⁸ See Morse, Richard and He, Gang, "The World's Greatest Coal Arbitrage: China's Coal Import Behavior and Implications for the Global Market

channels, such as the selling of stolen goods, certain drugs, or unregistered handguns. In the context of the Chinese coal industry, the grey market is often supplied by so-called “illegal” coal mines that almost always operate with adequate recognition of local governmental officials. Currently, national coal production in China equals the sum of coal output in all provinces and autonomous regions. While one would expect that a similar relation holds for national coal consumption, it is actually not the case in China. According to *China Energy Statistical Yearbook*, the summation of coal consumption in all Chinese provinces and autonomous regions is significantly higher than national coal consumption data reported by the NBS in recent years.

Figure 12: Unexplainable Coal Consumption at Provincial Level in China



Note: As a percent of national coal output in a specific year = (unexplained coal consumption at provincial level in China) / (original national coal output reported by the NBS in respective year). Data for 1991 to 1994 are interpolated according to 1990 and 1995 figures. Source: NBS (various years-b).

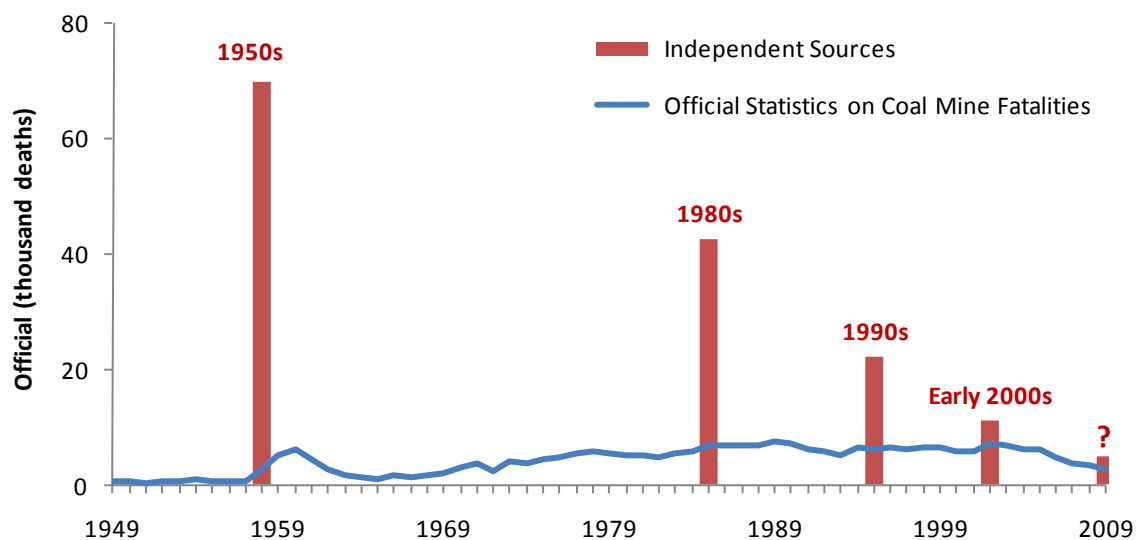
Taking coal imports/exports, storage change, and losses in coal washing and dressing into consideration, Figure 12 shows that unexplained amounts of coal consumption at the provincial level have increased rapidly since 1990 and first peaked at 561 Mt in 2001, when underreporting of coal statistics was officially recognized. Since then, the grey picture of coal statistical distortion in China has only improved marginally up until 2005 and then rebounded sharply thereafter, reaching 512 Mt in 2008. As a result, grey markets may still account for up to 18 percent of the national coal output originally reported by the NBS in 2008.

Similarly, coal mine safety statistics are full of controversy in China. According to official statistics, more than 250,000 coal miners have died in China’s numerous mining accidents since

1949. In comparison, independent sources put much higher fatalities than official statistics, though the Chinese government's safety campaign has significantly lowered official coal mining fatality rate from 5.06 death/Mt of coal in 1999 to 0.892 death/Mt of coal in 2009.

Key driving forces underlying China's notorious coal mining safety record include heavy reliance on underground mining operations; the gaseous nature of Chinese coal mines; too many small mines; collusion between local officials and colliery owners; lack of law enforcement; lack of media monitoring; absence of local NGOs and unionization of workers; conflict of interests among key stakeholders; and more. Solutions of China's coal mine safety challenge often lie outside its coal industry. For instance, drivers such as rampant corruption and lack of sufficient media monitoring cannot be solved within the Chinese coal industry alone.

Figure 13: Coal Mining Safety in China: Official Statistics versus Independent Estimates



Source: Guo et al. (2006), Tu (2007a), Elegant (2007), Safety Bureau of Former Ministry of Coal Industry (1998), CCII (various years), and State Administration of Work Safety.

Based on the aforementioned assessment, the author proposes several hypotheses regarding the status of China's coal statistical reporting, and it is highly recommended that the hypotheses below should be assessed with rigor by researchers, ideally with encouragement from the Chinese government:

- Since the mid-1990s, coal statistical distortion has become a systematic error in China's statistical collection system; it is caused by the existence of grey coal markets in China.

- Up to 100 to 200 Mt of coal output may be underreported in Shanxi in recent years, which needs to be corrected by the Shanxi Bureau of Statistics.
- Up to 300 to 600 Mt of coal output may be underreported at the national level in recent years, which needs to be corrected by the National Bureau of Statistics.
- The coal supply statistical revisions by the NBS in 2006 and 2010 have not fully corrected the aforementioned statistical distortion.

Currently, the size of grey markets in the Chinese coal value chain seems to have grown to dangerous levels that are too significant to be ignored; it is recommended that the Chinese government should consider assessing the current situation and fixing any inconsistency within its statistical reporting system. Otherwise, ongoing coal statistical distortion is likely to not only severely undermine China's policy initiatives on energy conservation and carbon intensity abatement in the years to come, but also to make it difficult for the international community to verify policy achievements claimed by the Chinese government.

Table of Contents

1.	INTRODUCTION.....	1
1.1	<i>Historical Evolvment of the Chinese Coal Industry</i>	2
1.2	<i>Current State of Government Policy and Regulations</i>	3
1.3.1	Review of the 11th Five Year Plan (FYP)	3
1.3.2	Outlook of the 12th Five Year Plan	3
1.3.3	Review of Coal Industry Policy	4
1.3	<i>Report Structure</i>	6
2.	COAL SUPPLY.....	7
2.1	<i>Coal Resources and Reserves</i>	7
2.2	<i>Coal Production</i>	10
2.2.1	Historical Production.....	10
2.2.2	Coal Production Bases	11
2.3	<i>Industry Structure and Organization</i>	13
2.3.1	Type of Enterprises	13
2.3.2	Cost Comparison of Different Producers	15
2.4	<i>The Role of Government.....</i>	16
2.5	<i>Reference Coal Production Trajectory</i>	17
3.	COAL DEMAND	19
3.1	<i>Overview of Coal Consumption in China</i>	19
3.1.1	Power Generation	20
3.1.2	Iron and Steel Industry.....	23
3.1.3	Chemicals.....	24
3.1.4	Building materials	29
3.2	<i>The Role of Government.....</i>	30
3.3	<i>Reference Trajectory of Power Generation Capacity</i>	32
4.	COAL TRANSPORT.....	36
4.1	<i>Major Coal Transport Corridors in China</i>	37
4.1.1	West to East Corridor.....	39
4.1.2	North to South Corridors.....	40
4.2	<i>Coal Transport by Mode</i>	42
4.2.1	Rail	42
4.2.2	Sea Transport.....	47

4.2.3	River (Barge).....	48
4.2.4	Road (Truck)	52
4.2.5	Pipeline.....	54
4.3	<i>The Role of Government</i>	54
4.4	<i>The Future of Coal Transport in China</i>	55
5.	GREY MARKETS AND COAL STATISTICAL DISTORTION.....	57
5.1	<i>Introduction to Shanxi and its Coal Industry</i>	58
5.2	<i>Grey Markets and Coal Statistical Distortion</i>	59
5.3	<i>Hypotheses</i>	65
6.	THE FUTURE OF COAL IN CHINA AND THE CLIMATE FACTOR.....	65
6.1	<i>Background</i>	65
6.2	<i>China's Carbon Intensity Abatement Approach</i>	66
6.3	<i>Summary and Recommendation for Future Research</i>	67
	REFERENCES	69
	APPENDIX A: CHRONICLE OF THE CHINESE COAL INDUSTRY	73

List of Tables

Table 1-1: Coal Industry Policy in China	5
Table 2-1: Coal Resources and Reserves in China at the End of 2006 (Gt)	8
Table 2-2: List of 13 Coal Production Bases in China	12
Table 2-3: Coal Production Cost Breakdown by Type of Enterprises in Shanxi (yuan/tonne)	15
Table 3-1: Energy Intensities of Key Chinese Iron and Steel enterprises (kgce/tonne)	24
Table 3-2: List of Major CTL Projects in China.....	27
Table 3-3: Demand and Governmental Targets for the Chinese Electricity Industry	33
Table 4-1: Coal Throughput at the Three Coal Transport Routes (Unit: Mt).....	39
Table 4-2: Overview of the Linkage between the N7 Ports and Railways	41
Table 4-3: Freight Transport Composition of Chinese Railways	43
Table 4-4: Railways Owned by Shenhua Group.....	46
Table 4-5: Selected Major Inland Coal Ports in China	50
Table 4-6: Coal Throughputs by Road during the 10th FYP Period (Mt)	52

List of Figures

Figure 2-1: Chinese Coal Resource Distribution Map.....	7
Figure 2-2: China's Coal Resource Distribution by Type of Coal	9
Figure 2-3: History of Fossil Fuel Production in China, 1949-2009	10
Figure 2-4: Coal Production by Type of Coal in China, 1952-2009	11
Figure 2-5: Coal Production by Enterprise Type in China, 1949-2009	14
Figure 2-6: Coal Mine Licensing Procedures	17
Figure 2-7: Reference Coal Production Trajectory in China by 2030	18
Figure 3-1: Coal Consumption by Sector in China.....	20
Figure 3-2: China's Electricity Generation by Fuel and Major Events, 1978-2010	21
Figure 3-3: Coal Consumption and Efficiency Trends at Power Plants, 1978-2009.....	22
Figure 3-4: Coke Production Composition by Type of Coke Ovens in Shanxi, 1985-2008	26
Figure 3-5: Coal, Electricity and Fuel Requirements for Different Types of Cement Kilns.....	30
Figure 3-6: Average Mine Mouth Sale Price for Coal Produced by Key SOEs in China	30
Figure 3-7: Reference Projection for China Electricity Generation Capacity Mix 2030	34
Figure 3-8: Coal Consumption and Efficiency Trend in the Chinese Power Industry	35
Figure 4-1: Major Coal Transport Routes in China.....	38
Figure 4-2: China's Major Coastal Ports and Marine Transport of Coal	40
Figure 4-3: Coal and Coke Transport vs. Freight Tonnage in China, 1978-2009	44
Figure 4-4: China's Inter-Regional Coal Flow by Rail in 2006 (Mt)	45
Figure 4-5: Coal Throughput at Major Coastal Ports, 1984-2009	47
Figure 4-6: China's Coal Imports by Province in 2009	48
Figure 4-7: High-Class Waterways and Major Inland Ports in China.....	49
Figure 4-8: Coal Handled at Major Chinese Inland Ports.....	51
Figure 4-9: Indices of Cargo Tonnage by Transport Mode (1978 = 1.0)	55
Figure 4-10: Possible Scenario of Coal Transport by Mode in China.....	56

Figure 5-1: Coal Output of Shanxi, Inner Mongolia, and China 1949-2009	58
Figure 5-2: Statistical Revisions of China's Coal Output in 2006 and 2010.....	61
Figure 5-3: Unexplainable Coal Usage: China vs. Shanxi	62
Figure 5-4: Unexplainable Coal Consumption at the Provincial Level in China	63
Figure 5-5: Official Statistics versus Independent Estimations of Coal Mining Safety in China	64
Figure 6-1: Fuel Combustion and Carbon Emissions: China vs. the United States	66

Industrial Organization of the Chinese Coal Industry

By Jianjun Tu

1. Introduction

Coal currently accounts for about 30 percent of the world's primary energy consumption, second only to oil. In China, coal is the most dominant fuel, representing 70 percent of the country's primary energy consumption and 93 percent of its proven reserves of fossil fuels (BP 2010). In 2010, China's reported coal output of 3.24 billion tonnes (Gt) represents nearly half of world total.¹ China's heavy reliance on indigenous coal, notably for more than 80 percent of its electricity generation, brings benefits in terms of energy security (NBS various years-a). The conversion of coal to chemicals, liquid fuels, and synthetic natural gas can allow an even greater reliance on its domestic resources than possible in many other countries. Recently, the Chinese government has encouraged state-owned energy companies to invest in coal mines outside of China to secure external coal supplies that would further enhance China's energy security.

Coal has undoubtedly played a key role in China's rapid economic growth since the Chinese economy was opened to the outside world in 1978; nevertheless, the unprecedented exploitation and utilization of coal has also created enormous environmental and social challenges such as 1) coal mining wastes and land subsidence-related environmental impacts in many areas of the country; 2) severe water shortage in major coal mining regions such as Shanxi, Shaanxi, and Inner Mongolia; 3) mounting safety challenges as more than 250,000 miners² have died in China's numerous coal mine accidents since 1949; 4) bottleneck of China's transport infrastructure (especially rail); 5) deteriorating air quality in many urban centres and adjacent regions; and 6) greenhouse gas (GHG) emissions abatement pressure especially after China overtook the United States as the lead in CO₂ emissions in 2006.³

¹ National Bureau of Statistics and BP. Statistics from industrial sources suggest 3.41 Gt as coal output in 2010.

² Official statistics. Independent sources suggest much higher fatalities; see section five for detail.

³ See Figure 6-1 for detail.

Historically, China has been a net coal exporter because of a large reserve base, low labor costs, attractive export prices, and government tax incentives. In 2003, China's coal exports peaked at 94 million tonnes (Mt) with net coal exports at 83 Mt. Since then, spiking domestic coal demand coupled with the central government's restrictions on coal exports has led to a decrease in exports (NBS various years-b). In 2009, the prolonged dispute on contract thermal coal prices between China's major coal enterprises and power companies and attractively priced coal from the international markets led turned the country into a net coal importer.

The world hard coal trade is dominated by seaborne transport mode (as opposed to overland transport via rail), which accounted for 91 percent of world coal exports in 2009 (IEA 2010). Given that the volume of world seaborne coal trade is less than one third of China's annual coal production, a moderate shift of China's coal import/export balance has the potential to disrupt the international coal trade.

This study examines the industrial organization of the Chinese coal industry. The objectives of this study are to 1) comprehensively review the Chinese coal value chain and 2) identify problems and policy challenges in the Chinese coal industry.

1.1 Historical Evolvement of the Chinese Coal Industry

While planning is a key characteristic of centralized, communist economies, a plan established for the entire country normally contains detailed economic development guidelines for all regions, and the five year plans of China are a series of such economic development initiatives. As China has transitioned from a planned economy before 1978 to an increasingly market-oriented one in recent years, the name for the 11th Five Year Plan was officially changed to "guideline" instead of "plan". Nevertheless, it is still commonly referred to as a plan.

Since 1949, the governance structure of the Chinese coal industry has witnessed continual change. The former Ministry of Coal Industry (MCI) has been created and abolished, several times. Since 1978, state-owned coal mines became encumbered by heavy welfare obligations to their bloated workforces and millions of retired workers. Unable to meet the burgeoning demand for domestic coal, Beijing had to encourage private investment in the coal industry. As a result, the share of coal production by township and village enterprises (TVE) grew from 15.4 percent in 1978 to 46.2 percent in 1995 (CCII various years). In 1998, the MCI was finally abolished. With the emergence of the National Energy Administration (NEA) under the National Development and Reform Commission (NDRC) in 2008, the era of the centralized governance

for the Chinese coal industry has been permanently ended. In 2010, the creation of the National Energy Commission is yet another attempt by Beijing to nationally coordinate China's energy sector. Nevertheless, the management responsibility of the Chinese coal industry is still fragmented among many governmental agencies. See Appendix A for more detail.

1.2 Current State of Government Policy and Regulations

1.3.1 Review of the 11th Five Year Plan (FYP)

China's 11th Five Year Guidelines (or Plan), issued in March 2006, set out the objectives and overarching principles of the country's continued modernization drive between 2006 and 2010. Under the overarching guidelines, detailed plans for each sector were prepared by the relevant government departments. The 11th FYP for the coal industry was issued by the NDRC in January 2007. The plan defines major tasks of the coal industry as follows: 1) to optimize distribution of coal production capacity across different mining districts; 2) to adjust and control coal output and resource capacity; 3) to establish 13 large-scale coal production bases; 4) to nurture large-scale coal mining groups; 5) to consolidate and retrofit small- and medium-scale coal mines; 6) to encourage scientific innovations in the coal industry; 7) to improve coal mine safety; and 8) to establish resource-efficient and environmentally friendly mining districts.

The plan devotes an entire chapter to environmental impact assessment, which indicates Beijing's increasing awareness of the detrimental ecological degradation caused by coal mining activities. In addition, the NDRC set detailed control targets for coal production, mine capacity development, and small coal mine consolidation for each coal-producing province. Nevertheless, the actual national coal production level in 2008 (2,802 Mt) has already exceeded the output control targets in 2010 (2,600 Mt) set by the NDRC, which indicates the difficulty of regulating an increasingly market-oriented industry through command-and-control style plans.

1.3.2 Outlook of the 12th Five Year Plan

The essence of the 12th Five Year Plan of the Chinese coal industry is reported to be the promotion of orderly, industry-wide harmonious development with due consideration of the ecology and environment. As a result, capacity expansion is expected not to be treated as the sole target of sector development. Instead, operational efficiency should be increased to alleviate coal's environmental impacts, and the safety record needs to be further improved. The experience gained during Shanxi's coal resource consolidation is expected to be introduced to

the rest of the country. In other words, small-scale private coal mines in the rest of the country are likely to be either merged with state-owned enterprise (SOE) mines or forcefully shut down. SOE mines will be expanded to improve operational efficiency of the coal industry. Not surprisingly, production restrictions, closure of small coal mines, and sector consolidation are expected to be the three main themes of the 12th FYP.

In addition, the Chinese government plans to stabilize coal output in central China, and state investment is expected to be discontinued in regions in east China that are unsuitable for the development of large-scale coal mines. Meanwhile, closure of small coal mines will be implemented in east China.⁴ While overcapacity has become a concern for the Chinese coal industry after the 2008/09 economic slowdown (an issue that has largely subsided by 2011), coal production capacity with appropriate safety configurations remains insufficient. As a result, safety standards and enforcement are expected to be further strengthened especially for small coal mines.

1.3.3 Review of Coal Industry Policy

The Chinese government has established the rule of law as fundamental to the country's long-term transformation from state control of the economy to a market economy within a state planning framework. The legal and regulatory system for the coal industry has been reformed along these lines. A multiplicity of laws, regulations, and standards currently in force deal with six core aspects of the coal industry: 1) resource administration; 2) safety supervision; 3) environmental protection; 4) industry administration; 5) energy conservation; and 6) emissions control. However, some existing laws, regulations, and standards are considered to be out-dated. Given the rapid development of the industry, the mechanisms and capacity required ensuring effective enforcement of these laws, regulations, and standards are sometimes inadequate, which leads to severe sustainability challenges.

The multiple laws, regulations, and standards listed in Table 1-1 aim to cover all aspects of the coal value chain and deal with various environmental issues simultaneously. However, though the coverage of these laws and policies is quite extensive, the ambiguous wording and the lack of supporting economic instruments, specific regulatory standards (e.g., on point source or ambient emissions or technologies), and technical support often make them difficult to be implemented at

⁴ <http://www.china5e.com/show.php?contentid=77252> [2010-10-18]

the local government levels. Other problems with the existing laws, regulations, and standards include 1) individual policy is often governed by too many agencies (compromising the effective implementation of government policy and resulting in inadequate monitoring) and 2) insufficient support and encouragement for enabling technologies (key to the sustainable development of the Chinese coal industry).

Table 1-1: Coal Industry Policy in China

Type of Policy	Title
Laws and Regulations	Environmental Protection Law
	Atmospheric Pollution Prevention and Control Law
	Solid Waste Pollution Prevention and Control Law
	Environmental Impact Assessment Law
	Energy Conservation Law
	Circular Economy Promotion Law
	Cleaner Production Promotion Law
	Coal Law
	Mineral Resources Law
	Water and Soil Conservation Law
	Land Administration Law
Administrative Orders and Standards	Decisions of the State Council on Implementing the Scientific Development Concept to Strengthen Environmental Protection
	Opinions of the State Council on Promoting the Sound Development of the Coal Industry
	Special Regulation on Land Reclamation, Provisional Measures for Environmental Protection in the Coal Industry, Emission Standard for Pollutants from the Coal Industry
	Cleaner Production Standard for the Coal Industry, Emission Standard of Coal Bed Methane/Coal Mine Gas (trial version)
	Guideline of Environmental Impact Assessment for Coal Mining Projects.
Other Relevant Government Policies	11th Five Year Plan on the Prevention of Acid Rain and Sulphur Dioxide Pollution
	11th Five Year Plan on the Development of the Coal Industry, Coal Industry Policy
	Opinions (of the NDRC) on Emission Reductions and Energy Conservation in the Coal Industry
	Opinions (of the NDRC) on Coal Mine Methane Control and Utilization, Technical Policies for Sulphur Dioxide Emission Prevention and Control
	Opinions of the NDRC on the Experiment of Sustainable Development in the Coal Industry in Shanxi

	9th Five Year Plan on Cleaner Coal Technology and Development Outline in 2010
	Preferential Policy on Power Generation Demonstration Projects with Cleaner Coal Technologies

Source: TFSUC (2009).

1.3 Report Structure

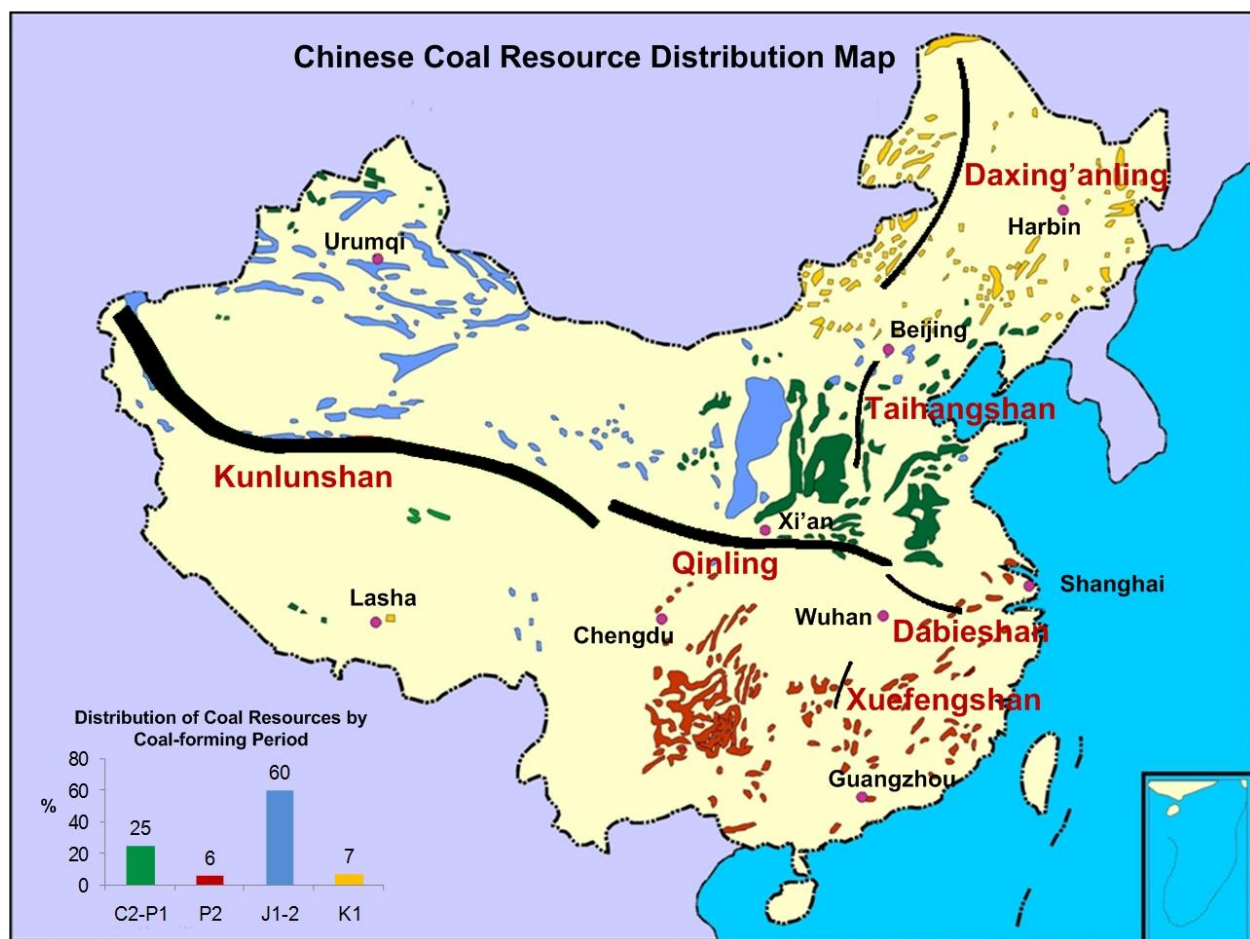
The author presents China's coal resources and reserves in section two, followed by an analysis and projection of China's coal demand to 2030 in section three. Section four details coal transportation by mode. In section five, the analysis focuses on grey coal markets and associated coal statistical distortion. In section six, China's increasing importance in the global climate change regime and the future of the Chinese coal industry are presented.

2. Coal Supply

2.1 Coal Resources and Reserves

As illustrated in Figure 2-1, 89 percent of China's gross coal resources are located in 12 provinces (or municipalities or autonomous regions) to the west of Daxing'anling-Taihangshan-Xuefengshan serial of mountain ranges; these provinces include Shanxi, Shaanxi, Inner Mongolia, Ningxia, Gansu, Qinghai, Xinjiang, Sichuan, Chongqing, Guizhou, Yunnan, and Tibet. Twenty provinces (or municipalities or autonomous regions) to the east of the above mountain ranges accounts for only 11 percent of gross coal resources in China.

Figure 2-1: Chinese Coal Resource Distribution Map



Source: Ministry of Land and Resources.

Similarly, 93.6 percent of gross coal reserves are located in 18 provinces to the north of the Kunlunshan-Qinling-Dabieshan serial of mountain ranges; these provinces include Beijing,

Tianjin, Hebei, Liaoning, Jilin, Heilongjiang, Shandong, Jiangsu, Anhui, Shanghai, Henan, Shanxi, Shaanxi, Inner-Mongolia, Ningxia, Gansu, Qinghai, and Xinjiang. Only 6.4 percent of gross coal reserves lie in 14 provinces to the south of these mountain ranges. Not surprisingly, the unbalanced resource distribution dominated by geologic conditions largely determines the pattern of coal transportation in China that generally follows routes from the north to the south and from the west to the east (TFSUC 2009).

Table 2-1: Coal Resources and Reserves in China at the End of 2006 (Gt)

Planning Area (Province/Municipalities/Autonomous Region)	No. of Mining Districts	Proven Reserves	Basic Reserves *	Prognostic Reserves*	Total Reserves *
Jing-Jin-Ji (Beijing, Tianjin, Hebei)	277	2.70	7.69	9.57	17.25
Northeast (Liaoning, Jilin, Heilongjiang)	1,208	5.45	14.45	17.57	32.03
East China (Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong)	1,440	11.01	25.38	31.17	56.54
Central South + Hainan (Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan)	1,576	8.37	15.79	17.12	32.91
Jin-Shang-Meng-Ning (Shanxi, Shaanxi, Inner Mongolia, Ningxia)	1,320	126.51	220.16	532.15	752.31
Southwest (Chongqing, Sichuan, Guizhou, Yunnan)	1,454	18.25	29.04	62.93	91.96
Xin-Gan-Qing + Tibet (Gansu, Qinghai, Xinjiang, Tibet)	690	10.25	20.98	155.80	176.77
Total Coal	7,965	182.54	333.48	826.30	1,159.78
Coking Coal		64.3	124.2	150.3	274.8

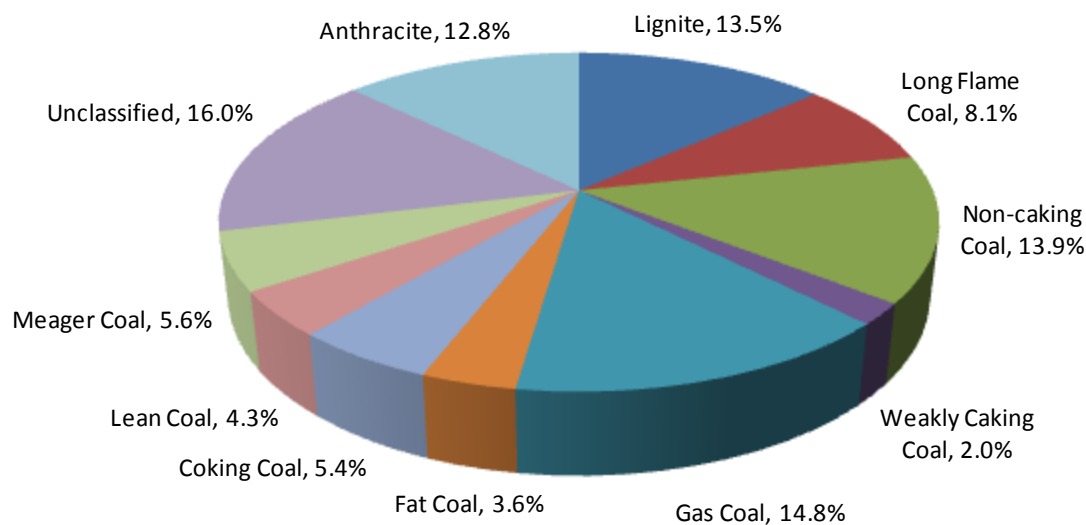
*: Resources. Note: Basic reserves are based on relatively extensive geological exploration activities; they are suitable for resource extraction in the near future or longer term. The proven coal reserves are the portion of basic reserves that can be economically recovered in the near future. Prognostic reserves are primarily based on geological inferring and modeling instead of extensive exploration activities. Total Reserves = Basic Reserves + Prognostic Reserves. Source: Huang et al. (2008) and CCTD.

China's coal resources cover a land area of 600,000 km², encompassing 6 percent of the country's 9.6 million km². There are five major coal endowment districts in China: northeast, north China, south China, northwest, and Tibet and Yunnan. The China Geological Survey reported that China's inferred coal resources total 5,555 Gt (MLR 1999). In 2006, the Ministry of Land and Resources (MLR) reported that China's total coal reserves stood at 1,160 Gt across 7,965 mining districts, comprising 334 Gt of "basic reserves" and 826 Gt of "prognostic reserves." China's coal resource classification is considered to be incompatible with international standards. BP's statistics have not updated China's proven coal reserves at 114.5

Gt for many years, which is significantly lower than the similar figure at 182.5 Gt in Table 2-1 (Huang et al. 2008, BP 2010).

Figure 2-2 shows China's coal resource distribution by type of coal.⁵ Lignite accounts for 13.5 percent of China's coal resource. Inner Mongolia and Yunnan alone possess 76.5 percent and 13.8 percent of China's lignite resources, respectively. Low-rank bituminous coals primarily concentrate on coalfields in the Erdos Basin, Datong, south Liaoning, and Xinjiang. Coking coals are primarily produced in Shanxi, Hebei, Shandong, north Jiangsu, north Anhui, Heilongjiang, Liaoning, Xinjiang, Guizhou, Sichuan, Hunan, and Jiangxi, and Shanxi alone accounts for 55 percent of China's proven coking coal reserves. Meager coal and anthracite are produced in Shanxi, Guizhou, Yunnan, south Hunan, west Beijing, Fujian, Jiangxi, Guangxi, Yunnan and Ningxia (Editorial Board of CCCI 1999).

Figure 2-2: China's Coal Resource Distribution by Type of Coal



Source: Editorial Board of CCCI (1999).

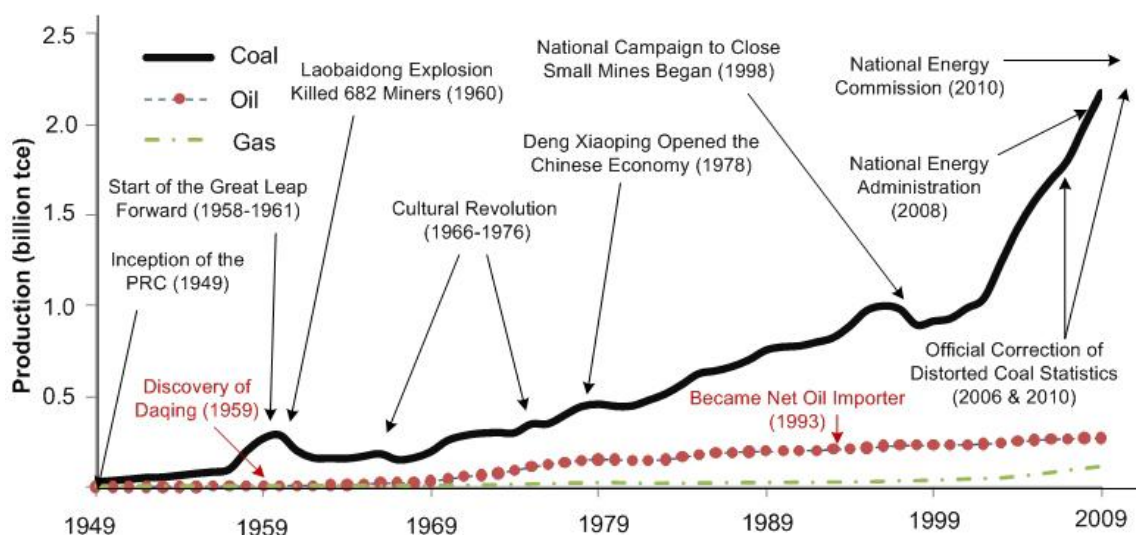
⁵ Classification of coals in China (GB/T 5751-2009 Chinese Classification of Coals) is not consistent with the international standards. For instance, ASTM D 388-2005 Standard Classification of Coals by Rank classifies coals as meta-anthracite, anthracite, semianthracite, low volatile bituminous, medium volatile bituminous, high volatile (A, B, C) bituminous, sub-bituminous (A, B, C), and lignite (A, B). In comparison, ISO 11760:2005 – Classification of Coals categorizes coals as anthracite (A, B, C), bituminous (A, B, C, D), sub-bituminous (A), and lignite/brown coal (B, C).

2.2 Coal Production

2.2.1 Historical Production

There are only 13 major coal mining districts or coalfields in China that are suitable for surface mining operations, and coal suitable for surface mining represents only 4.1 percent of China's ensured reserves.⁶ In the mid-1990s, surface mining accounted for only about 3 percent of national coal production (Wu 1996). This ratio increased slightly to 4 percent in 2001 (Fan et al. 2003) and about 5 percent to 8 percent in recent years. Though the Chinese government encourages the development of large-scale surface mines, coal output from surface mines are unlikely to exceed 10 percent of national production in the near future due to resource constraints.

Figure 2-3: History of Fossil Fuel Production in China, 1949-2009



Note: Coal output data between 1999 and 2004 was first revised by the National Bureau of Statistics in 2006. Coal output data between 1997 and 2008 were revised again by the same agency in 2010. Production unit is tce (tonnes of coal equivalent), 1 tce = 29.31 GJ. Source: NBS (various years-b) and CCTD.

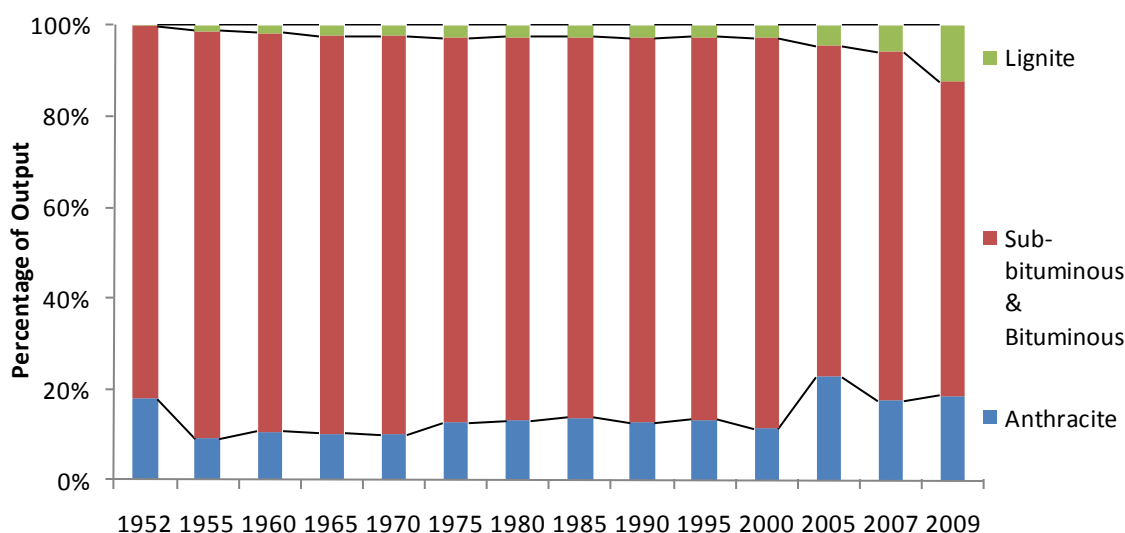
As illustrated in Figure 2-3, coal has been China's most dominant fossil fuel since the inception of the PRC in 1949 when coal accounted for 99.2 percent of China's fossil fuel output. In 1978, coal's share of China's total fossil fuel production was lowered to 72.6 percent due to the rapid development of the oil industry in the past decade. In 1990, the baseline year of the Kyoto

⁶ <http://kbs.cnki.net/forums/50150/ShowThread.aspx> [July 1, 2009].

Protocol, coal represented 78 percent of China's total fossil fuel output. In 2009, coal's share of China's total fossil fuel production has rebounded to 85 percent due to 1) the loss of oil self-reliance in 1993 making energy security a primary concern for Chinese decision makers (greatly benefiting domestically abundant and low-cost coal) and 2) the economic boom in the past three decades (requiring enormous amounts of energy that are difficult to meet by any alternative energy production, transport, and distribution infrastructure other than coal).

Figure 2-4 presents China's coal production by type of coal. Anthracite is primarily used in the fertilizer and coal chemical industries in China. In 2009, anthracites accounted for 18.5 percent of national coal production. Lignite is suitable for electricity generation and coal gasification. Lignite production in China increased rapidly from 2.7 percent of national coal production in 1990 to 12.3 percent in 2009. Finally, bituminous and sub-bituminous coals accounted for 69.2 percent of national coal output in 2009.

Figure 2-4: Coal Production by Type of Coal in China, 1952-2009



Source: CNCA (2006), CCII (various years) and industrial sources.

2.2.2 Coal Production Bases

Under the 11th FYP, 13 large coal bases were planned (see Rui, Morse and He for a detailed discussion of coal-power bases in China). Together these 13 large coal bases include 98 mining districts as listed in Table 2-2. They cover a land area of 103,388 km², with rich reserves at 853 Gt of a broad range of coal types, generally of high-quality, good mining conditions, and the

ability to support large-scale mining operations and ancillary facilities. Most large-scale Greenfield coal mines in China are expected to be added in these bases. In principle, each coal base allows the existence of only one primary developer. Given that many coal mining enterprises often operate at the same coal base, the emphasis on the single developer concept indicates that resource consolidation will continuously be the overarching policy of the Chinese coal industry in the years to come. In 2010, output at these 13 coal production bases reached 2.8 Gt, accounting for 87.5 percent of national total. During the 12th FYP period, Xinjiang has been promoted from a coal reserve base as the 14th coal production base in China.

Table 2-2: List of 13 Coal Production Bases in China

Planning Zone	Coal Base	Province	Acreage (Km ²) / Reserves (Gt)	List of Mining Districts (No. of Mining District)	Major Rail Lines
Coal Export Zone	Shendong	Inner Mongolia, Shanxi, Shaanxi	9,000 / 146.6	Shendong, Wanli, Zhungeer, Baotou, Wuhai, Fugu (6)	Shen-Shuo-Huang Line, Long-Hai Line
	Shaanbei	Shaanxi	14,440 / 109.8	Yunshen, Yuheng (2)	Zhengzhou-Xi'an Section of Long-Hai Line, Hou-Xi Line, Xi'an-Nanjing Line, Xi-Kang Line
	Huanglong	Gansu	3,262 / 15.7	Shanchang (inc. Yonglong), Huangling, Xun Yao, Tongchuan, Pubai, Chenghe, Hancheng, Huating (8)	Ning-Xi Line
	Jinbei	Shanxi	5,278 / 58.0	Datong, Pingshuo, Shuonan, Xuangang, Hebaopian, Lanxian (6)	Da-Qin Line, Feng-Sha-Da Line, Ji-Tong Line
	Jinzhong	Shanxi	8,372 / 917	Xishan, Dongshan, Fenxi, Huozhou, Liliu, Xiangning, Huodong, Shixi (8)	Shi-Tai Line, Tai-Jiao Line
	Jindong	Shanxi	8,209 / 76.7	Jincheng, Lu'an, Yangquan, Wuxia (4)	Hang-Chang Line, Tai-Jiao Line
	Mengdong (Northeast)	Inner Mongolia, Northeast	11,723 / 68.4	Zalainuoer, Baorixile, Yimin, Dayan, Huolinhe, Pingzhuang, Baiyinhua, Shengli, Fuxin, Tiefu, Shenyang, Fushun, Jixi, Qitaihe, Shuangyashan, Hegang (16)	Bin-Sui Line, Sui-Jia Line
	Ningdong	Ningxia	1,100 / 8.8	Shizuishan, Shitanjing, Lingwu, Yuanyanghu, Hengcheng, Weizhou, Majiatan, Jijiajing, Mengcheng (9)	Ning-Xi Line
Coal Import Zone	Lianghuai	Anhui	6,863 / 27.1	Huainan, Huaibei (2)	Jing-Hu Line, Huai-Nan Line
	Luxi	Shandong	4,500 / 18.6	Yanzhou, Jining, Xinwen, Zaozeng, Longkou, Zibo, Feicheng, Juye, Huanghebei (9)	Jing-Hu Line, Yan-Shi Line
	Henan	Henan	7,794 / 19.4	Hebi, Jiaozuo, Yima, Zhengzhou, Pingdingshan, Yongxia (6)	Zhengzhou-Guangzhou Section of Jing-Guang Line, Luoyang-Shimen Section of Jiao-Liu Line

Planning Zone	Coal Base	Province	Acreage (Km ²) / Reserves (Gt)	List of Mining Districts (No. of Mining District)	Major Rail Lines
	Jizhong	Hebei	2,556 / 6.5	Fengfeng, Handan, Xingtai, Jingxing, Kailuan, Yuxian, Xuanhuaxiahuayuan, North Xhangjiakou, Pingyuan Large Coal Fields (9)	Shijiazhuang-Guangzhou Section of Jing-Guang Line
Self-Reliance Zone	Yungui	Yunnan, Guizhou	20,191 / 43.5	Panxian, Puxing, Shuicheng, Liuzhi, Zhina, Qianbei, Laochang, Xiaolongtan, Zhaotong, Zhenxiong, Enhong, Junlian, Guxu (13)	Nan-Kun Line, Zhu-Liu Line, Qian-Gui Line

Source: Acreage and resources are based on Wu and Wang (2006) and <http://www.chinacoal.org.cn/coaljjyx/266/18786.aspx> [2011-02-11].

2.3 Industry Structure and Organization

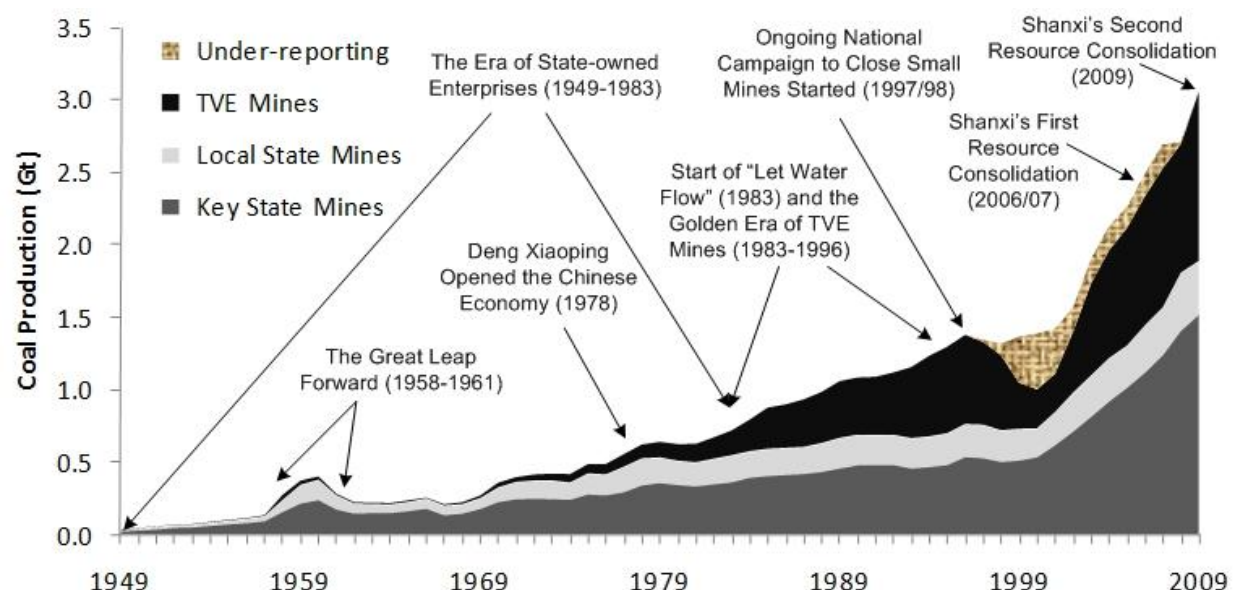
2.3.1 Type of Enterprises

There are three types of coal mines in China.

Key SOE mines, once managed by the former MCI, are currently supervised by provincial governments except for Shenhua Group and China Coal Energy Company. This group accounted for half of national coal output in 2009. Coal production and sales of Shenhua Group, the largest state-owned coal mining company in China, reached 328 Mt and 357 Mt in 2009.⁷ In comparison, Peabody Energy Corp., the world's largest private-owned coal mining company, produced only 172 Mt of coal in the same year (Peabody 2009, U.S. EIA 2009). Moreover, Shenhua's fatality rate was 0.027 death/Mt of coal in 2009, significantly lower than national average at 0.86 death/Mt of coal in the same year. Not surprisingly, the Chinese government is trying to promote the Shenhua model.

⁷ The difference was coal bought by Shenhua from other producers (e.g., TVE mines) primarily due to the latter's lack of access to rail transport network.

Figure 2-5: Coal Production by Enterprise Type in China, 1949-2009



Note: Underreporting represents coal statistical revisions made by the NBS in 2006 and 2010, which has not been disaggregated by the NBS in terms of type of coal enterprises. Source: Thomson (2003), CCII (various years), SXCOAL, and CCTD .

The numerous township and village enterprises (TVE) in the Chinese coal industry are mines invested and controlled by agricultural collective economic organizations or peasants. They have caused many regulatory challenges such as environmental degradation, tax evasion, and mining accidents; their number once exceeded 100,000 in 1991 but has been reduced significantly thereafter (CCII various years). TVE mines accounted for about 38 percent of national coal output in 2009.

Finally, local SOE mines are owned and supervised by the local instead of the central government; their market share shows a declining trend in recent years. In 2009, local SOE mines accounted for only about 12 percent of national coal output.

Due to the Chinese government's continuous policy initiatives to close small coal mines and consolidate the coal industry, the ownership boundary among different types of mines has been blurred by the establishment of joint ventures (either *de facto* or *de jure*) between SOE mines and private investors, which is especially applicable to local SOE mines. As a result, the statistical collection and regulations of the Chinese coal industry are expected to gradually shift away from the ownership-focused system towards a capacity-based one. The policy preference for large-

scale mines with capacity above 0.9 Mt/annum has successfully increased the production share of this category from 30 percent in 1991 to 46 percent in 2008. They are expected to become increasingly dominant at the expense of small-scale mines (CCII various years).

2.3.2 Cost Comparison of Different Producers

Table 2-3 lists coal production cost breakdown by type of enterprises in Shanxi. In recent years, production costs of all types of coal enterprises increased rapidly primarily due to the growth of wages, fuel prices, royalties, and other government taxes.

Generally speaking, key SOEs have the highest production costs due to 1) relatively higher technological, environmental, and safety standards maintained by key SOE mines and 2) a bloated workforce in many key SOE mines inherited from the central planning era. In comparison, TVE mines have the lowest production costs due to 1) poor technological, environmental, and safety standards at most TVE mines; 2) lowest wage rates; and 3) common practices of underreporting coal output.

Due to TVE mines' lower production costs, they have noticeable competitive advantages against SOE mines, and TVE mines can profit with significant lower retail coal prices than SOE mines. Nevertheless, their lack of access to the national railway network has weakened their marketing ability to coal end users in remote regions.

Table 2-3: Coal Production Cost Breakdown by Type of Enterprises in Shanxi (yuan/tonne)

Type	Cost	2000	2001	2002	2003	2004	2005	2006	2007
Key SOE Mine	Average retail prices	129.26	143.23	160.42	173.57	226.68	296.2	309.58	330.65
	Unit cost and expenditure	132.16	139.74	155.7	168.26	191.96	247.6	257.63	286.88
	Raw coal production costs	69.01	72.38	80.92	85.46	121.9	156.3	159.93	179.31
	Profit	-2.9	3.49	4.72	5.31	34.72	48.6	51.95	43.77
	Taxes	2.62	2.79	3.29	3.43	3.62	6.16	6.93	7.66
Local SOE Mine	Average retail prices	61.96	78.80	103.76	109.03	107.30	206.10	195.68	
	Production costs	45.76	62.29	75.71	86.09	74.98	116.82	152.28	
	Energy costs	10.06	10.36	10.35	13.19	10.84	10.58	15.74	
	Other materials	15.70	13.28	14.18	20.48	17.51	20.24	20.24	
	Labor	17.34	26.98	27.88	29.81	30.95	30.31	29.24	
	Investment	2.66	11.67	23.29	22.61	15.68	55.68	87.05	
	Interests	4.56	2.97	2.94	4.25	6.84	11.47	1.67	
	Taxes	6.08	7.97	10.82	13.04	12.98	24.59	26.44	
	Other fees	3.67	5.00	5.94	4.98	10.00	10.00	9.24	

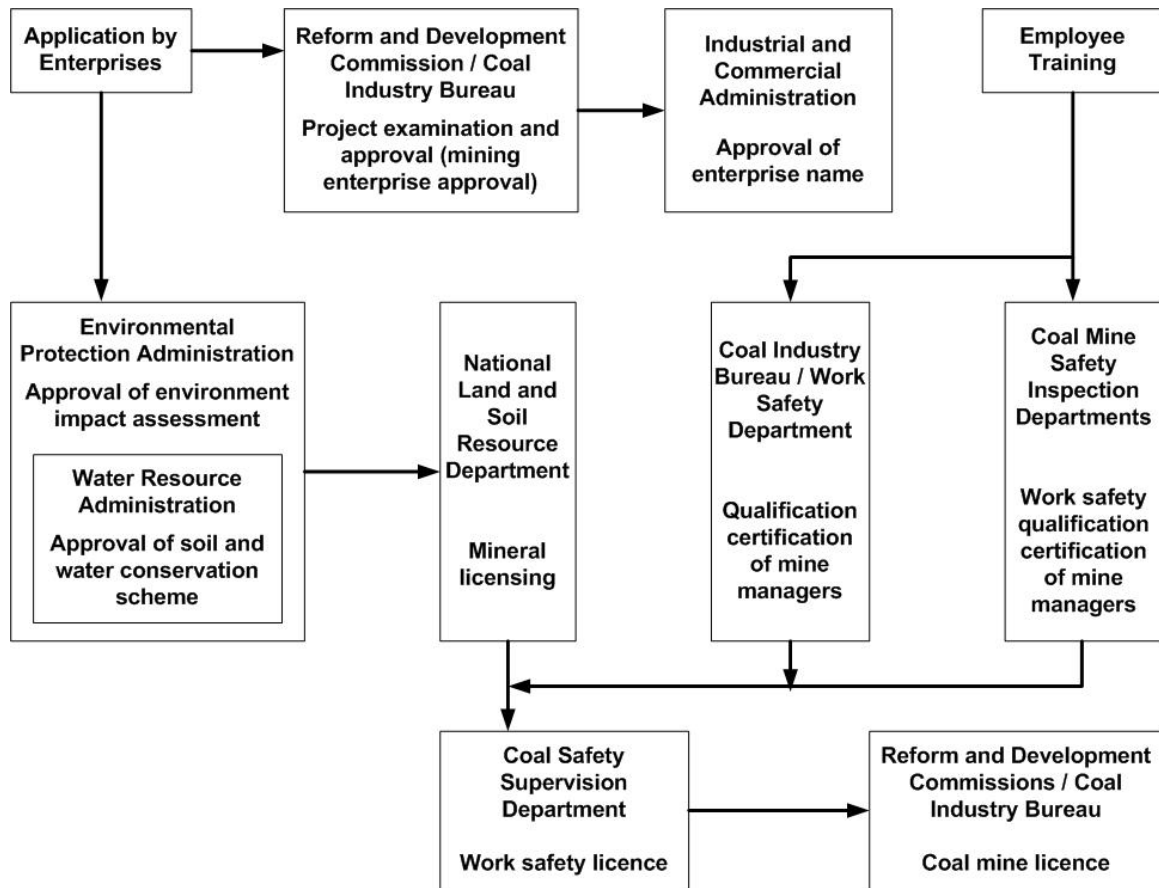
TVE Mine	Average retail prices				149.34	192.26	177.89	154.93	
	Production costs				100.03	115.63	94.03	100.15	
	Energy costs				12.24	13.67	12.00	13.23	
	Other materials				25.63	27.15	23.14	20.27	
	Labor				34.32	41.65	40.24	45.50	
	Investment				20.91	24.63	19.56	15.72	
	Interests				6.23	12.73	39.39	4.27	
	Taxes				10.55	15.16	17.53	24.52	
	Other fees				4.07	4.86	4.45	4.64	
	Expenditures for town and villages				1.53	10.76	5.59	15.13	

Source: Adapted from Wang and Horii (2008).

2.4 *The Role of Government*

Government supervision and administration of the Chinese coal industry is mainly performed through licensing and regulation of market entry, work safety, trading and processing, and other activities in the sector, as illustrated in Figure 2-6. According to Article 24 of the Coal Law 1996 and the Rules on the Administration of Coal Mining Licenses, a coal mine must obtain a coal mining license before commencing operation. At present, coal mining licenses are mostly issued by provincial development and reform commissions or coal industry administration. Agencies responsible for licensing differ from place to place; not every province has a coal industry bureau and other agencies assume responsibility. Issuance of coal mining licenses is restricted to the provincial level; county and city agencies are responsible for only initial or partial examination of applications (IEA 2009a).

Figure 2-6: Coal Mine Licensing Procedures



Source: Adapted from Figure 3.11 at IEA (2009a).

The importance of the government regulation in the coal mining industry is also reflected in the taxes and fees imposed on coal enterprises. The production costs of Chinese coal enterprises have increased significantly in recent years due to 1) higher taxes and fees imposed on coal mining enterprises; 2) the promotion of new pricing mechanisms for the acquisition of coal mining rights; 3) the establishment of the mechanism of coal mine environmental recovery deposit (a type of environmental fee); and 4) the improvements in the social insurance system for employees at industrial and commercial enterprises.

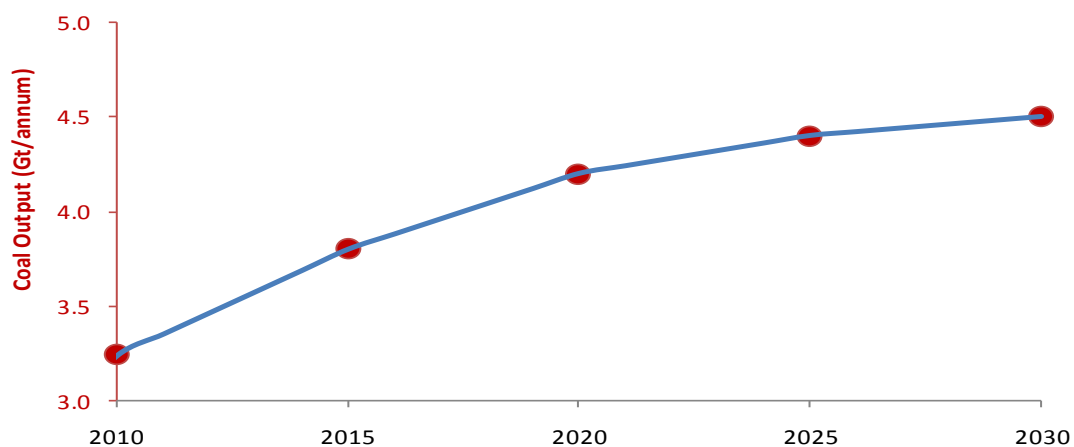
2.5 Reference Coal Production Trajectory

In the past, China appears to have maintained a short-term planning function whereby detailed projections for coal demand are provided for the coming years, but it is extremely rare to see projections for coal use in each subsector over longer time periods from official sources. Even when such information is available, benchmarking past projections with actual statistics

generally indicates very poor tracking records in terms of providing accurate and meaningful forecasts.

China is struggling to reconcile its centralized planning edict with a growing market-oriented economy with socialism characteristics. One example of central planning is the government's preference for setting coal production control targets. China's coal production control target in 2010 was set as low as 2.6 Gt in the 11th FYP for the coal industry. Over the medium to longer term, the government projections then assumed that coal consumption in 2020 will increase to 2.9 Gt (Minchener 2007). Given China's coal production has already reached 3.24 Gt in 2010, coal production control targets are likely to be revised to around 3.8 Gt by 2015 during the 12th FYP Period.

Figure 2-7: Reference Coal Production Trajectory in China by 2030



Note: Reference coal production forecast in this study is based on expert opinions solicited during the author's interview with Chinese academia and officials between 2009 and 2011 and the author's own estimation.

Figure 2-7 presents the reference trajectory of China's coal production growth by 2030. Though the Chinese government has a very strong political desire to control the national coal output level around 3.8 Gt/annum by the end of the 12th FYP period, coal output in China may be significantly higher than the reference trajectory under the following two scenarios: 1) the existence of sizable grey coal markets in China (i.e. the official coal output statistics in recent years have been seriously underreported); and 2) the Chinese government's ambitious planning targets are unable to effectively prevent a domestic coal consumption spike (similar to what happened during the 11th FYP period, when the original 2010 coal production control target of 2.6 Gt/annum was far exceeded later by an actual coal output level of 3.24 to 3.41 Gt/annum).

3. Coal Demand

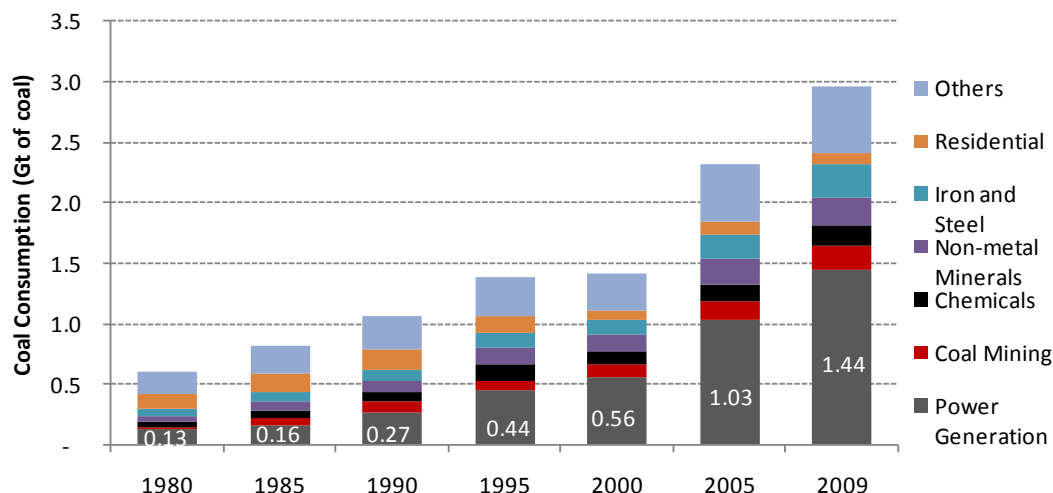
3.1 Overview of Coal Consumption in China

China first overtook the United States as the leading coal consuming country in 1986 with an annual consumption representing 21 percent of world total. Since then, China's coal demand increased by 251 percent, reaching 3.24 Gt in 2010. In comparison, global coal consumption has only grown by 55 percent during the same period. In 2010, China's coal demand accounted for 48 percent of global total and was 20 percent higher than the combined coal consumption of the remaining top 10 coal-producing countries (BP 2011).

At the inception of the PRC in 1949, coal accounted for more than 90 percent of China's primary energy consumption. Since then, this ratio gradually decreased to 86.5 percent in 1965 and 70.7 percent in 1978 due to the rapid development of the Chinese oil industry. Since the start of China's open-door policy era, coal's share of national primary energy consumption fluctuated over time, reaching 70.4 percent in 2009 (NBS various years-b).

Figure 3-1 shows China's coal consumption by sector over time. In 1980, electricity, residential, and iron and steel were the three largest coal-consuming sectors in China, accounting for 21 percent, 19 percent, and 9.8 percent of national coal consumption. In 2009, electricity, iron and steel, and non-metal minerals were the three largest coal-consuming sectors, accounting for 49 percent, 9.0 percent, and 7.9 percent of national coal demand. Since 1980, national coal consumption in China increased at 5.6 percent annually, reaching over 3 Gt in 2009. In comparison, coal consumption for power generation increased more rapidly at 8.7 percent annually during the same period, reaching 1.44 Gt in 2009.

Figure 3-1: Coal Consumption by Sector in China



Source: NBS (various years-a) and CNCA (2006).

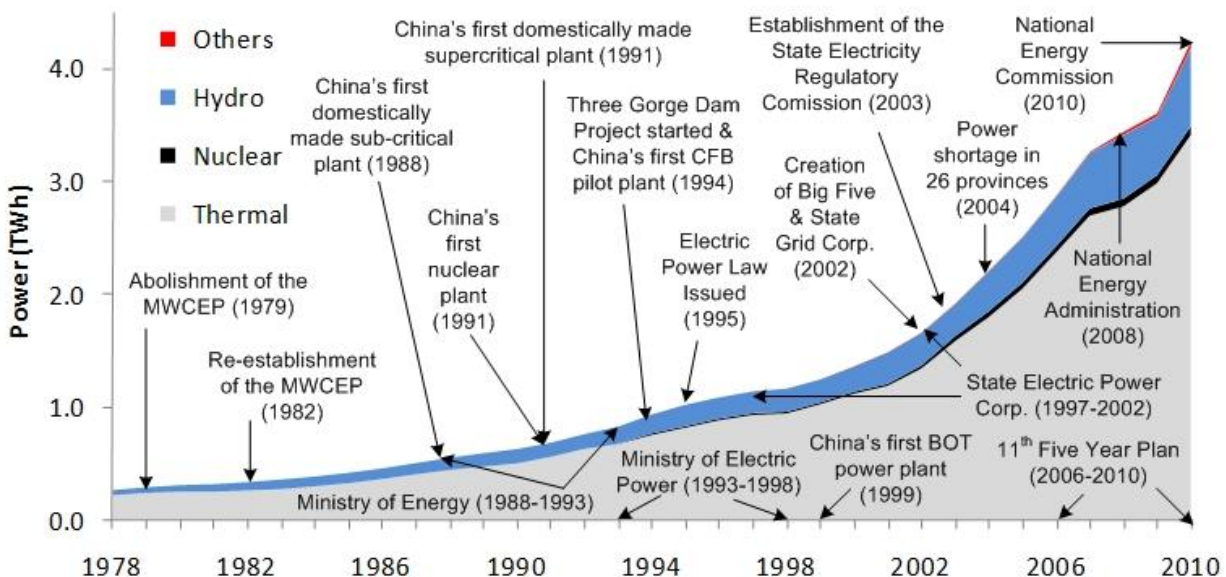
3.1.1 Power Generation

Since 1978, China's rapid economic development has propelled its power demand, growing at 9 percent annually. Due to coal's dominance in China's energy sector, the thermal power sector has grown at an almost identical pace as the power industry as a whole. Thermal power's share of national electricity generation has been maintained around 80 percent between 1978 and 2010 (NBS various years-a). In the Chinese context, the dominance of coal, the high cost of oil, and lack of available natural gas make coal-fired generation the vast majority of all thermal power (China classifies both coal and natural gas-fired power generation as thermal power).

Figure 3-2 presents coal consumed by the Chinese power sector and associated energy efficiency trends over time. Since 1978, coal consumption for power generation in China has increased at 7.6 percent annually, reaching 1.44 Gt in 2009. In comparison, thermal power increased at more than 8.9 percent annually during the same period. The lower growth rate of coal consumption can be largely explained by energy efficiency gains achieved by the power industry. For instance, average coal-fired generation efficiency in China has increased from 26 percent in 1978 to 36 percent in 2009, the equivalent of 38 percent improvement (NBS various years-a). In addition, industrial statistics show that the rate of electricity distribution loss was lowered from 9.64 percent in 1978 to 8.06 percent in 1990 and then from 7.81 percent in 2000 to 6.55 percent

in 2009, the equivalent of a 32 percent improvement on energy efficiency during the study period.⁸ If the Chinese power sector was still operating at the 1978 efficiency level, additional coal amounting to 543 Mt would have been wasted in 2009. As a result, energy conservation is expected to continue to be the top priority in the Chinese electricity industry in years to come.

Figure 3-2: China's Electricity Generation by Fuel and Major Events, 1978-2010



Source: NBS (various years-b) and CEC (various years).

The average size of new coal-fired units in China is about 500 MW, while increasingly larger units of up to 1.0 GW are commissioned that are close to state-of-the-art in their class. The rapid pace of construction, coupled with closures of small, less-efficient units, means that average power plant efficiency in China is rapidly catching up with that of developed countries. It is estimated that the average efficiency of China's coal-fired fleet is expected to approach 40 percent by 2030 (IEA 2009a).

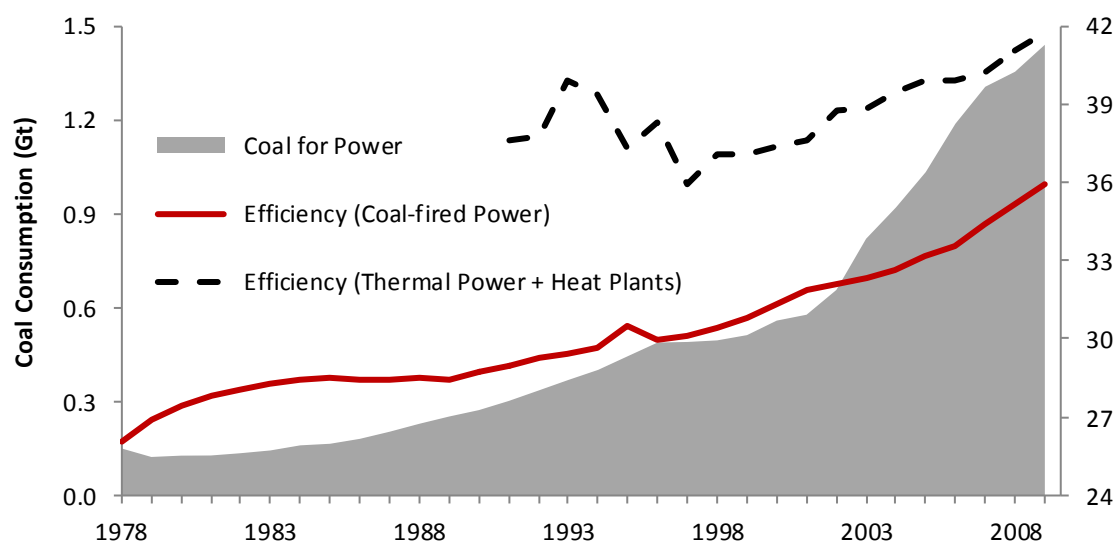
During the past decades, indigenous technological capacity of the Chinese electricity industry has become increasingly sophisticated. In October 1988, China's first domestically made subcritical power generator was commissioned at Pingwei Power Plant in Anhui. In June 1992, China's first 600 MW subcritical generator was commissioned at Shidongkou II Plant in

⁸ Source: China Electricity Council and NBS.

Shanghai. In November 2004, the first indigenous 600 MW supercritical generator started to operate at Qinbei Power Plant in Henan. In fewer than two years, China's first ultra-supercritical generator (1.0 GW) was commissioned at Huaneng Yuhuan Power Plant in Zhejiang.

In 2002, the State Council issued a Circular for the Reform Plan for the Electric Power System, which officially kicked off the "Plant-Grid Separation" reform in the Chinese electricity industry. Under this plan, the generation segment of the former State Power Corp., which included both power plants and electric grids all over mainland China, was divided into the so-called "Big Five" power generation groups: 1) China Guodian Corporation (Guodian); 2) China Datang Corporation (Datang); 3) China Huaneng Group (Huaneng); 4) China Huadian Corporation; and 5) China Power Investment Corporation (CPI).

Figure 3-3: Coal Consumption and Efficiency Trends at Power Plants, 1978-2009



Source: NBS (various years-a), CNCA (2006), Editorial Board of CEIYB (various years), and CEC (various years).

The transmission and distribution segment of the former State Power Corporation was divided into the State Grid Corporation, headquartered in Beijing with its five regional subsidiaries, and China Southern Power Grid Corporation, headquartered in Guangzhou. In addition, four auxiliary groups were established: 1) China Power Engineering Consulting Group Corporation (CPECC); 2) China Hydropower Engineering Consulting Corporation (CHECC); 3) Sinohydro Corporation (Sinohydro); and 4) China Gezhouba (Group) Corporation (CGGC).

In the generation segment of the Chinese electricity industry, competition was introduced following the Plant-Grid Separation reform in 2002. By the end of 2008, there were 4,300 electricity production enterprises in China with capacity above 6 MW, and SOE and state-held share enterprises accounted for 90 percent of the total (SERC various years).

3.1.2 Iron and Steel Industry

The Chinese iron and steel industry has expanded significantly in the past, reflecting a boom in construction and infrastructure development, as well as strong demand for consumer durables. Iron and steel outputs in China were 105 Mt and 95 Mt in 1995. Since then, they have increased by 347 percent and 425 percent, reaching 471 Mt and 501 Mt in 2008, respectively. China is currently the world's largest iron and steel producer. In comparison, Japan, the world's second largest producer, produced only 119 Mt of crude steel in 2008. In 1995, coke input to the Chinese iron and steel industry was 65 Mt. Since then, it has increased by 226 percent, reaching 255 Mt in 2008. In comparison, iron production in China has increased by 347 percent during the same period. As a result, the coke ratio at key Chinese iron and steel mills has dropped by 27 percent since 1994, reaching 392 kg of coke per tonne of iron in 2008, which indicates a significant resource efficiency gain (NBS various years-b, -a).⁹

The energy and feedstock intensity improvements witnessed by the Chinese iron and steel industry can be largely explained by 1) commissioning of large-scale state-of-the-art iron and steel mills and retrofitting of the existing ones; 2) higher levels of recycled steel production; and 3) reliance on merchant producers for coke production, since the average capacity of merchant producers has been increased significantly by the government's mandatory closure of small-scale and backward coking ovens in recent years.

Table 3-1 suggests that energy intensities of key Chinese iron and steel enterprises have improved rapidly. Between 1980 and 2008, average comprehensive energy intensity for steel production in China has improved by 62 percent. In comparison, fuel economy of major iron and steel manufacturing processes generally shows less significant improvements, which suggests that part of energy efficiency gains for steel production in China is related to increased level of steel recycling.

⁹ Additional source: Chinese Society of Metals.

Energy efficiency levels of Chinese iron and steel enterprises differ significantly with each other. While average energy intensity for steel rolling was 59 kce/t in 2008, the best operators only required half of the aforementioned energy to roll one tonne of steel. In comparison, energy consumed by the least efficient enterprise was more than 300 percent higher than an average producer. Currently, configurations of the best Chinese producers can be considered to be very close to best available techniques, and key Chinese iron and steel enterprises with the worst fuel economy performance lag far below national average standards and thus are the targets for closure, triggered by the government's mandate to improve energy intensity of the Chinese economy (Wang 2009).

Table 3-1: Energy Intensities of Key Chinese Iron and Steel enterprises (kgce/tonne)

Category	1980	1990	2000	2005	2008		
	Average	Average	Average	Average	Worst	Average	Best
Comprehensive Energy Intensity for Steel Production	1,646	1,274	920	876	783	630	557
Comparable Energy Intensity for Steel Production	1,285	1,017	781	714	842	610	504
Sintering*	105	80	69	65	91	55	39
Pelletizing*	74	63		40	49	30	17
Coking*	217	185	160	142	335	120	61
Iron Smelting*	556	526	466	456	531	428	364
Converter*	67	38	29	36	38	6	-13
Electric Furnace*	378	303	266	201	177	82	37
Steel Rolling*	266	187	118	89	238	59	27

*: Data in 1980 and 1990 are based on all iron and steel enterprises. Source: Cai et al. (2002) and Wang (2009).

3.1.3 Chemicals

Unlike in most parts of the world, coals have long been used as a dominant fuel and feedstock in the Chinese chemical industry due to resource constraints. The aggregate energy consumption in the Chinese chemical industry has increased by 87 percent since 2000, reaching 346 Mtce in 2009. During the same period, coal and coke inputs have increased by 59 percent and 86 percent, reaching 123 Mt and 21 Mt in 2009. As a result, coal and coke's share in the energy mixture of the Chinese chemical industry has been lowered from 48 percent in 2000 to 42 percent in 2009 (NBS various years-a). Considering the looming potential of coal-to-liquids (CTL) and other coal chemical development across the country, the Chinese chemical industry's reliance on coal may rebound in the future.

Currently, major end products of the Chinese coal chemical industry can be categorized under five technological routes: 1) coking; 2) coal gasification; 3) coal liquefaction; 4) coal to chemical products; and 5) coal to calcium carbide. Only coking and coal liquefaction are discussed below due to their existing scale or potential for growth in China.

Coking:

China's coke consumption spike in recent years is primarily driven by the rapid expansion of the Chinese iron and steel industry. Since 2000, coke consumption for iron and steel manufacturing in China increased by 215 percent, reaching 272 Mt in 2009. During the same period, iron and steel industry accounted for 83 percent of national coke consumption, followed by 8 percent at the chemical industry (NBS various years-a).

Compared with increasingly stringent environmental regulations and enforcement in the rest of world, the lax environmental enforcement and cheap labor in China have significantly strengthened Chinese coke producers' competitive advantage in the past. As a result, China's coke production as the percentage of world total increased rapidly from 20 percent in 1990 to about 60 percent in recent years¹⁰ and became increasingly important for international consumers. Between 2000 and 2007, coke exports from China were maintained at a level around 15 Mt/annum. Because of strong political desire for resource conservation and environmental protection, coke exports from China declined significantly to 12 Mt in 2008 and then to a mere 0.5 Mt in 2009.

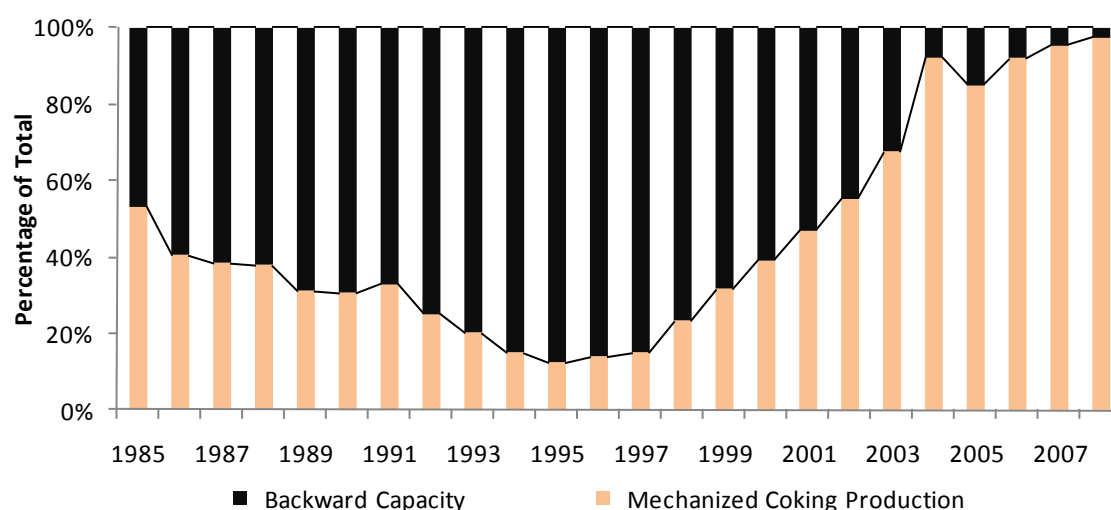
With 49 percent of China's coking coal proven reserves, Shanxi has long been China's leading coke-producing province. Between 1990 and 2009, Shanxi alone produced 32 percent of China's cumulative coke output (NBS various years-b, -a). Figure 3-4 shows coke production composition by type of coke ovens in Shanxi. In 1985, backward production capacity¹¹

¹⁰ Source: NBS (various years-a), *China Energy Statistical Yearbook*, National Bureau of Statistics, Beijing, and <http://www.resource-net.com>.

¹¹ This category includes both indigenous coke ovens and modified-indigenous coke ovens. Indigenous coke ovens are the oldest and most simple indigenous methods of making coke, with significant heat loss and pollutant emissions during the production process. Since the 1970s, the Chinese coke manufacturers have continuously made

accounted for 47 percent of coke output in Shanxi. Since then, “backward” capacity expanded rapidly and its share of provincial output peaked at 88 percent in 1995. Following the Chinese government’s ban on indigenous coke ovens in 1996, market share of backward capacity declined over time. Nevertheless, the spiking domestic demand coupled with lax enforcement especially at local levels left plenty of room for the survival and booming of backward coke manufacturers. The compulsory phase out of backward capacity in Shanxi was not targeted by the government with vigor until the early 2000s. With continuous governmental pressure for closure, the market share of backward capacity in Shanxi has eventually been reduced to a minimal level.

Figure 3-4: Coke Production Composition by Type of Coke Ovens in Shanxi, 1985-2008



Note: Backward capacity includes both indigenous coke ovens and modified-indigenous coke ovens. Source: Shanxi Bureau of Statistics (various years).

The Chinese coking industry has followed a similar trend as Shanxi. In 2001, mechanized coking ovens accounted for 72 percent of the national coke output at 131 Mt. Since then, large-scale producers have expanded their production capacity at a breakneck pace at the expense of backward coke oven operators. In 2008, market share of backward capacity was lowered to about 3 percent of the national coke output.¹² Because of the government’s continuous closure of

improved versions of coke ovens (the so-called “modified indigenous”). Though this process can improve the quality of coke product, it can still result in serious air pollution and groundwater contamination.

¹² Interview with several industrial contacts in 2009.

backward capacity, the implied resource savings are substantial. Nevertheless, given that the Chinese coking industry still lags far behind international best practice, resource conservation and environmental protection are expected to continuously be the top priority in this sector.

Coal-to-liquid (CTL):

Table 3-2 lists major CTL projects in China. Shenhua is the industrial leader in CTL development in China. In August 2004, Shenhua began the installation of the world's first commercial-scale direct coal liquefaction plant in Inner Mongolia. With an annual capacity at 1.08 Mt/annum,¹³ the first phase of this project has a price tag at 12.3 billion yuan. A trial operation of the plant in December 2008 achieved continuous operation of 303 hours. If this facility could be demonstrated as technologically viable, Shenhua is expected to expand its overall CTL capacity to 10 Mtoe/annum in the near future and 20 Mtoe/annum in the long run. In addition, a 180 kt/annum indirect CTL pilot plant was first added at the direct CTL plant site and then commissioned in 2010.

Table 3-2: List of Major CTL Projects in China

Developer	Location	Capacity (kt/yr)	Investment (billion yuan)	Process	Note
Shenhua	Inner Mongolia	1,080	12.3	Trial operation since 12/2008	One of the three direct CTL trial plant at phase one (3,240 Mt/annum in total)
Shenhua	Inner Mongolia	180	N/A	Depending on the direct CTL unit	Indirect CTL unit added to the above direct CTL process
Shenhua and Sasol	Ningxia	3,000	30	Feasibility study	Indirect CTL: the possibility for Shenhua to implement the project without Sasol
Lu'an Group	Shanxi	160	3.5	Trial operation in 12/2008	Indirect CTL: Lu'an to construct a 3 Mt/annum indirect CTL plant later and eventually expand its CTL capacity to 15 Mtoe/annum
Yitai Group	Inner Mongolia	160	2.5	Trial operation in 3/2009	The first commercial scale indirect CTL unit in China
Gun Mining Group	Shaanxi	1,000	10.5	Approved in 1/2008	Phase one: 5 Mt/annum with a price tag of 50 billion yuan; phase two: 10 Mt/annum

Source: Various Chinese media and industrial sources.

There are some important negative aspects of CTL that offset the advantages it appears to bring in terms of energy security enhancement, namely that CTL has 1) intensive water requirements

¹³ Liquid products of direct CTL plant include diesel, naphtha and LPG.

(3 to 4 tonnes of water per tonne of products for direct CTL and 4.5 to 5.5 tonnes of water for indirect CTL); 2) impacts on local air quality; 3) coal-combustion-related carbon emission and process GHG emissions; 4) substantial energy efficiency losses in the coal-to-oil conversion process, in contradiction with China's energy intensity abatement policy (3 to 4 tonnes of coal are required for direct CTL and 4.5 to 5.5 tonnes for indirect CTL to produce one tonne of liquid products); and 5) significant financial risks associated with the wide fluctuation of oil prices (8,000 to 1,100 yuan/t of capacity for direct CTL and 1,100 to 1,300 yuan/t of capacity for indirect CTL).¹⁴

Prospects of Coal Chemicals Development in China

To coordinate the development of the Chinese coal chemical industry, the NDRC developed a Draft Plan for Coal Chemical Development in China in 2006. According to this unpublished draft plan, cumulative investment of the Chinese coal chemical industry is expected to reach more than 1.0 trillion yuan between 2006 and 2020, with 50 percent expenses on equipment and 10 percent on technology development. In addition, CTL, DME for gasoline substitution, coal-to-olefin, and coal-based methanol are expected to grow to 30 Mt, 20 Mt, 8.0 Mt, and 66 Mt by 2020, respectively (NDRC 2006).

Since the circulation of the draft plan by the NDRC in 2006, the Chinese coal chemical industry has shown strong signs of overheating, with numerous CTL, DME, olefin, and methanol projects announced across the country. After the worldwide economic slowdown in late 2008, the existing coal-to-methanol capacity in China has already exceeded domestic demand especially when facing competition from gas-derived methanol from overseas markets. In addition, technological immaturity, significant financial risks, and negative environmental impacts of large-scale coal chemical development have raised doubts regarding the overly ambitious targets. As a result, this draft plan was not officially released by the NDRC and the Chinese government has become more cautious about coal chemical development.

¹⁴ <http://cccmcf.mofcom.gov.cn/aarticle/zhongyswhd/200806/20080605630580.html> [August 09, 2009].

3.1.4 Building materials

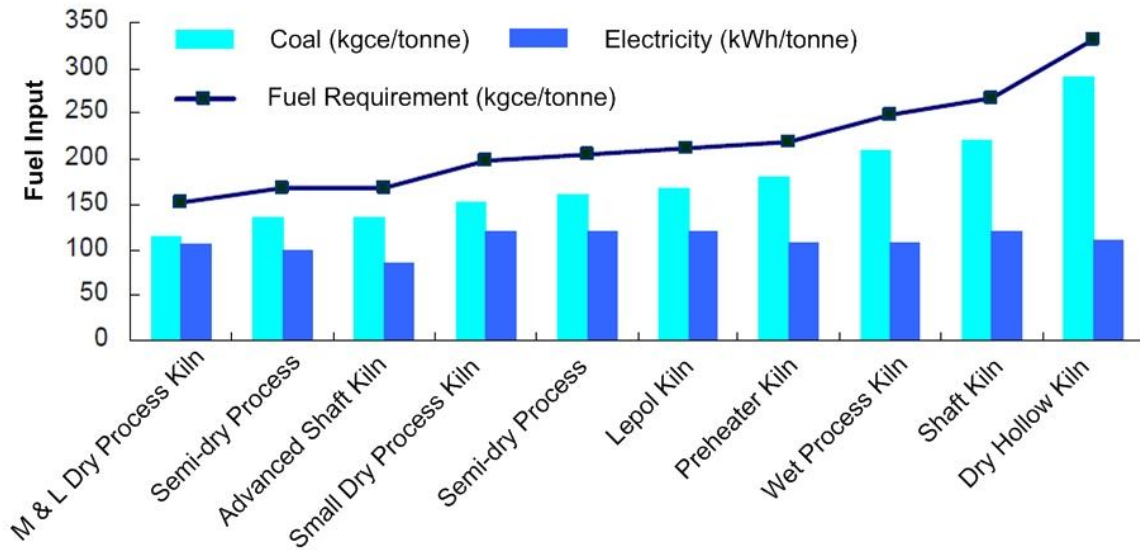
Building materials in China can be divided into 1) construction materials and products manufacturing; 2) non-metal mineral products; and 3) inorganic and non-metal mineral new materials.

Currently, China ranks No. 1 in the world in terms of cement, flat glass, and ceramics production. In 2006, coal consumption by the Chinese building materials industry reached 197 Mt, which represents 7.7 percent of national coal consumption and is the equivalent of a 13 percent growth over the 2005 level.¹⁵ Manufacturing of non-metal mineral products is the most dominant subsector. In 2006, coal consumption by this subsector accounts for 85 percent of sector total. Energy consumption of this subsector fluctuated over time but has still more than doubled since 1995, reaching 269 Mtce in 2009. In 1995, coal accounted for 73 percent of the subsector total energy consumption, which gradually decreased to 65 percent in 2009.

Cement kilns are the largest energy-consuming equipment in the Chinese building materials industry. Figure 3-5 compares energy intensity levels of various cement kilns. In most cement-producing countries, natural gas and electricity are the primary energy carriers. Due to coal's dominance in China's energy sector, coal and electricity are the primary energy sources consumed in the Chinese cement industry. Dry hollow kiln is the most inefficient type of cement kilns, with energy intensity at about 300 kgce/tonne. In comparison, medium- or large-scale dry process kilns' fuel economy performance can be as low as 150 kgce/tonne. Market share of more efficient kilns such as the dry process type has been expanded rapidly by the government's energy intensity initiatives and mandatory closure of small inefficient kilns.

¹⁵ Source: NBS and China Building Materials Network.

Figure 3-5: Coal, Electricity and Fuel Requirements for Different Types of Cement Kilns

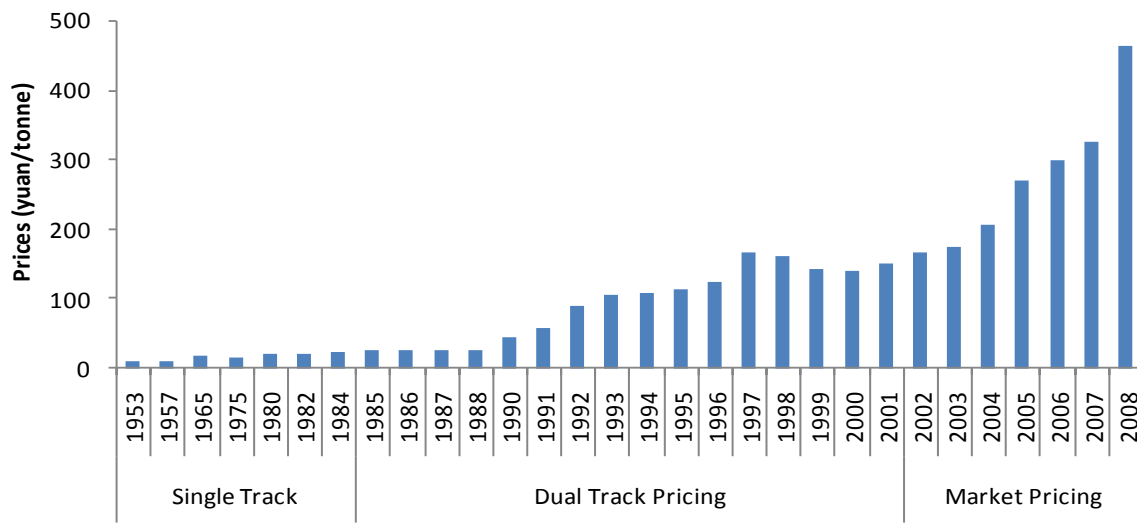


Source: China Cement Association.

3.2 The Role of Government

The government's influence on retail coal prices is one of the most important determinants of coal end uses in China. Figure 3-6 shows the historical development of average mine mouth sales price of coal produced by key state-owned enterprises in China over time.

Figure 3-6: Average Mine Mouth Sale Price for Coal Produced by Key SOEs in China



Source: Yang et al. (2009), Wang and Pan (2009), and the Energy Research Institute at NDRC.

During the transition from the planned economy, the regulation of coal prices in China underwent several major changes, described below (for a comprehensive discussion of the evolution of China's regulation of the coal market, see PESD Stanford's study by Peng Wuyuan).

Single-track pricing period (1949 - 1985): At the inception of the PRC, commodity pricing in China was dominated by the theory promoted by the former Soviet Union. According to this approach, part of value-added income in heavy industries should be realized in the light industry or other production sectors, so prices of raw materials including coal were set at arbitrarily low levels. Although coal production costs in China increased over time, coal prices were only adjusted marginally several times between 1949 and 1984; as a result, the Chinese coal mining industry ran deficit during most of this period.

Dual-track pricing period (1985 - 2002): After the Chinese economy entered a period of rapid development around 1985, energy demand in the country increased rapidly. To meet the surging coal demand, Beijing had to encourage the development of small coal mines and to deregulate prices for coal produced by TVE mines. In addition, state-owned mines were allowed to sale their above-quota output at market prices. Since 1993, the Chinese government has gradually deregulated coal retail prices in most sectors. Nevertheless, it still imposed "supervised prices" for thermal coal consumed by power plants between 1994 and 2001. During this period, average coal retail prices increased from 26.05 yuan/t in 1985 to 167.81 yuan/t in 2002.

Market-oriented pricing period (2002 - present): Following the Southeast Asia Financial Crisis, energy demand in China surged and coal prices rebounded. In 2002, the Chinese government abolished the "supervised thermal coal prices" implemented since 1994. To facilitate the thermal coal contract negotiation for utility use, the state still issued reference coal prices at the Annual Coal Trade Fair. Nevertheless, due to the immaturity of the Chinese coal market, thermal coal contract prices in 2002 and 2003 could be concluded only with extensive state intervention. In August 2004, the former State Development Planning Commission had to temporarily intervene in prices of thermal coal for utility use in Henan, Anhui, Shandong, Shanxi, and Shaanxi. Nevertheless, China still encountered a serious coal and power shortage throughout the country. To lower financial pressure of the power sector caused by spiking coal prices, the Chinese government issued the Coal-Electricity Price Linkage Mechanism in the same year (it was infrequently used in subsequent years due to political pressure to keep power prices low). In 2006, the NDRC finally allowed prices of thermal coal for utility use to be fully subject to market pricing (though numerous attempts to cap prices occurred in later years). According to the Guidelines Regarding Improving the Linkage Amongst Coal Production, Transport, and

Demand, issued by the NDRC on December 14, 2009, thermal coal contracts of power plants should be directly negotiated between coal enterprises and utilities, without state intervention, thus marking the complete deregulation of coal pricing at the central government level.

3.3 Reference Trajectory of Power Generation Capacity

Several key trends are likely to drive investment patterns in the Chinese power sector going forward. Given the Chinese government's emphasis on energy conservation and air pollution control (e.g., SO₂ emissions) during the 11th FYP period and the preference for domestically made equipment, capacity of large-scale supercritical and ultra-supercritical (USC) power plants has expanded rapidly in China. This trend is likely to continue. During the 12th FYP period, energy conservation and air pollution regulations have been continuously tightened, and a 17% GHG emissions intensity reduction target was also introduced. As a result, lower carbon fuels including renewables (especially wind), nuclear, and natural gas are planned to grow substantially in the coming decades, as shown in Table 3-3.

Table 3-3: Demand and Governmental Targets for the Chinese Electricity Industry

	Category	2005	2010	2015	2020	2025	2030
Power Demand Forecast*	GDP (trillion 2005 yuan)	18.5	31.4	45.9	64.4	88.7	118.1
	GDP Growth Rate (%)	11.2	7.9	7.0	6.6	5.9	
	Power Consumption (GWh)	2,494	4,192	6,019	8,054	10,605	13,572
	Power Consumption Growth (%)	10.9	7.5	6.0	5.7	5.1	
	Electricity to GDP Elasticity	0.98	0.95	0.86	0.86	0.86	
Hydro Target (GW)	Renewables Plan (2007)	117	190		300		
	12th Five Year Plan**			300			
Nuclear Target (GW)	2005-2020 Nuclear Plan (2007)	6.85	12.528	24.968	44.968		
	12th Five Year Plan**			50			
Wind Target (GW)	Renewables Plan (2007)	1.266	5		30		
	12th Five Year Plan**			90			
Biomass Target (GW)	Renewables Plan (2007)	2	4		24		
	12th Five Year Plan**			N/A			
Solar Target (GW)	Renewables Plan (2007)	0.07	0.3		1.8		
	12th Five Year Plan**			5.0			

Note: Cells with grey background indicate either forecast or planned government targets.

*: GDP growth rates between 2010 and 2030 are based on Li et al. (2010). Growth rates of power consumption levels by 2020 are based on forecast by the China Electricity Council. Electricity to GDP elasticity after 2020 is set as the same value of the previous FYP period.

** : Preliminary targets revealed by Chinese governmental officials during various conferences and media interview.

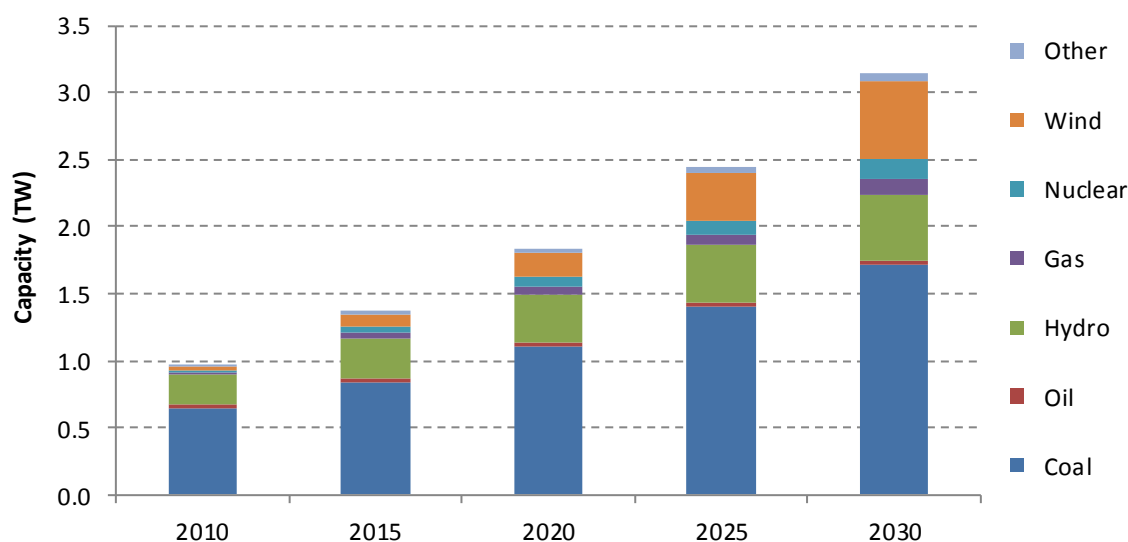
Source: China Electricity Council (CEC), NDRC, and Development Research Center of the State Council.

In this study, the reference scenario of the Chinese power sector by 2030 was simulated by the CIMS-China model,¹⁶ which was first developed by the author between 2001 and 2004 to explore the policy options to alleviate China's energy security, air pollution abatement, and climate change challenges (Tu et al. 2007). China's power consumption projection in Table 3-3 is used as the baseline input in the model, and the Chinese government's targets in the 12th FYP period have also been incorporated.

¹⁶ CIMS is an energy-economy simulation model developed by the Energy and Materials Research Group at Simon Fraser University; please refer to <http://www.emrg.sfu.ca/Our-Research/Policy-Modelling>.

Based on the update of the CIMS-China model,¹⁷ Figure 3-7 presents the reference forecast on generation capacity mixture in the Chinese electricity industry by 2030. In 2010, installed capacity of the Chinese electricity industry was 1.0 TW. To meet China's surging power demand, installed power capacity in China is expected to increase about 6 percent annually, exceeding 3.1 TW in 2030.

Figure 3-7: Reference Projection for China Electricity Generation Capacity Mix 2030



Note: Only grid-connected Greenfield power plants are included in the assessment. Source: 2010 capacity is based on data from China Electricity Council.

Among all the generation technologies, wind power is expected to show the strongest growth in percentage terms, at 16 percent annually during the study period. In comparison, installed capacity of coal-fired units is expected to expand moderately, at about 5 percent annually to meet rising domestic demand and build a sufficient reserve margin in the coming decades.

Despite the Fukushima Daiichi crisis, the nuclear share in China's electricity capacity mixture is expected to increase over time due to strong support by the Chinese government. As a result, its

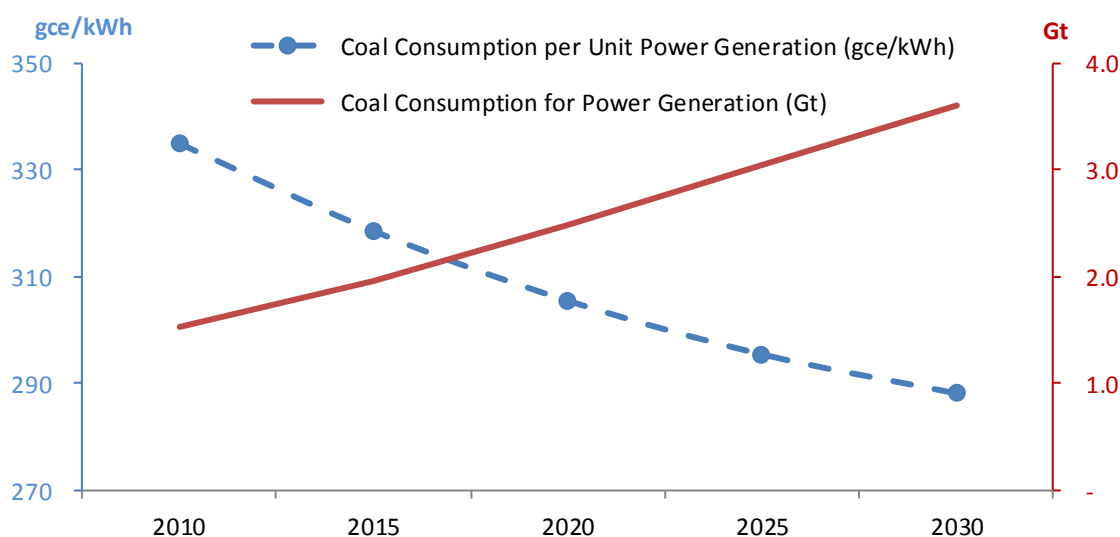
¹⁷ For more detail, please refer to 1) Bataille, C., J. Tu, and M. Jaccard (2008), Permit sellers, permit buyers: China and Canada's role in a global low-carbon society, *Climate Policy* 2008: 93-107, and 2) Tu and et al. (2007), The Application of a Hybrid Energy-Economy Model to a Key Developing Country – China, *Energy for Sustainable Development*, XI(1): 35-47.

share in total installed capacity is expected to increase from about 1 percent in 2010 to near 5 percent in 2030.

Natural gas-fired generation is projected to increase during the study period in order to 1) alleviate air pollution in the urban centers; and 2) meet peak load demand. The expected gas consumption growth is expected to be met with 1) pipeline gas imports from central Asia and Russia; 2) LNG imports in coastal China; and 3) exploration and development of domestic gas resources including unconventional plays.

In comparison, at the beginning of the 11th FYP period, China's installed oil generation capacity at about 10 GW was planned to be gradually phased out due to rising oil prices. Nevertheless, to meet energy intensity targets set by the central governments, restricting power supply has become a widespread practice at local government level by the end of 2010. As a result, diesel-fired engines have been installed across the country. If such practice continues in the future, oil-fired power generation is expected to maintain a marginal but still important role in China.

Figure 3-8: Coal Consumption and Efficiency Trend in the Chinese Power Industry



Note: This figure indicates that it is difficult to restrict China's national coal production below 4.5 Gt by 2030. "gce" on the left axis represents "grams coal equivalent".

Due to the rapid capacity addition of advanced coal units such as supercritical and ultra-supercritical power plants to China's thermal generation fleet, average coal consumption for power generation in China was simulated to fall from 335 gce/kWh in 2010 to 288 gce/kWh in

2030, the equivalent of about a 14 percent gain in efficiency within two decades. Nevertheless, the expected energy efficiency improvements alone are insufficient to retard rapid growth on coal consumption in the Chinese power sector. Figure 3-8 shows that national coal consumption for power generation in China is expected to grow by more than 4 percent annually, reaching 3.6 Gt in 2030, which suggests that China's national coal output will be difficult to cap below the reference trajectory defined in Figure 2-7.

Nevertheless, the aforementioned forecast on coal consumption is highly sensitive to assumptions about China's GDP growth rate in the coming decades. While a lower economic growth trajectory can lead to a significant drop of thermal coal consumption for power production, an rapidly growing Chinese economy will imply faster power demand growth, and thus faster coal demand growth (allowing for some gains in the efficiency of converting coal to electricity). Finally, resource constraints are considered to be one important factor underlying power generation technology composition in the Chinese electricity industry. For instance, gas-fired power capacity in China by 2030 could be significantly lower than the reference trajectory if access to gas resources is impeded by either political or technological obstacles in China.

4. Coal Transport

Rail, waterway (including inland waterway and coastal marine transport), and road are the three major transport modes to move coal in China. The characteristics of coal resource distribution and the long distance between China's major coal-producing and coal-consuming centers dictate that coal must be moved from west to east and from north to south.

Railway is by far the most important coal transport mode in China. The volume of coal and coal products moved by rail increased from 629 Mt in 1990 to 1,327 Mt in 2009, when it accounted for 48 percent of total cargo tonnage hauled by rail and 44 percent of national coal production. Water transport, especially coastal shipping from north to south, is the second largest coal transport mode. Coal throughput has increased rapidly from 78 Mt in 1990 to 949 Mt in 2009 at major coastal ports and from 63 Mt in 1990 to 374 Mt in 2009 at major inland ports (MOTC various years, NBS various years-b). In comparison, road transport has remained a supplement mode for moving coal within China, since it is used primarily for local distribution of coal.

Since 1985, coal production in China has increased by 250 percent, reaching 3.24 Gt in 2010. In comparison, growth of coal transport by rail lags far behind the national coal supply spike.

During the same period, coal transport by rail increased only by 156 percent. As a result of the severe bottleneck of the railway infrastructure, only 43.5 percent of national coal output was transported by rail in 2009, a sharp decline from the similar ratio at 59.4 percent in 1985 and 65.1 percent in 1978. In comparison, since 1985, coal and coal products transported by major coastal ports and major inland ports have increased by nearly 19-fold and more than 11-fold, respectively (MOTC various years, NBS various years-b). Not surprisingly, railway is so far the main constraint of coal transport in China.

To meet growing demand for traffic such as coal arising from the rapid booming economy, the Ministry of Transportation and Communications (MOTC) promulgated the 11th Five Year Development Plan for Road and Water Transportation in 2006. The plan seeks to 1) increase total distance of highways by 37 percent, reaching 2.3 million km in 2010, and 2) increase total length of highways in county and villages by 32 percent, reaching 1.8 million km in 2010. The above expansion is especially beneficial for small TVE mines, which rely heavily on road to truck their coal to end users due to lack of access to national railway network (LFRC 2007). Though the bottleneck of road infrastructure is expected to be eased over time, coal transport by road is likely to be increasingly constrained by costs and environmental concerns (e.g., dust emissions and air pollutant discharge of trucks).

4.1 Major Coal Transport Corridors in China

The 3-Xi¹⁸ region including Shanxi, Shaanxi, and west Inner Mongolia is China's primary coal producing region. Together with east Ningxia, the 3-Xi region supplies most of China's out-of-province coal transport volume (coal that is exported outside of the province it is produced in). Given the majority of China's coal resources lie in the 3-Xi region with major consuming centers in the distant coastal regions, two key coal transport corridors exist in China to move coal from 3-Xi region and east Ningxia to east and southeast China.

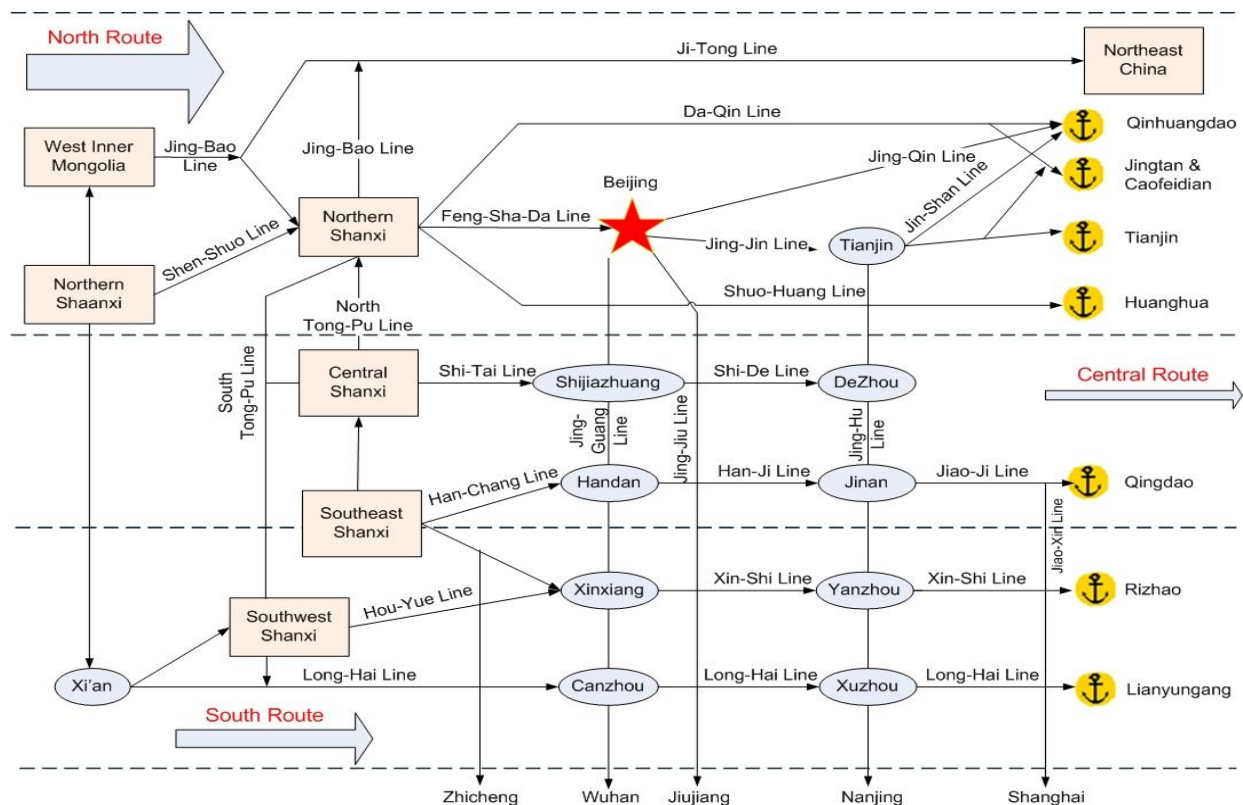
As illustrated in Figure 4-1, these two corridors include 1) the west to east coal transport corridor and 2) the north to south coal transport corridor. Coal between north and south China accounts for 75 percent of national coal transport tonnage—of which 53.5 percent of coal moves from north to south and 21.3 percent of coal moves along the south to north direction. The remaining

¹⁸ Xi in Chinese stands for “west”.

25 percent of China's total coal transport tonnage moves between west and east China—of which 21 percent moves west to east and only 4 percent from east to west (Duan 2007).

Railway transport in the 3-Xi region can be further divided into three interconnected routes: 1) the north route includes Feng-Sha-Da line, Da-Qin line, Shuo-Huang line, Jing-Yuan line, and Ji-Tong line and primarily transports coal produced in Datong, Pingshuo, Zhungeer, Hebaopian, Shenfu, Dongsheng, Wuda, and Haibowan; 2) the central route includes Shi-Tai line, Han-Chang line, and Tai-Jiao line and primarily transports coking coal and anthracite produced in Xishan, Yangquan, Jinzhong, and Lvliang and other coal produced in Lu'an, Jincheng, and Yangquan; and 3) the south route includes South Tong-Pu line, Long-Hai line, and Hou-Yue line. In addition, this route also transports small amounts of coal produced in Shaanxi through Xi-Kan line and Xiang-Yu line.

Figure 4-1: Major Coal Transport Routes in China



Source: (Sagawa et al. 2003), MOR (2008a), and interviews with Chinese academia and officials in 2009.

4.1.1 West to East Corridor

Table 4-1 details coal throughput at major rail lines in the three west to east coal transport routes in the 3-Xi region and east Ningxia. Since 2004, coal hauled by the north route increased by 83 percent, reaching 564 Mt in 2009. While the north route accounted for about 65 percent of coal throughput handled by the west to east coal transport corridor, Daqin is the most important coal rail transport route in China. Nevertheless, a bottleneck of railway infrastructure has long existed for this route, especially after coal demand in the coastal provinces spiked in the past decade. In comparison, the remaining two routes together accounted for only 35 percent of total coal throughput at the west to east corridor, thus the bottleneck of railway infrastructure has been an even more acute issue for these two routes. To tackle with the infrastructure challenge, on December 22, 2009, the construction of a dedicated coal railway between Xinxian in Central South Shanxi and Rizhao port in Shandong officially started. The 1,260 km rail line will provide coal mines in central south Shanxi an additional 200 Mt/annum transport capacity once the rail line is completed in 2014.¹⁹

Table 4-1: Coal Throughput at the Three Coal Transport Routes (Unit: Mt)

Transport Route / Line	Start	End	2004	2005	2006	2007	2008	2009
North Route			309	351	427	522	565	564
Da-Qin Line	Datong	Qinhuangdao	153	203	250	304	340	330
Shuo-Huang Line	Shenchinan	Huanghua	75	94	112	133	135	149
Jing-Yuan Line	Beijing	Yuanping	18	11	17	22	20	20
Ji-Tong Line	Jininnan	Tongliao	13	14	5	10	20	15
Feng-Sha-Da Line	Fengtai	Datong	50	30	42	53	50	50
Middle Route			67	72	76	70	76*	98*
Shi-Tai Line	Shijiazhuang	Taiyuan	61	67	69	62	68	90
Han-Chang Line	Handan	Changzhibei	6	5	7	8	8*	8*
South Route			89	109	175*	190*	210*	210*
Tai-Jiao Line	Xiuwen	Jiaozuobei	43	40	50	50	70	70
Hou-Yue Line	Houma	Yueshan	24	52	105	120	120	120
Xi-Zheng of Long-Hai	Xi'an	Zhengzhou	13	9	11	11*	11*	11*
Xi-Kang Line	Xi'an	Ankang	4	5	5*	5*	5*	5*
Ning-Xi Line	Xi'an	Nanjing	5	4	4*	4*	4*	4*
Total			465	532	678*	782*	851*	872*

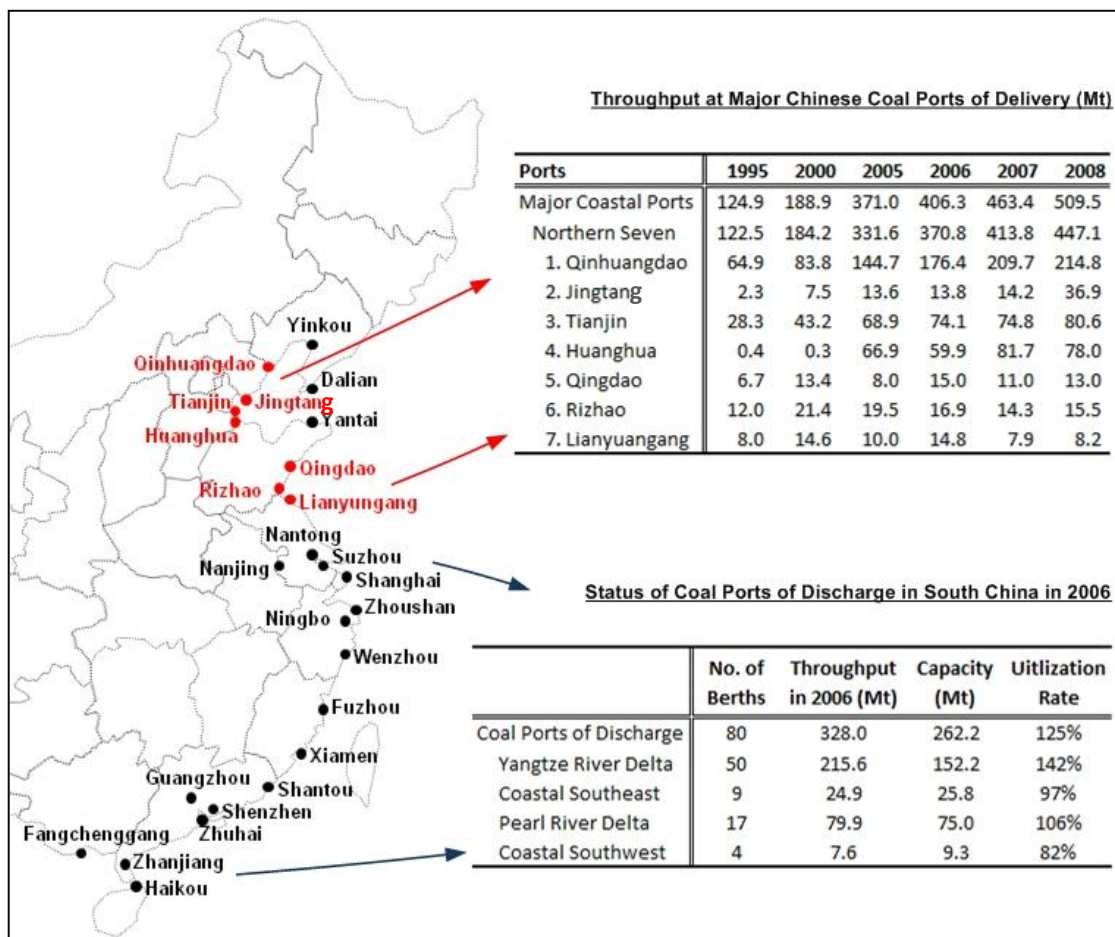
*: Estimated numbers. Starting from September 2010, Han-Chang line was under construction to expand its capacity. Source: Various industrial sources.

¹⁹ Based on Shanxi Daily, December 23, 2009.

4.1.2 North to South Corridors

Integrated rail-waterway transport is the primary mode to transfer coal from the 3-Xi region and east Ningxia to east and southeast China. The so-called “Northern Seven” (N7) ports are the primary linkage between rail lines traveling the west to east coal transport corridor and the north to south coastal marine transport corridor. According to the National Coastal Ports Layout Plan promulgated by the MOTC in 2006, the national marine coal transport network primarily consists of N7 ports for coal delivery and dedicated ports owned by utilities and public coal ports of discharge in east and southeast China.

Figure 4-2: China’s Major Coastal Ports and Marine Transport of Coal



Source: MOTC, CNCA, CCTD, and SXCOAL.

Figure 4-2 shows that the N7 ports include 1) Qinhuangdao Port in Hebei; 2) Jingtang in Hebei; 3) Tianjin Port in Tianjin; 4) Huanghua in Hebei; 5) Qingdao in Shandong; 6) Rizhao in

Shandong; and 7) Lianyungang in Shandong. They together account for about 90 percent of coal throughputs handled by major Chinese coal coastal ports of delivery, where coal is first shipped to end users. The major coal ports of discharge in China include 1) Shanghai Ports, which have 15 berths with design capacity at 45.7 Mt/annum in 2006; 2) Ningbo-Zhoushan Ports, which have 4 berths with design capacity at 34.2 Mt/annum in 2006; and 3) Guangzhou Port, which have 10 berths with design capacity at 40.5 Mt/annum in 2006.²⁰

Table 4-2 lists capacity of the N7 ports since 2006 and their primary railway connection, through which these ports are interconnected with a complex railway network in the west to east corridor. In 2006, total coal hauled by the west to east rail routes reached 693 Mt. In comparison, the aggregated throughput of the N7 ports was 447 Mt, and most cargoes were destined to end users in east and southeast China. More specifically, coal from Shanxi and Inner Mongolia is primarily transferred at Qinhuangdao and Tianjin. Coal from Shaanxi is primarily transferred at Tianjin and Huanghua. Coal from Shandong is primarily transferred at Rizhao.

Table 4-2: Overview of the Linkage between the N7 Ports and Railways

Port	Capacity (Mt)					Railway connection
	2006	2007	2008	2009**	2010**	
Qinhuangdao	193	193	193	193	193	Da-Qin line, Jing-Qin line
Tianjin	90	98	108	108	108	Huang-Wan line, Jing-Jin line
Jingtang	16	25	46	46	46	Jingtang Port line, Da-Qin line
Caofeidian*	-	-	50	50	80	Qian-Cao line, Da-Qin line
Huanghua	90	90	90	90	90	Shen-Shuo-Huang line
Qingdao	15	15	15	15	15	Jiao-Ji line
Rizhao	27	27	27	27	45	Xin-Shi line
Lianyungang	17	17	17	20	20	Long-Hai line

*: Caofeidian is often considered part of Jingtang port due to the geographic approximation.

** : Estimated capacity. Source: Interview.

Qinhuangdao is China's largest coal port of delivery and all coals in Qinhuangdao currently come from the Da-Qin line, which primarily serves mines owned by China National Coal, Shenhua, and Yitai Group in the 3-Xi region and east Ningxia. After the receipt of coal from Da-Qin, coal at Qinhuangdao is eventually sent to the following regions along the north to south

²⁰ <http://www.tadercn.com/mtxy/mtlt/hy/644361.shtml> [August 1, 2009].

marine transport corridor: 85 percent to east and southeast China (Shanghai and Zhejiang are the primary destination markets in east China), with remaining coal going to Jiangsu along the Yangtze River, and Guangzhou, Shenzhen and Fujian are the primary destination markets in southeast China, with remaining coal going to Guangxi and Shandong (Wu 2009).

The north to south inland coal transport corridor follows more complex routes: 1) major southward rail trunk lines such as Jing-Jiu and Jing-Hu can directly move coal from north China to central south and southeast China and 2) rail lines in east China can connect with ports along the Jing-Hang Great Canal to move coal along the canal region and the Yangtze River Delta. Wanzai Port, located at the intersection of Jing-Hu line, Long-Hai line, and the Jing-Hang Great Canal, thus is an increasingly important regional coal transfer hub and southward rail lines can connect with ports along the Yangtze River such as Zhicheng, Hankou, Yuxikou, and Pukou.

4.2 Coal Transport by Mode

4.2.1 Rail

At the end of 2009, the total length of Chinese railways in operation reached 85,518 km, ranking the third in the world after the United States and Russia and accounting for about 8 percent of the world total. In comparison, the freight throughput (tonne.km) handled by Chinese rail networks is estimated to represent more than a quarter of world total, which implies an overly congested traffic pattern.²¹ Table 4-3 shows the composition of freight transport by Chinese railways in terms of ownership of infrastructure. Rail freight transport in China is currently dominated by the national railway network, which accounted for 83.3 percent of freight tonnage and 93.7 percent of freight t.km in 2009. In comparison, though the share of cargo tonnage handled by local railways increased from 2.4 percent in 1978 to 7.2 percent in 2009, the share of freight t.km handled by local railways grew only from 0.2 percent in 1978 to 0.5 percent in 2009, which indicates that local railways focus their business on short-distance cargo transport. The importance of joint ventures has increased steadily over time, but their share of freight transport has not exceeded 10 percent market share.

Lack of competition in the rail sector has long made the growth of railway networks in China lag far behind the national coal output, especially in recent years. To make the situation worse, the

²¹ Statistics for China are based on data from the National Bureau of Statistics. Statistics for the rest of world are based on the World Bank's online database—World Development Indicators.

slow growth of rail line additions is especially acute in China's major coal-producing regions such as the 3-Xi region. In 2009, this region supplied about half of China's coal production but possesses only 17 percent of China's rail lines (NBS various years-b). As a result, the heavily congested railway network in major coal-producing regions has long been a bottleneck for moving coal to coastal ports in north China and end users in central south China and coastal provinces.

Table 4-3: Freight Transport Composition of Chinese Railways

	1978	1985	1995	1996	2000	2005	2006	2007	2008	2009
Freight (Gt)	1.10	1.31	1.66	1.71	1.79	2.69	2.88	3.14	3.30	3.33
National (%)	97.6	97.6	96.1	94.6	93.0	86.1	85.2	83.5	83.3	83.3
Local (%)	2.4	2.4	3.9	4.2	4.7	6.6	6.8	7.8	8.2	7.2
Joint Venture (%)	-	-	-	1.2	2.3	7.3	8.0	8.7	8.5	9.6
Freight (trillion tonnes.km)	0.53	0.81	1.30	1.31	1.38	2.07	2.20	2.38	2.51	2.52
National (%)	99.8	99.8	99.7	98.7	97.6	94.2	93.6	92.9	94.2	93.7
Local (%)	0.2	0.2	0.3	0.4	0.3	0.5	0.5	0.6	0.6	0.5
Joint Venture (%)	-	-	-	0.9	2.1	5.3	5.9	6.5	5.2	5.8

Source: NBS (various years-b).

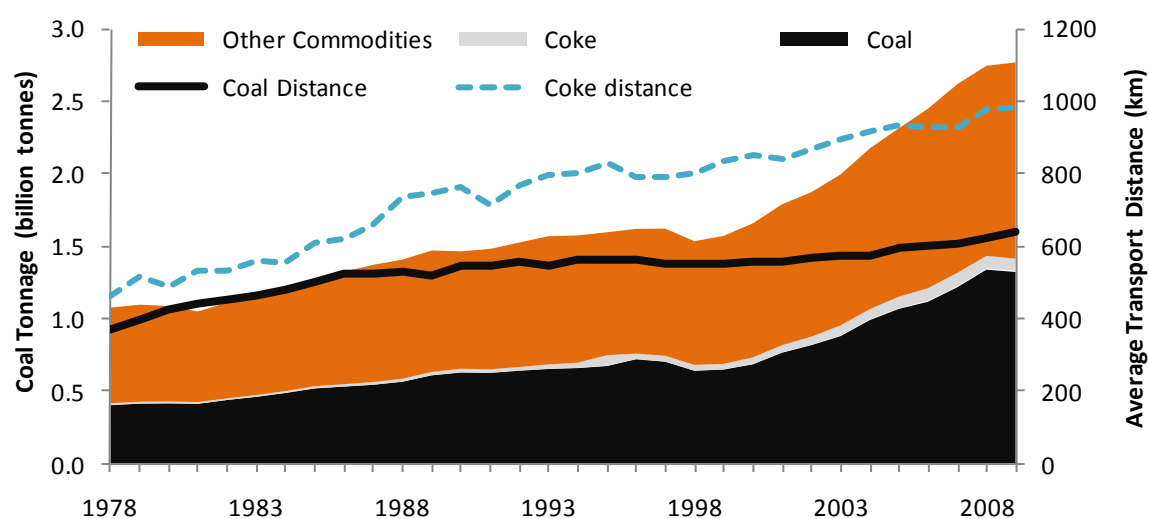
The primary driving force underlying the composition of coal transport in China is transport cost by mode. Average freight rate by rail in China has increased from 7.95 cents/t.km in 2000 to 10.31 cents/t.km in 2009²², and rail is still the most desirable mode to move large quantities of coal in China due to its large capacity, fuel efficiency, and relatively lower freight rate (especially when compared with much more expensive road transport). Rail freight rates in China are expected to increase to 15 to 20 cents/t.km by 2015 and 20 to 26 cents/t.km by 2020 (Li 2008).

To tackle over-congestion of the railway network, the construction of rail lines in China reached its heights following the promulgation of the Mid- and Long-term Railway Development Plan by the MOR in 2004. A revised plan was issued in 2008, which indicates that China will continue to extend rail coverage, improve the network structure, lift the quality of services, boost transport capacity, and upgrade equipment rapidly. The total length of Chinese railways in operation is

²² Source: CCTD.

estimated to reach 100,000 km, with passenger lines and freight lines separated for busy routes. The MOR also set the goal of having 50 percent of railways electrified and 50 percent double-tracked by 2020. According to the plan, coal rail network development was identified as a top priority. Greenfield coal rail lines are planned to be added for the central west corridor in Inner Mongolia and central south corridor in Shanxi, which are expected to serve as new high-capacity coal transport corridors for the 3-Xi region. In addition, existing coal rail lines will be expanded in 10 major coal export regions (MOR 2008b).²³

Figure 4-3: Coal and Coke Transport vs. Freight Tonnage in China, 1978-2009



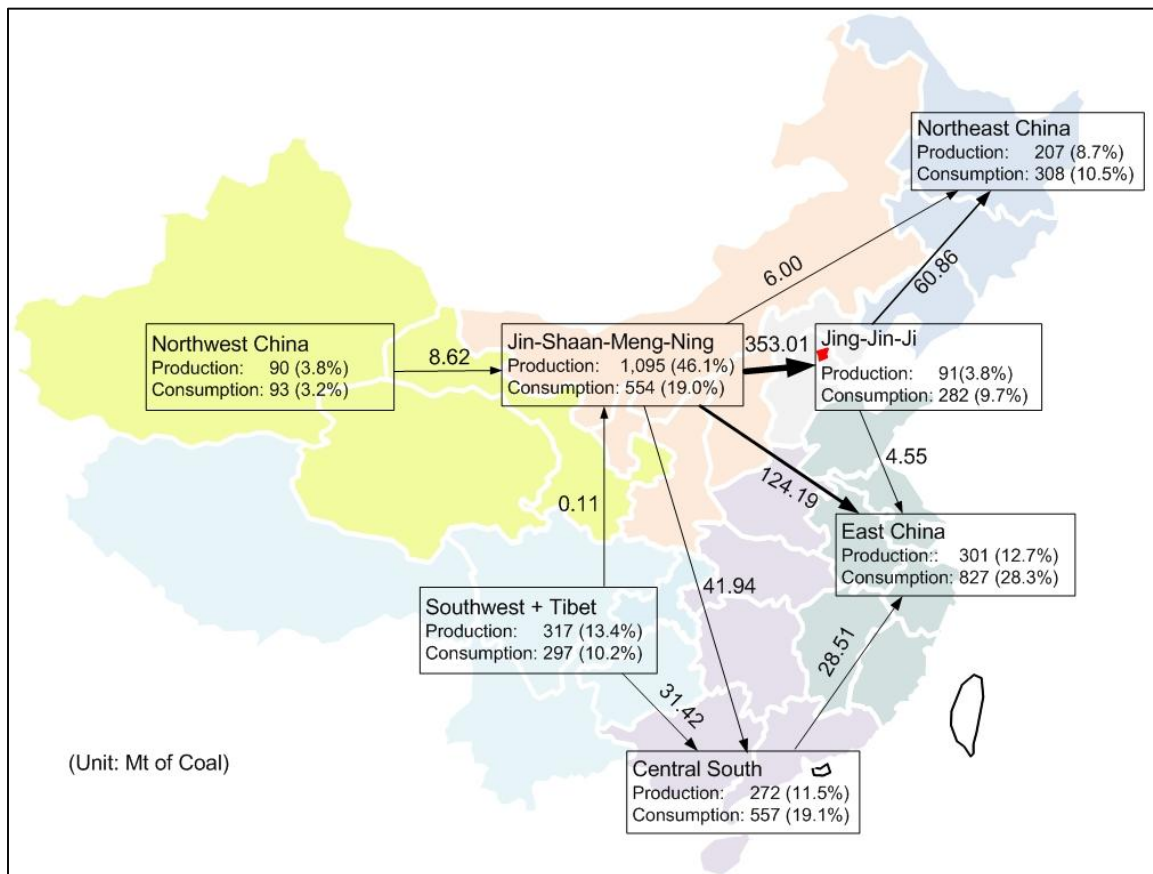
Source: NBS (various years-b).

Figure 4-3 shows the tonnage of coal and coke transported by rail over time. In 1978, the national rail network hauled 402 Mt tonnes of coal, which accounted for 37.4 percent of total tonnage handled by railway in China and 65 percent of national coal output. Since then, coal hauled by national railways more than tripled, reaching 1.343 Gt in 2008, and then declining slightly to 1.327 Gt in 2009. Due to the slower growth of coal hauled by railway compared with national coal output, coal handled by the national rail network accounts for only 44 percent of China's coal production in 2009. Nevertheless, coal's share of total cargo hauled by rail increased to 37 percent in 1978 to 48 percent in 2009. In addition, the average coal transport

²³ Datong including west Inner Mongolia, Shenfu; Taiyuan including Southern Shanxi, Southeast Shanxi, Shaanxi, Guizhou, Henan, Gunzhou, Huainan and Huaibei, East Heilongjiang and Xinjiang.

distance by national railways increased steadily from 358 km in 1978 to 639 km in 2009, which further aggravated the burdens on China's congested rail infrastructure. Local and joint venture railways play an increasingly important but still marginal role in China's rail transportation sector. In 2006, 1.39 Gt of coal was hauled by Chinese railways, with 1.12 Gt on the national network (IEA 2009a, NBS various years-b).

Figure 4-4: China's Inter-Regional Coal Flow by Rail in 2006 (Mt)



Note: Coal consumption reported at provincial level is much higher than coal production at a similar level provided by the NBS. Source: MOTC, MOR, and CCTD.

Figure 4-4 shows China's inter-regional coal flow by rail. In 2006, China's inter-provincial coal flow by rail reached 1.12 Gt, which is 63 percent higher than the 2000 level. Shanxi, Shaanxi, Inner Mongolia (especially the western part), and Ningxia (especially the eastern part) are primary coal supply and delivery centers in China. This region alone exported 525 Mt of coal to the rest of China and the international market by rail. Central south, east China, and northeast China are the primary coal recipient regions in China. In 2006, east China received 157 Mt of

coal by rail. Central south China received 73 Mt of coal by rail and sent 29 Mt to east China in the same year. In 2006, northeast China received 67 Mt of coal by rail.

In 2006, 37 percent of coal transported by rail moved less than 500 km, 45 percent moved between 500 and 800 km, 13 percent moved between 800 and 1,200 km, and only about 5 percent of coal transported by rail moved beyond 1,200 km in China. As a result, 1,200 km is the threshold of moving coal economically in China by rail (Zhang 2009).

Due to the MOR's monopoly status, the majority of Chinese railways, especially those strategically important trunk lines, are firmly controlled by the MOR. Nevertheless, there is still one exception. After Shenhua Group was founded in 1995, it was owned by the former State Development and Reform Commission. Since then, preferential treatment from the central government has allowed the company to expand at a breakneck pace, and it has become the largest coal mining company in the world. With strong state favoritism, Shenhua has even been able to break into the MOR's monopoly turf and build its own captive transportation capacity as shown in Table 4-4.

Table 4-4: Railways Owned by Shenhua Group

Railway	Year of Completion	Capacity (Mt/annum)	Length (km)	Start	End
Bao-Shen Line	March 1989	30	172	Wangshuiquan Station of Jing-Bao Line	Daliuta at Shenmu, Shaanxi
Shen-Shuo Line	1996	150	270	Daliuta at Shenmu, Shaanxi	Shuozhou in Shanxi
Shuo-Huang Line	October 2001	200	594	Shenchi S. Station at Shuozhou, Shanxi	Huanghua Port in Hebei
Da-Zhun Line	1997	45	264	Zhungeer, Inner Mongolia	Datong, Shanxi
Huang-Wang Line	October 2006	30	67	Huanghua S. Station of Shuo-Huang Line	Wangjia Port Station in Tianjin
Dong-Wu Line	March 2008	35	343	Wuhai, Inner Mongolia	Shashagetai Station of Bao-Shen Line

Source: Wang (2008).

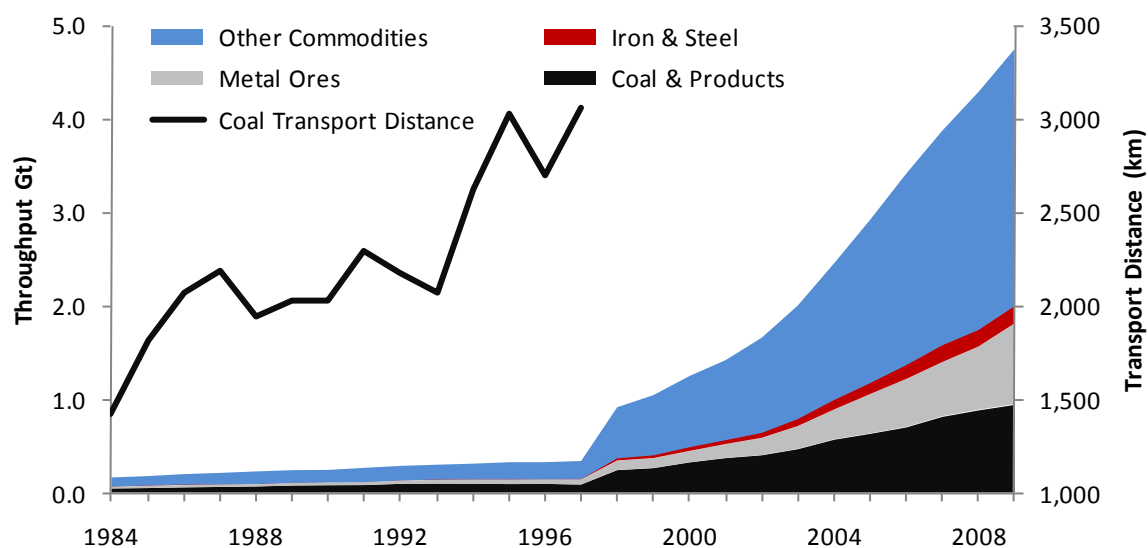
Shen-Shuo-Huang line is the Shenhua's coal transport trunk line, carrying coal produced at Shendong and Wangli coalfields, primarily to Huanghua and Tianjin. In 2007, this line hauled 136 Mt of coal, which accounted for 72 percent of Shenhua's coal transport tonnage. In addition, Huanghua port is 70 percent owned by Shenhua with the Hebei provincial government. Completed in 2006, Shenhua's Tianjin coal port (55 percent interest) has a capacity of 35 Mt.

Nevertheless, due to the MOR's monopoly status, Shenhua's success with captive coal rail line development is considered an exception in China.

4.2.2 Sea Transport

Port sector competition, unlike for rail transport, has already been introduced by the Chinese government. Figure 4-5 shows that coal and coal products transported by major coastal ports in China have increased by 12.6 percent annually since 2000, reaching 949 Mt in 2009. In comparison, national coal production grew at only about 9 percent annually during the same period. While the high growth rate of coal transport by major coastal ports is expected to be sustained by market competition, the bottleneck of coastal port capacity on coal transport will continuously be eased in the years to come.

Figure 4-5: Coal Throughput at Major Coastal Ports, 1984-2009



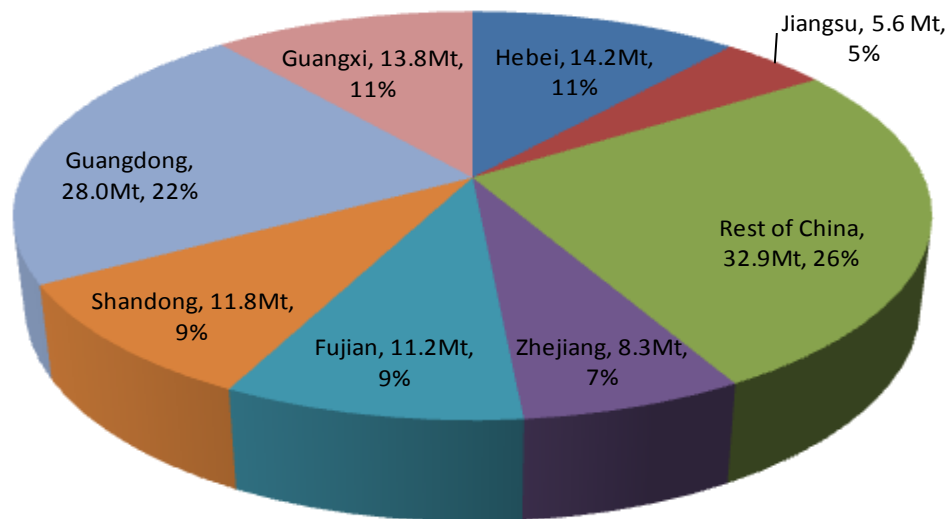
Source: NBS (various years-b).

In 2006, average freight rates of coastal marine transport were 5 to 6 cents/tonne.km, with cargo handling charges ranging from 8 to 22 yuan/tonne. Since then, freight rates of coastal marine transport increased rapidly until late 2008, when the world economy dipped into a recession. Since late 2009, freight rates of coastal marine transport started to increase again but have been volatile. Freight rates of coastal marine transport are expected to grow to 8 to 11 cents/t.km by 2015 and 10 to 14 cents/t.km by 2020. In comparison, cargo handling charges at coastal ports are projected to increase to 12 to 26 yuan/t by 2015 and 14 to 28 yuan/t by 2020 (Li 2008). Even so,

the relative cost competitiveness of different coal transport modes is expected to remain the same, with coastal marine transport the least expensive and road transport the most expensive. China's coal import export balance is an important driving force underlying coal transport at coastal ports. In the past, the N7 ports in north China not only transferred coal from 3-Xi region and east Ningxia to coastal provinces in east and southeast China but also exported large amounts of coal to the international market. With a quickly diminishing coal export levels and spiking coal imports, China first became a net coal importer in 2009.

As illustrated in Figure 4-6, coal consumers in China's coastal provinces, especially Hebei, Shandong, Fujian, Jiangsu, Zhejiang, Guangdong, and Guangxi, are expected to keep importing moderate levels of coal from overseas suppliers, which will inevitably affect coal flows among different Chinese coastal ports. In addition, China's ongoing coal imports are expected to stimulate inland waterway transport, particularly in the Yangtze River Delta and Pearl River Delta regions.

Figure 4-6: China's Coal Imports by Province in 2009



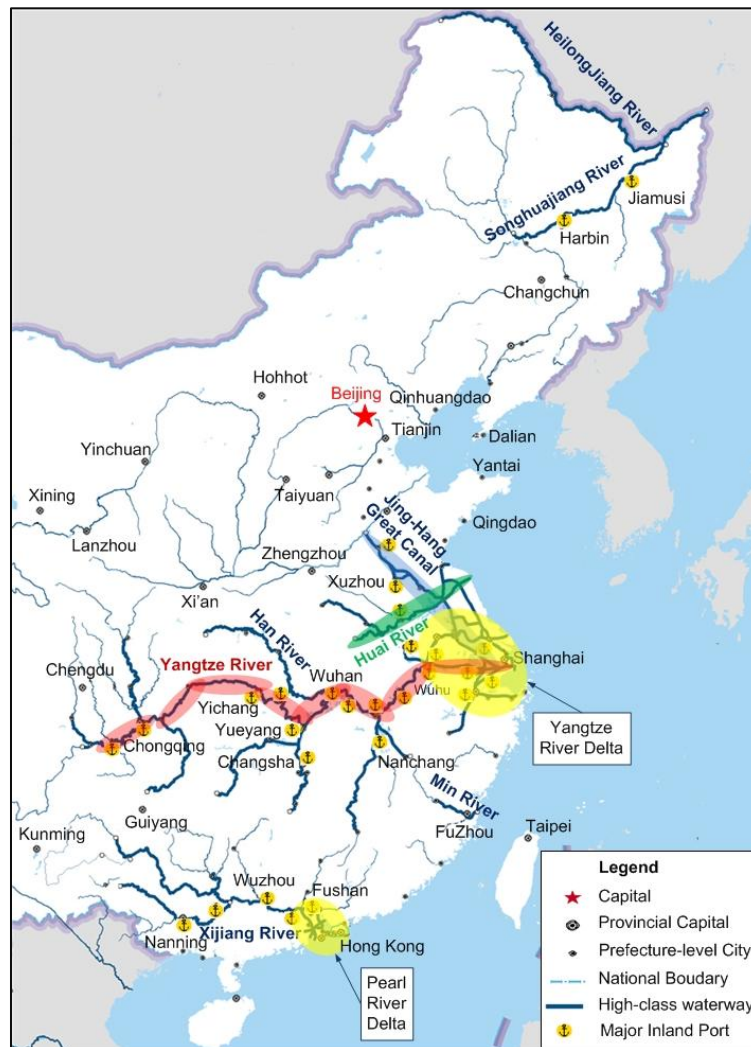
Source: China Customs.

4.2.3 River (Barge)

Transportation on the inland waterways is an important element of the domestic coal distribution system, carrying 374 Mt of coal in 2009, which accounted for approximately 12 percent of China's coal output in the same year. Currently, coal represents an important share of shipping

on the inland waterways, accounting for approximately 17 percent of total cargo tonnage (MOTC various years).

Figure 4-7: High-Class Waterways and Major Inland Ports in China



Source: MOTC.

In 2007, the MOTC announced the National Plan for Inland Waterways and Ports Layout, for the development of inland waterways and ports by 2020 (LFRC 2009). According to the layout, the development of an inland waterway network includes the following main streams as illustrated in Figure 4-7: 1) Yangtze River - In 2007, coal hauled by major ports along Yangtze River reached

179 Mt, accounting for 19.6 percent of total cargo tonnage at these ports.²⁴ 2) Beijing-Hangzhou (Jing-Hang) Grand Canal - The canal has become the most important inland waterway coal transport trunk line at the strategically important north to south coal transport corridor. 3) Yangtze River Delta - The high-class waterways network of the delta includes one of the largest cities in East China, Shanghai. 4) Pearl River Delta - In 2007 coal hauled through the Xijiang River and the Pearl River Delta reached to 4.8 and 30 Mt, respectively, accounting for 11.6 percent of inland waterway cargo tonnage in this region.²⁵ 5) The waterway network also comprises another 18 major tributaries of a number of rivers across the country.

The inland waterway coal transport network in China primarily consists of ports along the Yangtze River, Pearl River, Jing-Hang Great Canal, and Huai River. The following ports are specialized in coal transport: 1) Zhicheng, Hankou, Yuxikou, and Pukou along the Yangtze River (In 2007, 16.4 Mt of coal were transferred from railways to these ports, Zhicheng 1.27 Mt, Hankou 1.91 Mt, Yuxikou 7.56 Mt, and Pukou 5.65 Mt) and 2) Wanzhai, Pizhou, Shuanglou, and Mengjiagou along the Jing-Hang Great Canal. Spot prices at these ports have been widely used as benchmark coal prices due to their critical location to bridge China's major coal producing and consuming centers.

Table 4-5: Selected Major Inland Coal Ports in China

Port	Mainstream	Note
Zhicheng Port	Yangtze River	27 berths: The Shigu Main Port has 4 dedicated coal berths, with a capacity of handling above 3 kt dwt vessels. The capacity is expected to be increased to 15 Mt in five years.
Hankou Port	Yangtze River	250 berths: with maximum capacity of handling 5 kt dwt vessels.
Yuxikou Port	Yangtze River	China's first mechanized coal port: annual capacity at 3 Mt.
Pukou Port	Yangtze River	15 berths: with design capacity at 11.72 Mt/annum.
Wanzhai Port	Jing-Hang Great Canal	6 berths: annual capacity at 8.8 Mt with coal mixing facility.
Pizhou Port	Jing-Hang Great Canal	19 berths, 6.02 km of rail line: annual design capacity at 6.5 Mt with the maximum annual throughput of 4.38 Mt. Coal accounts for more than 95 percent throughput at this port.
Shuanglou Port	Jing-Hang Great Canal	Annual throughput has reached 3 Mt.
Mengjiagou Port	Jing-Hang Great Canal	Annual throughput has exceeded 3 Mt in 2005.

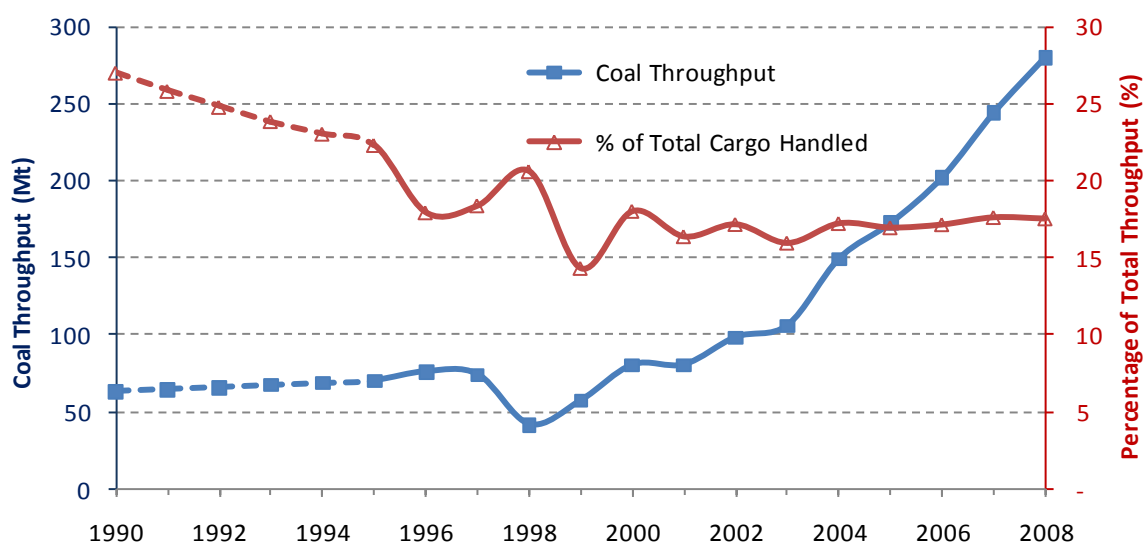
Source: CCTD, SXCOAL, tadercn.com, and Xuzhou Port Group.

²⁴ <http://www.tadercn.com/mtxy/mtlt/hy/644349.shtml> [July 15, 2009].

²⁵ <http://www.tadercn.com/mtxy/mtlt/hy/644347.shtml> [July 15, 2009].

Figure 4-8 shows that coal handled at major Chinese inland coal ports grew moderately by 17 percent between 1990 and 1997, then declined sharply by 44 percent in 1998, reaching 57 Mt in the same year, which is 34 percent lower than the 1990 level. Since then, coal handled at major Chinese inland ports rebounded strongly at 21 percent annually, reaching 374 Mt in 2009, which is 345 percent higher than the 1990 level. Nevertheless, coal's share of total cargo throughput handled at major inland ports still declined from 27 percent in 1990 to 17 percent in 2009.

Figure 4-8: Coal Handled at Major Chinese Inland Ports



Note: Data in 1991-1994 were interpolated according to 1991 and 1995 data. Source: MOC (various years).

In 2006, coal shipping rates on inland waterways were 5 to 7 cents/tonne/km with cargo handling charges ranging from 8 to 22 cents/tonne. Since then, freight rates for coal transport on the Yangtze River fluctuated widely and declined sharply in 2008, following the worldwide economic slowdown, and then rebounded strongly after July 2009.²⁶ According to Li (2008), freight rates of coal transport by inland waterway are expected to increase to 8 to 11 cents/t.km by 2015 and 10 to 14 cents/t.km by 2020, and cargo handling charges at inland ports are projected to grow to 12 to 26 yuan/t by 2015 and 14 to 28 yuan/t by 2020. Nevertheless, inland waterways will remain cost competitive to move large quantities of coal along long-distance transport corridors in China, and geographic suitability and availability of port facilities instead of freight rates are expected to be the primary constraint to sustain growth of inland waterway coal transport in China.

²⁶ Source: Changjiang River Administration of Navigational Affairs.

4.2.4 Road (Truck)

In this study, coal transport by road refers to coal tonnage hauled by truck from coal producers to coal consumers or transfer centers. In terms of coal transport, road is considered to be only a supplemental mode to rail and waterway due to the economy of scale of the latter two modes. Road is most likely to be used as an intermediate mode along the producer-rail-port-user transport chain. In addition, long-distance trucking of coal is both economically unattractive and environmentally undesirable; road is suitable only for short-distance coal delivery within a coal-producing province or between coal-producing and coal-consuming regions that are not far apart. Though when market conditions create high prices for delivered coal and rail capacity is tight, trucks have been profitably used to deliver “swing transport supplies” (which tend to be quite expensive as a substitute for rail; thus “swing truck capacity” is likely to enter the medium to long-distance transport market only when prices are high).

In 2005, the average freight rate by road was 55.3 cents/t.km in China, which was increased to 56.2 cents/t.km in 2006. In the past, overloading was a widespread practice by Chinese truck drivers. The government initiatives to eliminate overloading by trucks have significant impacts on road freight rates. For instance, since the Shanxi government initiated its campaign to control overloading by trucks, the average short-distance freight rate for coal transport has increased rapidly by 62.3 percent between December 19, 2007, and May 28, 2008 (Yang et al. 2009).

Table 4-6: Coal Throughputs by Road during the 10th FYP Period (Mt)

	2001	2002	2003	2004	2005
National coal production	1,161	1,391	1,660	1,956	2,190
Coal transport by road	192	273	378	426	400
Ratio of road transport tonnage to production in China (%)	16.5	19.6	22.8	21.8	19.3
Coal production in Jin-Shaan-Meng-Ning region	411	391	731	777	840
Coal export tonnage in Jin-Shaan-Meng-Ning Region	344	369	469	557	631
Coal export tonnage by road in Jin-Shaan-Meng-Ning Region	50	65	101	120	95
Ratio of road transport tonnage to production in Jin-Shaan-Meng-Ning (%)	12.2	16.6	13.8	15.4	12.6
Coal transport by road in Shanxi			79.78	107.41	132.42
Out-of-province coal transport	55.34	66.05	68.35	90.29	109.28
Intra-provincial coal transport by road			11.43	17.12	23.14

Source: Coal transport by road in Shanxi is based on NBS (various years-a) and Shanxi Bureau of Statistics (various years); the remaining data are from Li (2008).

Table 4-6 shows detailed statistics of coal throughput by road during the 10th FYP period. In 2005, coal transport tonnage by road was about 400 Mt, with inter-provincial transport accounting for 184 Mt of coal and intra-province transport accounting for the remaining 216 Mt. During the 10th FYP period between 2001 and 2005, coal transport by road grew at 17 percent annually at the national level and 19 percent annually in the Jin-Shaan-Meng-Ning region (Li 2008).

At the end of the 10th FYP period, road transport authorities tightened their control on overloading to protect road infrastructure and conserve the environment. As a result, coal transport tonnage by rail increased continuously at the expense of trucking since 2004, with a higher percentage drop on inter-provincial coal transport. In 2005, inter-provincial coal exports by road were 153.1 Mt. Major coal export provinces by road include Shanxi (65.18 Mt in 2005), Shaanxi (35.23 Mt), Inner Mongolia (14.33 Mt), Hunan (8.59 Mt), Hebei (7.54 Mt), Guizhou (6.94 Mt), and Yunnan (6.00 Mt). Major coal import provinces by road include Henan (14.42 Mt), Ningxia (2.33 Mt), Jiangsu (1.99 Mt), Hubei (1.65 Mt), and Zhejiang (1.54 Mt) (Li 2008).

In 2005, coal transport by road accounted for 19 percent of national coal production. In the Jin-Shaan-Meng-Ning region, coal export tonnage by road accounted for 13 percent of regional coal production in the same year, and Shanxi alone accounted for about 25 percent of national coal throughput by road during the 10th FYP period. In 2005, growth on coal transport by road in Shanxi was higher than coal hauled by rail, which again indicates the severity of the railway bottleneck in China.

In Table 4-6, coal trucked between mine mouth and railway stations is excluded. If this category is incorporated, coal transport by road was as high as 2.7 Gt in 2008. According to Dong Yan, head of the Comprehensive Transport Research Center at the NDRC, inter-provincial coal transport by road in China is estimated to be close to 500 Mt in the same year. With throughput at more than 400 billion t.km, coal accounted for about 12 percent to 15 percent of national cargo throughput by road (SWS Research 2010).

Road normally serves as a supplemental mode for coal transport in China, but it can play a more important role in certain regional markets with severe bottleneck of railway infrastructure. For instance, being both a major coal-producing and coal-consuming province, Henan has long been China's coal transport hub, especially given its geographic proximity to Shanxi. Since 1998, the bottleneck of railway network propelled coal tonnage hauled by truck to increase significantly in Henan. The 278 Mt of coal hauled by trucks in 2009 was 21 percent higher than volume

transported by rail in Henan in the same year. Average coal transport distance by road in Henan was below 100 km in the past, but a coal price spike in 2008 pushed average trucking distance increase from 96 km in 2007 to 256 km in 2008 and 279 km in 2009 (Henan Bureau of Statistics various years).

4.2.5 Pipeline

Coal pipelines are used to transport coal from coal producers to end users. There are two types of coal pipelines. Slurry pipelines transport a slurry of water and pulverized coal. The ratio of coal to water is about 1:1. Coal log pipelines use coal that has been compressed into logs with a diameter 5 percent to 10 percent less than the diameter of the pipeline and a length about twice the diameter of the pipeline. The ratio of coal to water is about 3 or 4 to 1 (Liu et al. 1993). Given the rapid development of other coal transport modes, the long-term prospect of coal pipeline development is not promising in China, especially given the widespread water shortage across China's major coal-producing regions.

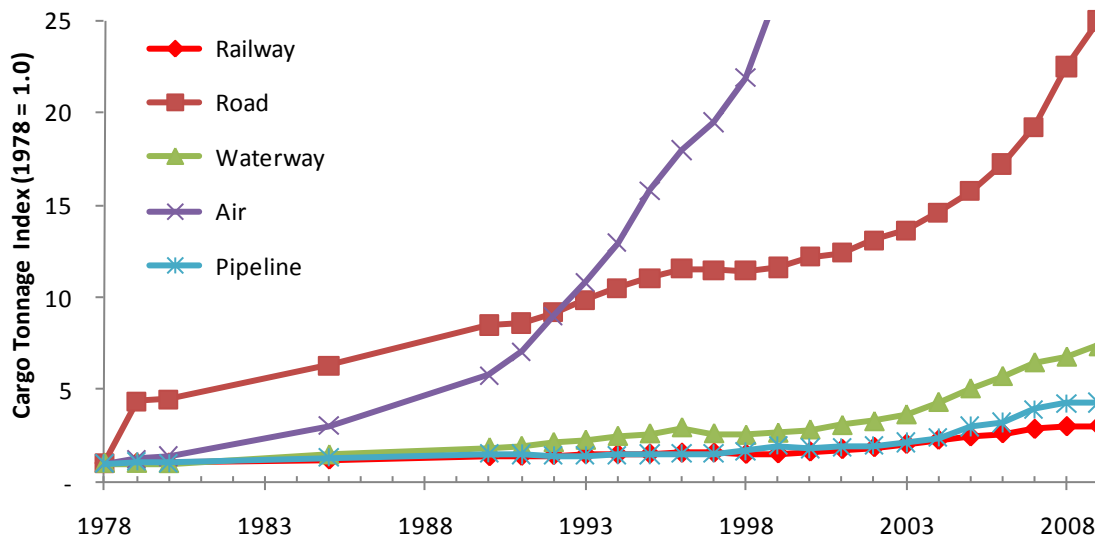
4.3 *The Role of Government*

Figure 4-9 shows the trends of cargo tonnage by transport mode in China. Since 1978, cargo tonnage by air grew at a much faster pace than any other transport modes, which can be explained by 1) the small freight tonnage handled by air in 1978 and 2) the successful introduction of competition in this sector. In comparison, cargo tonnage hauled by both rail and pipeline grew the least during the study period; this coincides with the fact that both the railway and petroleum industries are dominated by state-owned monopolies in China.

The Chinese government has long regarded rail transport as a strategically important industry, and the MOR is both the regulator of the industry and the operator of the majority of the country's rail lines. Since its inception, the MOR's management style can be considered quasi-militarized, which is unique compared with other ministries under the State Council. The MOR has survived China's turbulent government restructuring in the past decades, and it has never become part of the MOTC. As the Chinese economy has become increasingly market-oriented, decentralization and competition have been introduced to most parts of the transport industry—except the railway. Currently, the primary investor in China's rail transport industry is still the MOR, and the monopoly status enjoyed by the MOR has stymied investment from private-sector, state-owned enterprises that do not belong to the MOR, local governments, and even other ministries. Not surprisingly, the railway industry has the worst performance in the transport

sector in terms of cargo tonnage growth since 1978 (NBS various years-b). Even analysts from the NDRC publicly acknowledged that the railway industry is the weakest link of China's transportation industry (Guo 2008).

Figure 4-9: Indices of Cargo Tonnage by Transport Mode (1978 = 1.0)



Source: NBS (various years-b).

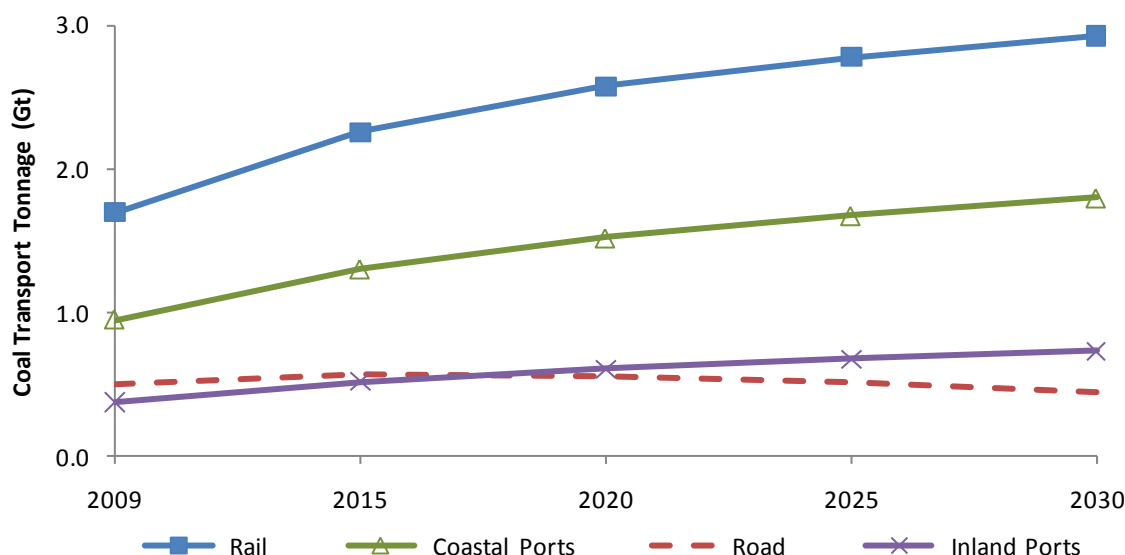
4.4 The Future of Coal Transport in China

Based on the reference coal production trajectory in this study, Figure 4-10 presents forecast of coal transport tonnages by mode in China by 2030. Rail is expected to continuously be the most dominant mode for moving coal from west China to the east and from the north to the south. In 2009, about 1.7 Gt of coal²⁷ were hauled by rail. In future years, coal tonnage by rail is expected to increase by 2.3 percent annually, approaching 3 Gt by 2030. After out-of-province coal sales from Heilongjiang, Henan, Chongqing, Sichuan, Yunnan, Gansu, and Xinjiang are lowered due to either depleting resource bases or increasingly higher regional coal consumption levels, the average coal transport distance by rail in China is expected to increase over time. Shanxi, Shaanxi, Inner Mongolia, and Ningxia are the primary coal export provinces, with major coal import provinces concentrating in the coastal region. The pattern of transporting coal from north to south and from west to east is expected to be further strengthened in the future. With high fuel

²⁷ This figure includes coal hauled by local railways and Shenhua.

costs and increasingly stringent regulatory countermeasures on truck overloading, railways are expected to haul most inter-provincial coal transport tonnages.

Figure 4-10: Possible Scenario of Coal Transport by Mode in China



Note: Only inter-provincial coal transport by road is included. Source: NBS (various years-b), MOTC (various years), Li (2008), and industrial sources.

Except in a few regions, road is only a supplemental coal transport mode. In 2009, coal transported by road was about 0.5 Gt. Since then, coal transport tonnage by road is expected to first increase slightly and then gradually decline to the late 2010s level by 2030. After out-of-province coal sales from Heilongjiang, Henan, Chongqing, Sichuan, Yunnan, Gansu, and Xinjiang are reduced, inter-provincial coal transport tonnage by road is expected to be lowered accordingly. With spiking fuel costs and increasingly stringent regulatory countermeasures on truck overloading, coal transport tonnage by trucking in the future is unlikely to be significantly higher than the current level. Coal transport by road is expected to concentrate at major coal-producing provinces such as Shanxi, Shaanxi, Inner Mongolia, Ningxia, Aihui, and Guizhou. Finally, road is expected to continuously be a supplemental coal transport mode.

In 2009, coal throughput at major inland ports was 0.4 Gt, which is expected to increase over time. After out-of-province coal sales from Chongqing, Sichuan, and Yunnan are reduced, coal throughput at the upstream and midstream sections of the Yangtze River is expected to be lowered accordingly. Following the expected coal output drop in Henan and Jiangsu and the

forthcoming railway capacity expansion in China, the share of coal throughput by inland waterways is expected to grow over time to handle coal produced in Shanxi, Shaanxi, Inner Mongolia, Anhui, and Guizhou. Coal transport capacity of the Jing-Hang Grand Canal is expected to increase significantly after major waterway expansion projects in recent years. With spiking fuel costs and increasingly stringent regulatory countermeasures on truck overloading, inland waterway is expected to partially substitute road for inter-provincial coal transport. Inland waterways will become increasingly cost competitive, and the integration of rail and inland waterway transport modes is expected to be strengthened in the future.

In 2009, coal throughput at major coastal ports was near 1.0 Gt, which is expected to grow at 2.7 percent annually, reaching 1.8 Gt in 2030. With coal exports primarily originating from Shanxi, Shaanxi, Ningxia, Anhui, Guizhou, and coal import provinces concentrating in the coastal region, coal handling capacity at coastal ports is expected to grow over time. With increasingly higher levels of coal imports, capacity of coal ports of discharge in southeast China is projected to increase over time. The geographic advantage of northern coal ports especially the N7 (close to the 3-Xi region and east Ningxia) will make them cost competitive in the long run, and the integration of rail and coastal marine transport modes is expected to be strengthened over time.

5. Grey Markets and Coal Statistical Distortion

A grey market is the trade of a commodity through distribution channels that, while legal, are unofficial, unauthorized, or unintended by the original producer. In contrast, a black market is the trade of goods and services that are themselves illegal and /or distributed through illegal channels. In the context of Chinese coal industry, a grey market consists of coal sold by private and sometimes state-owned collieries at local or even regional markets without appropriate permits from governmental authorities. Illegal mines may supply much of the coal traded in grey markets. These so-called “illegal” mines often operate with recognition of local officials. Because Shanxi has produced 23 percent of China’s aggregate coal supply since 1949 and has long been the largest out-of-province coal exporter in China until 2010, Shanxi was selected as the case study to investigate the formation of grey coal markets in China.

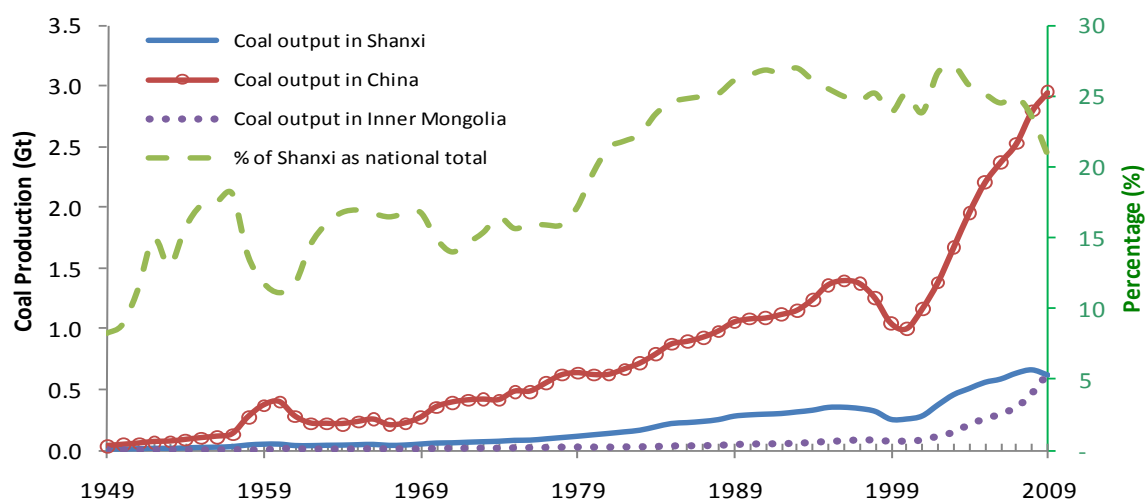
Understanding the grey market—and thus the degree to which market statistics do not capture the reality of the Chinese coal market—is important for researchers, policy makers, and investors. Analyses ranging from investment thesis to policy decisions and international climate models

that rely on Chinese coal statistics need to understand the potential for error and risks associated with making firm conclusions based on this data.

5.1 Introduction to Shanxi and its Coal Industry

Shanxi possesses 32 percent of China's proven coal reserves and more than half of its proven coking coal reserves. In 2008, Shanxi produced more than one quarter of China's coal output but only accounted for about 10 percent of China's coal consumption. As a result, it is the largest coal supplier in China (though 2010 statistics indicate Inner Mongolia produced slightly more than Shanxi).²⁸ Since Shanxi does not produce any oil and gas, which is in sharp contrast with its neighboring province Shaanxi, coal thus is the primary fossil fuel in its energy sector. Even with high per capita coal endowment, economic development in Shanxi lags behind the national average. In 2008, Shanxi's GDP accounted for only 2.3 percent of the national total, and per capita GDP in Shanxi was only 91 percent of the national average, when coal prices had already increased significantly compared with historical levels (NBS various years-b, Shanxi Bureau of Statistics various years).

Figure 5-1: Coal Output of Shanxi, Inner Mongolia, and China 1949-2009



Note: Coal output around 2000 are based on original statistics reported by the NBS, as outputs at provincial levels have never been revised by the provincial bureaus of statistics in late years. Source: NBS (2005, various years-b), Shanxi Bureau of Statistics (various years), and CCTD.

²⁸ In 2010, Inner Mongolia first passed Shanxi as China's largest coal-producing province.

Figure 5-1 presents the role of Shanxi's coal industry in China. After the inception of the PRC in 1949, Shanxi's coal output increased quickly from 8 percent of national total in 1949 to 27 percent of national total in 1993. Since then, Shanxi's share of national coal output fluctuated over time and decreased slightly to 23.5 percent in 2008. However, Shanxi government's second resource consolidation campaign had severe impacts on the province's coal production capacity, with its share of national coal output falling significantly to 20.9 percent in 2009. Even so, due to the existence of a sizable grey coal market in Shanxi, Inner Mongolia did not overtake Shanxi as China's largest coal producer until 2010.

5.2 Grey Markets and Coal Statistical Distortion

In 1949, there were fewer than 100 state-owned mines with an average capacity below 30 kt/annum. Though several thousand TVE mines existed, the extremely low capacities of these mines meant that most of them could supply only adjacent communities. Furthermore, the private coal industry in Shanxi had been stifled by the leftist fever, until 1978 when the Chinese economy was opened to the outside world.

In 1980, TVE mines played an important role in Shanxi by supplying about one third of the province's total coal output. Encumbered by heavy welfare obligations to their bloated workforces and millions of retired workers, China's state-owned mines were unable to meet the burgeoning coal demand, and the central government had to encourage private investment by issuing the "let water flow" policy in 1981. Since then, the number of registered TVE mines in Shanxi increased significantly and reached 6,659 in 1995. In comparison, the number of small coal mines across the country once exceeded 100,000 during this period (CCII various years).

The existence of too many small TVE mines soon became a major policy concern for the Chinese government. After the outbreak of the Southeast Asia Financial Crisis in 1997/98, Beijing grasped the opportunity (lower coal demand) and started to exert greater control over local coal mine operations in the service of national efficiency, safety, and environmental goals, with a later target of shutting down most of small mines to 10,000 by 2010. However, as the aged state-owned coal mines became increasingly unable to keep pace with the demand spike, many of the small mines ordered for closure managed to survive. Allured by tax revenue, local governments in coal mining regions especially Shanxi were unwilling to comply with the production cap and simply underreported the coal supply and demand within their geographic boundaries. Suffering a serious staffing shortage, NBS headquarters struggled just to compile

the country's energy balance tables, let alone conduct investigations for suspicious claims. As a result, China's coal statistics since 1998 have been seriously underreported (Tu 2006).

Grey markets have actually long existed before the government campaign to shut down small coal mines in 1997/98. China's energy statistical collection system was initially developed and functioned well under a planned economy, with the assumption of complete reporting from all units producing, transforming, delivering, and consuming commercial energy. However, as China moved quickly toward a market-oriented economy, the energy activities outside the state-owned enterprises grew rapidly. For example, the percentage of coal produced by TVE mines increased from 18 percent in 1980 to 46 percent in 1995 (CCII various years). As there was no reliable mechanism for collecting coal statistics from small, non state-owned mines, the quality of China's coal statistics deteriorated over time.

To rein in its chaotic coal mining industry, Shanxi Province (2006b) issued the Guidelines for Coal Development and Exploration in 2006. The number of small coal mines in Shanxi is expected to be lowered to 2,172 by 2010 and 1,000 by 2020. The average capacity of small coal mines is expected to be still below 20 kt/annum during the planning period. However, in the same year, Shanxi also launched its first resource consolidation campaign. According to Shanxi Province (2006a), small coal mines with capacity below 90 kt/annum will be closed and mines with capacity below 300 kt/annum are not allowed to acquire closed small collieries or undeveloped coal resources. As a result, the average capacity of coal mines in Shanxi showed an increase from 18.5 kt/annum in 2006 to 25 kt/annum in 2008. In addition, the number of operating coal mines in Shanxi decreased from 3,199 in 2006 to 2,598 by the end of 2008.

According to Shanxi Province (2008), the capacity of coal enterprises in Shanxi must be above 3 Mt/annum by 2010. In addition, the number of operating coal mines will be reduced to 1,500 by 2010, which is significantly lower than the previous governmental target. In February 2009, a methane blast at the Tunlan Coal Mine in Shanxi killed 78 miners, which soon prompted Shanxi to launch the second round of resource consolidation campaign (Tu 2009). According to Shanxi (2009), the number of operating mines in Shanxi will be lowered from the previous target of 1,500 to 1,000 by the end of 2010. In addition, capacity of any operating mine and a coal mining enterprise must be above 0.9 Mt/annum and 3.0 Mt/annum, respectively.

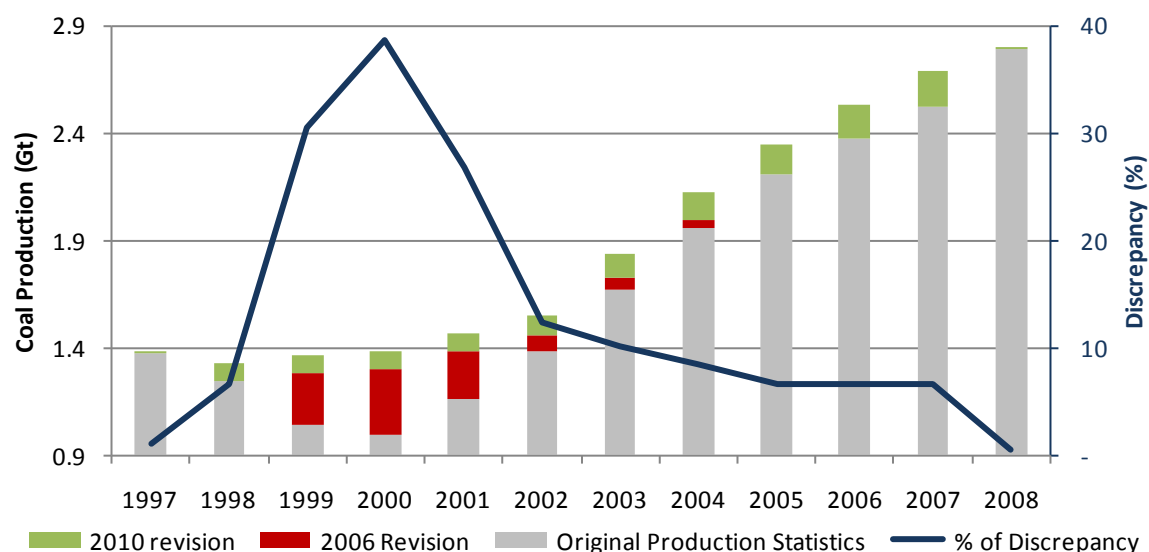
While the above administrative orders clearly shows Shanxi government's determination to rein in its chaotic coal mining industry, the measurements specified in the 2009 order are apparently

not compatible with the principle of Chinese laws (e.g., the Real Rights Law). The failure of Shanxi to govern its coal industry according to the principle of laws is expected to have very negative impacts in the long run by 1) further reducing the trust level of the Chinese society as a whole; 2) lowering the efficiency of the Chinese coal industry by eliminating competition from the private coal mining industry; and 3) encouraging coal production underreporting in Shanxi.

Eventually, pressure on energy demand prompted NBS officials to revise historical coal statistics in 2006. Since both the extent and coverage of the 2006 statistical revisions were considered to be insufficient, the NBS revised China's coal supply statistics in 2010 again. Nevertheless, the revision methodology and procedure have not yet been revealed.

Figure 5-2 compares the original statistics of the national coal output in China with the updated data revised in both 2006 and 2010. While the size of grey coal markets in 2000 was as high as 39 percent of originally reported national coal output in 2000, the discrepancy between original statistics and revised data is diminishing quickly thereafter. However, even after two major statistical revisions in 2006 and 2010, whether the size of grey coal markets has been fully identified by the Chinese government is still an open-ended question.

Figure 5-2: Statistical Revisions of China's Coal Output in 2006 and 2010

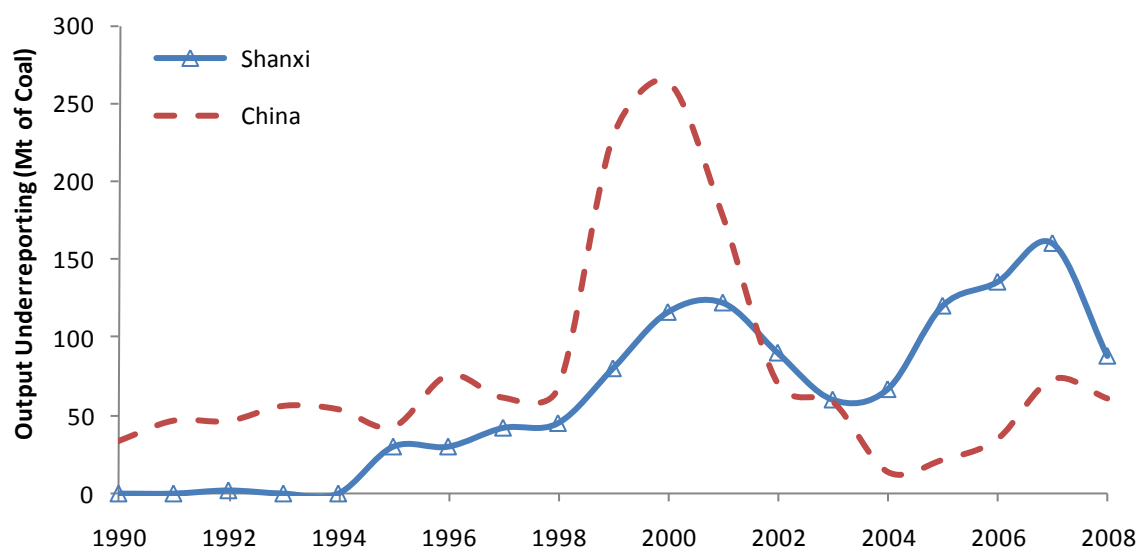


Note: Percent of discrepancy is based on the ratio between the sum of 2006 and 2010 revisions and original coal production statistics. Source: NBS (various years-b).

In an energy balance table, the “balance” category is used to capture energy consumption that cannot be balanced by either coal supply, storage change, or imports/exports. In this study, the balance category of coal in China is termed as “unexplainable coal usage,” which is the amount of coal production beyond the grasp of Chinese statistical agencies and is considered to reflect the possible size of the grey coal market in China.

Figure 5-3 compares the unexplainable coal usage in China and Shanxi. Between 1990 and 1997, national unexplainable coal usage fluctuated over time, ranging from 33 Mt to 75 Mt. The size of grey markets in China was generally below 5 percent of national coal output. Since 1998, national unexplainable coal usage increased abruptly and reached 228 Mt in 1999, 264 Mt in 2000, and 177 Mt in 2001, which accounted for 15 percent to 26 percent of national coal output originally reported by the NBS.

Figure 5-3: Unexplainable Coal Usage: China vs. Shanxi



Note: Trend lines are based on the “balance” category at coal balance tables in either Shanxi or China. The latest national statistics distortion quantification is based on China Energy Statistical Yearbook 2009, so the statistical revisions by the NBS in 2010 have not been incorporated. Source: NBS (various years-b) and Shanxi Bureau of Statistics (various years).

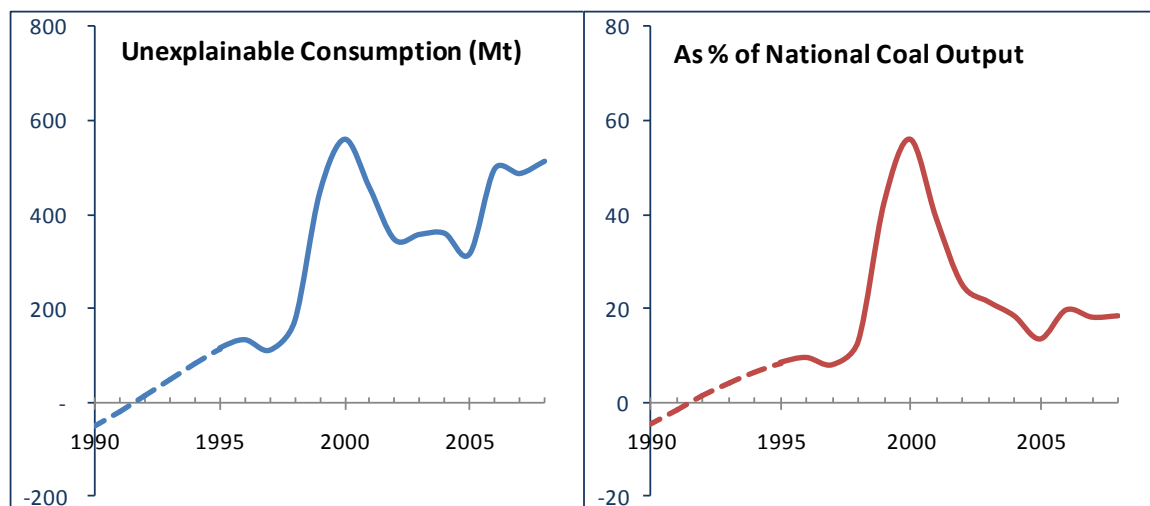
The national markets follow a similar trend as Shanxi. However, since 2003, the size of grey coal market in Shanxi increased significantly and was constantly above the national levels. In 2007, the “balance” category of coal in Shanxi was as high as 160 Mt, which suggests that 25

percent of coal usage in Shanxi cannot be reconciled with reported coal production in this province (with consideration of imports/exports and storage change).

Currently, national coal production in China equals to the summation of coal output in all provinces and autonomous regions. While one would expect that a similar relation holds for national coal consumption, it is actually not the case in China. According to China Energy Statistical Yearbook, the summation of coal consumption in all Chinese provinces and autonomous regions is significantly higher than aggregate coal consumption data at national level reported by the NBS in recent years.

Taking coal imports/exports, storage change and losses in coal washing and dressing into consideration, Figure 5-4 shows that unexplainable amounts of coal consumption at the provincial level have increased rapidly since 1990 and first peaked at 561 Mt in 2001, when underreporting of coal statistics was officially recognized as one of the most serious years. Since then, the grey picture of coal statistical distortion in China has only improved marginally until 2005 and rebounded sharply thereafter, reaching 512 Mt in 2008. As a result, grey markets may still account for up to 18 percent of national coal output reported by the NBS in 2008.

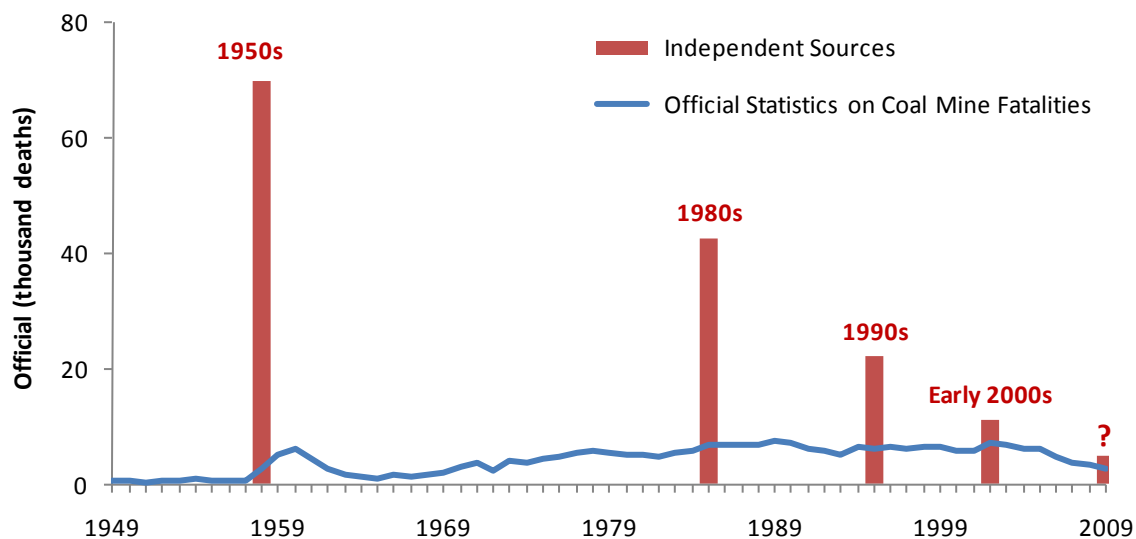
Figure 5-4: Unexplainable Coal Consumption at the Provincial Level in China



Note: As percent of national coal output in a specific year = (unexplained coal consumption at provincial level in China) / (original national coal output reported by the NBS in respective year). Data for 1991 to 1994 are interpolated according to 1990 and 1995 figures. Source: NBS (various years-b).

One important driving force underlying the existence of grey coal markets in China is the historic and chronic difficulty of compelling local officials to obey central policies, as local officials often have flexibility to interpret regulations and administrative orders from higher-level authorities, according to their departmental or personal interests. The statistical distortion on coal mine safety can best illustrate this phenomenon. The coal mine safety record in China is full of controversy. While the official coal mine fatality statistics at the beginning of the PRC range from 242 in 1951 to 6,036 in 1960, Guo et al. (2006) reported that annual fatalities were as high as 70,000. Since 1978, the official coal mine fatalities in China fluctuated over time but were generally between 5,000 and 7,000 deaths per year. Nevertheless, independent estimations suggest that annual coal mine fatalities were about 40,000 in 1980s, 20,000 in 1990s and 10,000 at the beginning of this millennium (Guo et al. 2006, Elegant 2007, Tu 2007a). The sharp contrast between official coal mine death tolls and independent estimations on coal mine fatalities in China again suggests the accuracy of China's coal statistics as a whole is problematic.

Figure 5-5: Official Statistics versus Independent Estimations of Coal Mining Safety in China



Source: Guo et al. (2006), Tu (2007a), Elegant (2007), Safety Bureau of Former Ministry of Coal Industry (1998), CCII (various years), and the State Administration of Work Safety.

5.3 Hypotheses

Based on the aforementioned assessment, the author proposed several hypotheses regarding the status of China's coal statistical reporting, and it is highly recommended that the hypotheses below should be assessed with rigor by researchers, ideally with encouragement from the Chinese government:

- Since the mid-1990s, coal statistical distortion has become a systematic error in China's statistical collection system. It is caused by the existence of grey coal markets in China.
- Up to 100 - 200 Mt of coal output may be underreported in Shanxi in recent years, which needs to be corrected by the Shanxi Bureau of Statistics.
- Up to 300 – 600 Mt of coal output may be underreported at national level in recent years, which needs to be corrected by the National Bureau of Statistics.
- The coal supply statistical revisions by the NBS in 2006 and 2010 have not fully corrected the aforementioned statistical distortion.

6. The Future of Coal in China and the Climate Factor

6.1 Background

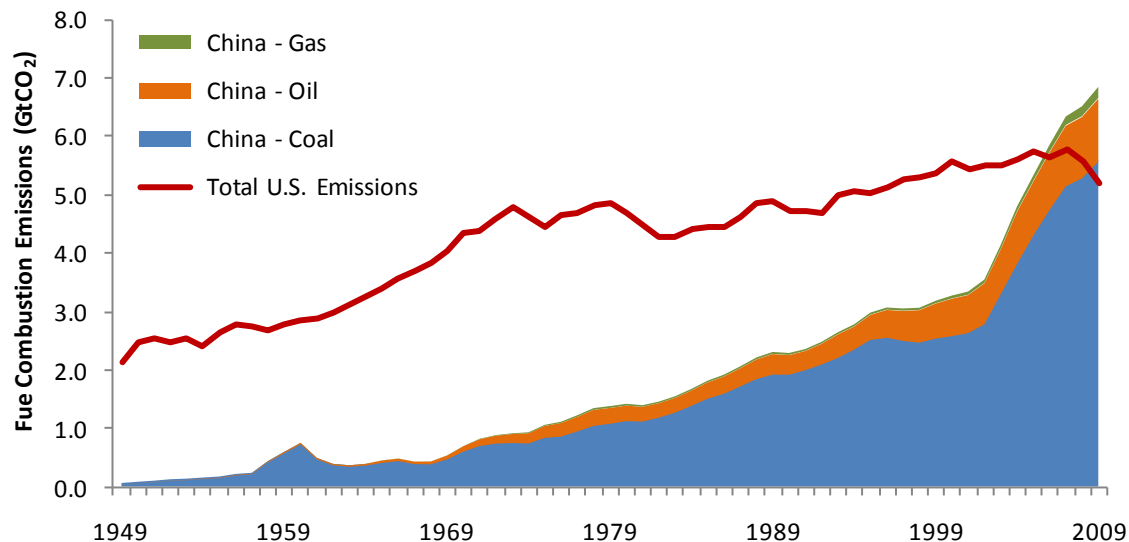
While the coal resource, because of its abundance and low cost, has been a sustained contributor to China's economic and social development, its extraction, processing, transport, and utilization are all associated with major sustainability challenges. The predominance of underground coal mining leads to significant amounts of fugitive methane emissions. In addition, coal combustion accounts for 82 percent of CO₂ emissions, 75 percent of SO₂ emissions, 85 percent of NO_x emissions, and 70 percent of particulate emissions in China.²⁹ For more than a decade, China has been the world's largest SO₂ emitter and Figure 6-1 shows that China first overtook the United States for the world lead in CO₂ emissions in 2006. Deteriorating air quality is a major environmental issue in many Chinese urban centers, and GHG emissions abatement becomes an increasingly important policy concern for Chinese decision makers.

Given the necessity of balancing economic growth with portraying itself as a responsible power, China understands that it cannot escape the responsibility of curbing its spiking carbon emissions

²⁹ Source: CCICED Task Force on Sustainable Use of Coal in China.

forever, so it started developing an increasingly proactive and comprehensive climate policy. During the United Nations Climate Summit in September 2009, Chinese president Hu Jintao first announced that China will cut its carbon emissions per unit GDP by an unspecified “notable margin” by 2020 from the 2005 level. In November 2009, the question of notable margin was specified by the State Council as a 40 percent to 45 percent reduction of 2005 levels by 2020.³⁰

Figure 6-1: Fuel Combustion and Carbon Emissions: China vs. the United States



Note: China’s updated energy statistics released in 2010 indicate that China has already passed the United States as the world’s largest carbon emitter in 2006, which is one year earlier than what the previous energy statistics imply.

Source: NBS (various years-b), ERI (2007), ONCCCC, U.S. EPA, and the author’s own estimation.

6.2 China’s Carbon Intensity Abatement Approach

Between 1990 and 2005, China’s national GDP increased 326 percent. In comparison, the country’s fuel combustion carbon emissions increased 129 percent. China’s carbon intensity per unit GDP declined significantly, by 46 percent for the period from 1990 to 2005 (IEA 2009b). In its 11th FYP (2006-2010), the Chinese government set a goal of cutting national energy intensity per unit GDP by 20 percent between 2005 and 2010; this can be translated into an annual reduction of more than 1.5 GtCO₂ by 2010, making the largely energy security and local pollution-based effort one of the most significant carbon mitigation initiatives in the world (Lin

³⁰ http://www.chinadaily.com.cn/china/2009-11/26/content_9058731.htm [December 1, 2009].

et al. 2008). If China pursues a similar energy intensity improvement target in the subsequent FYP periods, China's energy intensity in 2020 is expected to be 49 percent lower than the 2005 levels. Assuming no abrupt fuel mixture change, a carbon intensity reduction at 40 percent to 45 percent between 2005 and 2020 is still achievable in the absence of the aforementioned commitment.

The carbon intensity abatement approach proposed by the Chinese government before the 2009 Copenhagen conference represents a noticeable departure from past stances on climate change negotiation by developing countries. Though the percentage of carbon emissions reduction committed by China may be considered as insufficient to meet global carbon emissions control targets, the approach itself may open a window of opportunity to bring at least key emerging economies into the fold of global efforts on GHG emissions abatement.

6.3 Summary and Recommendation for Future Research

Chinese decision makers will continue to rely on carbon-intensive coal to fuel the country's booming economy in the decades to come, primarily because of coal's low cost, resource abundance, and the increasing availability of "clean coal" technology that can be applied to alleviate environmental impacts ("clean coal" in the context of the Chinese power sector primarily implies controls for SO₂, NO_x, and particulate emissions). New policies promoting a reduction in both the energy intensity of GDP and the carbon intensity of GDP are likely to gradually reduce the "coal intensity of GDP". But because China's dependence on coal will likely last decades into the future, understanding the complex coal value chain that delivers the vast majority of energy in the world's largest energy consuming economy is essential for understanding global energy markets and climate change.

At the time of writing, the size of grey markets in the Chinese coal industry seems to have grown to dangerous levels that are too significant to be ignored; it is recommended that the Chinese government should consider assessing the current situation and fixing any inconsistency within its statistical reporting system. Otherwise, ongoing coal statistical distortion is likely not only to severely undermine China's policy initiatives on energy conservation and carbon intensity abatement in the years to come but also make it difficult for the international community to verify policy achievements claimed by the Chinese government. Further, statistical distortions impact the investment, policy, and climate communities' ability to make sound, accurate decisions in the Chinese energy sector.

Finally, the complex Chinese value chain of Chinese coal, transport, and power generation is now undergoing major reforms. While this study has presented a comprehensive review of the Chinese coal value chain including resources, production, transport, end uses and environmental impacts, a follow up study is recommended to thoroughly explore the future of coal in China under an energy security- and carbon-constrained world.

References

- Bataille, C., J. Tu, and M. Jaccard (2008). Permit sellers, permit buyers: China's and Canada's role in a global low-carbon society. *Climate Policy* 2008: 93-107.
- BP (2010). BP statistical review of world energy 2010. British Petroleum, London.
- Cai, J., J. Hao, Z. Lu, G. Li, W. Wang, and L. Kong (2002). Analysis of energy saving and energy consumption in Chinese steel industry for last 20 years and next 5 years. *Iron & Steel* 37: 68-73.
- CCII (various years). *China Coal Industry Yearbook*. China Coal Information Institute, Beijing.
- CEC (various years). Express statistics of the Chinese electricity industry. China Electricity Council, Beijing.
- CNCA (2006). Statistics of the Chinese coal industry: 1949-2004. Coal Industry Press, Beijing.
- Duan Q (2007). Status of China's coal transport corridors and study on optimized policies. *Research and Approach* 29: 27-32.
- Editorial Board of CCCI (1999). Chronicles of the Chinese coal industry: The comprehensive volume. Coal Industry Press, Beijing.
- Editorial Board of CEIYB (various years). *China Electricity Industry Yearbook*. China Electric Power Press, Beijing.
- Elegant, S. (2007). Where the coal is stained with blood. *Time* 2007.
- Fan, Y., Z. Lu, J. Cheng, Z. Zhou, and G. Wu (2003). Major ecological and environmental problems and the ecological reconstruction technologies of the coal mining areas in China. *Acta Ecologica Sinica* 2003.
- Guo, G., M. Lu, H. Zhang, Y. Liu, and G. Ma (2006). Coal mine safety technology and management. Metallurgical Industry Press, Beijing.
- Guo, X. (2008). The experience on developing China's transport infrastructure. Experience-Sharing Program on Development between China and Africa. World Bank, Beijing.
- Henan Bureau of Statistics (various years). *Henan Statistical Yearbook*. China Statistics Press, Beijing.
- Huang, S., W. Liu, and Q. Dou (2008). China coal outlook 2008. National Insitute of Occupational Health, Beijing.
- IEA (2009a). Cleaner coal in China. International Energy Agency, Paris.
- IEA (2009b). World energy outlook 2009. International Energy Agency, Paris.
- IEA (2010). Coal information: 2010 edition. International Energy Agency, Paris.
- Jiang, K., X. Hu, X. Zhuang, and Q. Liu (2009). China's low carbon scenarios and low carbon development paths to 2050. *Sino-Global Energy* 14.

- LFRC (2007). Transport infrastructure development in China, Part I: Road - highway and expressway. Li & Fung Research Center, Hong Kong.
- LFRC (2009). An update on the transport infrastructure development in China: Water transportation. Li & Fung Research Center, Hong Kong.
- Li, H. (2008). Coal transport in China: Capacity, consumption and prices. China Market Publishing House, Beijing.
- Li, S., Y. Liu, Z. Xu, and J. He (2010). Outlook of China's economic development between the 12th Five-Year Plan period and 2030. Development Research Center of the State Council, Beijing.
- Lin, J., N. Zhou, M. Levine, and D. Fridley (2008). Taking out 1 billion tons of co2: The magic of China's 11th Five-Year Plan. *Energy Policy* 36: 954-970.
- Liu, H., R. Zuniga, J.L. Richards (1993). Economic analysis of coal log pipeline transportation of coal, CPRC report no. 93-1. University of Missouri, Columbia, Mo.
- Minchener, A.J. (2007). Coal supply challenges for China. IEA Clean Coal Centre.
- MLR (1999). Forecast and evaluation of China's coal resources. Ministry of Land and Resources, Beijing.
- MOC (various years). Report on China's shipping development. Ministry of Communications, Beijing.
- MOR (2008a). Illustrative maps of operating stations of the national railway bureaus. China Railway Publishing House, Beijing.
- MOR (2008b). Medium- to long-term railway network plan (2008 revision). Railway, Mo (ed). Beijing.
- MOTC (various years). Report on China's shipping development. Ministry of Transportation and Communications.
- NBS (2005). Comprehensive statistical data and materials on 55 years of new China. National Bureau of Statistics, Beijing.
- NBS (various years-a). *China Energy Statistical Yearbook*. National Bureau of Statistics, Beijing.
- NBS (various years-b). *China Statistical Yearbook*. National Bureau of Statistics, Beijing.
- NDRC (2006). Draft mid- to long-term development plan for the coal chemical industry. National Development and Reform Commission, Beijing.
- Office of the National Coordination Committee on Climate Change, Energy Research Institute (2007). The People's Republic of China: National greenhouse gas inventory. China Environmental Science Publishing House, Beijing.
- Peabody (2009). Peabody Energy: 2008 corporate & social responsibility. Peabody Energy, St. Louis, Mo.
- Safety Bureau of the MCI (1998). Assembly of statistical and analytic documents for coal mine injuries and fatal accidents in China,. Coal Industry Press, Beijing.

- Sagawa, A., A. Fukushima, Y. Mimuroto, and C.C. Siang (2003). Prospects for the supply and demand of coal and related coal transportation issues in China. Institute of Energy Economics, Tokyo, Japan.
- SERC (various years). Annual report on electricity regulation. State Electricity Regulatory Commission, People's Republic of China, Beijing.
- SETC (2000). 50 years of the Chinese industry. China Economic Publishing House, Beijing.
- Shanxi Bureau of Statistics (various years). *Shanxi Statistical Yearbook*. China Statistics Press, Beijing.
- Shanxi Government (2008). Opinions of Shanxi government on implementation of accelerating the merger and acquisition amongst coal mining enterprises.
- Shanxi Province (2006a). Administrative order on coal resource consolidation and compensated use in Shanxi, People's Government Order of Shanxi - No. 187. Shanxi Provincial Government, Taiyuan.
- Shanxi Province (2006b). Guidelines for coal production and exploration between 2006 and 2020 in Shanxi. Shanxi Provincial Government, Taiyuan.
- Shanxi Province (2009). Notice of Shanxi government on issues regarding further accelerating the merger, acquisition and consolidation amongst coal mining enterprises, Shanxi Government [2009] No. 10. Shanxi Provincial Government, Taiyuan.
- SWS Research (2010). Meeting minutes for SWS research coal market forecast conference 2011. SWS Research, Shanghai.
- TFSUC (2009). Conference proceedings of the Third Working Meeting of the CCICED Task Force on Sustainable Use of Coal. CCICED Task Force on Sustainable Use of Coal, Beijing.
- Thomson, E. (2003). The Chinese coal industry: An economic history. RoutledgeCurzon: London, New York.
- Tu, J. (2006). China's botched coal statistics? China Brief 6.
- Tu, J. (2007a). Coal mining safety: China's achilles' heel. China Security 3.
- Tu, J. (2007b). Coal mining safety: China's achilles' heel. China Security 3: 36-53.
- Tu, J. (2009). The Shanxi coal mine blast and the failure of safety governance in China. China Brief 9.
- Tu, J., M. Jaccard, and J. Nyboer (2007). The application of a hybrid energy-economy model to a key developing country - China. *Energy for Sustainable Development* XI: 35-47.
- U.S. EIA (2009). Annual coal report 2008. Energy Information Administration, Washington, D.C.
- Wang, H., and N. Horii (2008). Chinese energy market & reform on pricing mechanisms - case study and analysis of Shanxi's experiment. Institute of Developing Economies, China.
- Wang, W. (2009). Scientific assessment on the difference between energy intensities of the Chinese iron and steel industry and international best performance. China Iron and Steel Enterprises' Network, Beijing.

- Wang, Y., and W. Pan (2009). Analysis of the coal economy in 2008. *China Energy* 31.
- Wang, Z. (2008). Research on improving operation efficiency of Shenhua Group's Huanghua Port. Beijing Jiaotong University.
- Wu, R. (1996). Development and trends of China's coal production. *China Coal* 1996.
- Wu, S., and M. Wang (2006). Position of coal in Chinese energy supply. *Coal Processing & Comprehensive Utilization* 2006: 2-7.
- Wu, Y. (2009). Investigating the economy through coal transport - grass-root study on coal trade market at Qinhuangdao.
- Yang, X., C. Wu, and D. Wang (2009). *2009 Coal Marketing Handbook*. China University of Mining and Technology Press, Beijing.
- Zhang, P. (2009). Brief assessment on selection of rail routes to export coal in Shanxi. *Road and Bridge Economy* 2009: 59-60.

Appendix A: Chronicle of the Chinese Coal Industry

Period	Major Event	Average Annual Production (Mt)	Average Annual Fatalities	Output % of TVE Mines
Recovery Period (1949-1952)	The PRC was founded in 1949. The Administration of the Coal Industry (ACI) was created under the Ministry of Fossil Fuels (MFF).	48.7	530	4.5
1 st FYP (1953-1957)	Number of Greenfield mines under construction reached 194, with total capacity of 75.37 Mt. Number of completed mines reached 205, with total capacity of 63.76 Mt. Setting the target of raising annual national coal output to 131 Mt, which was the exact production level in 1957.	98.5	700	4.6
1955	MFF was abolished and the ACI was upgraded as the Ministry of Coal Industry (MCI).	98.3	677	4.8
2 nd FYP (1958-1962)	The Great Leap Forward started in 1958 and ended in 1961. As a result, the national coal production target was revised upward to an unrealistic level of 900 Mt. Not surprisingly, overreporting became rampant across the country, and the national economy entered a period of chaos.	306.6	4,120	6.8
1958	15 major coal-producing provinces have established regional ACIs.	270.0	2,662	12.8
Adjustment Period (1963-1965)	The coal industry was not recovered until 1965 when the output grew again.	221.1	1,261	4.1
3 rd FYP (1966-1970)	Setting the target of increasing national coal production capacity by 68.06 Mt, and the coal production actually grew as high as 7.1 percent annually during this period. Nevertheless, the political turmoil across the country soon forced the military to take over the management responsibility of the coal industry in August 1967.	259.3	1,848	5.9
1966	The beginning of the Cultural Revolution, which resulted in long-lasting and detrimental impacts on the Chinese economy as a whole	251.5	1,478	2.3
1970	The MCI was abolished, and the Ministry of Fuels and Chemical Industry (MFCI) was created.	354.0	2,903	8.9
4 th FYP (1971-1975)	Setting the target of raising national coal output to 400-430 Mt by 1975. As the average annual production growth rate was 4.2 percent during this period, this target was easily met, which indicates that the coal industry actually still functioned well in spite of the political turmoil.	423.0	3,837	11.3
1975	The MCI was re-created.	482.2	4,526	13.1
5 th FYP (1976-1980)	Setting the target of establishing 8 large-scale coal production bases.	581.6	5,325	16.2
1976	The end of the Cultural Revolution, and the Chinese economy soon took off thereafter.	483.5	4,826	14.8
1978	The Chinese economy was open to the outside world.	617.8	5,830	15.4
6 th FYP (1981-1985)	The start of the resurgence of the TVE mines in China.	732.8	5,534	25.7
1983	The State Council issued the Notice to Encourage the Private Sector's Investment in the Mining Industry, which marked the beginning of the so called "let the water flow" policy.	714.5	5,431	23.8
7 th FYP (1986-1990)	Setting the target of raising annual national coal production level to 1,000 Mt. With the private sector's rapid development, this target was met in 1990, when national output reached 1,080 Mt.	987.1	7,015	35.7
1988	The Ministry of Energy (MOE) was created, and the MCI was abolished. The creation of three key central level coal enterprises.	979.9	6,751	35.9
8 th FYP (1991-1995)	The private sector's market share peaked at the expenses of the state-owned enterprises, tax revenue losses, mounting	1,190.8	5,817	42.1

Period	Major Event	Average Annual Production (Mt)	Average Annual Fatalities	Output % of TVE Mines
	environmental degradation and daunting safety record.			
1993	The MOE and the three central level coal enterprises were all abolished. The MCI was re-created. Since 1993, coal produced by TVE and private mines has been freely sold in the market. But the former State Planning Commission still issued guidance prices for coal supplied to power plants and negotiators at the national coal-ordering conference simply used these in place of the earlier benchmark prices.	1,150	5,152	42.5
1995	The market share of TVE mines peaked at 46.2 percent.	1,361.0	6,222	46.2
9 th FYP (1996-2000)	In 1997/98, the ongoing national Campaign to close small coal mines formally started, with detrimental impacts on statistical collection.	1,373.0	6,049	38.3
1998	The MCI was downgraded as the State Coal Industry Bureau (SCIB) under the State Economic and Trade Commission (SETC), and authority over key state-owned mines was devolved to local governments.	1,332.0	6,304	41.9
10 th FYP (2001-2005)	Serious underreporting of national coal production occurred.	1,866.0	6,272	34.6
2001	The SCIB was abolished and most of its functions were handed over to the State Administration of Work Safety (SAWS). The State Administration of Coal Mine Safety (SACMS), under SAWS, oversees safety at coal mines.	1,384	5,670	23.9
2004	At the 2004 coal-ordering conference, the guideline price for utility coal was removed by the NDRC, but power prices remained fixed while coal prices soared.	2,123	6,027	38.0
11 th FYP (2006-2010)	The coal production target set for 2010 is 2.6 Gt, which has already been exceeded in 2008.	2,882	3,362	37.2
2006	The former Energy Bureau of the NDRC worked with the National Bureau of Statistics (NBS) to revise national coal statistics between 1999 and 2004. Shanxi's first resource consolidation campaign, setting minimum coal mine capacity as 0.3 Mt/annum.	2,529	4,746	38.3
2007	In Jan. 2007, the 11 th FYP for coal industry was issued by the NDRC.	2,692	3,786	38.0
2008	The National Energy Administration (NEA) replaced the Energy Bureau of the NDRC.	2,802	3,215	36.6
2009	Shanxi's second resource consolidation, setting minimum coal mine capacity as 0.9 Mt/annum. A prolonged dispute on contracted thermal coal prices between major coal enterprises and utilities. The complete deregulation of coal prices at the central government level.	2,973	2,631	38.2
2010	The creation of the National Energy Commission is another attempt by Beijing for national coordination of China's energy sector. NBS revised coal statistics between 1997 and 2008.	3,413	2,433	35.2

Note: Coal production statistics in recent years are based on revised figures from the NBS, but the share of TVE mines are based on original statistics from various sources including CCII, CCTD, CNCA and SAWS. The only exception is the production data of 2010, which is based on data from CCTD. In comparison, production data from the NBS in 2009 was 3,240 Mt, which is significantly lower than the similar figure of 3,413 Mt from CCTD. FYP stands for Five Year Plan. Source: Tu (2007b), Thomson (2003), CCII (various years), NBS (various years-b, a), IEA (2009a), SETC (2000), SXCOAL, and CCTD.