KEIO/KYOTO JOINT
GLOBAL CENTER OF EXCELLENCE PROGRAM
Raising Market Quality-Integrated Design of "Market Infrastructure"

KEIO/KYOTO GLOBAL COE DISCUSSION PAPER SERIES

DP2009-015

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Changes in the Domestic Coal Market in post-war Japan

SHIMANISHI Tomoki*

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Key words: coal market, energy revolution, fossil fuels, air pollution

JEL Classifications: N45, N55, N75

* I would like to thank Professor Kanda Sayako for her support and valuable suggestions on the earlier drafts of this paper. I am also grateful to Professor Sugihara Kaoru and other participants at the Asian International Economic History Workshop at Matsuyama University on 29th September 2008 and at the Asian-Pacific Economic and Business History Conference at Gakushuin University on 19th February 2009.

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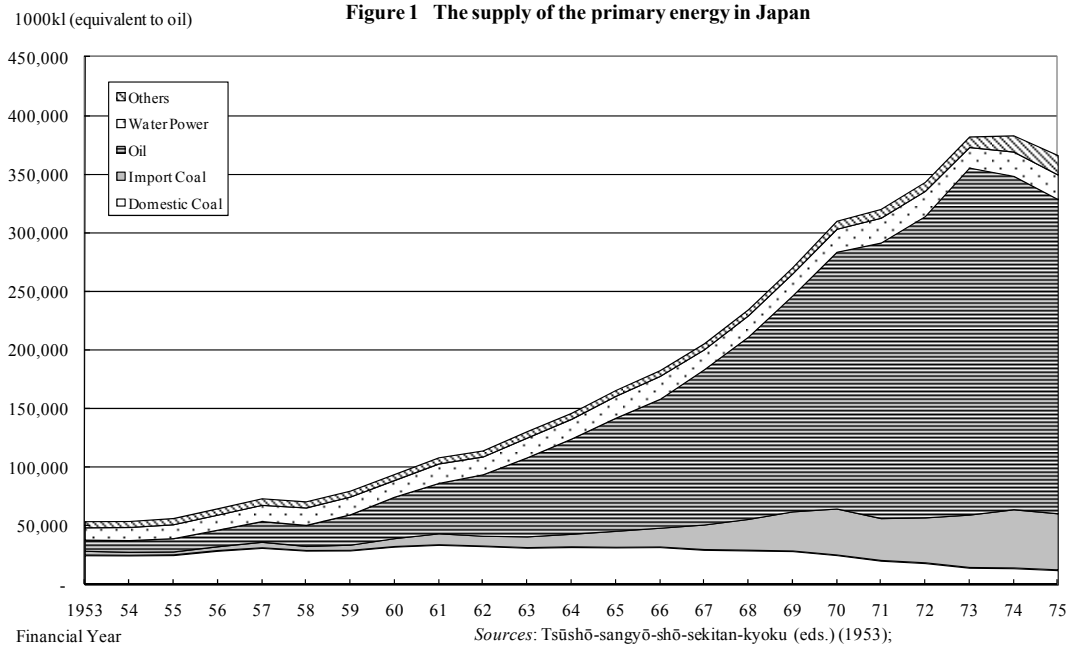
Figure 1 The supply of the primary energy in Japan



Sources: Tsūshō-sangyō-shō-sekitan-kyoku (eds.) (1953);
Tsūshō-sangyō-shō-daijin-kanbō-sōgō-enerugii-seisaku-ka (eds.) (1966－1973).

1. Introduction

The post-war Japanese economy was affected by heavy environmental loads caused by massive combustion of heavy oil, which was brought about by 'the energy revolution'. However, as **Figure 1** shows, the supply of domestic coal accounted for a constant amount until the end of the 1960s, although it was becoming proportionately much less than that of heavy oil. This suggests that both the consumers and suppliers of coal maintained the domestic coal market, and that during 'the energy revolution', the environment was severely damaged by combustion not only of heavy oil but also of domestic coal.

What made it possible to maintain the domestic coal market? And how did the use of domestic coal affect the environment? This study examines these questions by focusing on changes of three kinds of coal quality parameters: calorific value, ash content and sulphur content. The price of coal increases along with an increase in its calorific value. On the other hand, its price decreases as its ash or sulphur content increases. Furthermore, as the ash and sulphur content of coal increases, the damage to the environment also increases.

The studies by both Yada and Shimanishi demonstrated the processes in the development of domestic coal resources by the coal mining companies, and Kobori analyzed the

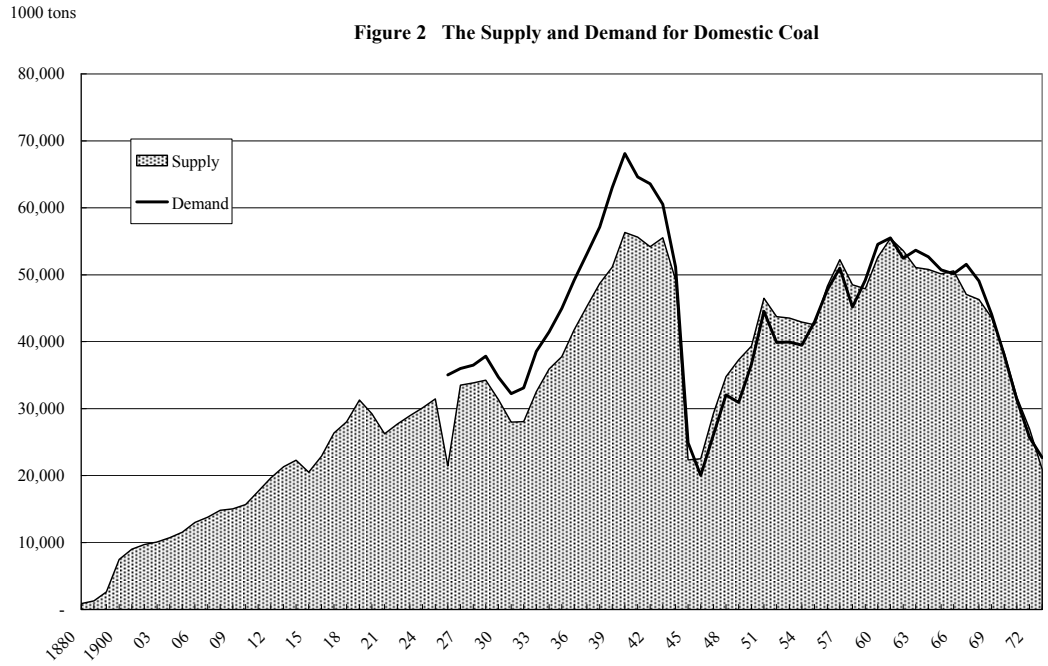


Figure 2 The Supply and Demand for Domestic Coal

Source : Sekitan-seisaku-shi-hensan-iinkai (eds.) (2002b).
Note : Until 1946, a demand for import coal is added to that for domestic coal.

characteristics of Japan's energy policy in the 1950s[1]. However, none of these authors mentioned either the coal quality or the environmental loads caused by the use of coal, although they showed the changes in the yield and/or resource productivity in order to cut production costs. Studies on environmental history have shown that the use of heavy oil had caused many types of environmental pollution[2]. However, they did not consider the use of domestic coal. This study reconsiders these studies from the viewpoint of an economic history of the environment[3].

2. Industrial and environmental changes caused by 'the energy revolution'

Problems of industrial smoke and mine pollution before the mid 1950s

Japan's industrialization after the end of the 19th century was deeply dependent on coal[4] as the primary energy resource, and the supply of coal increased from year to year[5] (see **Figure 2**). This created the environmental problem of smoke. In the case of Osaka city[6], which was known as '*Kemuri no Miyako*' [the city covered with smoke], we analyze the relationships among the use of

[1] Yada (1975); Shimanishi (2005), pp. 25-46; Kobori (2005), pp. 47-69.
[2] Ui (eds.) (1985); Kamioka (1987); Iijima (2000).
[3] For details, see Kanda (2007), pp. 3-11.
[4] In this section, 'coal' means both domestic and import coal.
[5] For the location of coalfields and industrial districts, see **Appendix**.
[6] Osaka city is located in Hanshin district.

coal, environmental loads and economic growth in the early 20th century[7].

Beginning at around 1900, increasing smoke became a problem of public concern as large-scale coal-burning factories became concentrated in Osaka. The Osaka prefectural government set up a research committee on the regulation of smoke in 1911, and in 1913, it drafted a smoke regulation law that obliged factories to install smoke removal devices. However, this law was not implemented because of strong objections by the industrial community. In the late 1920s, to achieve both fuel savings and smoke reduction, people in the industrial community began to tackle the complete combustion of coal and oil by employing technical guidance for fuel burning[8]. Although this was an economical way to make economic growth more environment-friendly, in the 1930s, it was gradually changed into heat control, which stressed saving fuel rather than reducing smoke[9]. In addition, there was little mention of devices for removing smoke or sulphur oxides (SOx).

Changes in the manner of washing coal also worsened the problem of smoke. To enable shipping of high-quality coal with low ash content, collieries used to wash raw coal repeatedly to remove the ash that causes smoke[10]. In the 1930s, however, the situation changed unexpectedly. As the new institution of the coal trade under the controlled economy stressed the amount rather than the quality, collieries began to increase the supply of low-quality coal with high ash content, by not washing coal sufficiently[11]. Thus, the combustion of low-quality coal caused more serious air pollution.

In coalfield areas, many collieries had mined coal in an irrational manner since the end of the 19th century[12]. This had resulted not only in serious mine pollution, such as the heaps of debris, exhaustion of well water, subsidence over goaf holes and outflow of waste water from coal-washing plants, but also in the abandonment of coal resources. Therefore, the government gradually began to regulate this irrational mining that had caused the abandonment of coal in the seams. First, Kōgyō-hō [the Mining Law] was revised to impose both the absolute liability for

[7] For details, see Kamioka (1987); Oda (1987).
[8] Kobori (2007), pp. 51-53.
[9] Kobori (2006), pp. 40-68.
[10] Horiuchi (1933), pp. 742-752.
[11] Nezu (1958), pp. 521-522. As a result, the calorific value of coal for steam locomotives decreased from 6310 kcal in 1940 to 5960 kcal in 1944.
[12] For details, see Sekitan-kōgai-jigyōdan (1971).

Table 1 Prices Per Calorie of Heavy oil and Domestic Coal

Financial Year	Type C Heavy Oil	Domestic Coal		Spreads	
		Keihin (C.I.F.)	Kyushu (O.R.)		
	A	B	C	B—A	C—A
1953	0.86	1.02	0.75	0.17	-0.11
54	0.81	0.89	0.58	0.08	-0.23
55	0.85	0.91	0.61	0.06	-0.24
56	0.93	0.93	0.66	0.00	-0.27
57	0.96	1.05	0.77	0.09	-0.19
58	0.81	0.98	0.70	0.17	-0.11

Unit: yen/kcal
Source: Kyushu-keizai-chōsa-kyōkai (1961).
Note: 'A' is the price in Tokyo. The carorific value of domestic coal is 6,200 kcal.

mining pollution and the obligation to prevent pollution in advance until 1950. Second, in 1952, the government started the recovery of the damaged areas by implementing Rinji-sekitan-kōgai-fukkyū-hō [the Extraordinary Law on Coal Mine Damage Recovery]. The cost of this was paid by fees from those who had mining rights and by government subsidies.

The findings here result in three observations. First, the government worked toward a solution to the problems of mine pollution, but it was not willing to tackle the problem of smoke. Second, rational mining would contribute to both solving the problem of mine pollution and the promotion of economic growth in terms of the sustainable use of coal resources. Finally, washing raw coal repeatedly caused not only a decrease in the smoke that covered cities, but also an increase in mine pollution, such as the heaps of debris and the outflow of waste water in coalfield areas.

Air pollution by sulphur oxides

The supply of coal decreased rapidly soon after the Second World War due to irrational mining during the war and the return of foreign workers to their homelands. However, as a result of the government-led priority allocation of funds, materials and labour force to collieries, the supply of coal started to increase again after 1947 (see **Figure 2**). This contributed to the recovery of the Japanese economy, although there remained the following problems regarding the use of coal in post-war Japan. First, a succession of strikes by labour unions made the supply of coal uncertain. Second, the price of domestic coal was becoming higher than that of heavy oil in consumption areas (see **Table 1**) because of mounting distribution costs and labour-intensive production organizations. Finally, fuel consumers realized that burning fluid fuels such as heavy oil lead to

Table 2 Amount of Fuel Conversion from Domestic Coal to Heavy Oil

Financial Year	Annual Amount	Total	F.Y.	Annual Amount	Total
1949	#N/A	#N/A	55	620	7,690
50	#N/A	#N/A	56	2,300	9,990
51	1,251	1,251	57	2,220	12,210
52	2,244	3,495	58	5,440	17,650
53	3,647	7,142	59	11,800	29,450
54	-72	7,070			

Unit: 1000 tons
Sources: Nihon-tekkō-renmei-sengo-tekkō-shi-hensan-iinkai (eds.) (1959); Sekitan-seisaku-shi-hensan-iinnkai (eds.) (2002a).
Note: The data after 1955 is dependent on the latter resource.

Table 3 Fuel Price by Districts (Purchase Price by Electric Power Industry)

Financial Year	Districts	Domestic Coal	Heavy Oil	Spread
		A	B	A-B
1958	Near Coalfield	3,381	4,769	-1,388
	Others	5,027	4,659	368
	Average	4,501	4,466	35
63	Near Coalfield	2,392	2,957	-565
	Others	3,921	3,432	489
	Average	3,582	3,297	285
65	Near Coalfield	2,357	2,773	-416
	Others	4,284	3,256	1,028
	Average	3,757	3,088	669
68	Near Coalfield	2,505	2,685	-180
	Others	4,333	3,194	1,139
	Average	3,749	3,041	708

Unit: yen/tons
Source: Shimanishi (2004).
Note: The price of domestic coal includes the ash disposal costs.

savings in energy consumption[13].

Therefore, starting in the early 1950s, fuel consumers continued to switch their fuel from domestic coal to heavy oil imported from the Middle East. This 'energy revolution' led to a drastic decrease in the demand for domestic coal. As **Table 2** shows, by 1959, about thirty million tons of domestic coal, corresponding to about 60% of the annual output, had been replaced with heavy oil. The supply of heavy oil continued to increase, in response to an increase in the demand for primary energy during Japan's rapid economic growth until 1973 (see **Figure 1**). Moreover, as **Table 3** shows, by the end of the 1960s, the price of domestic coal, even in coalfield areas where distribution costs were very low, had become higher than that of heavy oil. The dependence on imports in the supply of primary energy finally reached 95.9% in 1973[14]. As a result, beginning in the mid 1950s, the primary cause of environmental loads changed from the use of domestic coal

[13] Kobori (2005).
[14] Enerugii-keizai-kenkyūsho (eds.) (1986), p. 53.

to that of heavy oil.

Interestingly, this change brought about a new relationship between the use of domestic coal and environmental loads[15]. It was triggered by the establishment of regulations on air pollution, such as some Kōgai-bōshi-jōrei [Pollution Prevention Ordinances] in 1949, and Baien-kisei-hō [the Smoke and Soot Regulation Law] in 1962. The latter provided that the emissions of smoke, soot, SOx and sulphur trioxide (SO_3) were to be regulated in five industrial districts, and it gave the government the power to shut down the non-compliant facilities. Fuel consumers actively set up dust collectors to comply with these regulations, because the combustion of heavy oil as well as coal caused the emissions of smoke and soot. Moreover, consumers of heavy oil had to neutralize 'acid smut' (black particulate matter combined with sulphur contained in heavy oil, H_2O and ashes) by injecting ammonia into the flue gas. Thus, these regulations gradually helped to reduce 'black' smoke[16].

On the other hand, 'white' smog that contained considerable SOx created another problem of air pollution, because Middle Eastern heavy oil is a fossil fuel with very high sulphur content. In the case of Yokkaichi city[17], which had huge petrochemical complexes, the sulphur content of Middle Eastern heavy oil was over 3%, and the SOx concentration emitted by burning this oil was between 1 and 2.5 parts par million (ppm). This was much higher than the then legal standard of SOx concentration (under 0.22 ppm), even when we consider the diffusion of SOx into the atmosphere[18].

However, large fuel consumers were not willing to reduce SOx emissions, because the Baien-kisei-hō regulation used an unreliable method of measuring SOx concentration and emissions[19]. Therefore, as was clearly shown in the case of Yokkaichi asthma, air pollution by SOx seriously damaged not only the atmosphere but also people's health during post-war Japan's rapid economic growth.

[15] For details, see Sangyō-kankyō-kanri-kyōkai (eds.) (2002), pp. 44-122.
[16] Tokyo-denryoku-kabushiki-gaisha-karyokubu (eds.) (1986), pp. 71-75.
[17] Yokkaichi city is located in Chukyo district.
[18] Kawana (1985), p. 10.
[19] Kankyō-chō (1969).

Table 4 Sulphur Content and Carories of Domestic Coal by Grades

Chikuho Coalfield			Hokkaido		
Grade	Sulphur Content	Carorie	Grade	Sulphur Content	Carorie
Tagawa	0.20	5,760	Ponbetsu Washed	0.25	6,800
Onoura Washed	0.54	5,862	Taiheiyo	0.27	6,650
Yamano	0.70	6,880	Horonai	0.30	6,700
Takamatsu Washed	0.70	6,600	Sunagawa	0.50	7,030
Namazuda Washed	0.80	6,520	Akabira Washed	0.50	6,750
Iizuka Washed	1.12	6,040	Others		
Yoshikuma Washed	1.15	7,150	Grade	Sulphur Content	Carorie
Saga and Miike			Takahagi	0.30	5,000
Grade	Sulphur Content	Carorie	Kaminoyama	0.50	5,057
Kishima Washed	2.27	6,900	Yoshima	1.90	5,300
Sakito Washed	2.32	7,590	Ube	2.20	3,640
Miike Washed	3.10	6,930	Kashima	3.50	6,500
			Over-all Average	1.16	6,283

Unit: %, kcal
Source: Tsūshō-sangyō-shō-daijin-kanbō-chōsa-tōkei-bu (eds.) (1960).
Note: Coal grade with the highest sulphur content of each of the major collieries is extracted.

Domestic high-quality coal as an environment-friendly energy resource

The problem of air pollution by SOx emissions was becoming increasingly serious, and people recognized an unexpected characteristic of domestic coal. As **Table 4** shows, the sulphur content of domestic coal was under 1%, with a few exceptions (average = 1.16%). This was much lower than the sulphur content of Middle Eastern heavy oil. Given that the large fuel consumers barely reduced SOx emissions while dust collectors became more popular, it can be said that domestic coal became a more environment-friendly energy resource than Middle Eastern heavy oil.

Although the records of the electric power companies, which were the largest coal consumers, are unavailable as evidence of these companies' continued use of coal-fired power plants, the companies did continue to increase their demand for domestic coal until the end of the 1960s. Moreover, the following cases show that both these companies and the local governments knew at that time that the combustion of domestic coal emits less SOx than that of heavy oil. First, Chubu-denryoku[20] [Chubu Electric Power Company] organized a research committee on SOx emission by oil-fired power plants but not on that by coal-fired plants[21]. Second, Denpatsu [Electric Power Development Company] obtained the approval to build a new coal-fired power plant from the government of Takasago city[22] on the condition that it did not use a mixed fuel of coal and heavy oil, because the mayor of Takasago was worried more about SOx emissions from

[20] Chubu-denryoku is located in Chukyo district.
[21] Chubu-denryoku-kabushiki-gaisha-karyokubu (eds.) (1988), pp. 119 and 246-248.
[22] Takasago city is located in Hanshin district.

mixed combustion than about the smoke from the combustion of domestic coal[23]. Therefore, it is appropriate to conclude that these companies had incentives to maintain their coal-fired power plants until they found a possible solution to the problem of SOx emission[24].

Of course, domestic coal was only relatively superior to Middle Eastern heavy oil in industrial districts where the problem of SOx emission was very serious, such as Keihin, Chukyo, Hanshin and Kita-Kyushu. The coalfield areas were generally so far from these districts that collieries had to ship high-quality coal. The price of such coal was high enough to cover these distribution costs, because it was necessary to wash the raw coal repeatedly to improve its quality. On the other hand, as the next section shows, the collieries were able to commodify inferior-quality coal.

3. Commodification of inferior-quality coal and its impacts

Exploitation of the inferior-quality coal market[25]

Collieries were forced to cut their production costs as 'the energy revolution' proceeded. Along with the reduction of the workforce and the mechanization of production, an increase in the yield of coal provided another effective way to cut their costs. Therefore, the collieries tried to commodify inferior-quality coal, such as raw coal and low-calorie coal, which had been thrown away in the past[26].

The pioneers of this practice were the collieries in the Joban coalfield[27]. They planned to commodify inferior-quality coal as a fuel for thermal power generation by Tohoku-denryoku[28] [Tohoku Electric Power Company] in 1953, and in the following year, they succeeded in generating electricity by the combustion of inferior-quality coal. In 1955, Joban-karyoku [Joban Joint Power Company] was established jointly by Joban-Tankō [Joban Coalmining Company], Tokyo-denryoku[29] [Tokyo Electric Power Company], Tohoku-denryoku and others, and in 1957,

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[23] Sanjūnen-shi-hensan-iinkai (eds.) (1984), pp. 201-202.
[24] In fact, the electric power industry's demand for domestic coal increased from 6.7 million tons in 1955 to 25.94 million tons in 1968. For details, see Sekitan-seisaku-shi-hensan-iinnkai (eds.) (2002b).
[25] Following the then classification, we call coal with calorific value of under 3,500 kcal 'inferior-quality coal'.
[26] Low-calorie coal was partly commodified in Ube coalfield before the Second World War.
[27] For details, see Joban-kyodo-karyoku-50-nenshi-hensan-iinkai (eds.) (2005), pp. 20-25.
[28] Tohoku-denryoku is located near Joban coalfield.
[29] Tokyo-denryoku is located in Keihin district.

Table 5 Inferior-quality-coal-Fired Power Plants (Built after the 1960s)

Colliery	Company	Number of Generators	Carorie (Unit: kcal)	Built Year
Nakoso	Joban Karyoku	3	3,500	1960-61
Kanda	Nishi-nihon Kyodo	1	3,500	1963
Wakamatsu	Denpatsu	2	3,000	1963

Sources : Joban-kyodo-karyoku-50-nenshi-hensan-iinkai (eds.) (2005); Sanjūnen-shi-hensan-iinkai (eds.) (1984); Shashi-henshū-shō-iinkai (eds.) (2001); Sekitan-tsūshin-sha (eds.) (1962).

it started to operate its Nakoso Power Plant[30].

Interestingly, there was no great difference in thermal efficiency between inferior-quality-coal-fired power plants and middle-quality-coal-fired power plants as a result of technological innovations in thermal power generation. For example, the Nakoso Power Plant used coal with calorific values of 3,500 kcal, and its thermal efficiency was 30.5%[31]. The Shin-Ube Power Plant of Chugoku-denryoku[32] [Chugoku Electric Power Company] used the same coal as Nakoso in terms of calorific value, and its thermal efficiency was 34.58%[33]. These values were almost the same as the thermal efficiency of the Tanagawa Power Plant of Kansai-denryoku[34] [Kansai Electric Power Company], which used coal with calorific values of 5,300 kcal[35].

Moreover, the price of inferior-quality coal was much lower than that of high-quality coal. In 1960, in the case of Kyushu-denryoku[36] [Kyushu Electric Power Company], the purchase price of inferior-quality coal with a calorific value of only 3,000 kcal was 0.413 yen per kcal, whereas that of high-quality coal with a calorific value of 5,500 kcal was 0.649 yen per kcal[37]. Conveniently, this was also about 50% lower than the price of heavy oil (see **Table 1**). Of course, the active demand for inferior-quality coal was limited to consumers near coalfields, such as Kyushu-denryoku, Chugoku-denryoku and Joban-karyoku, because its price was not high enough to cover distribution costs. Electric power companies near coalfields thus built inferior-quality-coal-fired power plants after the 1960s (see **Table 5**).

[30] Nakoso is located in Joban coalfield.
[31] Ibid.
[32] Chugoku-denryoku is located near Ube coalfield.
[33] Abe (1960), pp. 127-129.
[34] Kansai-denryoku is located in Hanshin district.
[35] Ibid. The thermal efficiency of the Tanagawa Power Plant was 35.00%.
[36] Kyushu-denryoku is located in Kita-kyushu district.
[37] Sasaki (1995), p. 150.

Table 6 The Supply of Inferior-quality Coal by Takamatsu

Financial Year	Kyushu-denryoku	Chugoku-denryoku	Denpatsu (Wakamatsu)
1956	32	19	
57	13	23	
58	20	117	
59	105	282	
60	131	342	
61	89	291	
62	95	305	231
63	80	105	487
64	46	92	585
65	96		579
66	75	14	473
Total	782	1,590	2,355

Unit : 1000 tons
Source : Sasaki (1995).

Technical developments for supplying inferior-quality coal

In response to the increasing demand for inferior-quality coal in thermal power generation, the collieries actively developed techniques for supplying inferior-quality coal. First, coal washers for dense and medium separation were introduced for collecting inferior-quality coal from raw coal, because they made it possible to control the coal quality more strictly than the existing coal washers that used only water[38]. Second, part of the debris of the raw coal was commodified.

For example, after 1962, the Takamatsu Colliery[39] of Nihon-tankō [Nihon Coalmining Company], one of the major coal mining companies, started not only to wash raw coal slightly as there was no need to increase its calorific value but also to collect inferior-quality coal by re-washing debris. Furthermore, after 1963, it shipped such inferior-quality coal with a calorific value of 3,500 kcal to the Wakamatsu Power Plant of Denpatsu[40]. As **Table 6** shows, after 1963, the annual output of inferior-quality coal by Takamatsu was about 600,000 tons. Takamatsu eventually shipped 4.78 million tons of inferior-quality coal to Wakamatsu, whose fuel was wholly dependent on the inferior-quality coal of Takamatsu, until its closure in 1971[41]. Incidentally, the Wakamatsu Colliery[42] of Nihon-tankō used debris after re-washing as construction material for land reclamation and site preparation for housing.

On the other hand, small- and medium-sized collieries increased their supply of inferior-quality coal by mixing debris into high-quality coal. A small colliery would mix debris

[38] Mori (1998), pp. 22-26; Saito (1960), pp. 144-152.
[39] Takamatsu is located in Chikuho coalfield.
[40] Sasaki (1995), pp. 139-199. Wakamatsu Power Plant was located in Kita-kyushu district.
[41] Sanjūnen-shi-hensan-iinkai (eds.) (1984), p. 280.
[42] Wakamatsu is located in Chikuho coalfield.

Table 7 Sulphur Content of Debris and Washed Coal

Company	Colliery	Debris	Washed Coal
Kishima	Kishima	2.34-3.50	2.1-2.66
Nicchitsu	Emukae	0.54-3.62	0.7-1.5
Aso	Yoshio	0.21-0.78	0.38-0.69
Nittan	Ookimi and Takamatsu	0.495-0.819	0.3-0.7

Unit : % (the lowest－the highest)
Sources : Tsūshō-sangyō-shō-daijin-kanbō-chōsa-tōkei-bu (eds.) (1960); Santan-chiiki-shinkō-jigyōdan (eds.) (1964).

into high-quality coking coal, which was much more expensive than inferior-quality coal, and would ship this mixed coal to electric power plants as inferior-quality coal[43]. The major collieries producing coking coal also developed these techniques. For example, the Ashibetsu Colliery[44]of Mitsui-kōzan [Mitsui Mining Company], the largest coal mining company in Japan, restructured its coal washery in 1964. This new coal washery, equipped with a Baum jig washer that used water, coal washers for dense medium separation and flotation machines, enabled Ashibetsu not only to improve the quality of coking coal but also to collect inferior-quality coal. The Miike[45] Colliery of Mitsui also restructured its coal washeries after 1962 following Ashibetsu, and it succeeded in boosting the production of both high-quality coking and inferior-quality coal[46].

Needless to say, these technical developments for supplying inferior-quality coal contributed to the sustainable use of coal resources. Moreover, there were also those who collected inferior-quality coal from the heaps of debris or from the waste water released by the coal washeries into the rivers near the collieries. The amount of such coal in 1966 was an astonishing 1.7 million tons, corresponding roughly to the annual output of one major colliery[47]. Therefore, an increase in the demand for inferior-quality coal contributed to reducing mining pollution, such as larger heaps of debris and water pollution, although it remained a serious problem.

Serious air pollution caused by the combustion of fossil fuels

The combustion of inferior-quality coal caused four types of environmental loads due to its high ash content. First, smoke emission increased. However, this was not a serious problem, because it

[43] Fukuoka-tsūshō-sangyō-kyoku (1965), p. 69.
[44] Ashibetsu is located in the midland of Hokkaido coalfield.
[45] Miike is located in Miike coalfield.
[46] For details, see Mitsui-kōzan-kabushiki-gaisha (1963), p. 20; Mitsui-kōzan-kabushiki-gaisha (eds.) (1990), pp. 305-306; Ousaka (1989), pp. 5-7; Konishi (1990), pp. 15-17.
[47] For details, see Kyushu-denryoku-kabushiki-gaisha (eds.) (1982), p. 66.

was reduced by fitting dust collectors. Second, the amount of coal ash after combustion also increased. To deal with this problem, coal consumers and collieries developed a way to commodify coal ash as a construction material, known as 'fly-ash', for making concrete, reclaiming land and filling goafs[48]. Third, SOx emission increased. As **Table 7** shows, the sulphur content of the debris, which was present in inferior-quality coal, was generally higher than that in washed coal, because part of the sulphur was combined with the ash on the surface of the coal. According to a trial calculation, the sulphur content of Takamatsu's inferior-quality coal was an alarming 4.78%[49]. Therefore, the combustion of such inferior-quality coal caused more SOx emission than that of Middle Eastern heavy oil. Finally, coal causes more emission of nitrogen oxides (NOx) at the time of combustion than any other fossil fuel. Specifically, coal causes a NOx emission of 15.2 kg/10^7 kcal, whereas heavy oil causes an emission of 12.2 kg/10^7 kcal[50].

The problems of smoke emission and coal ash were not very serious, but the combustion of inferior-quality coal steadily worsened the air pollution resulting from SOx and NOx emissions. However, this problem went unnoticed because people were more concerned with the air pollution resulting from the massive combustion of Middle Eastern heavy oil.

4. Responses to a new regulation law

Stack gas purification techniques[51]

After the mid 1960s, in addition to the existing air and water pollution, new environmental pollution problems, such as stench, noise and eutrophication, became serious. In 1965, the Japanese government established Kōgai-bōshi-jigyōdan [the Pollution Control Service Corporation] to implement anti-pollution projects in industrial districts where the problem of SOx emission had become very serious. Moreover, the establishment of Kōgai-taisaku-kihon-hō [the Basic Law for Environmental Pollution Control] in 1967 served as the impetus for several regulatory laws for each problem. Taiki-osen-bōshi-hō [The Air Pollution Control Law], established in 1968, was an especially important example of such laws. As the government started

[48] Joban-kyodo-karyoku-50-nenshi-hensan-iinkai (eds.) (2005), pp. 43-44.
[49] Sasaki (1995), pp. 203-206.
[50] Tanaka and Yamada (1971), p. 41.
[51] For details, see Sangyō-kankyō-kanri-kyōkai (eds.) (2002), pp. 49-122.

to regulate SOx concentration on the ground under this law[52], fuel consumers were forced to lengthen their chimneys or to reduce their SOx emission.

The regulations introduced under this law became stricter the following year. The law prescribed SOx concentrations such as 'under 0.05 ppm/h a day during over 70% of the year' and 'under 0.1 ppm/h during over 80% of operation hours'. The concentration of oxidant, which is a type of peroxide NOx that reacts photochemically, was also regulated at under 0.06 ppm/h in 1970, because the oxidant caused another form of environmental pollution—photochemical smog.

The development of stack gas desulphurization techniques was very expensive for large fuel consumers—especially thermal power plants—to implement. For example, the desulphurization of a thermal plant's emission required a considerable amount of energy, corresponding to about 5% of its electrical generating capacity. Therefore, the stack gas desulphurization facilities of power plants did not immediately come into operation. Chubu-denryoku started to put its facilities into operation in 1973, and Denpatsu did so in 1975[53]. In an extreme case, Tokyo-denryoku confined its facilities to experimental use, not to operations.

Even worse, in the 1970s, the development of stack gas denitrification techniques was still in the research phase, and the lengthening of chimneys was also subject to a serious technical restraint[54]. Thus, the development of stack gas purification techniques stagnated, while the regulation of air pollution became stricter under Taiki-osen-bōshi-hō.

Use of low-sulphur fossil fuels

To deal with the strict regulation of SOx emission, given the poor technical potential of stack gas purification, fossil fuel consumers started to use several clean energy resources imported from all over the world[55]. First, starting in the mid 1960s, power plants in Tokyo, Chubu, Kansai and

[52] This regulation was called 'the K value regulation'. The K value indicates the SOx concentration at the top of the chimney, which is 594 times more than that on the ground. It also equals the amount of the SOx emission divided by the square of the height of the chimney.
[53] Ikeda (1975), pp. 28-46; Tokyo-denryoku-kabushiki-gaisha-karyokubu (eds.) (1986), pp. 156-157; Chubu-denryoku-kabushiki-gaisha-karyokubu (eds.) (1988), pp. 250-252.
[54] Tanaka and Yamada (1971), p. 40-43; Tokyo-denryoku-kabushiki-gaisha-karyokubu (eds.) (1986), pp. 150-152; Chubu-denryoku-kabushiki-gaisha-karyokubu (eds.) (1988), pp. 250-254.
[55] For details, see Tokyo-denryoku-shashi-henshū-iinkai (eds.) (1983), pp. 628-638; Tokyo-denryoku-kabushiki-gaisha-karyokubu (eds.) (1986), pp. 152-156; Chubu-denryoku-kabushiki-gaisha-karyokubu (eds.) (1988), pp. 247-252; Shashi-henshū-shū-iinkai (eds.) (2001), pp. 495-497; Kansai-denryoku-gojūnen-shi-hensan-jimukyoku (eds.) (2002), pp. 358-360, 378-380 and 432-435.

Chugoku-denryoku put the direct combustion of crude oil into operation. The oil refinery companies, whose business was to refine crude oil into gas oil or petrol, strongly objected to this action in terms of resource conservation. However, the electric power companies continued to burn crude oil because its sulphur content was slightly lower than that of Middle Eastern heavy oil.

Second, the import of heavy oil with ultra-low sulphur content from the Southeast Asian region began. For example, the sulphur content of Indonesian crude oil (Sumatra Light Crude and Lirik Crude Oil) or Bruneian crude oil (Light Seria Crude) is only between 0.09% and 0.1%. After the crude oils are refined into heavy oil, their sulphur content is between 0.2% and 0.3%. Therefore, after 1966, the electric power companies replaced Middle Eastern heavy oil with Southeast Asian oil. In the case of Kansai-denryoku, the consumption of Sumatra Light Crude as a percentage of the total consumption of heavy oil increased from 12.1% in 1966 to 46.2% in 1970.

Third, in 1970, Tokyo-denryoku succeeded in operating the world's first liquefied natural gas (LNG)-fired power plant. Smoke and SOx emissions from the combustion of LNG are near zero, and NOx emission is also very low. Later, Tokyo-denryoku, Kansai and Chubu-denryoku also put their LNG-fired power plants into operation.

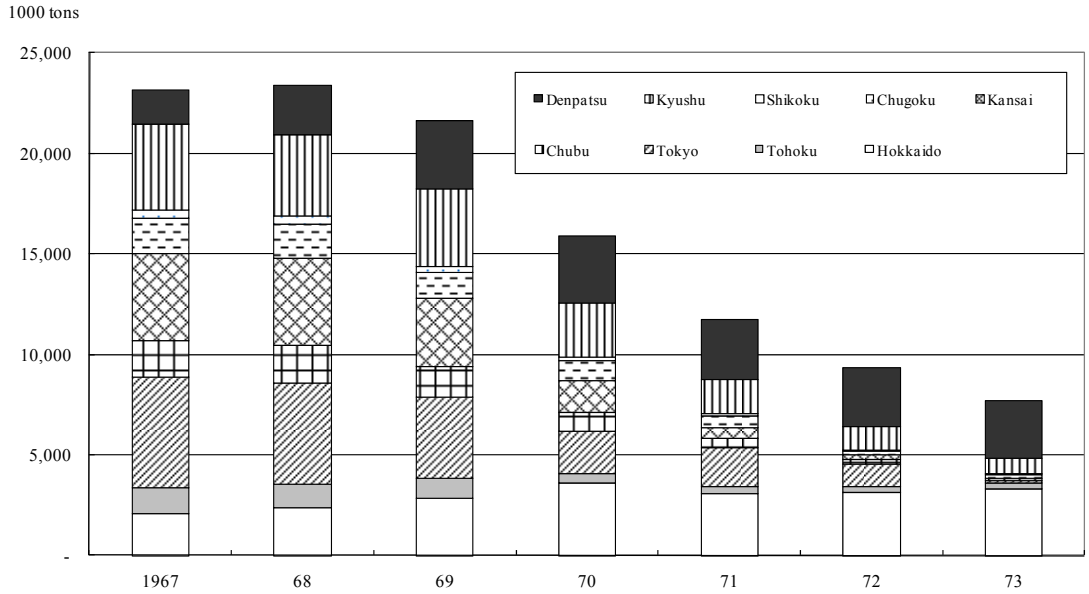
Finally, a few electric power plants used naphtha as part of their fuel, because its sulphur content is about 0.05%. However, it was not in common use because of its supply constraints.

Owing to the use of these low-sulphur fossil fuels and the desulphurization of Middle Eastern heavy oil by the oil refinery companies after the mid 1970s[56], the annual average SOx concentration was 0.02 ppm in 1975[57]. Thus, the problem of SOx emission was being resolved gradually, although that of NOx emission remained unresolved.

As the supply of these low-sulphur fossil fuels increased, the demand for domestic coal decreased. In particular, electric power plants' demand for domestic coal decreased rapidly. As **Figure 3** shows, almost all the electric power companies had virtually abandoned the use of domestic coal by the end of the 1960s, except Hokkaido-denryoku[58] [Hokkaido Electric Power Company], which put a new coal-fired power plant into operation in 1969, and Denpatsu, which

[56] Tsūshō-sangyō-shō-kōgai-hoan-kyoku (1970), pp. 155-156.
[57] Sangyō-kankyō-kanri-kyōkai (eds.) (2002), p. 98.
[58] Hokkaido-denryoku is located in Hokkaido.

Figure 3 The Consumption of Domestic Coal by Electric Power Companies



Source: http://www.jbhi.or.jp/files/toukei/Denryoku/D-27d.xls
Note: Denpatsu is a special government corporation, and the others are private companies.

was a special government corporation[59]. Neither inferior-quality coal with high sulphur content nor high-quality coal with low sulphur content was able to compete with these ultra-low sulphur fossil fuels.

Rapid decrease in the supply of domestic coal

After 1968, as the demand for domestic coal decreased, the supply of domestic coal also decreased (see **Figure 2**). What then made it impossible for the collieries either to reduce the sulphur content of domestic coal by more repeated coal washing, or to exploit new markets for domestic coal other than fuel?

Let us start with the first part of the question[60]. It was very difficult for collieries to reduce the sulphur content of this high-quality coal by re-washing, because this caused an increase in production costs. As the price of domestic high-quality coal became higher than that of heavy oil, collieries were forced to cut their production costs rather than to reduce the sulphur content of their coal. Repeated coal washing also caused an increase in high-sulphur debris. However, under the strict regulation of SOx emissions, there was no demand for inferior-quality coal mixed with high-sulphur debris.

[59] Hokkaido-denryoku-gojūnen-shi-hensan-iinkai (eds.) (2001), pp. 119-121.
[60] For details, see Shimanishi (2004), pp. 11-15.

Let us now consider the second part of the question[61]. First, there was an active demand for coking coal during the period of rapid economic growth. It was an attractive market for domestic coal, but steelmakers—the largest consumers of coking coal—preferred coal with high caking properties over coal without caking properties, which the electric power plants preferred. Therefore, it was difficult for collieries to sell their coal without caking properties to the steelmakers as coking coal. In addition, the steelmakers also preferred high-quality coal with low sulphur content, because increasing sulphur content worsened the quality of pig iron. Although Tsushō-sangyō-shō [the Ministry of International Trade and Industry] and several coal mining companies attempted to develop techniques for using coal without caking properties as coking coal, they were not able to put them to commercial use due to the cost, objections by steelmakers and other issues[62].

Second, after 1964, there was an attempt to make artificial light-weight aggregate (ALA) from debris and inferior-quality coal and use it in construction[63]. However, this also caused SOx emission, because ALA was made by calciting debris and inferior-quality coal with high sulphur content[64]. The Nihon-keiryou-kotsuzai Company was jointly established in 1966 by Santan-chiiki-shinkō-jigyōdan [the Development of Coal Mining Areas Corporation], Mitsubishi-semento [Mitsubishi Cement Company], Nittetsu-kogyō [Nittetsu Mining Company] and others to produce ALA. However, it was dissolved in 1975 as its operations were unprofitable because of investing in a stack gas desulphurizer between 1973 and 1974[65].

Many coal mining companies thus lost their markets and were forced to close their pits, even those with abundant reserves. On the other hand, a few major companies such as Mitsui were able to survive this management difficulty by specializing in shipping small quantities of high-quality coal or coking coal, both of which were, however, much more expensive than imported fossil fuels because of the need for repeated coal washing. Therefore, their management situations worsened so seriously that they had to discontinue independent operations.

[61] For details, see Shimanishi (2008).
[62] Taiheiyō-tankō-kabushiki-gaisha (1969).
[63] Santan-chiiki-shinkō-jigyōdan (1964).
[64] Ibid.
[65] Nittesu-kogyō-kabushiki-gaisha (eds.) (1979), pp. 208-210.

5. Conclusion

'The energy revolution' that began in the early 1950s brought about the following industrial and environmental changes. First, a wide range of industries began to switch fuel from coal to heavy oil, because heavy oil imported from the Middle East was more efficient, in terms of price and heat control, than high-quality domestic coal. Second, the conversion of fuel did not necessarily reduce the consumption of domestic coal. Coal mining companies successfully commodified inferior-quality coal, such as raw coal and low-calorie coal, which had been thrown away in the past. Several electric power companies preferred such inferior-quality coal to heavy oil because of its lower price. Finally, the combustion of those fossil fuels with high sulphur content, that is, both heavy oil and inferior-quality domestic coal, caused serious air pollution from SOx.

In 1968, when the government started to regulate SOx emissions by Taiki-osen-bōshi-hō, the electric power companies rapidly replaced Middle East heavy oil and domestic coal with fossil fuels having low sulphur content, such as crude oil, heavy oil from Southeast Asia, LNG and naphtha. Despite the relatively low sulphur content of domestic coal, its use under the new law required electric power companies to develop stack gas desulphurization techniques, which were very expensive to implement. Coal mining companies were thus forced either to close their pits, even those with abundant reserves, or to specialize in shipping high-quality coal, which was much more expensive than imported fossil fuels because it required repeated washing.

The findings here show that the Japanese domestic coal market during 'the energy revolution' consisted of two submarkets: the inferior-quality coal market near coalfields, which was characterized by a lower price than that of heavy oil, and the high-quality coal market in industrial districts, which was characterized by relatively low environmental loads than those of heavy oil. These submarkets made it possible to maintain the domestic coal market until 1968. However, Japan's economic growth after 1968 seems to have followed a more environment-friendly path; the power companies substituted domestic coal with low-sulphur fossil fuels imported from all over the world. Although this mitigated air pollution to some extent, it also led to a rapid decrease in the demand for domestic coal. The Japanese domestic coal market underwent a decline because of 'the energy revolution' and changes in coal quality relevant to environmental loads.

Appendix

Coalfields and Industrial Districts in Japan

Note: The underlined names are of coalfields, whereas those in boxes are of industrial districts.

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