CIRJE-F-851

Productivity Change and Mine Dynamics: The Coal Industry in Japan during World War II

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May 2012; Revised in November 2012 and October 2013

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Abstract

In the 1930s and 1940s, the Japanese coal industry experienced huge fluctuations in production and labor productivity. In this paper, I explore the micro-aspects of labor productivity change in the coal industry during World War II, using mine-level data, compiled from official statistics and original documents of the Coal Control Association (*Sekitan Toseikai*). The coal industry in this period was characterized by dynamic changes in market structure: a number of mines entered and exited the industry, and shares of incumbent mines changed substantially. These mine dynamics had significant productivity implications. In the early stage of the war, many low productivity mines entered the industry, which reduced average labor productivity considerably. The government and the Coal Control Association implemented a policy to concentrate resources and production on efficient mines during the war, which curbed the decline in average labor productivity. Despite the deteriorating environment during the war, coal production in Japan was maintained fairly well. One of the factors that made this possible was the policy of resource reallocation.

Key words: Productivity, Producer dynamics, War economy, Coal, Japan
JEL Classification Numbers: L11, L52, L71, N45, N75, N85

1. Introduction

The Japanese economy, which had been growing steadily since the late nineteenth century, suddenly ceased to grow after 1937, when a full-scale war with China broke out. Indeed, the average annual growth rate of real GNP in the period from 1937 to 1944 was −0.41%. However, it should be noted that the environment of the Japanese economy deteriorated tremendously in this period. A blockade and restriction on international trade caused real imports to Japan to be 47% smaller in 1944 than that in 1937[1]. This raises the question of how Japan was able to maintain production in this deteriorating environment.

One of the basic conditions that enabled the Japanese economy to withstand the blockade was that it was almost self-sufficient in energy throughout this period. Japan was richly endowed with coal, which was the major source of energy until the postwar high growth period, when petroleum took over that position. Coal accounted for 62.2% and 58.8% of the total energy supply in 1935 and 1944, respectively[2]. Therefore, the coal industry was regarded as being of strategic importance.

As we will see below, coal production in Japan experienced huge fluctuations in the 1930s and 1940s, as well as substantial changes in labor productivity. In this paper, I explore the micro-aspects of these productivity changes. Focusing on the micro-aspects is particularly important in analyzing the coal industry during the war, because the government implemented a policy to concentrate production and resources on efficient mines, which induced substantial changes in the market structure. To investigate the micro-aspects, I use mine-level data on coal production and labor input. Reflecting the strategic importance of the coal industry, comprehensive mine-level data were officially recorded. For the time the official statistics are not available, I use data collected by the industrial association (Coal Control Association, *Sekitan Toseikai*).

Since the seminal work of Dunne et al.[3], producer dynamics has been one of the major issues in industrial studies, given the increasing availability of comprehensive

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[1] *Bank of Japan*, *Meiji-iko Honpo Shuyo Keizai Tokei (Hundred-Year Statistics of the Japanese Economy)*, Tokyo: Bank of Japan, 1966, p.51.

[2] *Toyo Keizai Shinposha*, *Kanketsu Showa Kokusei Soran (Statistical Handbook of Showa Japan: The Complete Version)*, vol.1, Tokyo: Toyo Keizai Shinposha, 1991, p.449.

[3] *T. Dunne, M. Roberts/L. Samuelson*, “Patterns of Firm Entry and Exit in U.S. Manufacturing Industries,” *Rand Journal of Economics* 19(4), 1988, pp.495-515; *T. Dunne/M. Roberts/L. Samuelson*, “The Growth and Failure of U.S. Manufacturing Plants,” *Quarterly Journal of Economics* 104, 1989, pp.671-698.

plant-level data. In the same vein, a number of studies have investigated the productivity implications of producer dynamics[4]. In this paper, I apply the methodology and insights developed in this growing literature to a historical study of the micro-aspects of the war economy in Japan.

The remainder of the paper is organized as follows. Section 2 overviews the Japanese coal industry and the government coal policy during World War II. In Section 3, I analyze labor productivity at the district-level. Section 4 describes the mine dynamics and investigates the implications for labor productivity change. Section 5 concludes the paper.

2. Overview of the coal industry during World War II

Figure 1 depicts the indices of production and labor productivity in the Japanese coal industry from the early 1930s to the end of the war, with 1930 as the benchmark year. Labor productivity is measured by production per worker. We can identify some phases in this figure. Coal production increased from the early 1930s until 1940, when it reached a plateau. It was maintained at this high level until 1944, in the final stage of the war. Then, in 1945, it declined sharply. Labor productivity behaved rather differently from production; it reached its peak as early as 1933, and then continued to decline until 1945.

Figure 1

An important regime change took place in the general economic system around the middle of the phase of increasing coal production. The starting point of the regime change was the acceleration of inflation and the sharp increase in imports from the end of 1936, caused by the announcement of the huge expansion of the military budget. To

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[4] *M. N. Baily/C. Hulten/D. Cambell*, "Productivity Dynamics in Manufacturing Plants," *Brooking Papers on Economic Activity, Microeconomics*, 1992, pp.187-249; *Z. Griliches/ H. Regev*, "Productivity and Firm Turnover in Israeli Industry: 1979-1988," Journal of Econometrics 65, 1995, pp.175-203; D*. T. Ellerman/M. Stoker/ E. R. Berndt*, "Sources of Productivity Growth in American Coal Industry: 1972-95," in *C. R. Hulten/E. R. Dean/M. J. Harper (ED.)*, *New Development in Productivity Analysis*, Chicago: The University of Chicago Press, 2001; *L. Foster/J. Haltiwanger/C. J. Keizan (ED.)*, "Aggregate Productivity Growth: Lessons from Microeconomic Evidence," in *C. R. Hulten/E. R. Dean/and M. J. Harper (ED.)*, *New Development, op cit.*.

restrict imports, the government imposed direct control on use of foreign exchange. In addition to the short-term increase in the military budget, the army drew up a long-term expansion plan for munitions industries including coal, steel and machine tools (Five Year Plan for Important Industries, *Juyo Sangyo Gokanen Keikaku*), and requested the government to implement it in May 1937, just before the Sino-Japanese War.

When the full-scale war with China began in July 1937, the Japanese government expanded its economic controls to mobilize resources for the war. In 1938, the government drew up a plan for allocating strategic commodities including coal and steel (Material Mobilization Plan, *Busshi Doin Keikaku*), and imposed controls on production and distribution of those commodities to implement the plan. At the same time, price controls were also introduced. That is, in August 1938, the Commodity Price Control Rule (*Buppin Hanbai Kakaku Torihismari Kisoku*) was enacted to authorize the government the authority to enforce an upper-bound price for each commodity. As a long-term plan for expanding munitions industries, the Four Year Plan for Production Capacity Expansion (*Seisanryoku Kakuju Keikaku*), was set by the Cabinet in January 1939. Thus, the basic system of planning and control was established by 1939[5].

The coal industry was substantially affected by this general regime change. In early 1937, the government requested the Coal Mining Association (*Sekitan Kogyo Rengokai*) to make a five years plan for production expansion. In response, the Coal Mining Association made a five years forecast on coal demand and supply, which the government referred to in drawing up its Four Year Plan (Table 1). Control on coal prices was introduced in September 1938, when the government ordered Showa Coal Co. (*Showa Sekitan*), the joint sales company of the Coal Mining Association, to reduce coal prices by 10%. Meanwhile, the prices set by smaller mines that were not members of the Coal Mining Association, were not strictly controlled; this stimulated entry of smaller mines. To resolve this problem, a new joint sales company, Nihon Coal Co. (*Nihon Sekitan*), was established in May 1940, taking the place of Showa Coal Co.. Using government subsidies, Nihon Coal Co. purchased all the coal produced in Japan at a price covering the production cost of each mine, which was pooled to be sold at the

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[5] *T. Okazaki*, "Senji Keikaku Keizai to Kakaku Tosei" (Wartime Economic Planning and Price Control), in Kindai Nihon Kenkyukai (ED.), *Senji Keizai (War Economy)*, Tokyo: Yamakawa Shuppansha, 1987; T. Okazaki/M. Okuno-Fujiwara, "Japan's Present-Day Economic System and Its Historical Origins," in *T. Okazaki/M. Okuno-Fujiwara*(ED.), *The Japanese Economic System and Its Historical Origin*s, New York: Oxford University Press, 1999.

official price[6]. Subsequently, differences between the average purchasing price (price for producer) and selling price (price for consumer) of Nihon Coal Co. widened, thus giving coal mines incentives for increasing production as well as curbing inflation (Figure 2).

Table 1, Figure 2

The year 1940 was a turning point not only for the whole Japanese war economy, but also for the coal industry. In September 1940, the diplomatic conflict with the U.S. reached its decisive point because of Japan's invasion of northern Indochina and its military alliance with Germany and Italy. The U.S. responded by placing an embargo on steel scrap trade with Japan, which had a serious impact on Japan's munitions production. In order to cope with this change and prepare for the war with the U.S. expected in the near future, the Japanese government tried to strengthen the system of war economy. One of the key reform measures was to establish powerful industrial associations (control association, *toseikai*) in strategic industries, including coal and steel. In principle, each control association would organize all the companies in the industry, and the president of the association was granted wide-ranging authority to command member companies, under the Major Industrial Association Directive (*Juyo Sangyo Dantai Rei*)[7].

The Coal Control Association (*Sekitan Toseikai*) was founded in November 1941. It played an essential role in drawing up and implementing mine-level production plans and other policies for the coal industry. In the following month, December 1941, the war with the U.S. (Pacific War) broke out. Mobilization of resources for the war restricted the supply of materials, particularly steel, to the coal industry. Consequently, steel-labor ratio in the coal industry declined sharply from 1940 (Figure 3). As steel was one of the essential inputs for the coal industry to build and sustain galleries of mines, decline of steel supply gave a serious impact on the coal mining industry as we will see below.

Figure 3

Under these conditions, the government and the Coal Control Association adopted a policy to concentrate resources and production on efficient mines. As a result, inefficient mines were closed and workers were moved to more efficient mines. This

6 *T. Nezu*, (ED.), *Sekitan Kokka Tosei Shi (History of State Control on Coal)*, Tokyo: Nihon Keizai Kenkyujo, 1958, pp.202-208, pp.275-285.

7 *Okazaki/Okuno-Fujiwara*, "Japan's Present-Day".

selective policy was continued until the final stages of the war[8], and gave a substantial impact on the market structure.

3. Productivity change and its sources: District-level analysis

To investigate the implication of these policies for productivity, we first look at district-level data. In this period, five local bureaus of the Ministry of Commerce and Industry were responsible for supervising mines[9]: Sapporo, Sendai, Tokyo, Osaka and Fukuoka. Each bureau was responsible for between one and three districts (Sapporo: Hokkaido; Sendai: Tohoku; Tokyo: Kanto and Chubu; Osaka: Kinki; Chugoku except Yamaguchi Prefecture; Fukuoka: Kyushu, Yamaguchi Prefecture and Okinawa Prefecture). A series of official statistics, *Honpo Kogyo no Susei (Mining Yearbook of Japan)*, edited by the Ministry of Commerce and Industry, contains production and input data for the jurisdiction of each mine supervision bureau. Here, we refer to these data as district-level data, for simplicity.

Table 2 summarizes the data for four time points: 1930, 1935, 1939 and 1944. As shown, more than 90% of coal was produced in two districts, Sapporo (Hokkaido) and Fukuoka (Kyushu). Of these two districts, production in Kyushu was much larger, but its share declined during the war. Indeed, coal mines in Kyushu were aging, whereas those in Hokkaido were newly developed. Labor productivity varied substantially across districts, and was substantially higher in Hokkaido than elsewhere. Here, labor productivity is measured by production per worker as in Figure 1. Finally, over time changes in labor productivity were similar across districts: generally it rose from 1930 to 1935, and then declined.

Table 2

It is possible to analyze cross-sectional and time series variation in labor productivity by regression analysis. To do that, we assume the following standard Cobb-Douglas type production function. Besides labor, we include three inputs, namely steel, electricity and explosive. Steel was mainly used to build and sustain galleries, a part of the basic capital stock of the coal mines. Electricity is a proxy for the service of machinery, because most of motors at coal mines were driven by electrical power[10].

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[8] *Nezu (ED.)*, *Sekitan*, pp.302-328.
[9] In November 1943, the Ministry of Commerce and Industry was reorganized into the Ministry of Munitions.
[10] Concerning the coal mining industry, the ratio of electric motors in the total motor equipment in terms of kilowatt, was 78.3 % in 1939 (*Ministry of Commerce and Industry* (ED.) *Honpo Kogyo no Susei (Mining Yearbook of Japan)*, 1939-40 issue, 1948,

Explosive was an intermediary input to dig coal beds.

$$Y_{it} = A^* STEEL_{it}^{\alpha} * ELECTRICITY_{it}^{\beta} * EXPLOSIVE_{it}^{\gamma} * L_{it}^{\delta} \quad (1)$$

Y: Coal production

STEEL: Steel inputs

ELECTRICITY: Electricity inputs

EXPLOSIVE: Explosive inputs

L: Number of workers

i : District index

t: Year index

Then, labor productivity is,

$$Y_{it}/L_{it}=A^*(STEEL_{it}/L_{it})^{\alpha} *(ELECTRICITY_{it}/L_{it})^{\beta} *(EXPLOSIVE_{it}/L_{it})^{\gamma} *L_{it}^{\alpha+\beta+\gamma+\delta-1} \quad (2)$$

Taking the log and adding district dummies (κ_i) and year dummies(λ_t) as well as the error term (ε_{it}), we have

$$\ln(Y_{it}/L_{it})=\ln A+\alpha \ln(STEEL_{it}/L_{it}) + \beta \ln(ELECTRICITY_{it}/L_{it})+\gamma \ln(EXPLOSIVE_{it}/L_{it}) +(\alpha+\beta+\gamma+\delta-1)\ln(L_{it})+\kappa_i+\lambda_t+\varepsilon_{it} \quad (3)$$

The term of $\ln(L_{it})$ captures the scale effect. In case its coefficient is positive, zero and negative, the production function is increasing, constant and decreasing return to scale, respectively. The sum of district dummies (κ_i), year dummies (λ_t) and error term (ε_{it}) is a measure of the Total Factor Productivity (TFP), where district dummies and year dummies represent its district-specific and year-specific components, respectively. Using the annual data from 1930 to 1944, we estimate equation (3). The observations are 75 district-year (5 districts * 15 years). The basic statistics and the estimation result are reported in Table 3 and Table 4.

Table 3, Table 4

Some interesting findings emerge. Concerning the district-specific component of TFP, with Hokkaido as the reference, all of the district dummies except Kyushu are negative and statistically significant. The Kyushu dummy is positive but statistically

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pp.290-291.

insignificant. Also remarkable is the fairly large magnitude. For example, the difference in the district-specific component of TFP between Hokkaido and Sendai was 1.29 times larger than the standard deviation of labor productivity, 0.599 (Table 3). This implies that the two centers of coal mining in Japan, Hokkaido and Kyushu had substantially higher TFP than the other districts, other conditions being equal. Meanwhile, no time trend is observed in the year-specific component of TFP. On the other hand, the coefficient of $\ln(L_{it})$ is significantly negative and the magnitude is large, which means the production function (1) has a property of diminishing return to scale. As we control for district-specific shocks, the scale effect here reflects intertemporal variation of scale in each district. Given that, diminishing return at the district-level suggests that good coal beds were limited in each district and rapid expansion of coal production in a district led to deterioration of coal beds there. Also, it is possible that expansion of production was accompanied by deterioration of labor force. I will discuss this issue in the next section.

Based on the estimates in Table 4, we can decompose the labor productivity change into contributions of input-labor ratios and TFP using the following formula.

$$\Delta \ln(Y_t/L_t) = \hat{\alpha}\Delta\sum_i \ln(STEEL_{it}/L_{it}) * w_{it} + \hat{\beta}\Delta\sum_i \ln(ELECTLICRTY_{it}/L_{it}) * w_{it}$$
$$+ \hat{\gamma}\Delta\sum_i \ln(EXPLOSIVE_{it}/L_{it}) * w_{it} + (\hat{\alpha}+\hat{\beta}+\hat{\gamma}+\hat{\delta}-1)\Delta\sum_i \ln(L_{it}) * w_{it} + \sum_i \hat{\kappa}_i * w_{it} + \Delta\hat{\lambda}_t \quad (4)$$

where Δ denotes the operator to take difference, and w_{it} denotes the weight of district i in year t in terms of number of workers.

Table 5 decomposes the average labor productivity using the above formula. Before the war (1930－35), there were three major sources of labor productivity improvement, namely increase in the input-labor ratio, positive scale effect and TFP growth; the start of the war affected all of these sources. During 1935-39, the contribution of input-labor ratio fell to zero, and contribution of scale effect and TFP declined substantially to become negative. In the late stage of the war, 1939－44, the contribution of the input-labor ratio, particularly the contribution of steel-labor ratio, became negative. This reflects the restriction of steel supply, as discussed in the previous section. On the other hand, it is remarkable that the magnitude of the negative impact of scale effect decreased, and furthermore contribution of TFP became positive under the deteriorating conditions in the coal industry. In the next section, I analyze mine-level data to explore the cause of large TFP decline in the early stage of the war and efforts to mitigate it in the late stage.

Table 5

4. Mine dynamics and productivity change

As mentioned in Section 2, the government and the Coal Control Association cut off resources to inefficient coal mines and closed them, with the aim of concentrating production on efficient mines. This means that, mine dynamics in this period was related to a key policy issue. To see the scale of mine dynamics and its productivity implications, we need comprehensive mine-level data on production and inputs. For this purpose also, the basic data source is *Honpo Kogyo no Susei* (*Mining Yearbook of Japan*), which contains mine-level data on production and numbers of workers for almost all coal mines with an annual production over 10,000 tons. Unfortunately, input data on factors other than workers are not available, so mine-level TFP cannot be measured. Nevertheless, using these data does make it possible to observe mine dynamics and the implications for labor productivity.

For this analysis, I use the 1930, 1935 and 1939-40 issues of *Honpo Kogyo no Susei*. Because the issue covering 1941－1945 lacks data on workers, we obtained the data for 1944 from the original Coal Control Association records, held at the Ibaraki Prefectural Museum of History[11]. A document entitled "*Tanko Ichiranhyo*" (List of Coal Mines) by the Labor Department of the Coal Control Association, contains mine-level data on coal production and number of workers for August 1944.

Using these data, we now examine the entry and exit of coal mines. Table 6 reports entry and exit for three periods: 1930－35, 1935－39, and 1939－44. First, let us look at the period 1930-35, just before the war, as a benchmark. In 1930, there were 156 coal mines whose annual production was over 10,000 tons. Thirty five of these had exited by 1935. These exiting mines accounted for 22.4% of the total in terms of number of mines, but only 6.5% in terms of production. During the same period, 76 new mines entered the industry, with a production share of 9.1% in 1935. These data imply that despite the frequency of entry and exit, most of these mines were small; hence market structure remained basically stable in this period.

[11] These documents were originally held by an ex-staff member of the Coal Control Association.

Table 6

By contrast, the period 1935－39, the early stage of the war, was characterized by accelerations of entry. That is, 144 mines entered the industry and their production share was 14.2%. This is attributable to the growth of military demand and the sharp rise in coal prices from the end of 1936 (Figure 2). New entries were also encouraged by the price control policy that excluded smaller mines that were not the members of the Coal Mining Association (*Sekitan Kogyo Rengokai*). On the other hand, exit did not change substantially.

In 1939-44, the landscape substantially changed again. This period, the late stage of the war, was characterized by a surge in exit and a decline in entry. Indeed, 142 mines with a total production share of 14.1%, exited, whereas the new entrants had a share of just 7.3% in 1944. This reflects the policy of concentrating resources and production on efficient mines and to close inefficient mines, discussed above.

The wartime policy of concentrating production on efficient coal mines was based on the belief that the productivity varied greatly across mines, and this was indeed the case. Table 7 summarizes the basic statistics of each coal mine's labor productivity. For example, in 1939, average labor productivity was 164.0 tons per worker, with a standard deviation was 82.4, which is around half the average, as the coefficient of variation indicates. Also, the maximum and minimum values indicate that the most efficient mine's labor productivity was 33.7 times (626.2/18.6) larger than that of the most inefficient mine. This implies that shifting resources and production from inefficient mines to efficient ones could potentially raise average labor productivity of the coal industry.

Table 7

To confirm whether this potential productivity effect was realized, Table 8 compares the labor productivity of surviving, exiting and entering mines in each period. Looking at 1935-39, we find that the average labor productivity of exiting mines in 1935 was substantially lower than that of surviving mines, which implies that exit improved total average labor productivity. On the other hand, the average labor productivity of entering mines in 1939 was substantially lower than that of surviving mines in 1935, which implies that new entry reduced total average labor productivity. The condition that the labor productivity of new entrants was lower than that of survivors was common to the prewar period, 1930－35, but differences in labor productivity between the two groups grew in 1935－39.

Table 8

Another channel through which mine dynamics had productivity implications is change in the share of surviving mines. Table 8 classifies surviving mines into two groups, namely the share-up group and the share-down group, to compare their labor productivity. Share-up (share-down) group refers to the group of mines whose share increased (decreased) in each period, and here share is measured by the number of workers. In 1935, the share-up group had much higher average labor productivity than the share-down group, which implies that changes in the share of the surviving mines raised total average labor productivity. Furthermore, the difference between the two groups was substantially larger in 1935 than in 1930. During the late stage of the war, 1939－44, the relative labor productivity for the two groups was similar to that in 1935–39.

In summary, during the war, mine dynamics had productivity implications in two ways: whereas exit and share change had a positive impact on the total average labor productivity, entry had a negative impact. The next question, then, concerns the magnitudes of those impacts. To examine this issue, I decompose labor productivity change in each period using the formula of Baily et al. (1992) and Foster et al. (2001). That is, the change in labor productivity from year t-1 to year t is decomposed into the following five components.

within effect	$\Sigma_{i \in S}\theta_{it-1}\,\Delta LP_{i,t}$
between effect	$\Sigma_{i \in S}\Delta\theta_{it}\,(LP_{it-1} - LP_{t-1})$
covariance effect	$\Sigma_{i \in S}\Delta\theta_{it}\Delta LP_{i,t}$
exit effect	$\Sigma_{i \in X}\theta_{it-1}\,(LP_{t-1} - LP_{it-1})$
entry effect	$\Sigma_{i \in N}\theta_{it}\,(LP_{it} - LP_{t-1})$

, where, LP_{it} denotes labor productivity of mine i in year t, and θ_{it} denotes share of mine i in year t in terms of the number of workers. S, X and N refer to the sets of surviving, exiting and entering mines, respectively.

The within effect is the portion of productivity change caused by the labor productivity change of each mine, weighted by the initial share of each mine. The between effect represents the portion of labor productivity change caused by share change, weighted by the initial labor productivity deviation of each mine from the industry average. The covariance effect is the cross term of the above two effects. These three terms relate to the mines that survive from year t−1 to year t. The exit effect represents the portion caused by the labor productivity difference between exiting mines and the industry average in year t−1, while the entry effect represents the portion caused by the difference between the labor productivity of entering mines in year t and the industry average in year t−1.

Table 9 reports the results of labor productivity change decomposition using the above formula. As seen in Figure 1, average labor productivity increased in the early 1930s and then declined until the end of the war. Table 9 indicates that the labor productivity increase in the early 1930s was basically caused by the within effect, namely the labor productivity increase of each mine. In the early stage of the war (1935−39), the within effect became negative. At the same time, it is notable that the negative entry effect had substantial magnitude, and the between effect was positive and not negligible. In the late stage of the war, 1939−44, while the within effect continued to be negative and large, whereas magnitude of the negative entry effect declined and the between effect continued to be positive.

Table 9

As mine-level TFP estimates are not available, the results in Table 9 cannot be directly compared with those in Table 5, but some speculations are possible. Of the five components in Table 9, the between effect, the exit effect and the entry effects are attributable to the reallocation of resources in a broad sense. If we assume that the total resources for the coal industry are given, these effects are reflected in "TFP change within district" in Table 5. It is notable that this assumption nearly held during the war, because the government allocated resources to each industry according to the Material Mobilization Plan, as mentioned in Section 2. If this is the case, the large negative TFP growth in Table 5 at least partly reflects the large negative entry effect in this period, while the reduction in negative TFP growth in Table 5 reflects a decline of the negative entry effect together with continuation of the positive between effect.

Finally, as was shown in Table 9, within effects accounted for the largest portion of the labor productivity decline during the war. A closer look at the mine-level data can help us understand more about this phenomenon. Table 10 lists the mines with the largest negative within effects for the periods 1935−39 and 1939−44. As seen, most of these mines increased their share in terms of workers, and had much higher labor productivity than the average in Table 7. The government and the Coal Control

Association made great efforts to expand the labor force of efficient mines. However, as the supply of ordinary Japanese workers was restricted, expansion of work force in the coal mining industry mainly depended upon introduction of Korean workers. Indeed, the ratio of Korean workers in the total labor force in the coal mining industry increased to be around 30% in the period from 1943 to 1945 (Table 11). It is notable that Korean workers were also concentrated on the efficient mines that were requested to expand production, and the ratio of Korean workers was higher in those mines. For example, for Hokkaido Tanko Kisen Co., one of the largest coal mining firms, the ratio of Korean workers was 53.1% at the end of June 1945[12], when the average ratio in Japan was 31.3%, as indicated in Table 11. On the other hand, it is reported that their efficiency was 60 to 70 % of ordinary Japanese workers[13]. Deterioration of labor force as well as deterioration of coal beds, mentioned above at the district-level, caused sharp decline in the labor productivity, especially in efficient mines. The same situation also explains the large negative covariance effect in this period. This implies that leveling of labor productivity was attributable to the resource reallocation. To illustrate that, Figure 4 depicts the changes in the number of workers and labor productivity for mines in the upper and lower tertiles in terms of labor productivity in 1935. It is clear that workers were concentrated in the upper tertile mines, and the labor productivities of these two groups of mines converged. That labor productivity leveled is also confirmed by Table 7, which shows a decline in the standard deviation and the coefficient of variation from 1935 to 1944.

Table 10, Table 11, Figure 4

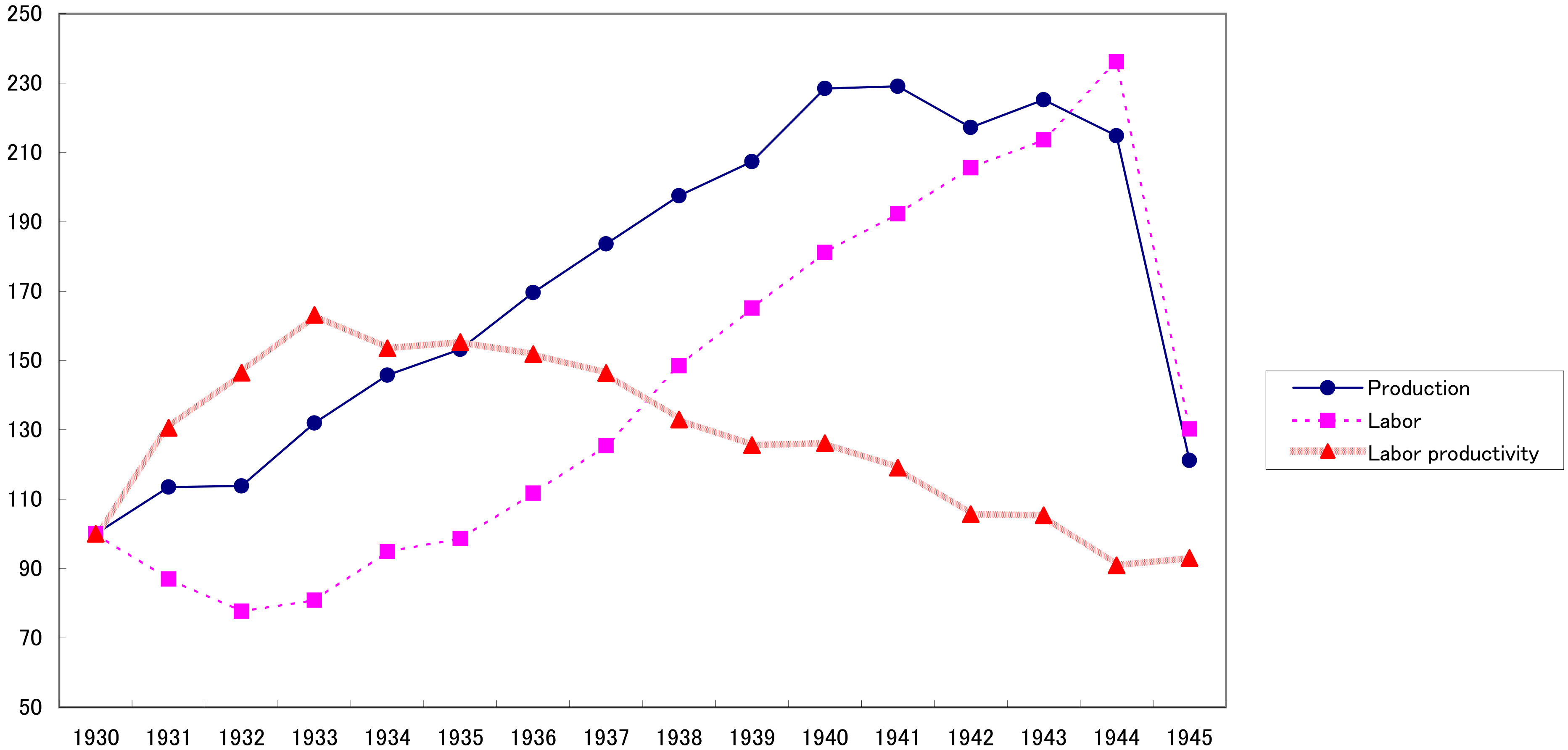
5. Concluding remarks

In the 1930s and 1940s, the Japanese coal industry experienced huge fluctuations in production and labor productivity. In this paper, I explored the micro-aspects of labor productivity change in the coal industry during World War II, using district -level and mine-level data compiled from official statistics and the original documents of the Coal Control Association. During this period, the coal industry was characterized by dynamic changes in market structure. That is, a number of mines entered and exited the industry, and the shares of incumbent mines also changed substantially. These mine dynamics had substantial productivity implications. In the

[12] *K. Endo*, "Senji kano Chosenjin Rodosha Renko Seisaku no Tenkai to Roshi Kankei," (Development of the Policy to Introduce Korean Workers during World War II and Labor -Management Relations), *Rekishigaku Kenkyu*, vol. 567, 1987, p.11.
[13] *Nezu (ED.) Sekitan*, pp.167-168.

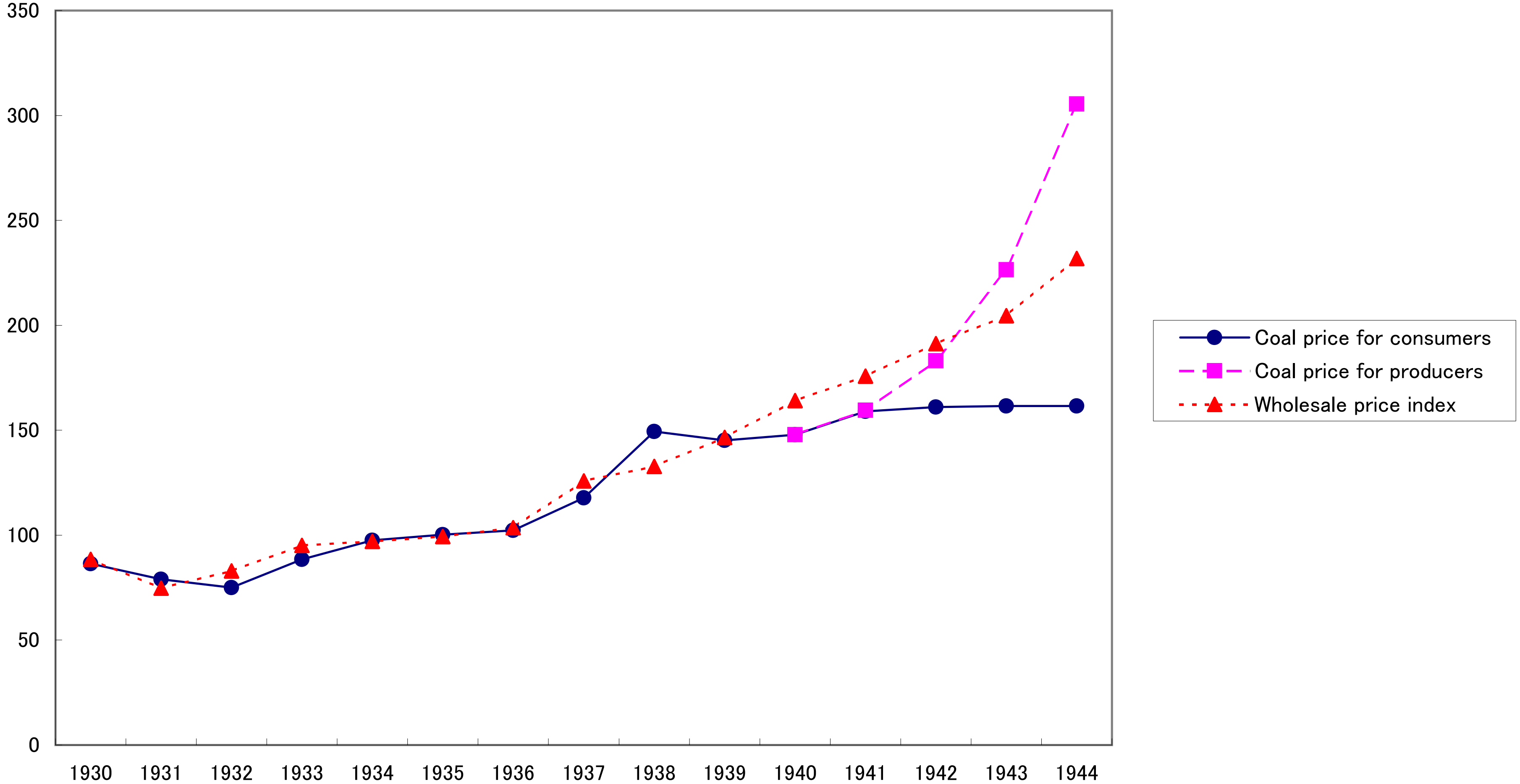
early stage of the war, many inefficient mines entered the industry, which lowered average labor productivity considerably. However, the government and the Coal Control Association implemented a policy to concentrate resources and production on efficient mines during the war, which curbed the decline in average labor productivity and TFP. Despite the deteriorating environment, coal production in Japan was maintained fairly well during the war. One of the conditions that made this possible was the policy of resource reallocation.

Figure 1 Coal production and labor productivity in Japan (1930=100)



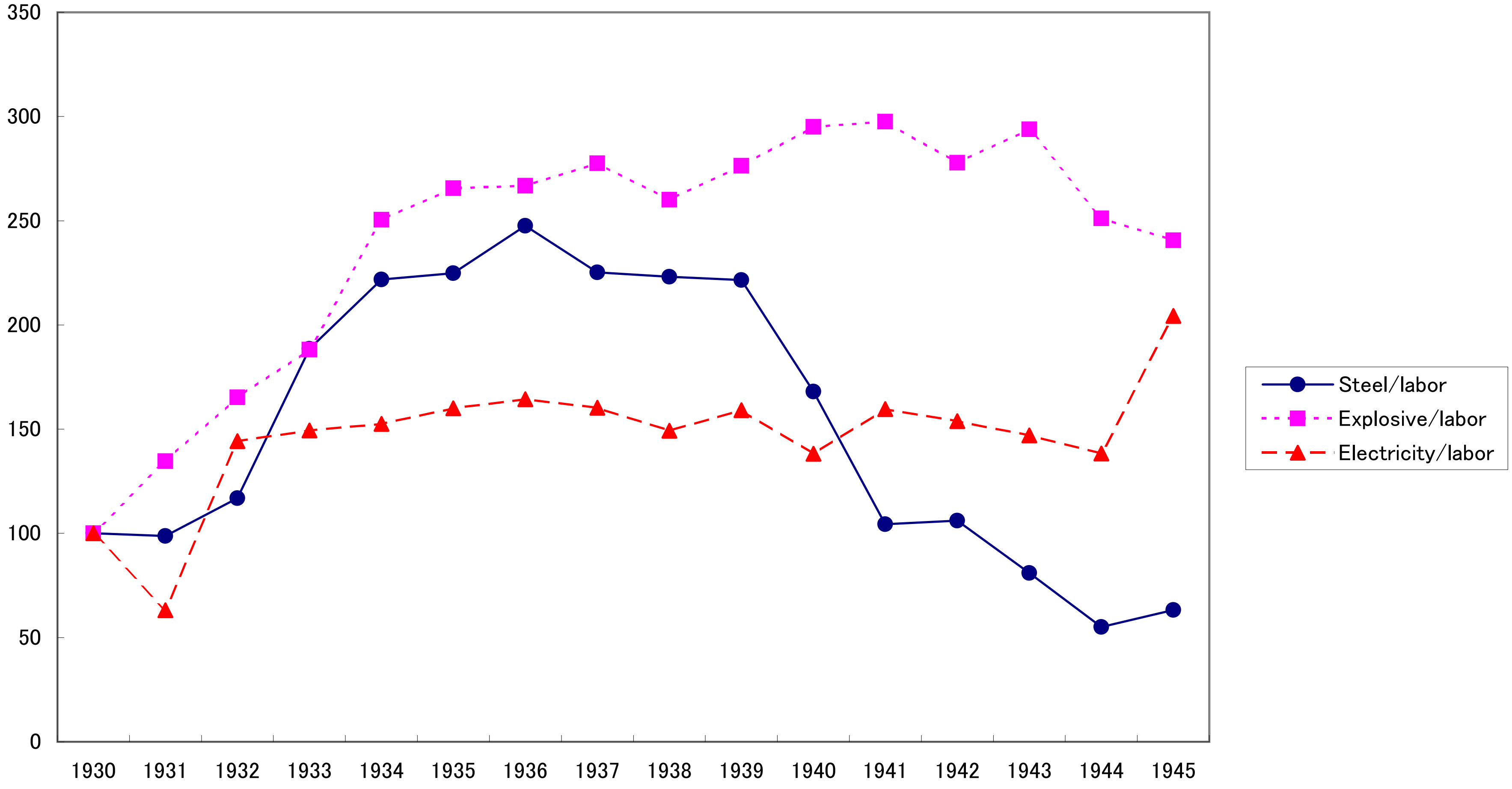
Source: *Ministry of Commerce and Industry (ED.), Honpo Kogyo no Susei (Mining Yearbook of Japan),* various issues.
Note: See the text.

Figure 2 Coal price and wholesale price index （1934-36 average=100）



Source: *Nezu (ED.), Sekitan Kokka Tosei Shi (History of State Control on Coal*), Tokyo: Nihon Keizai Kenkyujo, 1958, p.914; Bank of Japan, *Meiji 20nen-Showa 37nen Oroshiuri Bukka Shisu (Wholesale Price Index, 1887-1962*), Tokyo: Bank of Japan, 1964.

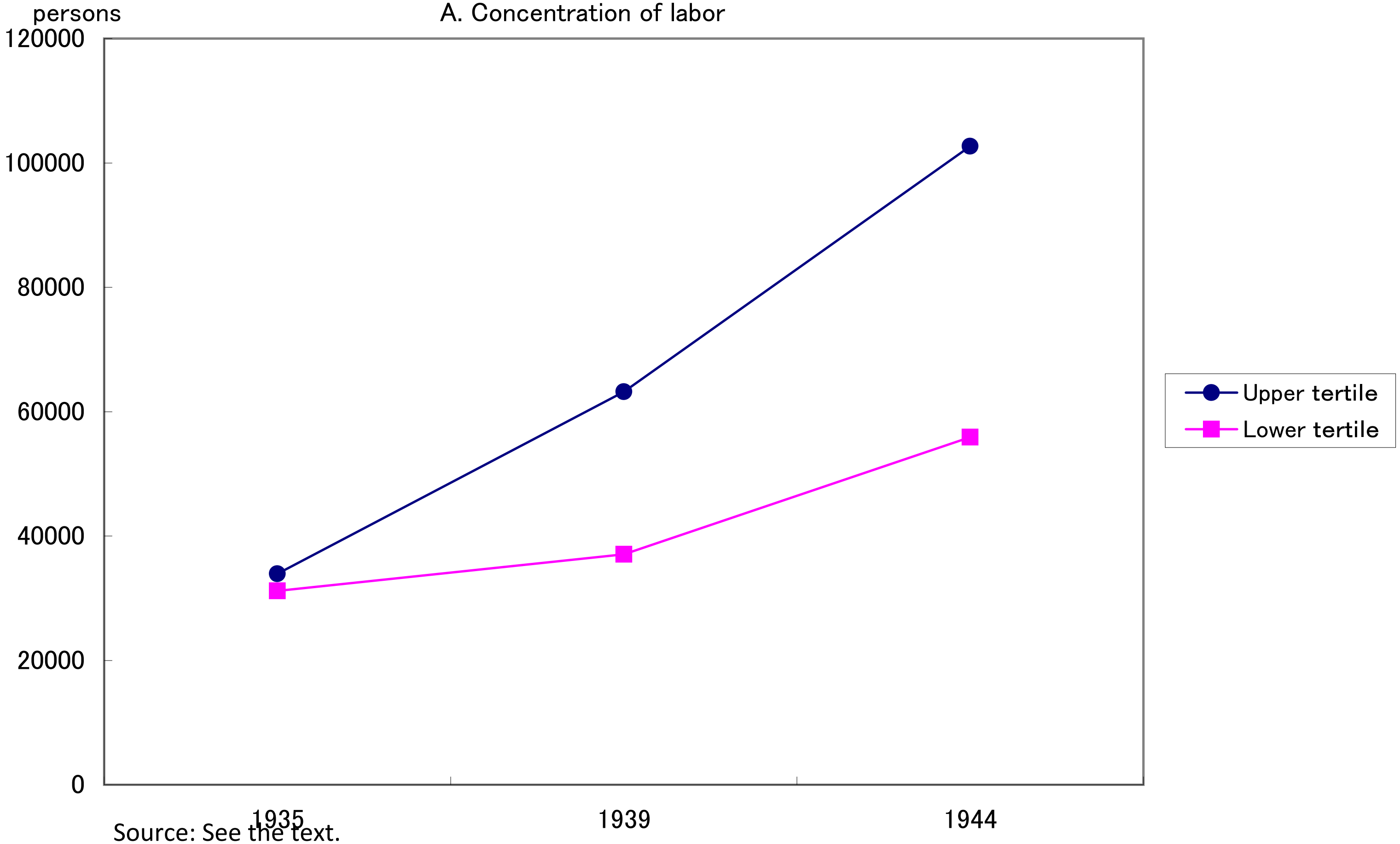
Figure 3 Material inputs-labor ratios (1930=100)



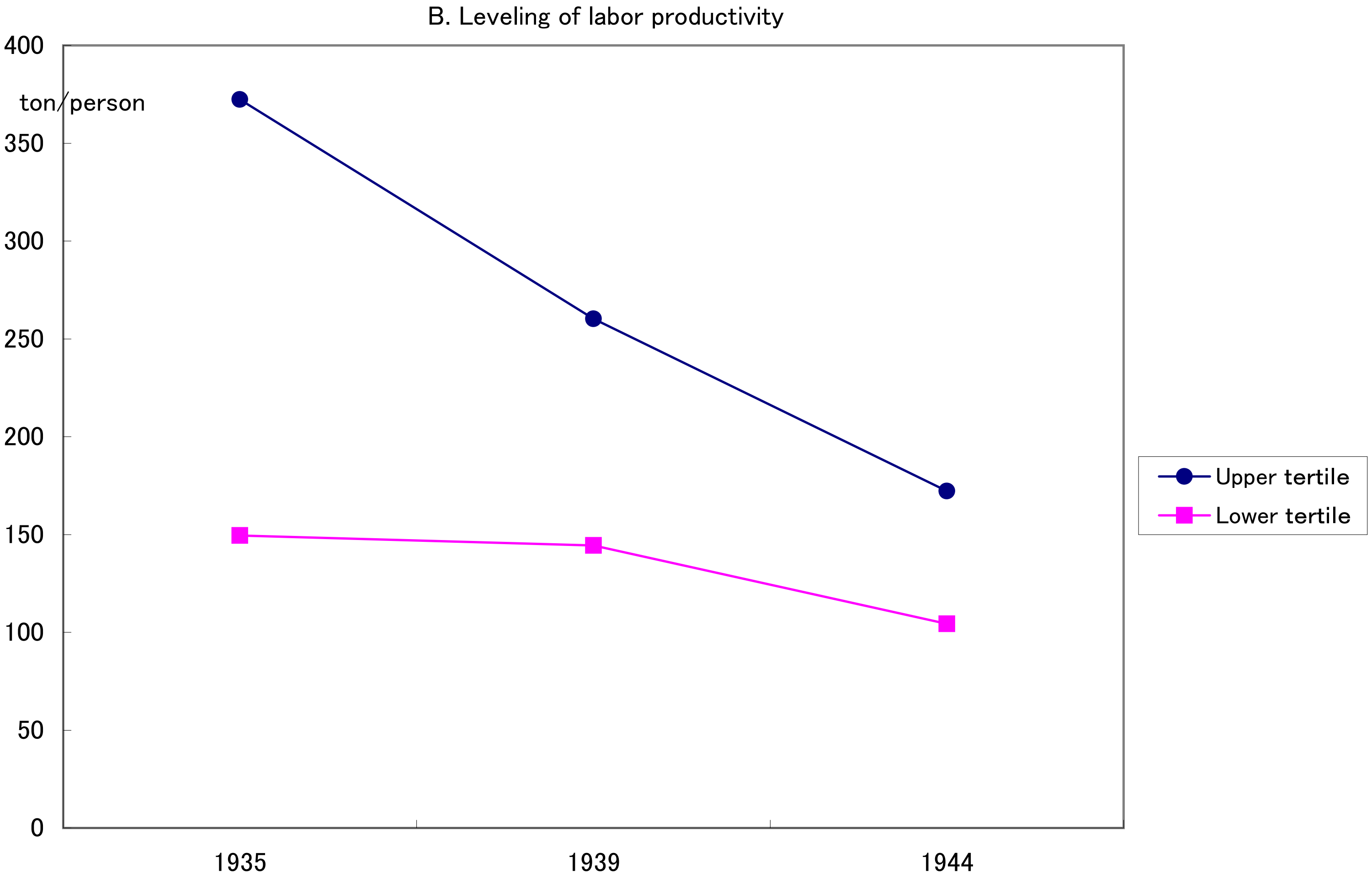
Source: *Ministry of Commerce and Industry (ED.), Honpo*, various issues.
Note: See the text.

Figure 4 Concentration of labor force and leveling of labor

A. Concentration of labor



Source: See the text.



Source: See the text.

Table 1 Long-term plans for coal production expansion

1,000 tons

	Prediction by Showa Sekitan Co.	Production Capacity Expansion Plan I	Production Capacity Expansion Plan II	Practical plan for each year	Actual Production
	June 1937	January 1939	June 1942		
1937	50,810				45,258
1938	54,450	58,363			48,864
1939	58,700	65,803		53,896	51,111
1940	61,550	71,725		58,000	56,313
1941	65,490	78,182		59,000	56,472
1942			73,300	57,000	53,540
1943			75,300	55,000	55,500
1944			77,600	58,200	52,945
1945			82,000	20,566	29,879

Source: *Nezu (ED.), Sekitan*, op cit., p.101; *Kokumin Keizai Kenkyu Kyokai and Kinzoku Kogyo Chosakai*, *Seisanryoku Kakuju Keikaku to sono Jisseki (Production Capacity Expansion Plans and Their Results)*, 1946; *Ministry of International Trade and Industry (ED.)*, *Honpo Kogyo no Susei (Mining Yearbook of Japan)*, 1955 issue, Tokyo: Research Institute of International Trade and Industry, 1956.

Table 2 District-level data on coal production and inputs

Year	District	Production		Input: Labor	Input: Steel	Input: Electricity	Input: Explosive	Labor productivity (Production /labor)	Steel/labor	Electricity /labor	Explosive /labor
		1,000 tons		persons	tons	1,000 KWH	tons				
1930	Sapporo	6,727	(21.4)	26,988	7,654	87,927	759	0.249	0.284	3.258	0.028
1935	(Hokkaido)	8,318	(22.0)	22,337	13,326	167,028	1,192	0.372	0.597	7.478	0.053
1939		12,905	(25.2)	48,417	32,951	332,513	2,371	0.267	0.681	6.868	0.049
1944		15,317	(28.9)	89,600	14,984	573,263	2,876	0.171	0.167	6.398	0.032
1930	Sendai	2,037	(6.5)	11,889	2,046	108,312	156	0.171	0.172	9.110	0.013
1935		2,288	(6.1)	13,236	4,487	137,920	401	0.173	0.339	10.420	0.030
1939		2,919	(5.7)	22,627	6,906	183,874	485	0.129	0.305	8.126	0.021
1944		2,918	(5.5)	31,171	3,127	273,582	504	0.094	0.100	8.777	0.016
1930	Tokyo	511	(1.6)	3,484	379	10,180	10	0.147	0.109	2.922	0.003
1935		370	(1.0)	2,346	209	8,427	4	0.158	0.089	3.592	0.002
1939		581	(1.1)	4,259	783	4,479	19	0.137	0.184	1.052	0.004
1944		778	(1.5)	8,076	497	17,423	234	0.096	0.061	2.157	0.029
1930	Osaka	11	(0.0)	359	4	34	0	0.031	0.011	0.094	0.000
1935		12	(0.0)	243	0	2	1	0.049	0.000	0.010	0.004
1939		40	(0.1)	1163	168	8	5	0.034	0.144	0.007	0.004
1944		90	(0.2)	1199	75	3,716	25	0.075	0.062	3.099	0.021
1930	Fukuoka	22,091	(70.4)	161,806	30,648	545,590	2,127	0.137	0.189	3.372	0.013
1935	(Kyushu)	26,774	(70.9)	136,975	55,320	734,527	4,411	0.195	0.404	5.362	0.032
1939		34,666	(67.8)	216,553	80,115	1,222,762	7,580	0.160	0.370	5.646	0.035
1944		33,842	(63.9)	289,141	24,350	1,300,155	9,958	0.117	0.084	4.497	0.034

Source: See the text.
Note: District refers to the area that each mine supervising bureau took charge of. See the text.
Percentage in parentheses.

Table 3 Basic statistics of district-level observations

	Obs.	Mean	Srdev.	Max.	Min.
ln(Y/L)	75	4.934	0.599	5.938	3.410
ln(STEEL/L)	75	−1.842	0.997	−0.385	−5.493
ln(ELECTRICITY/L)	75	7.377	3.153	9.378	−5.814
ln(EXPLOSIVE/L)	75	−4.139	1.010	−2.930	−7.029
ln(L)	75	9.343	2.101	4.771	12.575

Table 4 Estimation result of production function

Dependent variable: ln (Y/L)		
ln (STEEL/L)	0.161	(4.59) ***
ln(ELECTRICITY/L)	0.054	(4.02) ***
ln(EXPLOSIVE/L)	0.125	(3.33) ***
ln(L)	−0.381	(−3.59) ***
Sendai	−0.771	(−7.51) ***
Tokyo	−1.002	(−3.47) ***
Osaka	−2.472	(−5.95) ***
Fukuoka (Kyushu)	0.189	(1.12)
1931	0.241	(1.98) *
1932	0.094	(0.74)
1933	0.104	(0.83)
1934	0.048	(0.46)
1935	0.088	(0.89)
1936	0.155	(1.67) *
1937	0.142	(1.61)
1938	−0.016	(−0.15)
1939	0.007	(0.07)
1940	0.090	(0.76)
1941	0.067	(0.53)
1942	0.081	(0.60)
1943	0.123	(0.84)
1944	0.079	(0.55)
Constant	9.639	(26.47) ***
R^2	0.965	

Note: Heteroschedasticity robust t-values are in parentheses.
*** statistically significant at 1% level.
* statistically significant at 10% level.

Table 5 Decomposition of labor productivity change

	1930–35	1935–39	1939–44
Total	0.394	−0.261	−0.288
Contribution of input–labor ratio	0.250	0.000	−0.241
STEEL/L	0.118	−0.004	−0.225
ELECTRICITY/L	0.027	−0.001	−0.007
EXPLOSIVE/L	0.105	0.005	−0.009
Contribution of scale effect	0.066	−0.164	−0.110
Contribution of TFP	0.077	−0.098	0.063
TFP change within district	0.088	−0.081	0.072
Reallocation between districts	−0.011	−0.017	−0.009

Table 6 Entry and exit of coal mines

A. 1930–1935		1930		1935	
Total	Number of mines	156	(100.0)	197	(100.0)
	Number of workers (persons)	198,598	(100.0)	166,516	(100.0)
	Production (1,000 tons)	30,955	(100.0)	37,278	(100.0)
Survive	Number of mines	121	(77.6)	121	(61.4)
	Number of workers (persons)	181,372	(91.3)	142,665	(85.7)
	Production (1,000 tons)	28,935	(93.5)	33,889	(90.9)
Exit	Number of mines	35	(22.4)	–	–
	Number of workers (persons)	17,226	(8.7)	–	–
	Production (1,000 tons)	2,019	(6.5)	–	–
Entry	Number of mines	–	–	76	(38.6)
	Number of workers (persons)	–	–	23,851	(14.3)
	Production (1,000 tons)	–	–	3,389	(9.1)
B. 1935–1939		**1935**		**1939**	
Total	Number of mines	197	(100.0)	280	(100.0)
	Number of workers (persons)	166,516	(100.0)	270,250	(100.0)
	Production (1,000 tons)	37,278	(100.0)	49,817	(100.0)
Survive	Number of mines	136	(69.0)	136	(48.6)
	Number of workers (persons)	144,860	(87.0)	217,528	(80.5)
	Production (1,000 tons)	33,720	(90.5)	42,756	(85.8)
Exit	Number of mines	61	(31.0)	–	–
	Number of workers (persons)	21,656	(13.0)	–	–
	Production (1,000 tons)	3,558	(9.5)	–	–
Entry	Number of mines	–	–	144	(51.4)
	Number of workers (persons)	–	–	52,722	(19.5)
	Production (1,000 tons)	–	–	7,061	(14.2)
C. 1939–1944		**1939**		**1944**	
Total	Number of mines	280	(100.0)	183	(100.0)
	Number of workers (persons)	270,250	(100.0)	351,880	(100.0)
	Production (1,000 tons)	49,817	(100.0)	49,667	(100.0)
Survive	Number of mines	148	(52.9)	148	(80.9)
	Number of workers (persons)	224,060	(82.9)	323,765	(92.0)
	Production (1,000 tons)	42,795	(85.9)	46,019	(92.7)
Exit	Number of mines	132	(47.1)	–	–
	Number of workers (persons)	46,190	(17.1)	–	–
	Production (1,000 tons)	7,022	(14.1)	–	–
Entry	Number of mines	–	–	35	(19.1)
	Number of workers (persons)	–	–	28,115	(8.0)
	Production (1,000 tons)	–	–	3,648	(7.3)

Source: see the text.

Table 7 Heterogeneity of coal mines in terms of productivity and production

		Average	Median	Stdev.	Coefficient of variation	Max.	Min.
Productivity	1930	159.6	144.0	71.3	0.447	482.9	37.4
(tons/person)	1935	199.8	170.6	118.1	0.591	871.8	19.3
	1939	164.0	147.2	82.4	0.503	626.2	18.6
	1944	129.0	124.2	51.7	0.401	501.4	15.4
Production	1930	197.2	96.8	282.5	1.433	2269.5	10.4
(1,000 tons)	1935	188.3	84.2	294.7	1.565	2488.5	10.0
	1939	177.3	50.2	345.5	1.949	3362.4	10.0
	1944	269.3	117.6	440.8	1.637	4031.2	10.1

Table 8 Productivity implication of mine dynamics

tons/person

A. 1930–1935	1930	1935
Total	155.9	223.9
Survive	159.5	237.5
Share up	166.4	202.4
Share down	154.6	287.0
Exit	117.2	–
Entry	–	142.1
B. 1935–1939	**1935**	**1939**
Total	223.9	184.3
Survive	232.8	196.6
Share up	286.8	210.4
Share down	194.4	178.8
Exit	164.3	–
Entry	–	133.9
C. 1939–1944	**1939**	**1944**
Total	184.3	140.7
Survive	191.0	142.1
Share up	214.3	144.0
Share down	172.4	136.1
Exit	152.0	–
Entry	–	124.0

Table 9 Decomposition of productivity change

tons/person

	Total	Within	Between	Covariance	Exit	Entry
1930-35	68.0	84.9	3.2	−21.4	3.4	−2.0
1935-39	−39.5	−32.4	13.8	−11.1	7.8	−17.5
1940-44	−43.6	−39.4	10.9	−15.9	5.5	−4.8

Table 10 Break down of within effect (Mines with largest negative within effects)

tons/person, tons

Period	Name	District	Within effect	Productivity		Worker share		Number of workers	
				First year	Last year	First year	Last year	First year	Last year
1935–39	Miike	Fukuoka	−3.84	239	178	0.0624	0.0699	10,396	18,898
	Onoura	Fukuoka	−2.34	276	197	0.0295	0.0303	4,917	8,199
	Akaike	Fukuoka	−2.14	215	19	0.0109	0.0104	1,819	2,812
	Sakito	Fukuoka	−1.98	355	232	0.0161	0.0176	2,684	4,762
	Mitsui Tagawa	Fukuoka	−1.93	261	192	0.0277	0.0379	4,613	10,253
1939–44	Mitsubishi Bibai	Sapporo	−2.65	407	203	0.0130	0.0214	3,521	7,533
	Takamatsu	Fukuoka	−2.43	212	104	0.0225	0.0271	6,075	9,544
	Yubari	Sapporo	−2.24	315	191	0.0180	0.0333	4,869	11,701
	Onoura	Fukuoka	−1.93	197	133	0.0303	0.0282	8,199	9,909
	Mitsui Tagawa	Fukuoka	−1.89	192	142	0.0379	0.0378	10,253	13,285

Table 11 Change in the composition of labor force

	Japanese workers		Korean workers	War prisoners	Chinese workers	Total (persons)
					%	
	Ordinary	Temporal				
1936	100.0	0.0	0.0	0.0	0.0	198,346
1937	97.2	0.0	2.8	0.0	0.0	222,696
1938	97.0	0.0	3.0	0.0	0.0	263,632
1939	96.5	0.0	3.5	0.0	0.0	293,019
1940	89.4	0.0	10.6	0.0	0.0	322,941
1941	86.8	0.0	13.2	0.0	0.0	332,943
1942	83.8	1.3	15.0	0.0	0.0	341,288
1943	67.9	2.5	29.0	0.5	0.0	369,610
1944	62.0	3.5	33.0	1.1	0.4	380,962
1945	58.6	5.4	31.3	2.4	2.3	396,712

Source: *Nezu (ED.), Sekitan, p.435*
Note: As of the end of June in each year.