Mineral Mining and Regional Growth in Industrializing Japan

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March 7, 2023

Abstract

This study investigates the impact of coal mining on the regional economy in industrializing Japan. By linking the location information of mines with registration- and census-based statistics, I found that mines increased the local population via internal migration. While the influx of migrants changed the demographics, these reverted to trend as migrants formed their families. This also led to a local structural shift from the primary to the production and service sectors, depending on sex. I also found suggestive evidence that the occupational hazards of female miners and not mining pollution increased the risk of infant mortality via a mortality selection mechanism before birth. However, further analysis suggests that these effects differ across the type of mines: heavy metal mines had much smaller impacts on the local population and labor supply, and rather improved early-life mortality.

Keywords: coal; mines; mortality selection; occupational hazard; pollution; regional economy; resource; structural shifts

JEL Codes: N30; N50; N70; N90;

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I wish to thank Kazushige Matsuda, Eric Schneider, and the participants at the Tokyo Tech seminar (2020), EHESC 2022 (Groningen), and WEHC 2022 (Paris) for their helpful comments. I would also like to thank Daisuke Haraguchi for providing access to the archives on Chikuho coalfield from the Manuscript Library at Kyushu University. I thank Erika Igarashi and Minami Yumitori for their research assistance. This study was supported by JSPS KAKENHI (19K13754). There are no conflicts of interest to declare. All errors are my own. A previous version of this paper was circulated under the title “Prosperity or pollution? Mineral mining and regional growth in industrializing Japan.”
1 Introduction

Coal and metals are resources necessary for industrialization. Economic activities rely heavily on these resources, which are used not only for industries, but also for transportation and infrastructure. Predictions regarding agglomeration theory imply that resource abundance can increase the demand for local labor in the mining sector and related industries, thereby causing an influx of population and agglomeration \cite{Duranton2004, Lederman2004, Rosenthal2004}. However, an increase in the resource extraction industry may stagnate the development of non-resource extraction industries by reallocating resources from the non-resource tradable sector \cite{Sachs1999, Sachs2001}. Another pivotal risk is pollution, which can increase the health costs in resource-abundant locations and decrease agricultural productivity \cite{Aragon2015, von2019}.

In this study, I investigate the impact of coal mining on the regional economy and population health in industrializing Japan. By linking the location information of mines with a set of registration- and census-based statistics from the 1930s, I estimate the impact of coal mines on the regional population, labor supply, and early-life health outcomes. The results show that mines increase the local population, mainly via internal migration. While the influx of workers initially disturbed the demographics of the local economy, these demographics reverted to trend when the migrants formed their families. Importantly, this local population growth occurred with the local structural shifts from the primary to the production and service sectors. Thus, the magnitudes depend on sex: female (male) workers’ labor force participation rates decreased (did not change). Nevertheless, adverse health effects on infants were observed in coal mining areas. A higher risk of infant mortality was associated with the occupational hazards of female miners rather than the coal mining pollution. Regulatory revisions in 1933 reduced the risk of fetal and infant deaths to a certain extent. Additional falsification analysis using heavy metal (gold, silver, and copper; hereafter, GSC) mine samples suggests that these mines rather improved the health status of infants because, unlike coal, they are not bulky minerals, suggesting the advantage of structural shifts.

This study contributes to the literature in four ways: First, it expands our understanding of the relationship between mining and regional growth. There are still debates on whether proximity to coal mines is necessary for regional economic growth during Europe’s industrialization. For example, some studies on economic history have argued for the importance of agglomeration in improving efficiency in the local labor markets through, for instance, better matching and learning, causing spillover effects in the non-mining sectors \cite{Bjornland2016, Black2003}. See \cite{Corden1984, Corden1982, Eastwood1982, Neary1984, van1984} for earlier theoretical studies on the impact of resource discoveries.

\footnote{Induced agglomeration can improve efficiency in the local labor markets through, for instance, better matching and learning, causing spillover effects in the non-mining sectors \cite{Bjornland2016, Black2003}. See \cite{Corden1984, Corden1982, Eastwood1982, Neary1984, van1984} for earlier theoretical studies on the impact of resource discoveries.}

\footnote{The wealth effect mechanism suggests that resource abundance increases the demand for commodities, thereby reallocating resources from the tradable to non-tradable sector and increasing the imports of tradables. This can reduce labor supply, leading to greater earnings in the local economy. The direct effect on relative demand of extraction firms and workers is higher prices of personal and business services. Other political-economic factors that may disrupt the growth of the non-resource sector are rent-seeking and corruption \cite{Caselli2009, Caselli2013}. See \cite{Papyrakis2007} for empirical evidence using US states’ data.}
Importance of better access to coalfields in subsequent industrial development (Mathias 2001; Pollard 1981). Further, a recent study by Fernihough and O’Rourke (2020) found that after the mid-eighteenth century, European cities closer to coalfields had a larger population than other cities. By contrast, Mokyr (1977) observed that the distribution of coal supplies did not contribute to industrialization. My results support the former assertion by showing that mines lead to population growth and structural shifts in mining areas, and thus, contributed to Japan’s industrialization. Meanwhile, to the best of my knowledge, this study is the first to show the heterogeneity in the impact of mining by mineral type between coal and GSC mines.

Second, this study analyzes the mechanism behind local population growth due to resource extraction. Although studies have analyzed the impact of resource abundance on local population growth (Black et al. 2005; Fernihough and O’Rourke 2020; Michaels 2010), little is known about the mechanisms underlying this relationship. I find suggestive evidence that local population growth in the mining area initially occurred due to internal migration, rather than increases in local marriage and fertility rates; however, the migrants then formed families over time.

Third, this study simultaneously investigates the effects of mines on the regional economy and health outcomes. I find evidence that the occupational hazards experienced by female miners lead to mortality selection in utero, which increases the risk of early-life deaths. While previous studies have focused on pollution, my results shed light on the importance of mortality selection due to occupational hazards, which has been neglected in the literature. My findings on regional health are in line with Hanlon (2020), who found that coal-related pollution disturbed the growth of cities in the late nineteenth century in the UK, and with the negative aspects of rapid economic development in modern Japan (Tang 2017). In contrast, my results concerning the GSC mines provide supportive evidence to Drixler (2016), who argued for the exiguous contribution of industrial pollution from copper mines to the high stillbirth rates in Japan in the late 19th century. This finding is also consistent with Benshaul-Tolonen (2019), who shows that in northwestern Tanzania, local industrial development by gold mining can reduce the risk of infant mortality.

Fourth, this study utilizes data on demographic, labor, and health outcomes constructed using census-based statistics. These data allows me to eliminate the risks caused

3 Development economics research has typically focused on either the regional economy or health effects of mining (Aragón and Rud 2015; Benshaul-Tolonen 2019). Meanwhile, economic history studies have predominantly focused on the health costs of air pollution (Beach and Hanlon 2017; Heblich et al. 2018). Another strand of the literature investigates the adverse impact of using lead pipes on mortality rates (Grönvist et al. 2017). To the best of my knowledge, however, the potential health risks of mining during historical industrialization have not been evaluated.

4 Another potential contribution is that I investigate the mechanism behind the observed adverse health effects of metal pollution exposure. While most studies did not provide empirical evidence on the mechanism behind the adverse effects of air pollution, I present a pathway for the observed damaging health effects by referring to the Trivers-Willard theory (Trivers and Willard 1973).

5 See Heblich et al. (2018) and Beach and Hanlon (2017) for the adverse health effects of air pollution due to coal use during historical developments in Britain. These authors found that extensive coal use during economic growth increased infant mortality rates and decreased the average adult height.

6 Most studies have focused on large-scale (particularly gold) mines and utilized the location information combined with survey datasets (Aragón and Rud 2013, 2015; Kotsadam and Tolonen 2016).
by selection bias in the statistical inference. Using comprehensive data, this study provides the first evidence of a past-developing country in Asia, given that research has mainly focused on European countries, the US, Latin America, and African countries.

The remainder of this study paper is organized as follows. Section 2 provides a brief overview of the historical context. Section 3 summarizes the data. In Section 4, I describe the proposed identification strategy. Section 5 presents the main results, while Section 6 summarizes the additional analyses. Finally, Section 7 presents the conclusion of this study.

2 Background

The Mining Code of 1892 allowed Japanese private companies to have mining concessions, which accelerated the installation of modern technologies in mines and the development of Japan’s mining sector. Before the First World War (WWI), the coal industry had developed as an export labor-intensive industry. However, WWI increased the average wage rates of miners, which reduced the comparative advantage of the Japanese coal industry. Figure 1 illustrates the development of the coal industry and shows the negative shock in the early 1920s. This motivated coal mining firms to reduce the number of miners as well as adopt new extraction machines to improve firm productivity. Mining firms also reallocate resources to relatively productive mines to improve their average productivity. Consequently, average labor productivity in the coal mining sector increased from the 1920s, particularly in the 1930s (Okazaki 2021). Figure 1 shows that total coal production increased during the interwar period.

In the early 1930s, coal accounted for approximately 55% of total mineral output in Japan (Mining Bureau, Ministry of Commerce and Industry 1934, p.44). This large share of coal production indicates that coal extraction was an influential economic activity at that time. The higher wage rates of miners have motivated peasants to move into the extraction industry, shifting the local industrial structure from the primary to the production sector. Besides the original inhabitants, therefore, mining workers would include a certain proportion of migrants. An important feature of coal mines is that, while miners included single male workers, a large proportion of them were married couples as miners usually worked in teams of two to three (Sumiya 1968, pp. 300–308). This may have influenced the structure of both the marriage market and fertility in the local community.

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Footnotes:

7See for example, Domenech (2008), Fernihough and O’Rourke (2021) for European countries, Black et al. (2005), Michaels (2010), for the US, Aragón and Rud (2015), Sachs and Warner (1999) for Latin America, and Aragón and Rud (2013), Benshaul-Tolonen (2019) for African countries.

8For instance, winding engines were installed in the coal and copper mines in the 1890s, and the flame-smelting process was adopted in gold and silver mines in the 1900s (Ishii 1991, pp.220–221).

9See Sumiya (1968, pp. 387–393) for details on the adoption process of these machines.

10Generally, during the interwar period, the mine and manufacturing industries experienced steady capital investments, including investments in production facilities and machines, and public investments (Nakamura 1971, pp.138–143). Consequently, the relative contribution of manufacturing and mining, which provided energy and resources to manufacturing, was the largest at 42-51% among all sectors during this period (Minami 1994, p.90).

11For instance, the average daily wage of ato yama (see this section) was one and a half to two times higher than that of the female workers in the silk and spinning industries (Nishinarita 1985, pp. 84–85).
economy surrounding mines. However, quantitative evidence of these changes in the regional economy is still lacking in literature.

When male breadwinners were the main form of household income, it was peculiar for wives to work in mines with their husbands. Moreover, the nature of their work was harsh. The male skilled miner, called saki yama, extracted coal at the face; meanwhile, the female miner, called ato yama, brought coal to the coal wagon at the gangway through steep pits using bamboo baskets called sura. As coal is a bulky resource, the heavy work burden on pregnant women could have increased the risk of adverse pregnancy outcomes. This may have also increased infant mortality risks because the overall decline in fetal health endowments can also decrease the health status of surviving infants. Miners worked in pits with very dirty air containing particulates, which eventually damaged their lungs and increased the risk of respiratory diseases such as tuberculosis. A growing body of medical literature has revealed that particulates and radionuclides from coal increase the risk of stillbirths and premature deaths due to respiratory diseases in mothers.

Miners worked in pits with very dirty air containing particulates, which eventually damaged their lungs and increased the risk of respiratory diseases such as tuberculosis. In addition, rockfalls were a frequent cause of death and injury, and carbon monoxide poisoning and asphyxiation from explosions and gases could also occur. Although reliance on ato yama decreased after the enactment of the Revised Miner’s Labor Assistance Regulations of 1933, female miners played an important role in the coal mines throughout the interwar period. Online Appendix A.1 provides finer details of the labor patterns of female miners.

Pollution may be another potential incidence that could influence the regional economy. However, industrial pollution was not recognized as a common social problem among the people of pre-war Japan. As a result, there is little documentation of pollution due to coal mining, and thus, the health costs of coal mining during industrialization are understudied. Anecdotes suggest that there might be a few potential pathways that generated pollution around coal mines. First, was the soot and smoke caused by coal consumption to run steam winding machines. Steam-winding engines were introduced early in the mechanization of the hauling process and exhausted the smoke from burning coal in the boiler. However, these steam-powered winders were gradually replaced with electric winders during the interwar period.

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12 Most research on mines in prewar Japan comprises business history studies that investigated the features of the management and industrial organization in coal mining companies.

13 The infant deaths due to accidents in the pits are less likely to occur in the interwar period because mining companies had their own day care centers in the mines to guarantee the employment of female miners and to control their attendance. Before the introduction of day care centers, however, female miners cared for infants in the pits, which sometimes resulted in accidental deaths.

14 Moreover, a health survey for miners found that the coal miners had the highest prevalence among all type of miners at that time, which suggests how hard the work in the mines was.

15 An exception is the Ashio Copper Mine Incident in the late 19th century. In the field of development economics, von der Goltz and Barnwal (2019) provides evidence that mining is associated with child stunting among today’s developing nations.
channel was unlikely to impact regional population health. Second, and presumably more relevant, would be pollution from wastewater generated during the mining process. The coal preparation process produces liquid waste and coal sludge, whose impacts on living organisms have been studied in previous literature (Sergeant et al. 2022). This sludge contains several metal toxicities including mercury (Hg) and cadmium (Cd) which are known to be associated with the incidence of miscarriages and stillbirths (Amadi et al. 2017). In Japan, as coal mining became increasingly mechanized, some mines began to introduce water washing machines during coal sorting. Unfortunately, there is little historical documentation describing pollution caused by wastewater from coal mines. However, coal sludge from coal selection might have contaminated rivers to some extent at that time (Chiba and Yamada 1964).

3 Data

This study created a unique dataset of demographic outcomes, labor supply, and early life health outcomes across mining areas in the Japanese archipelago. Because mining is a localized economic activity, a smaller lattice dataset is preferred to identify the impact of mines. I collected and digitized a set of official census-based municipal-level statistics published in the 1930s.

3.1 Mine Deposit

I use official reports named Zenkoku kōgyō kōzan meibo (lists of factories and mines) published by Association for Harmonious Cooperation (1932, 1937) (hereafter, called the AHC), which document coal mine locations measured in October 1931 and October 1936. The AHC listed all mines with 50 miners and more, meaning that very small-scale mines with fewer than 50 miners are out of this study’s scope. Thus, the main target of this study is the average impact of small- to large-scale coal mines and not the very small-scale collieries. This does not discount the comprehensiveness of the AHC because it still includes information on small-scale mines, which have been neglected in the literature.

I define the treatment group as the municipalities located within 0–5 km of the centroid of a municipality with mines. A 5 km threshold is fundamentally plausible because the mean value of the distance to the nearest neighborhood municipality is approximately 4 km. In fact, the estimated effects are disappeared in the statistical sense outside the 5 km range, which means that the potential spillover effect is captured under this threshold. Finer details of the validity of this threshold is summarized in Section 6.1. For the control group, I set the threshold as 5–30 km from the centroid.

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16 I used an official shapefile provided by the Ministry of Land, Infrastructure, Transport and Tourism for geocoding. See Online Appendix B.1 for the details.

17 My definition of both groups is conservative compared with that in the literature, which uses 10–20 km and 100–200 km as the thresholds of the treatment and control groups, respectively (Aragón and Rud 2015; Benshaul-Tolonen 2016; Kotsadam and Tolonen 2016; Wilson 2012). This is plausibly because Japan has a relatively smaller and thinner archipelago than countries studied in the literature, such as South Africa (Online Appendix Figure 2). In Section 6.4, I further provide evidence that 5–30 km is a plausible distance for the control group given that the impacts of the coal mines are concentrated within
Figure 2 indicates the coal mine locations from the AHC and the corresponding treatment and control groups by year. Most coal mines are located in three specific areas in the southernmost, central, and northeastern regions: these are representative coalfields called Chikuhō, Jyōban, and Ishikari-Kushiro Tanden, respectively. Importantly, a comparison of Figures 2a and 2b shows that these agglomerations were stable over time. For a closer look, Figure 3 provides an example map for a representative coalfield called Chikuhō-tanden in Kyushū Island, Japan’s southernmost region (indicated in Figure 2a). One can see that the distribution of mines was stable over time; only a few mines were opened or closed between 1931 and 1936. This feature of coal mines makes it difficult to use within-variation in the spatial distribution of the mines for the identification. I will discuss this point in details later in Section 6.5.

Finally, I explain the creation of the analytical samples. From 11,151 total municipalities, I first retain the municipalities within a 30 km radius from the centroid of the municipalities with mines. I then exclude the intersection of the different types of mines, such as municipalities within 5 km from a GSC mine. Panel A of Table 1 presents the summary statistics of the treatment variables. The number of municipalities in the analytical sample based on the 1931 and 1936 AHC were 1,140 and 1,364, respectively. Meanwhile, the proportion of treated municipalities were approximately 15% and 13%, respectively, for each sample.

3.2 Geological Stratum

The spatial distribution of the geological stratum created in the Cenozoic era, which includes some carboniferous ages, is used as an instrumental variable (IV) for the location of coal mines (Section 4). Data on the geological strata are obtained from the official database of the Ministry of Land, Infrastructure, Transport and Tourism, which includes roughly nine thousand stratum-points. I matched each municipality in my analytical sample with the nearest stratum point to identify the municipalities with the relevant stratum. Online Appendix B.2 provides finer details of the IV’s definition as well as an example of a geological columnar section of a representative coal mine to show the relevance of the IV. Panel A of Table 1 presents the summary statistics of the indicator variables for the stratum.

5 km distance from the mines.

In short, it was infeasible to implement a difference-in-differences estimator for my full sample because of the lack of information (i.e., the number of municipalities that experienced the opening/closing of the coal mines). Nevertheless, in Section 6.5 I will show the results from the two-group by two-period difference-in-differences setting for a small subsample including Ogawa and Miyoshiyama coal mines (Figure 2b), which provide the reasonable results for my main findings.

The number of municipalities with coal mines in each analytical sample is 93 and 115, respectively. The slight reduction in the share of the treatment group is due to the increase in the number of enclaves, which I explained above. A mine opening in the enclave area increases the number of controlled (i.e., surrounding) municipalities, which leads to a decrease in the relative share of the treatment group. See, for example, Ogawa and Miyoshiyama coal mines in Tohoku region (Figure 2b).
3.3 Outcomes

Demographics

The main dependent variable, population, is obtained by digitizing the municipal-level statistics documented in the 1930 and 1935 Population Censuses (Statistics Bureau of the Cabinet 1935b, 1939). To investigate the mechanism behind the potential local population growth due to mining, I also digitized the Municipal Vital Statistics of 1930 and 1935 (Statistics Bureau of the Cabinet 1932, 1938), which document the total number of marriages and live births in all municipalities in the survey years. I then consider four dependent variables: crude marriage rate, crude birth rate, mean household size, and sex ratio. These demographic variables represent the characteristics of marriage markets and family formation in the local economy. Using these variables, I assess whether the local population growth due to mining activity depended on immigrants and/or changes in the family planning of local people. Importantly, as the census documents the total number of people in all municipalities in the census years, it helps us avoid sample selection issues. Panel B of Table 1 presents the summary statistics of the demographic outcomes by treatment status and census year. The mean differences are statistically significant for most variables, implying that systematic demographic changes may have occurred around the mining extraction area.

Labor Supply

I consider the labor force participation rate, the number of workers per 100 people, to investigate the impacts on local labor supplies. To analyze structural shifts, the employment share of workers in the mining, agricultural, manufacturing, commercial, and domestic sectors are considered; these are calculated as the number of workers in each sector per 100 workers. I use the labor force participation rates of both sexes to better understand the potential gender bias among the changes in local labor markets. These labor statistics were obtained from the prefectural part of the 1930 Population Census. Panel C of Table 1 presents the summary statistics of these variables by treatment status and census year. Similar to the demographic outcomes, the mean differences are statistically significant for most variables, which implies the potential impact of mining extraction.

See, for instance, Angrist (2002) and Abramitzky et al. (2011). The crude marriage and birth rates are defined as the number of marriages and live births per 1000 people, respectively. The mean household size is the number of people in households divided by the number of households. The sex ratio is the number of males divided by the number of females.

For instance, if population growth is caused by increased births, both marriage and fertility rates should be high in areas around a mine. Conversely, if it is caused by immigrant laborers, the household size should be small, whereas the sex ratio must be high as migrant workers include single males (Section 2).

The employment share in the mining sector has a set of censored observations because mining is a localized economic activity (Panel C of Table 1). However, the estimates from the Tobit estimator (Tobin 1958) confirm that the main results are not affected by censoring (not reported).
Early-life Health

Next, I examine the infant mortality rate (IMR) to assess the impacts on early-life health. To analyze the potential mechanisms behind the shifts in infant mortality, I use the fetal death rate (FDR). To obtain both variables, I digitized the 1933 and 1938 reports documenting municipal-level statistics on births and infant deaths published by the Aiikukai and Social Welfare Bureau. I also consider the mortality rate of children aged 1–4 to assess the potential impacts of air pollution. All these statistics are based on official vital statistics. An important advantage of using these vital statistics is that since Japan has a comprehensive registration system, the data cover almost all fetal and infant death incidences in the measured years. Panel D of Table I shows the summary statistics of the early life health variables. Again, the mean differences were statistically significant.

3.4 Additional Control Variables

Accessibility to Railway Stations

As coal is a bulky mineral, railways were used to transport the extracted coal. Firms may have preferred setting extraction points closer to railway stations to reduce transportation costs (Sumiya 1968, pp. 440–441). Further, the local population size could be larger if one moves closer to stations. Therefore, it is preferable to control for the distance between each municipality and the nearest-neighboring station to deal with this potential endogeneity issue. I used the location information of all stations obtained from the official dataset provided by the Ministry of Land, Infrastructure, Transport and Tourism to compute the nearest-neighbor distance to stations in 1931 and 1936. Online Appendix B.4 summarizes the details of the data, and Online Appendix Figure B.5 shows the locations of these stations across the Japanese archipelago. Panel A of Table I shows the summary statistics.

Accessibility to Sea Ports

Although railways were primarily used to transport coal because coal mines were usually located inland (Online Appendix Figure 2), marine transportation was also used for secondary logistics. Hence, similar to railway transportation, I include the distance to

\[^{24}\text{FDR is defined as the number of fetal deaths per 1,000 births, while the IMR is the number of infant deaths per 1,000 live births. The censored observations in the FDRs are less than 11% in both census years and do not significantly change the results. The estimates from the Tobit estimator (Tobin 1958) confirm this finding (not reported). The number of censored observations in IMRs is practically negligible.}\]

\[^{25}\text{The child mortality rate is defined as the number of deaths of children aged 1–4 in 1933 (or 1938) per 1,000 children aged 1–5 in 1930. Note that the number of children aged 1–5 from 1930 is used as it is only documented in the 1930 population census. Given that child deaths, especially at age 5, were rarer than infant deaths at that time, the mismatch in the age bins between numerator and denominator should not be a critical issue. The difference in the survey points does add noise to the estimation of the standard error. However, the coefficient estimate is close enough to zero and thus, should not be a practical issue in this setting (Panel A-2 of Table 4).}\]

\[^{26}\text{The potential imprecision of birth data in prewar Japan was improved by a great degree by the 1920s (Drixled 2012).}\]
the nearest neighboring seaport as a variable to control for accessibility to marine transportation (Online Appendix Figure B.5 shows seaport locations). Online Appendix B.4 summarizes the details of the data and Panel A of Table I shows the summary statistics.

**Accessibility to Rivers**

Finally, I consider the accessibility to rivers. Not all mining areas have large rivers suitable for water transportation (Online Appendix, Figure B.7). This means that the locations of coal mines were not dominated by rivers. However, several mines used river transport as primary logistics until the development of railways before the late 1920s (Chiba and Yamada, 1964). This implies that the location of mines in such mining areas might have been influenced by the spatial distribution of the river. Thus, I included the distance to the nearest neighboring river as a control variable. Online Appendix B.5 describes the details of the data, and Panel A of Table I shows the summary statistics. I also used the river accessibility variable to test the potential pollution from wastewater in Section 5.3.

4 Identification Strategy

I leverage the random nature of mineral deposits to identify the effects of mines. The linear regression model is as follows:

\[ y_i = \alpha + \beta \text{MineDeposit}_i + x_i'\gamma + e_i, \]

where \( i \) indexes municipalities, \( y \) is the outcome variable, \( \text{MineDeposit} \) is an indicator variable that equals one for municipalities within 5 km from a mine, \( x \) is a vector of control variables, and \( e \) is a random error term.

Because the placement of a mine is determined by a geological anomaly, \( \text{MineDeposit} \) is random in nature (Benshaul-Tolonen, 2019, p.1568). However, the rest of the variation may be correlated with the local variation in infrastructure. For instance, if a mineral deposit is found at a point between a village and a city, the mining firm may choose the city as its main mining point because the city is likely to have better infrastructure than the village. Then, \( \text{MineDeposit} \) can be positively correlated with the error term, leading to a positive (negative) omitted variable bias in the estimate of \( \beta \) if the placement of the city is positively (negatively) correlated with the outcome variable. To deal with this systematic bias in the ordinary least squares, I included two indicator variables that equal one for cities and towns (i.e., zero for villages), respectively. As explained in Section 3.4, I also include the distances to the nearest neighboring railway station and seaport to control for accessibility to railway and marine transportation, respectively. The differences in the estimates from both specifications, including and excluding the control variables, indicate

\[ \frac{\text{MineDeposit}}{\gamma} = \frac{\text{City}}{\gamma} + e_i. \]

When the municipality type (\( \text{City} \)) is unobserved, the linear projection coefficient can be written as \( \beta^* = \beta + \Xi\gamma \), where \( \Xi = (E[\text{MineDeposit}^2] - 1)(E[\text{MineDeposit City}]). \) As explained, \( \text{MineDeposit} \) and \( \text{City} \) may be positively correlated such that \( \Xi > 0 \). Thus, when \( y \) is the population, conditional on mine deposits, it is reasonable to suppose that the town has a greater number of people than villages (\( \gamma > 0 \)). This result implies that \( \beta^* = \beta + \Xi\gamma > \beta \).
the extent to which this omitted variable mechanism influences the results. Thus, I can partially assess the randomness of the main exposure variable (MineDeposit). As I show later, the estimates from the simple regressions are materially similar to those from the specifications, including the control variables, thereby supporting the randomness of the exposure variable. To be conservative, I prefer to use the specification including the control variables (equation 1).

A potential threat in the identification may be measurement errors in time-dimensional assignments. As explained in Section 3.1, mine data were surveyed in October 1931 (1936), whereas the Population Census was conducted in October 1930 (1935). Similarly, data on fetal death and infant mortality were obtained from the 1933 (1938) Vital Statistics. The lags in the matching allow me to consider the exposure durations. For instance, fetus miscarriages in 1933 (1938) were in utero conceived in 1932 (1937), whereas their mothers should have been exposed to any shocks at the time of conception in 1932 (1937). The same argument can be applied to infant mortality: infants who passed away in 1933 (1938) were born at the beginning of 1932 (1937) at the earliest. Therefore, they should have been in utero in 1931 (1936). Consequently, the mining data that list the mines in October 1931 and 1936 may be reasonably matched with the health data of 1933 and 1938, respectively. However, one must be careful as there is still a one-year lag in matching with both the census and vital statistics datasets. This may lead to attenuation bias due to miss assignments in the time dimension, because the number of coal mines should be increased during that year.

To deal with such potential measurement error issues, I consider the IV estimator using the exogenous variation in the geological stratum. In this IV approach, Equation 1 is regarded as a structural form equation because the least-squares estimator (β) is assumed to be attenuated by the measurement error in the exposure variable.

The reduced-form equation for MineDeposit is designed as follows:

\[ \text{MineDeposit}_i = \kappa + \tau \text{Stratum}_i + x'_i \mu + \epsilon_i, \]  

where \( \text{Stratum} \) is a binary IV that equals one for municipalities with sedimentary rock created during the Cenozoic era, and \( \epsilon \) is a random error term. The IV is plausibly excluded from the structural equation because the location of mines is essentially dominated by the distribution of geological stratum, which is exogenously given in nature and unobservable by people in the prewar period. In addition, the relevance condition holds because the location of coalfields is determined by the distribution of the stratum created in the Cenozoic era, which includes the Carboniferous period when the strata containing coal were created [Fernihough and O’Rourke 2020]. Online Appendix B.2 summarizes the geological strata variable in finer detail and shows that the location of coal mines is determined by specific strata created in the Cenozoic era. Online Appendix C.2 discusses the validity of identification assumptions in more rigorous way.

I use the heteroskedasticity-consistent covariance matrix estimator as a baseline esti-

Note that this sort of mis-assignments (i.e., measurement error) never overstate the estimates but causes attenuation. For instance, if a few treated (untreated) municipalities were regarded as the untreated (treated) municipalities, the impacts of mines shall be discounted. See Online Appendix C.1 for a brief explanation of this mechanism.
For the sensitivity check, I also use the standard errors clustered at the county level based on the cluster-robust covariance matrix estimator (Arellano 1987) to determine the influence of the potential influences of the local-scale spatial correlations. Online Appendix C.3 summarizes the results, which show that both standard errors are materially similar. Therefore, the potential spatial correlations were negligible in this empirical setting.

5 Results

5.1 Population Growth

Panel A-1 of Table 2 presents the main results for the population in 1930. Columns (1), (2), and (3) show the results from the specifications excluding the control variables, including the city and town fixed effects, and including both the fixed effects and control variables, respectively. Columns (4), (5), and (6) show the results for the IV estimations for the same column layouts. First, including city and town fixed effects marginally shrinks the estimates (column (2)). Similarly, controlling for transportation accessibility slightly reduces the estimate (column (3)). This indicates that the location of the coal mines may be weakly positively correlated with the development of local infrastructure and related agglomeration. Second, the estimates based on the IV estimator are greater than those under the reduced-form assumption. Even after conditioning on the control variables, the estimate in column (6) is substantially greater than that in column (3); 0.447 versus 0.812. This implies that measurement errors systematically attenuate the estimates. Considering these, the baseline result from the preferred specification of column (6) of Panel A-1 indicates that coal mines increased the local population by 125%.

Panel B-1 of Table 2 shows the results for the population in 1935. These results are materially similar to those in Panel A-1. The estimate in column (6) of Panel B-1 indicates that coal mines increased the local population by 145%.

The magnitude of the local population changes are economically meaningful. Thus, my results imply that municipalities with coal mines in the 1930s experienced local population growth. A natural question may be whether it is a consequence of natural increase or labor migration. If the population grows naturally from family planning, municipalities with mines should have had higher marriage and fertility rates, larger household sizes, and a stable sex ratio. Conversely, if labor migrations were the main cause, municipalities with...
mines should have had a disproportionate (i.e., higher) sex ratio and smaller household sizes because new miners were usually single males and couples.

Panel A-2 of Table 2 presents the results for several demographic variables to assess this mechanism. Columns (1)–(4) show the results for the crude marriage rate, crude birth rate, average household size, and sex ratio, respectively. All regressions include the fixed effects as well as the control variables, and are estimated using the IV estimator. Overall, the estimated coefficients suggest that municipalities with coal mines experienced a decline in the marriage rate, fertility rate, and household size. In contrast, mines increased the sex ratio by 0.115 points. This is economically meaningful, given that it accounts for roughly one standard deviation in the sex ratio (Panel B in Table 1). Thus, the mechanism behind local population growth may be explained by labor migration rather than by a natural increase in the population. 32

Panel B-2 of Table 2 presents the results for the demographic outcomes in 1935 in the same column layout as Panel A-2. Although the signs of the estimates are unchanged from those reported in Panel A-2, the magnitudes are much smaller than those for the 1930 sample. This result is consistent with the findings of the descriptive analysis in Section 3.1. Although several coal mines were newly opened by 1935, most coal mines already existed in 1930. Thus, single males (couples) entering the coal mine area around 1930 could have had their spouses (or even children) by 1935. In fact, the estimates for marriage rate, fertility rate, and average household size are estimated to be much smaller in the absolute sense (columns (1)–(3)). Specifically, the fertility rate estimate is close to zero and no longer statistically significant. Correspondingly, the estimate for sex ratio decreases, meaning that the sex ratio tended to revert to its natural trend. This may reflect the attenuation in the overall sex ratio due to the regular sex ratio of infants and children born in coal mining areas after 1930.

As mechanization progressed, miners were required to accumulate knowledge and experience in operating machinery. Management, therefore, had an incentive to encourage miners to form families and continue employment over a long term (Morimoto 2013). In the 1920s, many coal mines were equipped with nurseries and other welfare facilities, which may have increased the opportunity cost of changing jobs (Ministry of Commerce and Industry 1926). The results obtained seem to be consistent with this attitude of companies.

In summary, the coal mine leads local population growth in the following two ways. First, internal migration to coal mining areas increases the local population, which leads to an unbalanced sex ratio and lower marriage, fertility, and household size. This may correspond to the results for the 1930 sample. Second, as households in the coal mine areas formed their families, the local population grew naturally, which reverted the fertility rate and overall sex ratio to natural trends. Although there may still be migrants to these mining areas, the result for the 1935 sample may indeed reflect a part of the local population growth at this stage.

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32 This tendency is generally consistent with the fact that in prewar Japan, urban areas had a relatively higher sex ratio than localities due to the internal migration of male workers (Ito 1990, p.243–247).
5.2 Labor Supply

Next, I start the analysis of labor supply by observing the results for male labor first. Panel A-1 of Table 3 presents the results for the labor force participation rate of male workers. The columns are listed in the same layout as in Panel A-1 of Table 2. The estimates in columns (1)–(3) are negative but close to zero, and statistically insignificant. The estimates from the IV approach have much greater magnitudes in columns (4)–(6). However, the estimated coefficients are still statistically insignificant in these columns, implying that coal mines did not influence the labor supply of male workers in the local economy.

Panel A-2 of Table 3 shows the results for employment share of male workers. Column (1) indicates that coal mines increased the mining sector’s employment share by approximately 34%, which leads to a similar decline in the agricultural sector’s employment share (column (2)). This suggests that the structural shift in male workers’ employment occurred mainly in the agricultural sector. The estimate for the manufacturing sector is statistically insignificant but positive. This may imply a moderate spillover effect of mines on the manufacturing industry in the mining areas (column (3)). The estimates for the commercial and domestic sectors are moderately negative and close to zero (columns (4) and (5), respectively). This is consistent with the fact that male workers are less likely to work in these service sectors (Panel C of Table 1).

The results for female labor suggest different responses from those of male workers. Panel B-1 of Table 3 provides evidence that the coal mines decreased the female labor force participations. Column (1) shows a statistically significantly negative estimate, which is unchanged after considering the fixed effects in column (2) and control variables in column (3). The results from the IV estimator provide clearer effects. The estimate from the preferred specification suggests that coal mines decreased the female labor force participation rate by approximately 19% (column (6)).

Panel B-2 of Table 3 shows the results for employment share of female workers. Column (1) indicates that coal mines increase the mining sector’s employment share by 24% and decrease the agricultural sector’s share by the same degree (column (2)). Interestingly, the estimated magnitude is smaller than that for male workers (column (1) of Panel A-2). This may be because single females were less likely to work in mines than single males (Section 2). The estimates for the commercial and domestic sectors are moderately positive (columns (4) and (5), respectively), whereas the manufacturing sector’s employment share decreases in the mining area (column (3)). This is consistent with the increased relative demand for personal services from mining workers in mining areas (Caselli and Coleman II 2001).

Overall, my results suggest structural shifts from primary to other sectors. In these shifts, the division of roles based on gender was observed: males were engaged in manual tasks and females in the service sector.

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33Black et al. (2005) found that the 1970s coal boom in the US increased employment and earnings with modest spillovers into the non-mining sectors.

34The clear gender difference in the labor force participation seems to be consistent with the wealth effect (“spending effect” in the Dutch-Disease literature) of mines: it may result in higher wage rates and lower overall non-resource GDP (Caselli and Coleman II 2001). Although it is difficult to analyze the impact of mines on wages, my results are in line with the findings on structural shifts presented in this subsection.
work, whereas females were more likely to work in the service industries or even be housewives instead of working in any sector. Kotsadam and Tolonen (2016) found that opening of mines in African countries decreased the workers in the agricultural sector but stimulated the non-agricultural sectors. This increased the number of female workers in the service sector and male manual laborers in the mining sector. My findings demonstrate a similar experience as a historical case. However, it is still important to remember that some females did work in mines in the case of prewar Japan. They worked with males, usually their husbands, in the pit under harsh environments (Section 2). This may have adversely affected not only their own health but also their children’s health. I consider this possibility in the following subsection.

5.3 Early-life Health

Panel A-1 of Table 4 presents the results for the IMRs in 1933. The estimates are positive and statistically significant, indicating that coal mines increased the infant mortality risk. As expected, the estimates based on the IV estimator listed in columns (4)–(6) are greater than those in columns (1)–(3). This is consistent with the rough time-dimensional assignments in health outcomes (Section 4). By contrast, the inclusion of the city and town fixed effects as well as the transportation accessibility variables had little influence on the estimates. This suggests that unobservables depending on the type of municipality are likely to be orthogonal to mine location. This result is particularly interesting given that railways could have increased local exposure to infectious diseases (Tang 2017). Thus, my result implies that the greater risk of infant mortality around coal mining areas may be explained by different pathways, such as occupational hazards and/or pollution.

Panel A-2 of Table 4 assesses the mechanism behind the higher infant mortality risk in coal mining areas. First, I test the biological sorting mechanism in utero suggested by the Trivers-Willard hypothesis (TWH) (Trivers and Willard 1973). If greater infant mortality risk was associated with a reduction of the fetal health endowments by coal mining, the FDRs should also be increased in the coal mining area; this leftward shift of the initial health distribution is called the “scarring mechanism” (see Online Appendix C.6 for a finer theoretical illustration on the TWH). In column (1) of Panel A-2, I run the IV regression by replacing the IMR with FDR. The estimate is positive and statistically significant, providing support for the scarring mechanism before birth.

Panel B of Table 4 provides the results for the 1938 sample in the same panel and column layout. Panel B-1 shows positive, but much smaller estimates relative to those in Panel A-1, suggesting that the impact of coal mining on IMRs decreased from 1933 to 1938. Column (1) of Panel B-2 shows a positive, but much smaller and statistically insignificant estimate for FDR. This results is in line with the results for the IMR in Panel B-1, and with the fact that the FDRs showed a secular decreasing trend at that
time (Online Appendix Figure C.3).

Next, I test whether this scarring mechanism was led by the occupational hazard or pollution due to coal mining. In column (2) of Panel A-2, I limited my sample to 93 municipalities with coal mines to analyze the correlation between the FDR and the number of female miners as well as accessibility to rivers. If heavy manual work during pregnancy affects fetal health, FDRs should be positively correlated with the number of female miners. To control for the scale effect and provide a placebo test, I included the number of male workers at the same time in the same specification. As shown, the estimated coefficient for female miners is significantly positive, whereas that for male miners is rather negative. This result supports the evidence that occupational hazards for females (not males) alone increased the risk of death before birth. The estimate indicates that a one standard deviation increase in female miners (equal to 269.2 miners) increases the number of fetal deaths by approximately 9.4 (0.035 × 269) per 1000 births. This is economically meaningful because the mean difference in the FDR between the treatment and control groups was also 9.4 fetal deaths per 1000 births (Panel D of Table I). Column (3) of Panel A-2 shows the result for the IMR. It further provides suggestive evidence that this reduction in fetal health endowment via occupational hazards for females is associated with higher infant mortality risks. Therefore, the results from columns (2) and (3) indicate that occupational hazards could increase infant mortality risk through the scarring mechanism in utero. The estimates for the 1938 sample listed in columns (2) and (3) in Panel B-2 are similar, but are much smaller in magnitude. The estimate shows that a one standard deviation increase in female miners (equal to 179.3 miners) increased the number of fetal deaths by approximately 4.5 (0.025 × 179) per 1000 births. This magnitude was less than half of that in 1933 (i.e., 9.4).

Finally, I test the pathway via the pollution. Section 2 suggests that the coal sludge generated from the coal mining process might have been a potential factor for pollution. If such wastewater increased the health risk of fetuses and infants, municipalities with mines close to rivers should have significantly higher mortality rates because the wastewater had been discharged into the rivers (Chiba and Yamada 1964). However, the estimated coefficients of the river accessibility variable are statistically insignificant in both columns (2) and (3) in Panel A-2. This result does not change in 1938 (columns (2) and (3) in Panel B-2). This suggests that, although wastewater was indeed occurring as anecdotes suggest, it was not enough to harm the health conditions of mothers and infants.

In addition, air pollution is unlikely to increase mortality risks. If air pollution increased early-life mortality, then the estimated coefficients on the male miner should be positive in columns (2) and (3) in Panels A-2 and B-2 because larger mines should emit more coal smoke from boilers of the steam winding machines. Column (4) of Panel A-2 tests the potential influence of air pollution using an alternative outcome, the mortality rate of children aged 1–4. If air pollution mattered, the child mortality rate should be greater in the coal mining area than in surrounding areas because younger children are more susceptible to pollutants because they are more likely to play outside than infants. The estimate is, however, close to zero and is statistically insignificant. Column (5) in Panels A-2 uses data on 93 municipalities with coal mines, and provides further evidence on this: the estimated coefficients on the number of female and male miners are very close to zero, suggesting that child mortality did not depend on the scale of emissions.
The results for child mortality in 1938 are similar to those in 1933 (columns (4) and (5) in Panel B-2). Thus, air pollution does not seem to be a channel which can explain the greater IMR in the mining area. This is consistent with the historical fact that winding machines were electrified in the interwar periods (Section 2).

To summarize, the results suggest that the mortality selection mechanism before births may have been attenuated over time. The decline in the estimated magnitude of these health outcomes between 1933 and 1938 may partly be associated with an improving trend in health-related risk-coping strategies, such as increments in the number of medical doctors and installation of modern water supply (Online Appendix Figure C.3). However, the city and town fixed effects control for a large part of such variations. Therefore, this reduction is likely to be associated with the Revised Miner’s Labor Assistance Regulations, which decreased the number of female miners throughout the 1930s (Section 2). The moderate adverse effects observed in 1938 may be associated with changes in the working conditions of female miners during the 1930s.

6 Additional Analysis

This section assesses the validity of threshold for the treatment variable (Section 6.1), potential influence of the altitude (Section 6.2) and of regional heterogeneity in labor patterns (Section 6.3), compares the results for heavy metal mines (Section 6.4), and discusses the feasibility of an alternative estimation strategy utilizing within variations of each unit (Section 6.5).

6.1 Validity of Threshold

First, I test the validity of threshold for the exposure variable (MineDeposit in 1). In Figure 4, I provide the results from the expanded regression of equation 1 that includes the five indicator variables for each 5 km bin from a mine. Figures 4a, 4b, and 4c present the results for local population, labor force participation rate, and IMR, respectively. Overall, while the estimates are larger in the absolute sense within 5 km, those for the areas outside the 5 km bin are close to zero and statistically insignificant. This evidence provides a basis for defining the exposure variable that uses 5 km as the threshold.

Only a 10-15 km bin for the infant mortality rate in 1938 shown in Figure 4d shows a moderately positive estimate. In Online Appendix C.4, I analyzed the mechanism behind this hike in greater details. In short, this positive estimate in the 10-15 km bin is caused by the observations in Fukuoka prefecture, which coincidentally have relatively greater IMRs. Therefore, the hike observed is practically ignorable given that it is a random event occurred in a narrow bin in one prefecture.36

36 Intuitively, if it was derived from any systematic factors behind the regression, such a hike in the 10-15 km bin should be observed in all the prefectures that have coal mines for all the years. However, this is not the case in my empirical setting (Online Appendix C.4).
6.2 Sensitivity to the Altitude

The location of mine might had been correlated with the altitude because terrain relates to the distribution of the locational fundamentals such as the climatic conditions and fixed cost of transportation. I confirmed that the results from the expanded regression including the average altitude in each municipality as an additional control variable show very similar results to my main results (not reported). Descriptions on the grid cell data on the average altitude are summarized in Online Appendix B.7.

6.3 Sensitivity to the Regional Heterogeneity in Labor Patterns

I assess the influence of regional heterogeneity in the female labor pattern in the mining sector. Nishinarita (1985) argues that, due to its geographical characteristics, coal mines in Hokkaidō (a northernmost island) tended to employ men from rural villages in the Tōhoku (northeastern) region of the main island as their main miners. This forced the coal mines in Hokkaidō to use a sloping-face haulage method instead of using ato-yama. As a result, female miners in the Hokkaido mines were mainly engaged in the coal selection process rather than working in pits. It is unlikely that this regional heterogeneity could affect the location of mines, because the location of coal mines depends on the presence or absence of coal-bearing strata (Section 4). In addition, the number of mines in Hokkaidō are relatively small, meaning that such regional heterogeneity in labor supply is less likely to disturb the estimates. Despite this, to test whether such features lead to omitted variable bias, I added an indicator variable for the municipalities of the Hokkaidō prefecture in the regressions. These results are similar to those of the main results listed in Tables 2, 3, and 4. Online Appendix C.5 summarizes the results.

6.4 Alternative Minerals: Heavy Metal Mines

I assess the validity of my main results on coal mines by comparing the results for heavy metal mines. Specifically, I focus on three heavy metals: gold, silver, and copper (GSC). This is because GSC mines comprise more than 80% of all metal mines and generally the mines extracted these metals at one place. Although the AHC documented other types of metal mines, they were indeed much smaller subsets: the number of lead and zinc, pig iron and steel, and tin mines documented were only one, five, and four in 1931, respectively.

Historical evidence indicates that coal mining requires many more workers than heavy metal mining because coal is a bulky mineral (Section 2). Panel A of Table 1 indicates that the scale of GSC mines was much smaller than that of coal mines. In addition, unlike coal mines, the GSC mines were scattered across the archipelago and were less likely to agglomerate than coal mines (Online Appendix Figure B.2). In fact, the “enclave effect” suggests that some GSC mines are less likely to interact with local economies (Aragón and Rud 2013, 2015). This means that the impact of GSC mines on the regional economy is likely to be different from that of coal mines.

\[37\] A potentially relevant study is Stijns (2005): using a country-level dataset, the author provided suggestive evidence that the impact of resource abundance on socioeconomic outcomes may vary among resource types.
economy would be smaller than those of coal mines. To assess this, I compare the estimates of the reduced-form equation for the coal and GSC mines because unlike coal, a fuel mineral, no specific stratum can predict the spatial distribution of GSC mines.

Table 5 lists the results. Panel A summarizes the results for the main outcome variables. The estimates for the local population listed in columns (1) and (2) are 0.160 for 1930 sample and 0.227 for 1935 sample, respectively. These are less than half of the estimates for the coal mine sample (column (3) of Panels A-1 and B-1 in Table 2). Similarly, columns (3) and (4) list smaller estimates for the labor force participation rates of male and female workers in mining areas (column (3) of Panels A-1 and B-1 in Table 3).

An interesting result was observed for the early life health outcomes. Generally, heavy metal mining releases toxic metals, such as mercury (Hg), cyanide (CN), and cadmium (Cd), which are associated with incidences of miscarriages and stillbirths. However, columns (5) and (6) indicate that the results for IMRs are rather negative and statistically significant. This means that infant mortality risk is even lower in the GSC mining areas than that in the surrounding municipalities. Investigating this difference is beyond the scope of this study; however, this result suggests that unlike in coal mines, the positive economic effect of mines may exceed the negative health effects, as found in a recent related study by Benshaul-Tolonen (2019). My results also provide supportive evidence for Drixler (2016), who found that industrial pollution from copper mines was not associated with the risk of high stillbirth rates in Japan in the late 19th century. In addition, this difference may be related to the characteristics of the pollutants. While particulates generated around coal mines may immediately deteriorate the mother’s and infant’s health conditions, the heavy metals from GSC mines might not immediately affect mothers. In other words, my empirical setting does not capture the accumulation effects of heavy metals on humans.

### 6.5 Alternative Identification Strategy

I used IV estimation to obtain the baseline estimates. For the outcome variables that can be used as a panel dataset, an alternative estimation strategy may be the DID approach, which uses both cross-sectional and within variations for the identification. To implement the DID technique, municipalities that had been treated throughout the measured years would have to be excluded, while municipalities that had newer mines during the sampled periods were left. However, the number of municipalities with coal mines increased by only 23 between 1931 and 1936 (Online Appendix A.3 presents the raw number of mines). Consequently, as explained in Section 5.1 in detail, the proportion of treated municipalities

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38 The FDR does not have clear correlations in both years. Among the municipalities with GSC mines, there were no meaningful correlations between the early-life health outcomes (i.e., both the FDR and IMR) and the number of miners (not reported).

39 Drixler (2016) illustrates higher stillbirth rates in the potentially poisoned areas in the late 19th century by effluents from Ashio, modern Japan’s richest copper mine, by calculating the rate of increase in stillbirth rates in the affected districts after the toxic flood of 1896. The author also shows a relatively greater increase in the stillbirth rates in some neighboring unpolluted areas, suggesting an exiguous contribution of industrial pollution to the high stillbirth rates at that time.

40 Instantaneous effects of coal consumption on mortality rates have been widely investigated (e.g., Beach and Hanlon 2017).
decreased from 15% to 13% (Panel A of Table 1). This feature of the assignments makes it difficult to employ the DID approach as main identification strategy for the coal mine sample because the information that can be used for the identification is insufficient. 

Nevertheless, I provide a brief case study using the DID approach for the subsample including Ogawa coal mine in Iwate prefecture and Miyoshiyama coal mine in Akita prefecture. As indicated in Figure 2b, both mines were located in the northeastern (Tōhoku) region, where the coal mines were not existed in 1931. In this light, it is expected to provide relatively clean experimental condition for the DID estimation, albeit the available sample size is limited.

For municipal \( i \) at time \( t \in \{1930, 1935\} \), the two-way fixed effect (TWFE) model for the DID estimation is specified as follows:

\[
y_{i,t} = \pi + \delta D_{i,t} + x'_{i,t}\phi + \eta_i + \lambda_t + \omega_{i,t},
\]

where \( \eta, \lambda, \) and \( \omega \) are the municipal fixed effect, year fixed effects, and random error term, respectively. \( D_{i,t} \) is a treatment indicator variable that takes one for the treatment group in the post treatment period and zero for otherwise. \( x \) includes the accessibility measures on the stations and sea ports. Accessibility measure on the rivers is not included as it is a time-constant variable. However, the municipal fixed effect effectively controls for all these time-constant unobservable factors including the geological strata and terrain that were potentially correlated with the location of mines.

Notice that this is a two-by-two DID setting for the TWFE model, which provides the unbiased DID estimator \( \hat{\delta} \) for the average treatment effect in the treated municipalities in the post treatment period (Abadie 2005). The identification assumptions are the independency of the treatment, which is confirmed already, and the parallel trends assumption. Online Appendix C.8 provides evidence that the latter assumption is likely to be held in my setting. The cluster-robust variance-covariance matrix estimator is used to deal with the heteroskedasticity and serial dependency (Arellano 1987).

Table 6 provides the results. Column (1) shows the result for the local population, whereas columns (2)–(5) shows those for the crude marriage rate, crude birth rate, average household size, and sex ratio, respectively. Column (6) presents the result for the IMR. The results for the LFP rates are unavailable because those rates were measured only in one population census of 1930.

Overall, the DID results are in line with the findings from my baseline results. First, the opening of these two coal mines increased the local population by approximately 7.2%. Although the estimated magnitude is much smaller than the baseline magnitude listed in Panel B-1 of Table 2, this is rather consistent with the fact that both coal mines are considerably smaller mines with roughly 100 miners. The results for the other

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41 Similarly, the number of municipalities with GSC mines increased by only 55 mines from 57 to 112 between 1931 and 1936 (see Online Appendix A.3 for the number of mines). The proportion of treated municipalities remained almost unchanged, from 5.0% to 5.3% (Panel A of Table 1).

42 For a comprehensive review on the recent discussions on the TWFE-DID models, see de Chaisemartin and D’Haultfoeuilld (2022).

43 Notice that I compare my estimates with those for the results in 1935 or 1938 because the DID estimator captures the average treatment effect in the treated municipalities at the post treatment period.

44 In fact, this magnitude is rather similar to those estimated for the smaller coal mines in my expanded regressions (Online Appendix Table C.5).
demographic outcomes are also similar to those listed in Panel B-2 of Table 2. Second, the estimate for the IMR is positive but statistically insignificant, suggesting that the opening of coal mines did not increase the local infant mortality in the late 1930s. This is consistent with the fact that the impacts of coal mines on the infant mortality could have been mitigated in the late 1930s by the regulations for the use of female miners in the pits (Section 5.3). In fact, both coal mines did not use many female miners: only 9 and 44 miners in Ogawa and Miyoshiyama coal mines, respectively.

6.6 Heterogeneity with Respect to the Scale of Mines

Finally, I assess the heterogeneity in the scale of mines. While most of the municipalities with mines have similar number of mines (i.e., one or two mines), there are several municipalities having many mines. Importantly, the causal effects are essentially heterogeneous across municipalities. This means that the municipalities with large scale mine could have greater impacts than those with small scale of mine. Since I am interested in estimating the local average treatment effect utilizing the IV approach, estimating such heterogeneous treatment effects are basically out of scope in this study. Rather, stratifying the treatment group does disturb the inference due to the small sample size in each subsample. Nonetheless, I confirmed that the results from the regressions using subgroup indicators based on the median of the number of miners as a threshold are in line with the findings from my baseline specification. Online Appendix C.9 summarizes those results.

7 Conclusion

This study examines the impact of mines on the regional economy during historical industrialization in pre-war Japan. I found that coal mines increased the local population. This population growth was initially accomplished by internal migration rather than due to increases in local marriage and fertility rates. However, after these migrants formed their families, these demographics started to revert to trend. Local structural shifts from agricultural to mining, manufacturing, and service sectors also occurred in the mining areas, while a clear potential gender bias against female workers was observed in the shifts. I also found evidence suggesting that the occupational hazards of female miners led to mortality selection before births, which increased the risk of infant mortality in the coal mining area. Another pivotal finding is that the magnitude of this impact varies according to the mine type. Coal mines extracting bulky minerals caused comparatively greater changes to the local population and structures than heavy metal mines. While the mining industry can contribute to macroeconomic growth and create a temporary boom in the local economy, it will locally experience bust in due course. Therefore, it is important to investigate the long-run, and entire costs and benefits of mining sector in the spirit of Black et al. (2005).

45In the 1930 (1935) sample, 85 (108) out of 93 (115) municipalities with mines have one to four mines, whereas the other 8 (7) municipalities have more than five mines. The average number of miners in the former group is roughly 1300 (1400) in 1930 (1935) sample, whereas that in the latter group is roughly 4000 (5400) in 1930 (1935) sample.
Figure 1: Coal Production in Japan from 1912 to 1940

Note: The solid line shows the coal output in giga tons (Gt). The dashed line indicates the coal price in yen per giga tons. The unit price is defined as the total price of coal output divided by the total coal output in each year.

Source: Created by the author. Data on coal output are from Ministry of International Trade and Industry (1954).

Figure 2: Spatial Distribution of the Treated and Controlled Municipalities

Notes: The white circles indicate the location of municipalities with coal mines. The treatment (control) group highlighted in red (pink) includes the municipalities within 5 (between 5 and 30) km from a mine,. The excluded municipalities are shown as empty lattices in the figures.

Source: Created by the author.
Figure 3: Location of Coal Mines around Chikuho Coalfield in Kyushu

Notes: 1. The white circles indicate the location of municipalities with coal mines around Chikuho coalfield (Figure B.2a) in Kyushu region. Figure 3a shows the coal mines in Chikuho, Kasuya, and Miike coalfields in Fukuoka, Karatsu coalfield in Saga, and Miike coalfield in Kumamoto. Amakusa coalfield in Kumamoto is added in Figure 3b (on the lower left of the figure). Oita prefecture does not have coal mines but is shown in the figures to explain the border of the sample.

2. Treatment (control) group includes municipalities within 5 (between 5 and 30) km from a mine. The excluded municipalities are shown as empty lattices in the figures.

Source: Created by the author.

Figure 4: Heterogeneity in the Impact of Mines by Distance from the Mines

Notes: This figure shows the results from the expanded regressions of equation 1 that includes the five indicator variables for each 5km bin from a mine to 25 km away from the origin. 0–5 km distance from mines indicates the municipalities within 5 km of a mine. 5–10 (10–15, 15–20, 20–25) km distance from mines indicates the municipalities within (5, 10] ((10, 15], (15, 20], (20, 25]) km of a mine. (20–30] km bin is used as a reference group.

Figures 4a, 4b, and 4c show the results for the local population, labor force participation rate, and infant mortality rate (IMR), respectively. The dots and solid lines with caps show the estimates and their 95 percent confidence intervals, respectively. The confidence intervals are calculated using the standard errors based on the heteroskedasticity-robust covariance matrix estimator.

Source: Created by the author.
Table 1: Summary Statistics

Panel A: Reports the summary statistics for the demographic outcomes: population, crude marriage rates, crude divorce rates, and household size. Distance to the nearest neighboring station/port/river is in kilometers. Significant at the 1% and 5% levels, respectively. The treatment (control) group is 0–5 (5-30) km from the centroid of a distribution in nature. The crude marriage rate is the number of marriages per 1,000 births. The CMR is the number of deaths of children aged 1–4 per 1,000 children aged 0–4. The IMR is the number of infant deaths per 1,000 live births. The variables with * have a set of censored observations; the results from the Tobit models are materially similar to the main results in most cases.

Panel B: Reports the summary statistics for the demographic outcomes: population, crude marriage rates, crude divorce rates, and household size. Distance to the nearest neighboring station/port/river is in kilometers. Significant at the 1% and 5% levels, respectively. The treatment (control) group is 0–5 (5-30) km from the centroid of a municipality that has a mine. The crude marriage rate is the number of marriages per 1,000 births. The crude divorce rate is the number of divorces per 1,000 married persons. The household size is the average number of people in a household. The variables with * have a set of censored observations; the results from the Tobit models are materially similar to the main results in most cases.

Panel C: Reports the summary statistics for labor force participation rates and employment shares. Labor force participation is the number of workers per 100 people. The employment share is the number of workers in each sector per 100 workers.

Panel D: Reports the summary statistics for infant mortality (IMR), fetal death rates (FDR), and child mortality (CMR). The IMR is the number of infant deaths per 1,000 live births. The FDR is the number of fetal deaths per 1,000 births. The CMR is the number of deaths of children aged 1–4 per 1,000 children aged 1–5. The variables with * have a set of censored observations; the results from the Tobit models are materially similar to the main results in most cases.

Notes: † and ‡ in Panels B-D indicate that the mean difference between treatment and control groups is statistically significant at the 1% and 5% levels, respectively. The treatment (control) group is 0–5 (5-30) km from the centroid of a municipality that has a mine.
Table 2: Results: Local Population Growth

Panel A: 1930 Census

| Panel A-1: Main Result | (1) | (2) | (3) | (4) | (5) | (6) |
|------------------------|-----|-----|-----|-----|-----|-----|
| MineDeposit            | 0.678*** | 0.462*** | 0.447*** | 1.386*** | 0.829*** | 0.812*** |
| (0.078)                | (0.058) | (0.058) | (0.291) | (0.197) | (0.211) |       |
| City and Town FEs      | No   | Yes | No  | Yes | Yes | Yes |
| Railway accessibility  | No   | No  | Yes | No  | No  | Yes |
| Port accessibility     | No   | No  | Yes | No  | No  | Yes |
| River accessibility    | No   | No  | Yes | No  | No  | Yes |
| Observations           | 1,140| 1,140| 1,140| 1,140| 1,140| 1,140|
| Estimator              | OLS  | OLS | OLS | IV (Wald) | IV | IV |
| First-stage F-statistic| –    | –   | 43.39 | 37.70 | 32.19 |       |

Panel A-2: Mechanism

| (1) Marriage | (2) Fertility | (3) Size | (4) Sex Ratio |
|--------------|---------------|----------|---------------|
| MineDeposit  | -2.586***     | -7.020*** | -0.438***     | 0.115***      |
| (0.825)      | (2.055)       | (0.145)  | (0.036)       |               |
| City and Town FEs | Yes | Yes | Yes | Yes |
| Railway accessibility | Yes | Yes | Yes | Yes |
| Port accessibility | Yes | Yes | Yes | Yes |
| River accessibility | Yes | Yes | Yes | Yes |
| Observations | 1,140 | 1,140 | 1,140 | 1,140 |
| Estimator | IV | IV | IV | IV |
| First-stage F-statistic | – | – | 48.87 | 44.11 | 40.48 |

Panel B: 1935 Census

| Panel B-1: Main Result | (1) | (2) | (3) | (4) | (5) | (6) |
|------------------------|-----|-----|-----|-----|-----|-----|
| MineDeposit            | 0.662*** | 0.463*** | 0.457*** | 1.301*** | 0.870*** | 0.803*** |
| (0.075)                | (0.058) | (0.057) | (0.278) | (0.188) | (0.194) |       |
| City and Town FEs      | No   | Yes | Yes | No  | Yes | Yes |
| Railway accessibility  | No   | No  | Yes | No  | No  | Yes |
| Port accessibility     | No   | No  | Yes | No  | No  | Yes |
| River accessibility    | No   | No  | Yes | No  | No  | Yes |
| Observations           | 1,364| 1,364| 1,364| 1,364| 1,364| 1,364|
| Estimator              | OLS  | OLS | OLS | IV (Wald) | IV | IV |
| First-stage F-statistic| –    | –   | 48.87 | 44.11 | 40.48 |       |

Panel B-2: Mechanism

| (1) Marriage | (2) Fertility | (3) Size | (4) Sex Ratio |
|--------------|---------------|----------|---------------|
| MineDeposit  | -1.387**     | -1.144   | -0.284**     | 0.050**      |
| (0.677)      | (1.576)      | (0.128)  | (0.024)      |              |
| City and Town FEs | Yes | Yes | Yes | Yes |
| Railway accessibility | Yes | Yes | Yes | Yes |
| Port accessibility | Yes | Yes | Yes | Yes |
| River accessibility | Yes | Yes | Yes | Yes |
| Observations | 1,364 | 1,364 | 1,364 | 1,364 |
| Estimator | IV | IV | IV | IV |

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors based on the heteroskedasticity-robust covariance matrix estimator are reported in parentheses.

Notes: Panels A and B show the results for the 1930 and 1935 samples, respectively. Panels A-1 and B-1 show the main result for log-transformed population, whereas Panels A-2 and B-2 show the result for mechanism analysis. “Marriage,” “Fertility,” “Size,” and “Sex Ratio” indicate the crude marriage rate, crude birth rate, household size, and adult sex ratio, respectively (Panel B of Table 4).
Table 3: Results: Local Labor Supply

Panel A: Male Workers

| Panel A-1: Main Result | (1)    | (2)    | (3)    | (4)    | (5)    | (6)    |
|------------------------|--------|--------|--------|--------|--------|--------|
| MineDeposit            | −0.277 | −0.320 | −0.008 | −0.960 | −1.192 | −0.695 |
| (0.298)                | (0.295)| (0.301)| (1.068)| (1.139)| (1.167)|        |
| City and Town FEs      | No     | Yes    | Yes    | No     | Yes    | Yes    |
| Railway accessibility  | No     | No     | Yes    | No     | No     | Yes    |
| Port accessibility     | No     | No     | Yes    | No     | No     | Yes    |
| River accessibility    | No     | No     | Yes    | No     | No     | Yes    |
| Observations           | 1,140  | 1,140  | 1,140  | 1,140  | 1,140  | 1,140  |
| Estimator              | OLS    | OLS    | OLS    | IV (Wald)| IV   | IV     |
| First-stage F-statistic| –      | –      | –      | 43.39  | 37.70  | 33.57  |

Dependent Variable: Employment Share (%)

| Panel A-2: Structural Shift | (1) Mining | (2) Agricultural | (3) Manufacturing | (4) Commerce | (5) Domestic |
|-----------------------------|------------|------------------|-------------------|--------------|--------------|
| MineDeposit                 | 34.452***  | −35.140***       | 1.752             | −1.914       | −0.499***    |
| (5.076)                     | (6.540)    | (2.192)          | (1.577)           | (0.139)      |              |
| City and Town FEs           | Yes        | Yes              | Yes               | Yes          | Yes          |
| Railway accessibility       | Yes        | Yes              | Yes               | Yes          | Yes          |
| Port accessibility          | Yes        | Yes              | Yes               | Yes          | Yes          |
| River accessibility         | Yes        | Yes              | Yes               | Yes          | Yes          |
| Observations                | 1,140      | 1,140            | 1,140             | 1,140        | 1,140        |
| Estimator                   | IV         | IV               | IV                | IV           | IV           |

Panel B: Female Workers

| Panel B-1: Main Result | (1)    | (2)    | (3)    | (4)    | (5)    | (6)    |
|------------------------|--------|--------|--------|--------|--------|--------|
| MineDeposit            | −7.863*** | −5.653*** | −4.391*** | −25.997*** | −20.682*** | −18.951*** |
| (0.911)                | (0.826) | (0.812) | (4.357) | (4.272) | (4.214) |        |
| City and Town FEs      | No     | Yes    | Yes    | No     | Yes    | Yes    |
| Railway accessibility  | No     | No     | Yes    | No     | No     | Yes    |
| Port accessibility     | No     | No     | Yes    | No     | No     | Yes    |
| River accessibility    | No     | No     | Yes    | No     | No     | Yes    |
| Observations           | 1,140  | 1,140  | 1,140  | 1,140  | 1,140  | 1,140  |
| Estimator              | OLS    | OLS    | OLS    | IV (Wald)| IV   | IV     |
| First-stage F-statistic| –      | –      | –      | 43.39  | 37.70  | 33.57  |

Dependent Variable: Employment Share (%)

| Panel B-2: Structural Shift | (1) Mining | (2) Agricultural | (3) Manufacturing | (4) Commerce | (5) Domestic |
|-----------------------------|------------|------------------|-------------------|--------------|--------------|
| MineDeposit                 | 24.342***  | −25.148***       | −9.720**          | 3.058        | 4.731***     |
| (4.162)                     | (5.964)    | (2.210)          | (2.666)           | (1.434)      |              |
| City and Town FEs           | Yes        | Yes              | Yes               | Yes          | Yes          |
| Railway accessibility       | Yes        | Yes              | Yes               | Yes          | Yes          |
| Port accessibility          | Yes        | Yes              | Yes               | Yes          | Yes          |
| River accessibility         | Yes        | Yes              | Yes               | Yes          | Yes          |
| Observations                | 1,140      | 1,140            | 1,140             | 1,140        | 1,140        |
| Estimator                   | IV         | IV               | IV                | IV           | IV           |

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors based on the heteroskedasticity-robust covariance matrix estimator are reported in parentheses.

Notes: Panels A and B show the results for male and female worker samples, respectively, from the 1930 Population Census (Panel C of Table 1). Panels A-1 and B-1 show the main result for the labor force participation rate, whereas Panels A-2 and B-2 show the result for employment share in each industrial sector (Panel C of Table 1).
Table 4: Results: Early-life Health

Panel A: 1933 Vital Statistics

### Table A-1: IMR

| Dependent Variable: Infant Mortality Rate | (1) | (2) | (3) | (4) | (5) | (6) |
|------------------------------------------|-----|-----|-----|-----|-----|-----|
| MineDeposit                              | 26.966** | 25.857** | 22.577*** | 49.121*** | 60.942** | 60.912** |
| (3.692)                                  | (3.757) | (3.763) | (14.526) | (15.808) | (16.976) |
| City and Town FEs                        | No | Yes | Yes | No | Yes | Yes |
| Railway accessibility                     | No | Yes | No | No | Yes | Yes |
| Port accessibility                        | No | No | Yes | No | No | Yes |
| River accessibility                       | No | No | Yes | No | No | Yes |
| Observations                              | 1.140 | 1.140 | 1.140 | 1.140 | 1.140 | 1.140 |
| Estimator                                 | OLS | OLS | OLS | IV (Wald) | IV | IV |
| First-stage F-statistic                   | – | – | – | 43.39 | 37.70 | 32.19 |

### Table A-2: Mechanism

| (1) FDR | (2) FDR | (3) IMR | (4) CMR | (5) CMR |
|---------|---------|---------|---------|---------|
| MineDeposit | 24.920** | –0.109  | (10.146) | (2.906) |
| Female Miner | 0.035** | 0.008*** | (0.013) | (0.034) |
| Male Miner | –0.002 | –0.007* | (0.002) | (0.004) |
| River accessibility | –0.401 | –1.345 | –0.552 | –0.243* | 0.168 | (0.538) | (2.466) | (0.135) | (0.318) |
| City and Town FEs | Yes | Yes | Yes | Yes | Yes |
| Railway accessibility | Yes | Yes | Yes | Yes | Yes |
| Port accessibility | Yes | Yes | Yes | Yes | Yes |
| Observations | 1.140 | 93 | 93 | 1.140 | 93 |
| Estimator | OLS | OLS | OLS | IV (Wald) | IV | IV |
| First-stage F-statistic | – | – | – | 48.87 | 44.11 | 40.48 |

Panel B: 1938 Vital Statistics

### Table B-1: IMR

| Dependent Variable: Infant Mortality Rate | (1) | (2) | (3) | (4) | (5) |
|------------------------------------------|-----|-----|-----|-----|-----|
| MineDeposit                              | 20.287*** | 19.203*** | 16.458*** | 29.839*** | 27.997** | 17.411 |
| (3.034)                                  | (3.077) | (3.005) | (11.470) | (12.206) | (12.420) |
| City and Town FEs                        | No | Yes | Yes | No | Yes | Yes |
| Railway accessibility                     | No | No | Yes | No | No | Yes |
| Port accessibility                        | No | No | Yes | No | No | Yes |
| River accessibility                       | No | No | Yes | No | No | Yes |
| Observations                              | 1,429 | 1,429 | 1,429 | 1,429 | 1,429 | 1,429 |
| Estimator                                 | OLS | OLS | OLS | IV (Wald) | IV | IV |
| First-stage F-statistic                   | – | – | – | 48.87 | 44.11 | 40.48 |

### Table A-2: Mechanism

| (1) FDR | (2) FDR | (3) IMR | (4) CMR | (5) CMR |
|---------|---------|---------|---------|---------|
| MineDeposit | 6.680 | 1.416 | (8.236) | (2.558) |
| Female Miner | 0.025* | 0.066** | (0.015) | (0.030) |
| Male Miner | 0.001 | 0.000 | (0.001) | (0.002) |
| River accessibility | –0.382 | 0.186 | –0.922 | –0.285* | –0.285 | (0.475) | (1.588) | (1.655) | (0.152) | (0.395) |
| City and Town FEs | Yes | Yes | Yes | Yes | Yes |
| Railway accessibility | Yes | Yes | Yes | Yes | Yes |
| Port accessibility | Yes | Yes | Yes | Yes | Yes |
| Observations | 1,429 | 115 | 115 | 1,429 | 115 |
| Estimator | OLS | OLS | OLS | IV | OLS | OLS |

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors based on the heteroskedasticity-robust covariance matrix estimator are reported in parentheses.

Notes: Panels A and B show the results for the 1933 and 1938 Vital Statistics samples, respectively (Panel D of Table 1). Panels A-1 and B-1 show the main results for the infant mortality rate (IMR). Panels A-2 and B-2 show the results for the fetal death rate (FDR), IMR in the coal mining municipalities, and the child mortality rate (CMR) (Panel D of Table 1).
### Table 5: Additional Results: Heavy Metal Mines

| Dependent Variable | ln(Population) (1) 1930 | LFP Rate in 1930 (2) 1935 | IMR (3) Male (4) Female (5) 1933 (6) 1938 |
|--------------------|------------------------|--------------------------|--------------------------------------|
| MineDeposit        | 0.160***               | 0.227***                 | −1.104***                            | −3.182***                            | −7.142**                           | −6.389**                           |
|                    | (0.047)                | (0.049)                  | (0.321)                              | (0.942)                              | (3.107)                             | (3.013)                             |
| City and Town FEs  | Yes                    | Yes                      | Yes                                  | Yes                                  | Yes                                 | Yes                                 |
| Railway accessibility| Yes                    | Yes                      | Yes                                  | Yes                                  | Yes                                 | Yes                                 |
| Port accessibility | Yes                    | Yes                      | Yes                                  | Yes                                  | Yes                                 | Yes                                 |
| River accessibility| Yes                    | Yes                      | Yes                                  | Yes                                  | Yes                                 | Yes                                 |
| Observations       | 2,498                  | 3,293                    | 2,498                                | 2,498                                | 2,498                               | 3,293                               |
| Estimator          | OLS                    | OLS                      | OLS                                  | OLS                                  | OLS                                 | OLS                                 |

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors based on the heteroskedasticity-robust covariance matrix estimator are reported in parentheses.

Notes: This table shows the results for the GSC mines sample (Panel A of Table 1). Columns (1) and (2) show the results for the log-transformed population measured in the 1930 and 1935 population censuses, respectively. Columns (3) and (4) show the results for the labor force participation rates of male and female workers, respectively. Columns (5) and (6) show the results for the infant mortality rates (IMR) measured using the 1933 and 1938 vital statistics, respectively.

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### Table 6: Additional Results: Difference-in-Differences for Two Coal Mine Areas in Iwate and Akita Prefectures

| Dependent Variable | (1) Ln(Population) | (2) Marriage | (3) Fertility | (4) Size | (5) Sex Ratio | (6) IMR |
|--------------------|--------------------|--------------|---------------|----------|---------------|---------|
| MineDeposit        | 0.072***           | −1.478       | −0.977        | −0.101** | 0.047***      | 22.359  |
|                    | (0.025)            | (1.506)      | (2.558)       | (0.050)  | (0.011)       | (24.066) |
| Municipal and Year FEs | Yes              | Yes         | Yes           | Yes      | Yes           | Yes     |
| Railway accessibility | Yes              | Yes         | Yes           | Yes      | Yes           | Yes     |
| Port accessibility  | Yes                | Yes         | Yes           | Yes      | Yes           | Yes     |
| Observations       | 136                | 136          | 136           | 136      | 136           | 136     |
| Clusters           | 68                 | 68           | 68            | 68       | 68            | 68      |
| Years              | 1930 and 35        | 1930 and 35  | 1930 and 35   | 1930 and 35 | 1930 and 35 | 1933 and 38 |
| Estimator          | DID                | DID          | DID           | DID      | DID           | DID     |

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors based on the cluster-robust covariance matrix estimator are reported in parentheses.

Notes: This table shows the results for the coal mines subsample in Iwate and Akita prefectures. Column (1) show the result for the log-transformed population. Columns (2)–(5) show the results for the crude marriage rate, crude birth rate, average household size, and sex ratio, respectively. Columns (6) shows the result for the infant mortality rates. The results for the labor force participation rates are unavailable as those rates are measured only in the 1930 Population Census.
References

Alberto Abadie. Semiparametric Difference-in-Differences estimators. *The Review of Economic Studies*, 72(1):1–19, January 2005.

Ran Abramitzky, Adeline Delavande, and Luis Vasconcelos. Marrying Up: The Role of Sex Ratio in Assortative Matching. *American Economic Journal: Applied Economics*, 3(3):124–157, July 2011.

Parvez Ahmed and Jouni J K Jaakkola. Maternal occupation and adverse pregnancy outcomes: a finnish population-based study. *Occupational Medicine*, 57(6):417–423, September 2007.

Aiikukai. *Shussan, shusshō, shizan oyobi nyūjisibō tōkei (The statistics of birth, live births, fetal deaths, and infant deaths).* [in Japanese]. Aiikukai, Tokyo, 1935.

Cecilia Nwadiuto Amadi, Zelinjo Nkeiruka Igweze, and Orish Ebere Orisakwe. Heavy metals in miscarriages and stillbirths in developing nations. *Middle East Fertility Society Journal*, 22(2):91–100, June 2017.

Josh Angrist. How do sex ratios affect marriage and labor markets? Evidence from America’s second generation. *Quarterly Journal of Economics*, 117(3):997–1038, August 2002.

Fernando M Aragón and Juan Pablo Rud. Natural Resources and Local Communities: Evidence from a Peruvian Gold Mine. *American Economic Journal: Economic Policy*, 5(2):1–25, May 2013.

Fernando M Aragón and Juan Pablo Rud. Polluting industries and agricultural productivity: Evidence from mining in Ghana. *The Economic Journal*, 126(597):1980–2011, September 2015.

Manuel Arellano. Computing standard errors for robust within-groups estimators. *Oxford Bulletin of Economics and Statistics*, 49(4):431–434, November 1987.

Association for Harmonious Cooperation. *Zenkoku kōgökōzan meibo (The lists of factories and mines, 1932 edition).* [in Japanese]. Association for Harmonious Cooperation, Tokyo, 1932.

Association for Harmonious Cooperation. *Zenkoku kōgökōzan meibo (The lists of factories and mines, 1937 edition).* [in Japanese]. Association for Harmonious Cooperation, Tokyo, 1937.

Brian Beach and W Walker Hanlon. Coal Smoke and Mortality in an Early Industrial Economy. *The Economic Journal*, 128(615):2652–2675, November 2017.

Anja Benshaul-Tolonen. Local Industrial Shocks and Infant Mortality. *The Economic Journal*, 129(620):1561–1592, May 2019.
Hilde C Bjørnland and Leif A Thorsrud. Boom or Gloom? Examining the Dutch Disease in Two-speed Economies. *The Economic Journal*, 126(598):2219–2256, May 2016.

Dan Black, Terra McKinnish, and Seth Sanders. The economic impact of the coal boom and bust. *The Economic Journal*, 115(503):449–476, April 2005.

Francesco Caselli and Wilbur John Coleman II. The U.S. structural transformation and regional convergence: A reinterpretation. *Journal of Political Economy*, 109(3):584–616, June 2001.

Francesco Caselli and Michaels Guy. Do oil windfalls improve living standards? Evidence from Brazil. *NBER Working Paper*, 15550:1–60, December 2009.

Francesco Caselli and Michaels Guy. Do Oil Windfalls Improve Living Standards? Evidence from Brazil. *American Economic Journal: Applied Economics*, 5(1):208–238, January 2013.

Hiroshi Chiba and Takashi Yamada. Chikuhō coalfield and onga river [in japanese]. *Suiri kagaku*, 8(1):88–103, 1964.

Max W Corden. Booming sector and Dutch disease economics: Survey and consolidation. *Oxford Economic Papers*, 36(3):359–380, November 1984.

Max W Corden and J Peter Neary. Booming sector and de-industrialisation in a small open economy. *The Economic Journal*, 92(368):825–848, December 1982.

Clément de Chaisemartin and Xavier D’Haultfœuille. Two-way fixed effects and differences-in-differences with heterogeneous treatment effects: a survey. *Econometrics Journal*, page utac017, June 2022.

Jordi Domenech. Mineral resource abundance and regional growth in Spain, 1860-2000. *Journal of International Development*, 20(8):1122–1135, November 2008.

Fabian F Drixler. Hidden in Plain Sight: Stillbirths and Infanticides in Imperial Japan. *Journal of Economic History*, 76(3):651–696, September 2016.

Gilles Duranton and Diego Puga. Micro-foundations of urban agglomeration economies. In Vernon J Henderson and Jacques-François Thisse, editors, *Handbook of Regional and Urban Economics, vol.4*, pages 2063–2117. Elsevier, Amsterdam, 2004.

R K Eastwood and A J Venables. The macroeconomic implications of a resource discovery in an open economy. *The Economic Journal*, 92(366):285–299, June 1982.

Alan Fernihough and Hjortshøj Kevin O’Rourke. Coal and the European Industrial Revolution. *The Economic Journal*, 131(635):1135–1149, April 2020.

Hans Grönqvist, Peter J Nilsson, and Pre-Olof Robling. Early lead exposure and outcomes in adulthood. *IFAU Working Paper*, 4:1–72, May 2017.

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Walker W Hanlon. Coal smoke, city growth, and the costs of the industrial revolution. *The Economic Journal*, 130(626):462–488, February 2020.

Stephan Heblich, Alex Trew, and Yanos Zylberberg. East side story: Historical pollution and persistent neighborhood sorting. *School of Economics and Finance Discussion Papers*, pages 1–77, March 2018.

David V Hinkley. Jackknifing in unbalanced situations. *Technometrics*, 19(3):285–292, August 1977.

Susan D Horn, Roger A Horn, and David B Duncan. Estimating Heteroscedastic Variances in Linear Models. *Journal of the American Statistical Association*, 70(350):380–385, June 1975.

Kanji Ishii. *Japanese Economic History, second edition [in Japanese]*. University of Tokyo Press, Tokyo, 1991.

Japan Mining Association. *Nihon k¯ ozan ky¯ okai siry¯ o, dai issh¯ u (Japan Mining Association Materials, volume 1)*. [in Japanese]. Japan Mining Association, Tokyo, 1928.

Japan Mining Association. *Nihon k¯ ozan ky¯ okai siry¯ o, dai jy¯ uyon sh¯ u (Japan Mining Association Materials, volume 14)*. [in Japanese]. Japan Mining Association, Tokyo, 1930.

Japan Mining Association. *Nihon k¯ ozan ky¯ okai siry¯ o, dai jy¯ ugo sh¯ u (Japan Mining Association Materials, volume 15)*. [in Japanese]. Japan Mining Association, Tokyo, 1931.

Andreas Kotsadam and Anja Tolonen. African mining, gender, and local employment. *World Development*, 83:325–339, July 2016.

Philip J Landrigan, Richard Fuller, Nerus J R Acosta, Olusoji Adeyi, Robert Arnold, Niladri Nil Basu, Abdoulaye Bibi Baldé, Roberto Bertollini, Stephan Bose-O’Reilly, Jo Ivey Boufford, Patrick N Breysse, Thomas Chiles, Chulabhorn Mahidol, Awa M Coll-Seck, Prof Maureen L Cropper, Julius Fobil, Valentin Fuster, Michael Greenstone, Andy Haines, David Hanrahan, David Hunter, Mukesh Khare, Alan Krupnick, Bruce Lanphear, Bindu Lohani, Keith Martin, Karen V Mathiasen, Maureen A McTeer, Christopher J L Murray, Johanita D Ndahimananjara, Frederica Perera, Janez Potoñik, Alexander S Preker, Jairam Ramesh, Johan Rockström, Carlos Salinas, Leona D Samson, Kari Sandilya, Peter D Sly, Kirk R Smith, Achim Steiner, Richard B Stewart, William A Suk, van Schayck Onno C P, Gautam N Yadama, Kandeh Yumkella, and Ma Zhong. The Lancet Commission on pollution and health. *The Lancet*, 391(10119):1–51, October 2017.

Daniel Lederman and William F. Maloney. *Natural resources: Neither curse nor destiny*. Stanford University Press, Washington, 2007.
Ja-Liang Lin, Pao-Hsien Chu, Dan-Tzu Lin-Tan, Ching-Wei Hsu, Wen-Hung Huang, Kuan-Hsing Chen, and Tzung-Hai Yen. Cadmium excretion predicting 30-day mortality and illness severity of patients with acute myocardial infarction. *International Journal of Cardiology*, 168(5):4822–4824, October 2013.

Peter Mathias. *The First Industrial Nation: An Economic History of Britain, 1700-1914, 3rd edition*. Routledge, 2001.

Guy Michaels. The long term consequences of resource-based specialisation. *The Economic Journal*, 121(551):31–57, November 2010.

Ryōshin Minami. *The Economic Development of Japan: A Quantitative Study, Second Edition*. The Macmillan Press, Hampshire, 1994.

Mining Bureau, Ministry of Commerce and Industry. *Hongoku kogyō no süsei (Trend of mining in Japan, 1933 edition)*. [in Japanese]. Mining Bureau, Ministry of Commerce and Industry, Tokyo, 1934.

Ministry of Commerce and Industry. *Honpou jyūgō kōzan yōran (Handbook of Important Mines in Japan)*. [in Japanese]. Bureau of Mines, Ministry of Commerce and Industry, Tokyo, 1926.

Ministry of International Trade and Industry. *Honpō kogyō no süsei (Trends in Mining Industry of Japan, 1950 edition)*. [in Japanese]. Ministry of International Trade and Industry, Tokyo, 1954.

Joel Mokyr. *Industrialization in the Low Countries, 1795-1850*. Yale University Press, New Haven, CT, 1977.

Mayo Morimoto. *Naibū rōdō shijyō no keisei (Formation of Internal Labor Market)*. In Masaki Nakabayashi, editor, *Long Wave of Modernization in the Japanese Economy [in Japanese]*, pages 259–302. University of Tokyo Press, Tokyo, 2013.

Takafusa Nakamura. *An analysis of the economic growth in prewar Japan. [in Japanese]*. Iwanami shoten, Tokyo, 1971.

J Peter Neary and S van Wijnbergen. Can an oil discovery lead to a recession? A comment on eastwood and venables. *The Economic Journal*, 94(374):390–395, January 1984.

Yutaka. Nishinarita. *Jyōshirōdō no shoruikei to sono hen'yō*. In Masanori Nakamura, editor, *Technological Innovation and Women’s Labor [in Japanese]*, pages 71–106. Tokyo Daigaku Shuppan Kai, Tokyo, 1985.

Fred G Notehelfer. Japan’s first pollution incident. *Journal of Japanese Studies*, 1(2):351–383, 1975.

Yoshihiro Ogino. *Chikuhō tankō rōshi kankeishi (History of Labor-Management Relations in Chikuhō Coal Mine)*. [in Japanese]. Kyushi University Press, Fukuoka, 1993.
Tetsuji Okazaki. Intrafirm resource reallocation and labor productivity growth in the Japanese coal mining industry: Comparative study on Mitsubishi Mining Co., Mitsui Mining Co., and Hokkaido Colliery & Steamship Co. in the 1930s [in Japanese]. CIGS Working Paper Series, 21-001J:1–23, September 2021.

Elissaios Papyrakis and Reyer Gerlagh. Resource abundance and economic growth in the United States. European Economic Review, 51(4):1011–1039, May 2007.

Sidney Pollard. Peaceful Conquest: The Industrialization of Europe, 1760-1970. Oxford University Press, 1981.

Stuart S Rosenthal and William C Strange. Evidence on the nature and sources of agglomeration economies. In Vernon J Henderson and Jacques-François Thisse, editors, Handbook of Regional and Urban Economics, vol.4, pages 2119–2171. Elsevier, Amsterdam, 2004.

Jeffrey D Sachs and Andrew M Warner. The big push, natural resource booms and growth. Journal of Development Economics, 59(1):43–76, June 1999.

Jeffrey D Sachs and Andrew M Warner. The curse of natural resources. European Economic Review, 45(4-6):827–838, May 2001.

Christopher J Sergeant, Erin K Sexton, Jonathan W Moore, Alana R Westwood, Sonia A Nagorski, Joseph L Ebersole, David M Chambers, Sarah L O’Neal, Rachel L Malison, F Richard Hauer, Diane C Whited, Jill Weitz, Jackie Caldwell, Marissa Capito, Mark Connor, Christopher A Frissell, Greg Knox, Erin D Lowery, Randal Macnair, Vicki Marlatt, Jenifer K McIntyre, Megan V McPhee, and Nikki Skuce. Risks of mining to salmonid-bearing watersheds. Science Advances, 8(26):eabn0929, July 2022.

Social Welfare Bureau. Shussan, shushô, shizan oyobi nyûgûisibô tôkei (The statistics of birth, live births, fetal deaths, and infant and child deaths). [in Japanese]. Social Welfare Bureau, Tokyo, 1941.

Douglas Staiger and James H. Stock. Instrumental variables regression with weak instruments. Econometrica, 65(3):557–586, May 1997.

Statistics Bureau of the Cabinet. Shichôsonbetsu jinkôtaitôkei (The vital statistics for municipalities, 1930 edition). [in Japanese]. Statistics Bureau of the Cabinet, Tokyo, 1932.

Statistics Bureau of the Cabinet. Shôwagonen Kokuseichôsahôkoku, fûkenhen (1930 Population Census of Japan, prefecture part). [in Japanese]. Statistics Bureau of the Cabinet, Tokyo, 1933.

Statistics Bureau of the Cabinet. Shôwagonen Kokuseichôsahôkoku, fûkenhen (1930 Population Census of Japan, prefectural part). [in Japanese]. Statistics Bureau of the Cabinet, Tokyo, 1935a.
Statistics Bureau of the Cabinet. *Shōwagonen Kokuseichōshōkoku, daiikkan (1930 Population Census of Japan, volume 1).* [in Japanese]. Statistics Bureau of the Cabinet, Tokyo, 1935b.

Statistics Bureau of the Cabinet. *Shichōsonbetsu jinkōtōtaitōkei (The vital statistics for municipalities, 1935 edition).* [in Japanese]. Statistics Bureau of the Cabinet, Tokyo, 1938.

Statistics Bureau of the Cabinet. *Shōwajyūnen Kokuseichōshōkoku, daiikkan (1935 Population Census of Japan, volume 1).* [in Japanese]. Statistics Bureau of the Cabinet, Tokyo, 1939.

Jean-Philippe C Stijns. Natural resource abundance and economic growth revisited. *Resources Policy*, 30(2):107–130, June 2005.

Mikio Sumiya. *Nihon sekitan sangyō bunseki (Study of Japanese Coal Industry).* [in Japanese]. Iwanami Shoten, Tokyo, 1968.

John P Tang. The engine and the reaper: Industrialization and mortality in late nineteenth century Japan. *Journal of Health Economics*, 56:145–162, October 2017.

James Tobin. Estimation of relationships for limited dependent variables. *Econometrica*, 26(1):24–36, January 1958.

Robert L Trivers and Dan E Willard. Natural Selection of Parental Ability to Vary the Sex Ratio of Offspring. *Science*, 179(4068):90–92, January 1973.

Sweder van Wijnbergen. The ‘Dutch Disease’: A disease after all? *The Economic Journal*, 94(373):41–55, March 1984.

Jan von der Goltz and Prabhat Barnwal. Mines: The local wealth and health effects of mineral mining in developing countries. *Journal of Development Economics*, 139:1–16, June 2019.

Nicholas Wilson. Economic booms and risky sexual behavior: Evidence from Zambian copper mining cities. *Journal of Health Economics*, 31(6):797–812, December 2012.
Appendices
Appendix A  Background Appendix

A.1 Female Miners in Coal Mine

By the end of the 19th century, a large part of mines in the Chikuho coal fields had finished mechanizing the processes involved in hauling, such as drainage pumps and hoisting machines. However, this did not mean that the miner’s workload related to hauling operations reduced. Rather, such mechanization in the main shafts had increased the workload of miners extracting and transporting coal around the face (Sumiya 1968, pp. 310–312).

Figure A.1a shows a photo of miners at the mine face (kiriha) in the 1910s. A male skilled miner (saki-yama) extracted coal, whereas a female miner (ato-yama) brought the coal using a bamboo basket called sura. Figure A.1b shows that ato-yama tied a rope around her body to prevent the heavy sura from slipping off in the steep pits. The environment in the pit was generally poor. The air was polluted with dust, oxygen levels were low, and there was a risk of carbon monoxide poisoning. There was also a high risk of fire from dynamite blasting and spontaneous combustion of gas and coal. Moreover, accidents caused by falling rocks occurred frequently.

![Figure A.1: Male (saki-yama) and Female Miners (ato-yama)](image)

Notes: Figure A.1a shows the skilled male miner (saki-yama) extracting coal and the female miner (ato-yama) supporting her husband at the face. Figure A.1b illustrates an ato-yama bringing coal using a bamboo basket (sura) at the gangway through the steep pits. Both figures were taken in the early Taisho period. Source: Fumoto (1961, p. 2).

Introduction of new mining technologies such as coal cutters were gradually adopted in the 1920s. The introduction of these technologies was accompanied by a transition from the traditional room-and-pillar mining method to the longwall method, which is more suitable for mechanical coal extraction. The number of miners, both male and female, declined during this transition. However, this did not entirely change the labor

46Accidents caused by explosions, poisoning, and suffocation were fewer than those caused by falling rocks, but they still occurred 311 times per year on average between 1917 and 1926 (Japan Mining Association 1928, p. table.6).

47Available statistics indicate that the average number of accidents per year that occurred in the pits between 1917 and 1926, causing injuries and deaths of miners, was 142,595, of which 61,112 were from falling rocks. (Japan Mining Association, 1928, p. table.6).

48Compared to the room-and-pillar method, the coal extraction space of the longwall method is larger, allowing for the introduction of larger machinery (Nishinarita 1985, p. 91).
patterns of female miners. In fact, approximately one in five miners was a woman in 1930 (Table A.1) and they still worked inside the pits as *ato-yama*.

An important event that changed the labor pattern of female miners was an institutional change that occurred in the early 1930s. Following the International Labor Conference after World War I, the Social Affairs Bureau held a consultation meeting with miners in the 1920s to revise the Miners’ Labor Assistance Regulations of 1916. Mining companies, who relied heavily on female miners for production, opposed the Social Affairs Bureau’s insistence on prohibiting women from working underground and late-night, but the Revised Miners’ Labor Assistance Regulations of September 1928 prohibited some underground and late-night work. Since the grace period for enforcement of the regulations lasted until 1933, the number of female miners gradually declined from around 1930. Table A.1 shows that the number of female miners in the pits (*ato-yama*) dropped from 1930 to 1933, when the Revised Miner’s Labor Assistance Regulations were enacted in September. Mining companies responded to this decline by introducing coal conveyors (Tanaka and Oghino 1977, p. 79). Importantly, however, the revised regulations did not eliminate female miners altogether. Female miners were allowed to work in the pits of the thin layer and were primarily responsible for coal selection and other out-of-pit labor.

There were still more than 15,000 women working in the mines in the late 1930s, which represented approximately 10% of all the miners measured.

### A.2 Influence of Great Depression in Japan

The impact of the Great Depression was not substantial in Japan compared to that in other countries (Miyamoto 2008, pp. 56–57; Abe 2008, p. 106; Blumenthal 1981, pp. 46). Blumenthal (1981, p. 43) shows that the index of industrial production in Japan did not decrease dramatically between 1929 (=100) and 1930 (=97), whereas the US and the UK suffered much greater reductions (81 in the US and 92 in the UK) in the same period. Blumenthal (1981, p. 45) also reports that the unemployment rates between 1930 and...
1935 in the US, the UK, and Japan were approximately 27%, 15%, and 6%, respectively. Consequently, the GNP growth rate (from 1929 to 1930) in Japan was positive at 1.1%, whereas it was −7.7 and −0.1, respectively, in the US and UK. This evidence supports the validity of using the systematic data from the census and vital statistics of the 1930s.

A.3 Shares of Coal and GSC Mines

Figure A.2a shows the number of coal and oil mines documented in the AHCs in 1931 and 1936. Similarly, Figure A.2b shows the numbers of GSC and other metal mines. As shown, approximately 90 (85)% of mines extracting fuels (metals) were coal (GSC) mines. Figure A.2 shows the number of mines and not municipalities. Since several mines coexist in a municipality, the number of municipalities with mines reported in the main text is smaller than the number of mines.

Figure A.2: The Number of Coal, Oil, GSC, and the Other Metal Mines in 1931 and 1936

Notes: This figure shows the number of coal and oil (Figure A.2a), and metal mines (Figure A.2b) documented in the AHCs of 1931 and 1936. GSC indicates gold, silver, and copper mines.

Source: Created by the author. Data on mines are from the Association for Harmonious Cooperation (1932, 1937).

Appendix B Data Appendix

B.1 Mine Deposit

Data on the location and type of mines are obtained from the official reports published by the Association for Harmonious Cooperation (1932, 1937). They document all mines with more than 50 miners in October 1931 and October 1936. The documents list three types of mines: metal, coal, and oil. In these documents, the mine’s

50 The metal mine includes minerals such as gold, silver, copper, blister copper, pig iron, steel, iron sulfide, lead, zinc, bismuth, arsenious acid, tin, mercury, chromium, manganese, and sulfide minerals. A smelting mine is also included in the metal mine category. Coal mines include a few mines mining lignite. Oil mines include oil, crude oil, gas, volatile oil, kerosene, light oil, machine oil, and heavy oil.
location is indicated by the name of the municipality. Hence, the name of the municipality was used while geocoding to match the mine dataset with the datasets of the other variables. The shapefile used for geocoding was obtained from the official database of the Ministry of Land, Infrastructure, Transport and Tourism (available at: https://nlftp.mlit.go.jp/ksj/gml/datalist/KsjTmplt-N03-v2_2.html (accessed on 23rd February 2021)). Several municipalities were consolidated between the years 1930 and 1938. Thus, I used the municipality boundaries defined in 1938 and aggregate statistics for consolidated municipalities. A very small number of municipalities were divided; these were excluded from the original dataset. To check all consolidations and divisions of municipalities, I usedZenkoku shichôsonmei hensen sôran (Municipal Autonomy Research Association 2006), the most comprehensive book on the history of municipalities’ names.

The initial dataset included both coal and heavy metal mines. To prepare the analytical samples, therefore, I had to exclude the duplications to better identify the impacts of coal mines. Panel A of Table B.1 summarizes duplications in the coal mine sample. Columns (1) and (2) show the figures based on the 1931 (1936) AHC which is used for matching with the 1930 (1935) Population Census and 1933 (1938) Vital Statistics datasets. Initially, there are 11,151 municipalities in columns (1) and (2); note that the municipality boundaries are defined based on the 1938 boundaries. The number of municipalities within 30km of a coal mine are 1,147 and 1,386 in columns (1) and (2), respectively. The number of duplications in the treatment groups based on the 5 km radius definition is 0 and 2 in columns (1) and (2), respectively. Similarly, the number of duplications in the control groups based on the 5 km radius definition is 7 and 20 in columns (1) and (2), respectively. Following the trimming step shown in Figure B.1a, the analytical coal mine samples are 1,140 (= 1,147 − 7) and 1,364 (= 1,386 − 22), respectively. Panel B of Table B.1 summarizes the duplications in the GSC mine sample. Following the same procedure as in Figure B.1b, the GSC mine samples used in the robustness analysis are 2,498 (= 2,510 − 22) and 3,293 (= 3,337 − 44), respectively.

The red (blue) circles in Figure B.2 indicate the coal (GSC) mine locations from the AHC. Figure 2 illustrates the spatial distribution of the coal mine sample by year and group. Figure 3 shows the distribution in Chikuhô coalfield in Kyushû in detail.

### B.2 Geological Stratum

I used the location information on geological strata (chisô) obtained from the official database of the Ministry of Land, Infrastructure, Transport and Tourism (available at: http://nrbo-www.mlit.go.jp/kokjo/inspect/landclassification/download/index.html, accessed on 27th February 2020). The instrumental variable (IV) was defined as follows: First, I matched each municipality with the nearest stratum point (there are 11,151 municipalities with 8,748 stratum points). Figure B.3 illustrates the spatial distributions of geological strata and the mine locations (shown as circles). The average distance from the municipality’s centroid to the nearest stratum point was approximately 4 km (median = 3 km). This is shorter than the main treatment indicator variable of 5 km as the threshold for treatment. Second, using the analytical sample (Section 3.1), I regressed the indicator variable for coal mines on the strata to determine a plausible stratum that is strongly correlated with the location of coal mines. The data on the strata included 19 types of
Table B.1: Duplications between Coal and GSC Mines

|                            | (1) 1930 or 1933 | (2) 1935 or 1938 |
|-----------------------------|------------------|------------------|
| **Panel A: Coal mine sample** |                  |                  |
| Number of total municipalities | 11,151           | 11,151           |
| Number of municipalities within 30km from a coal mine | 1,147            | 1,386            |
| Duplications in treatment group |                |                  |
| Number of municipalities with a coal mine | 93              | 115              |
| of which has a GCS mine | 0                | 1                |
| Number of municipalities within 5km from a coal mine | 167             | 179              |
| of which has a GCS mine within 5km | 0                | 2                |
| Duplications in control group |                |                  |
| Number of municipalities with no coal mines | 1,054           | 1,335            |
| of which has a GCS mine | 3                | 12               |
| Number of municipalities with no coal mines within 5km | 980             | 1,271            |
| of which has a GCS mine within 5km | 7                | 20               |
| **Panel B: GSC mine sample** |                  |                  |
| Number of total municipalities | 11,151           | 11,151           |
| Number of municipalities within 30km from a coal mine | 2,510           | 3,337            |
| Duplications in treatment group |                |                  |
| Number of municipalities with a GSC mine | 67              | 111              |
| of which has a coal mine | 0                | 1                |
| Number of municipalities within 5km from a coal mine | 125             | 174              |
| of which has a coal mine within 5km | 0                | 2                |
| Duplications in control group |                |                  |
| Number of municipalities with no GSC mines | 2,437           | 3,196            |
| of which has a coal mine | 6                | 29               |
| Number of municipalities with no GCS mines within 5km | 2,373           | 3,119            |
| of which has a coal mine within 5km | 12              | 42               |

Source: See Online Appendix B.1.
Figure B.1: Construction of Analytical Samples
Notes: This figures show how to trim the municipalities into the analytical samples. Figures B.1a and B.1b show the trimming steps for the coal and GSC (gold, silver, and copper) mines, respectively.
Sources: Created by the author.

Figure B.2: Location of Coal and GSC mines in 1931 and 1936
Notes: The red and blue circles indicate the locations of coal and GSC (gold, silver, and copper) mines, respectively. Chikuhō coalfield in Fukuoka prefecture in Kyushū region is indicated with an arrow in Figure B.2a. Figure B.2b illustrates the coal mines around Chikuhō coalfield in detail.
Source: Created by the author.
strata (with 4 categories of rock (and field) and 6 categories of era). I ran 19 regressions for each year’s (1931 and 1936) coal mine sample on the location of coal mines. Table B.2 presents the results. As shown, two strata, Tn and Tp, have statistically significant and positive correlations with the location of mines. Among them, the estimated coefficient for Tp has the largest value (0.323 versus 0.143 in the 1931 sample).

Both Tn and Tp are sedimentary rocks created during the Cenozoic era (shinseidai). Tp was created during a much earlier period, called the Paleogene period (ko daisanki), compared to Tn, which was created during the Neogene period (shin daisanki). Evidence indicates that Tp includes some coal layers that were created in the carboniferous ages (Nagao 1975). Figure B.4 shows a geological columnar section of the Iizuka coal mine, a representative coal mine in the Chikuho coalfield.

### B.3 Outcomes

#### B.3.1 Demographics

The official 1930 and 1935 Population Censuses published by the Statistics Bureau of the Cabinet document the number of people (by sex) and households in municipalities. The number of marriages and live births used to calculate crude marriage and birth rates were

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51 There were originally 20 types of strata. I excluded the landfill category because it had just one observation in the 1936 sample.

52 $R^2$-squared for Tp was also larger. Since the regression is a linear probability model, the $R^2$-squared suggests that the average predicted probability is greater in municipalities having coal mines than in other municipalities.
Table B.2: Defining Instrumental Variables for the Coal Mine Subsample

| Stratum          | Mining points in 1931 | Mining points in 1936 |
|------------------|-----------------------|-----------------------|
|                  | Coeff.    | Std. Err. | R-squared | Coeff.    | Std. Err. | R-squared |
| Sedimentary rock |           |           |           |           |           |           |
| M                | 0.060     | (0.073)   | 0.001     | 0.025     | (0.051)   | 0.000     |
| P                | 0.036     | (0.122)   | 0.000     | -0.034    | (0.055)   | 0.000     |
| Pls              | 0.020     | (0.167)   | 0.000     | 0.037     | (0.167)   | 0.000     |
| Tn               | 0.143***  | (0.040)   | 0.017     | 0.193***  | (0.042)   | 0.028     |
| al               | -0.038    | (0.031)   | 0.001     | -0.033    | (0.025)   | 0.001     |
| ds               | -0.147*** | (0.011)   | 0.001     | -0.131*** | (0.009)   | 0.001     |
| lm               | 0.020     | (0.167)   | 0.000     | -0.072    | (0.060)   | 0.001     |
| tr               | -0.106*** | (0.020)   | 0.015     | -0.075*** | (0.019)   | 0.008     |
| wf               | -0.123*** | (0.030)   | 0.004     | -0.109*** | (0.026)   | 0.003     |
| Metamorphic rock |           |           |           |           |           |           |
| Gn               | -0.147*** | (0.011)   | 0.000     | -0.132*** | (0.009)   | 0.002     |
| Sch              | -0.011    | (0.046)   | 0.000     | -0.007    | (0.042)   | 0.000     |
| Body of water    |           |           |           |           |           |           |
| w                | -0.147*** | (0.011)   | 0.001     | -0.131*** | (0.009)   | 0.001     |
| Igneous rock     |           |           |           |           |           |           |
| An               | -0.108*** | (0.025)   | 0.007     | -0.107*** | (0.020)   | 0.007     |
| Bs               | -0.031    | (0.051)   | 0.000     | -0.027    | (0.046)   | 0.000     |
| Gd               | 0.133     | (0.051)   | 0.002     | 0.122     | (0.112)   | 0.002     |
| Gr               | -0.059**  | (0.025)   | 0.004     | -0.058*** | (0.021)   | 0.004     |
| Lp               | -0.150*** | (0.011)   | 0.004     | -0.134*** | (0.009)   | 0.005     |
| Sp               | 0.054     | (0.200)   | 0.000     | 0.013     | (0.143)   | 0.000     |

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors based on the heteroskedasticity-robust covariance matrix estimator (Horn et al. 1975) are reported in parentheses.

Notes: The number of observations for 1931 and 1936 are 1,140 and 1,364, respectively.
Figure B.4: Geological Columnar Section of the Iizuka Coal Mine

Note: This geological columnar section shows the strata around the Iizuka coal mine that include coal layers. The first to third columns include the names of layers created in the Paleogene period. The fourth to seventh columns examine the length of each layer, columnar, and legend. The black layers shown in the columnar of the sixth column are the coal layers: more than ten coal layers are included in the layers created in the Paleogene period.

Source: Fumoto (1961, p. Chishitsu chūjyō zu).
obtained from the Municipal Vital Statistics of 1930 and 1935 published by the Statistics Bureau of the Cabinet.

B.3.2 Labor Market

The number of workers in the mining, agricultural, manufacturing, commercial, and domestic sectors was digitized using the official report of the 1930 Population Census. The number of total workers and people were obtained from the same report.

B.3.3 Early-life Health

Data on the number of fetal, infant and child deaths were digitized using the official reports of municipal-level vital statistics of 1933 and 1938 published by the Aiikukai and Social Welfare Bureau. Data on the number of births and live births used to calculate fetal death and IMRs were obtained from the same report. Data on the number of children aged 1–5 were obtained from the 1930 Population Censuses.

B.4 Railway Stations

The location information of railway stations was obtained from the official shapefile file created by the Ministry of Land, Infrastructure, Transport and Tourism (https://nlftp.mlit.go.jp/ksj/gml/datalist/KsjTmplt-N05-v1.3.html, accessed 29th July 2022). The railway stations used to match the 1931 (1936) mining dataset included all stations (i.e., national, public, and private rails) in the railway sections in 1931 (1936). Figure B.5a (B.5b) illustrates the distribution of stations in 1931 (1936). The shortest distance between the centroid of each municipality and station was used as the distance from the nearest neighboring station. Both figures confirm that railway stations were not concentrated in the mining areas. This is consistent with evidence that accessibility to railways does not influence the results.

B.5 Seaports

Seaport locations were obtained from the official shapefile file created by the Ministry of Land, Infrastructure, Transport and Tourism (https://nlftp.mlit.go.jp/ksj/gmlold/datalist/gmlold_KsjTmplt-C02.html, accessed 1st October 2022). The seaports used to match the 1931 (1936) mining dataset included all seaports (both commercial and fishery) listed in the 1931 (1936) edition of the Harbor Statistics of the Great Empire of Japan (Dainihon teikoku kōwan tōkei). The ports listed in the Harbor Statistics, but not included in the original shapefile of the Ministry of Land, Infrastructure, Transport, and Tourism, were added manually. Figure B.6a (B.6b) shows the distribution of seaports in 1931 (1936).

B.6 Rivers

The location of rivers were obtained from the official shapefile provided by the Ministry of Land, Infrastructure, Transport, and Tourism (https://nlftp.mlit.go.jp/ksj/jpgis/datalist/KsjTmplt-W05.html, accessed August 21, 2018). The rivers used to match the mining dataset included those managed by the government or prefectures. As the rivers had not moved, the location
Figure B.5: Spatial Distribution of Railway Stations
Notes: The blue circles indicate the location of railway stations. The base map used in this figure is Figure 2. The treatment (control) group highlighted in red (pink) includes the municipalities within 5 (between 5 and 30) km from a mine. The excluded municipalities are shown as empty lattices in the figures.
Source: Created by the author.

Figure B.6: Spatial Distribution of Sea Ports
Notes: The blue circles indicate the location of sea ports. The ports in Okinawa prefecture and a few ports in the islands far from the main island are not shown in the figures. The base map used in this figure is Figure 2. The treatment (control) group highlighted in red (pink) includes the municipalities within 5 (between 5 and 30) km from a mine. The excluded municipalities are shown as empty lattices in the figures.
Source: Created by the author.
Figure B.7: Spatial Distribution of Rivers

Notes: The blue lines indicate the location of rivers. The rivers in Okinawa prefecture and a few points in the islands far from the main island are not shown in the figures. The base map used in this figure is Figure 2. The treatment (control) group highlighted in red (pink) includes the municipalities within 5 (between 5 and 30) km from a mine. The excluded municipalities are shown as empty lattices in the figures.

Source: Created by the author.

Information is time constant. Figure B.7a (B.7b) shows the distribution of the rivers matched to the 1931 (1936) base map.

B.7 Altitude

The grid cell data on altitude are taken from the official GIS database of the Ministry of Land, Infrastructure, Transport, and Tourism (https://nlftp.mlit.go.jp/ksj/gml/datalist/KsjTmplt-G04-d.html, accessed February 24, 2023). The average altitude in a 1 km square grid cell is calculated using the altitude measured in the 250 square grid cells in a third mesh-code originally assigned by the Ministry of Land, Infrastructure, Transport, and Tourism. The nearest neighbor grid cell is then linked to each municipality. The average distance to the nearest neighbor is 0.49 km, which is enough close to represent the average altitude in each municipality. Figure B.8 shows the spatial distribution of the altitude.

Appendix C Empirical Analysis Appendix

C.1 Attenuation due to Measurement Error

Consider a simplified projection of \( y_i \) on \( \text{MineDeposit}_i \) as \( y_i = \theta \text{MineDeposit}_i + u_i \). When \( \text{MineDeposit}_i \) has a classical measurement error, as \( \text{MineDeposit}_i^* = \text{MineDeposit}_i + u_i \), the observable model becomes \( y_i = \theta^* \text{MineDeposit}_i^* + \nu_i \). Consequently, I use \( \text{cov}(\text{MineDeposit}_i^*, \nu_i) = E[\text{MineDeposit}_i^* \nu] = -\theta \text{var}(u_i) \neq 0 \) for \( \theta^* = \theta + \text{cov}(\text{MineDeposit}_i^*, \nu_i) / \text{var}(\text{MineDeposit}_i^*) \).
C.2 Assumptions for the Identification

In order to simplify the discussion on the identification assumptions, I focus on the simplest structural equation considered in this study, a dummy endogenous variable model taking the form:

$$y_i = \alpha + \beta \text{MineDeposit}_i + \epsilon_i,$$

$$\text{MineDeposit}_i = \kappa + \tau \text{Stratum}_i + \epsilon_i.$$  \hspace{1cm} (4)

All the variables are those defined in Section 4. Note that I use the same greek symbols to those used in equations 1 and 2 to simplify the expressions of the model, albeit those shall be different parameters to those considered in Section 4.

There are five assumptions to identify the parameter of interest under this setting: stable unit treatment value assumption (hereafter SUTVA), random assignments, exclusion restriction, nonzero average causal effect of the IV, and monotonicity (Angrist et al. 1996). Section 4 shows that the assumptions of the random assignments and exclusion restriction are essentially plausible given the nature of the spatial distributions of mines and strats. In this subsection, I then discuss the rest of three assumptions.

First, the SUTVA argues that the potential outcomes for municipality $i$ in the system (1) are only related to its own treatment status. Under my empirical setting that utilizes the municipal-level dataset, this assumption is less likely to be violated because there are certain distances among different treated municipalities, even in the agglomerated area such as Chikuhō coalfield. Moreover, to minimize the risk of SUTVA violation, I consider a certain threshold to define the treatment group. The results from the specifications show that the baseline definition of the treatment distance is plausible to model the potential spillover effects in the regression (Section 6.1).
Second, let \( \text{MineDeposit}_i(\text{Stratum}_i) \) be an indicators for whether \( i \) is treated given the random assignments of the geological strata, under the SUTVA. The nonzero average causal effect indicates that \( E[\text{MineDeposit}_i(1) - \text{MineDeposit}_i(0)] \neq 0 \). This assumption clearly holds because the likelihood of having the coal mines increases with the IV strata (Online Appendix B.2).

Third, the monotonicity assumption suggests that \( \forall i, \text{MineDeposit}_i(1) \geq \text{MineDeposit}_i(0) \).

In sum, combination of the nonzero average causal effect and monotonicity assumptions argue that strong monotonicity should be satisfied at least in one unit as \( \text{MineDeposit}_i(1) > \text{MineDeposit}_i(0) \) (Angrist et al. 1996). Although this assumption is an idea for the potential outcome and is untestable (Imbens and Angrist 1994), there is fundamentally no reason for mining companies to avoid the stratum that contain coal seams. Thus, the instrument should affect the selection decision monotonically.

### C.3 Alternative Variance Estimation

To assess the potential influences of the local-scale spatial correlations, I use the standard errors clustered at the county level based on the cluster-robust covariance matrix estimator (Arellano 1987). The finite-sample adjustment proposed by Hansen (2007) is implemented to the estimator. Table C.1, C.2, and C.3 show the results for the demographic outcomes, labor outcomes, and early-life health outcomes under the cluster-robust variance covariance matrix estimator, respectively. All the results are materially similar to those of my baseline results presented in the main text.

### C.4 Assessing a Hike in the 10-15km Bin in Figure 4c

This section assesses the potential mechanism behind the hike in the estimate for the 10–15 km bin in Figure 4c. First of all, to detect the region causing the hike, I split the entire sample into two subsamples: the municipalities belongs to Fukuoka prefecture, and the others. The former might be an influential prefecture in the entire sample because it includes a number of mines in the Chikuhō coalfield. Figure C.1a shows the estimated coefficients for each subsample, which suggests that the hike is originated from the variations in Fukuoka prefecture.

Figure C.2a illustrates the distribution of the bins in Fukuoka. Figure C.2b clips the 10-15 km bin in the map. From a comparison of the distribution of the bins and the IMRs shown in Figure C.2c, it appears that some municipalities in the 10-15 km bin suffered relatively higher risk of infant deaths, which is consistent with the tendency in Figure C.1a.

Notice that given a point of an origin (i.e., a mine), a point on the concentric circle is a function of the distance. Therefore, to assess whether the hike in the 10-15 km bin is random event or not, it is sufficient to check whether the location of mine is still endogenous and leading the omitted variable bias, even after conditioning on the accessibility to railway stations, sea ports, and rivers.

A potential factor that is not considered in the baseline specification is the spatial distribution of the altitude. Terrain relates to the distribution of the locational fundamentals such as the climatic conditions (e.g., temperature and precipitation) and fixed
Table C.1: Additional Results using the CRVE: Local Population Growth

Panel A: 1930 Census

|                | (1)          | (2)          | (3)          | (4)          | (5)          | (6)          |
|----------------|--------------|--------------|--------------|--------------|--------------|--------------|
| MineDeposit    | 0.678***     | 0.402***     | 0.447***     | 1.386***     | 0.820***     | 0.812***     |
|                | (0.098)      | (0.079)      | (0.083)      | (0.318)      | (0.225)      | (0.234)      |
| City and Town FEs | No          | Yes          | Yes          | No           | Yes          | Yes          |
| Railway accessibility | No        | No           | Yes          | No           | No           | Yes          |
| Port accessibility   | No          | No           | Yes          | No           | No           | Yes          |
| River accessibility   | No          | No           | Yes          | No           | No           | Yes          |
| Observations        | 1,140       | 1,140        | 1,140        | 1,140        | 1,140        | 1,140        |
| Estimator           | OLS         | OLS          | OLS          | IV (Wald)    | IV           | IV           |
| First-stage F-statistic | –          | –            | –            | 14.29        | 13.18        | 11.35        |

Notes: Panels A and B show the results for the 1930 and 1935 samples, respectively. Panels A-1 and B-1 show the main result for log-transformed population, whereas Panels A-2 and B-2 show the result for mechanism analysis. “Marriage,” “Fertility,” “Size,” and “Sex Ratio” indicate the crude marriage rate, crude birth rate, household size, and adult sex ratio, respectively (Panel B of Table 1).

Panel B: 1935 Census

|                | (1)          | (2)          | (3)          | (4)          | (5)          | (6)          |
|----------------|--------------|--------------|--------------|--------------|--------------|--------------|
| MineDeposit    | 0.662***     | 0.463***     | 0.457***     | 1.401***     | 0.870***     | 0.895***     |
|                | (0.102)      | (0.088)      | (0.089)      | (0.294)      | (0.201)      | (0.193)      |
| City and Town FEs | No          | Yes          | Yes          | No           | Yes          | Yes          |
| Railway accessibility | No       | No           | Yes          | No           | No           | Yes          |
| Port accessibility   | No          | No           | Yes          | No           | No           | Yes          |
| River accessibility   | No          | No           | Yes          | No           | No           | Yes          |
| Observations        | 1,364       | 1,364        | 1,364        | 1,364        | 1,364        | 1,364        |
| Estimator           | OLS         | OLS          | OLS          | IV (Wald)    | IV           | IV           |
| First-stage F-statistic | –          | –            | –            | 14.63        | 13.72        | 12.54        |
Table C.2: Additional Results using the CRVE: Local Labor Supplies

### Panel A: Male Workers

#### Dependent Variable: Labor Force Participation Rate (%)

| MineDeposit | (1) | (2) | (3) | (4) | (5) | (6) |
|-------------|-----|-----|-----|-----|-----|-----|
| City and Town FEIs | −0.277 | −0.320 | −0.117 | −0.960 | −1.192 | −0.261 |
| Railway accessibility | No | Yes | Yes | No | Yes | Yes |
| Port accessibility | No | No | Yes | No | No | Yes |
| River accessibility | No | No | Yes | No | No | Yes |
| Observations | 1,140 | 1,140 | 1,140 | 1,140 | 1,140 | 1,140 |
| Estimator | OLS | OLS | OLS | IV (Wald) | IV | IV |

| First-stage F-statistic | – | – | – | 14.29 | 13.18 | 11.35 |

#### Dependent Variable: Employment Share (%)

| MineDeposit | (1) | (2) | (3) | (4) | (5) | (6) |
|-------------|-----|-----|-----|-----|-----|-----|
| City and Town FEIs | Yes | Yes | Yes | Yes | Yes | Yes |
| Railway accessibility | Yes | Yes | Yes | Yes | Yes | Yes |
| Port accessibility | Yes | Yes | Yes | Yes | Yes | Yes |
| River accessibility | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 1,140 | 1,140 | 1,140 | 1,140 | 1,140 | 1,140 |
| Estimator | IV | IV | IV | IV | IV | IV |

### Panel B: Female Workers

#### Dependent Variable: Labor Force Participation Rate (%)

| MineDeposit | (1) | (2) | (3) | (4) | (5) | (6) |
|-------------|-----|-----|-----|-----|-----|-----|
| City and Town FEIs | −7.865*** | −5.655*** | −4.958*** | −25.099*** | −20.682*** | −17.683*** |
| Railway accessibility | No | Yes | Yes | No | Yes | Yes |
| Port accessibility | No | No | Yes | No | No | Yes |
| River accessibility | No | No | Yes | No | No | Yes |
| Observations | 1,140 | 1,140 | 1,140 | 1,140 | 1,140 | 1,140 |
| Estimator | OLS | OLS | OLS | IV (Wald) | IV | IV |

| First-stage F-statistic | – | – | – | 14.29 | 13.18 | 11.35 |

#### Dependent Variable: Employment Share (%)

| MineDeposit | (1) | (2) | (3) | (4) | (5) | (6) |
|-------------|-----|-----|-----|-----|-----|-----|
| City and Town FEIs | 24.776*** | −25.089*** | −8.942*** | 2.816 | 4.393*** |
| Railway accessibility | Yes | Yes | Yes | Yes | Yes | Yes |
| Port accessibility | Yes | Yes | Yes | Yes | Yes | Yes |
| River accessibility | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 1,140 | 1,140 | 1,140 | 1,140 | 1,140 | 1,140 |
| Estimator | IV | IV | IV | IV | IV | IV |

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors based on the cluster-robust covariance matrix estimator are reported in parentheses. Standard errors are clustered at the 107 counties.

Notes: Panels A and B show the results for male and female worker samples, respectively, from the 1930 Population Census. Panels A-1 and B-1 show the main result for the labor force participation rate, whereas Panels A-2 and B-2 show the result for employment share in each industrial sector (Panel C of Table 1).
### Table C.3: Additional Results using the CRVE: Early-life Health

**Panel A: 1933 Vital Statistics**

|                | (1)  | (2)  | (3)  | (4)  | (5)  | (6)  |
|----------------|------|------|------|------|------|------|
| Dependents     |      |      |      |      |      |      |
| Infant Mortality Rate |      |      |      |      |      |      |
| **MineDeposit** | 26.066*** | 25.857*** | 22.577*** | 29.121*** | 60.942** | 66.912** | (5.223) | (5.313) | (5.133) | (20.437) | (22.819) | (23.656) |
| City and Town FEs | No | Yes | Yes | No | Yes | Yes |
| Railway accessibility | No | No | Yes | No | No | Yes |
| Port accessibility | No | No | Yes | No | No | Yes |
| River accessibility | No | No | Yes | No | No | Yes |
| Observations | 1,140 | 1,140 | 1,140 | 1,140 | 1,140 | 1,140 |
| Estimator | OLS | OLS | OLS | IV (Wald) | IV | IV |
| First-stage F-statistic | – | – | – | 14.29 | 13.18 | 11.35 |

|                | (1) | (2) | (3) | (4) | (5) |
|----------------|-----|-----|-----|-----|-----|
| Mechanism      |      |      |      |      |      |
| **MineDeposit** | 22.920** | – | – | 0.009 | (4.848) |
| Female Miner | 0.034** | 0.098*** | 0.004 | (9.014) | (0.029) |
| Male Miner | –0.002 | –0.007* | –0.001 | (0.002) | (0.001) |
| City and Town FEs | Yes | Yes | Yes | Yes | Yes |
| Railway accessibility | Yes | Yes | Yes | Yes | Yes |
| Port accessibility | Yes | Yes | Yes | Yes | Yes |
| River accessibility | Yes | Yes | Yes | Yes | Yes |
| Observations | 1,140 | 93 | 93 | 1,140 | 93 |
| Estimator | IV | OLS | OLS | IV | OLS |
| First-stage F-statistic | – | – | – | 14.63 | 13.72 | 12.54 |

**Panel B: 1938 Vital Statistics**

|                | (1)  | (2)  | (3)  | (4)  | (5)  |
|----------------|------|------|------|------|------|
| Infant Mortality Rate |      |      |      |      |      |
| **MineDeposit** | 20.257*** | 19.203*** | 16.458*** | 29.839* | 27.997 | 17.411 | (4.423) | (4.492) | (3.841) | (17.099) | (18.305) | (16.218) |
| City and Town FEs | No | Yes | Yes | No | Yes | Yes |
| Railway accessibility | No | No | Yes | No | No | Yes |
| Port accessibility | No | No | Yes | No | No | Yes |
| River accessibility | No | No | Yes | No | No | Yes |
| Observations | 1,364 | 1,364 | 1,364 | 1,364 | 1,364 |
| Estimator | OLS | OLS | OLS | IV (Wald) | IV | IV |
| First-stage F-statistic | – | – | – | 14.63 | 13.72 | 12.54 |

|                | (1) | (2) | (3) | (4) | (5) |
|----------------|-----|-----|-----|-----|-----|
| Mechanism      |      |      |      |      |      |
| **MineDeposit** | 6.890 | 1.415 | (11.384) | (3.306) |
| Female Miner | 0.025*** | 0.066** | 0.005 | (0.009) | (0.030) |
| Male Miner | 0.001 | 0.000 | 0.000 | (0.001) | (0.002) |
| City and Town FEs | Yes | Yes | Yes | Yes | Yes |
| Railway accessibility | Yes | Yes | Yes | Yes | Yes |
| Port accessibility | Yes | Yes | Yes | Yes | Yes |
| River accessibility | Yes | Yes | Yes | Yes | Yes |
| Observations | 1,364 | 116 | 116 | 1,364 | 116 |
| Estimator | IV | OLS | OLS | IV | OLS |

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors based on the cluster-robust covariance matrix estimator are reported in parentheses. Standard errors are clustered at the 107 (124) counties in 1933 (1938) sample. In the trimmed sample in Panels A-2 and B-2, the number of clusters are 31 and 36, respectively.

Notes: Panels A and B show the results for the 1933 and 1938 Vital Statistics samples, respectively. Panels A-1 and B-1 show the main results for the infant mortality rate (IMR). Panels A-2 and B-2 show the results for the fetal death rate (FDR), IMR in the coal mining municipalities, and the child mortality rate (CMR) (Panel D of Table 1).
cost of transportation. The climatic conditions are likely to affect agricultural productivity, suggesting the possibility that the altitude could be correlated with the opportunity cost of mining. Similarly, highlands are more expensive to transport, which may influence firm’s decisions on narrowly defined coal extraction areas.

To test this pathway, I created a new variable of the average altitude in each municipality using a set of grid cell datasets on the altitude (Online Appendix B.7). Figure C.2d shows the average altitude in each municipality in Fukuoka. Although this does not immediately provide a clear answer to the relationship between the location of mines and altitude, there seems to be no specific correlation between both events. To delve into this relationship, I added the altitude as an additional control variable into the regressions in Figure C.1a. The result is shown in Figure C.1b, which is a near identical picture to Figure C.1a. Thus, the altitude is near independent to the location of mines.

To summarize, the hike observed in the 10-15 km bin shall be randomly occurred, but not be led by any systematic factors that relate to the distribution of mines. Given my empirical setting, this rather makes sense because using many bins reduces the available observations in each bin, which makes the moment estimator vulnerable to this kind of random shocks.

Another evidence supporting this randomness is the fact that such a hike in the 10-15km bin is not observed in the results for the 1933 sample (see Figure 4c). If there were systematic factors, it is likely that both 1933 and 1938 samples suffer the greater risks of infant deaths in this bin. Similarly, the fact that only a 10-15 bin in Fukuoka prefecture suffers such a hike also supports this argument. Overall, the hike is practically negligible in the sense that it does not generated by any systematic endogenous mechanism in the regression.

C.5 Robustness to the Regional Heterogeneity of Labor Patterns

Table C.4 shows the results from the IV regressions including an indicator variable for the municipalities in the Hokkaido prefecture (Section 6.3). Panels A, B, and C show the results for the population growth, labor supplies, and early-life health outcomes, respectively. The estimates listed in Panels A, B, and C are materially similar to those of my main results summarized in Tables 2, 3, and 4, respectively.

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53 This supports the evidence that the spatial distribution of the mines are dominated by the geologic stratum (Section 4).
54 Note that the models considered herein still allows the existence of unobservables that relate only to the IMR such as the social norms for the child rearing because these socioeconomic factors unrelate to the distribution of mines. Although there was a large typhoon hit Miyazaki and Kagoshima prefectures in 1938 that might had increased the mortality rates, both prefectures are not included in my dataset.
55 As shown in Figure C.3, the infant mortality rates in Japan had moderate fluctuations during the 1930s, and the IMR in 1938 had slightly higher values than the surrounding years. This may further makes the cross-sectional variation in the mortality rates greater.
Table C.4: Additional Results: IV Regressions including a Hokkaido Dummy

| Panel A-1: Population Growth (1930) | (1) ln(Population) | (2) Marriage | (3) Fertility | (4) Size | (5) Sex Ratio |
|-------------------------------------|--------------------|--------------|--------------|---------|--------------|
| **MineDeposit**                     | 0.922***           | -2.737***    | -5.664***    | -0.346*** | 0.125***     |
| Control variables                   | Yes                | Yes          | Yes          | Yes     | Yes          |
| Observations                        | 1,140              | 1,140        | 1,140        | 1,140   | 1,140        |

| Panel A-2: Population Growth (1935) | **MineDeposit** | -0.978*** | -1.512** | -0.426 | -0.207* | 0.059** |
| Control variables                   | Yes                | Yes          | Yes          | Yes     | Yes          |
| Observations                        | 1,429              | 1,429        | 1,429        | 1,429   | 1,429        |

| Panel B-1: Male Labor Supplies (1930) | (1) LFP | (2) Mining | (3) Agricultural | (4) Manufacturing | (5) Commerce | (6) Domestic |
|---------------------------------------|--------|-----------|-----------------|-------------------|--------------|--------------|
| **MineDeposit**                       | -0.694 | 34.452*** | -34.140***      | 1.752             | -1.914       | -0.439***    |
| Control variables                     | Yes    | Yes       | Yes             | Yes               | Yes          | Yes          |
| Observations                          | 1,140  | 1,140     | 1,140           | 1,140             | 1,140        | 1,140        |

| Panel B-2: Female Labor Supplies (1930) | **MineDeposit** | 40.946** | 21.558** | 0.029** | 0.093*** | 0.006 |
|----------------------------------------|-----------------|---------|---------|---------|---------|-------|
| Control variables                      | Yes             | Yes     | Yes     | Yes     | Yes     | Yes   |
| Observations                           | 1,140           | 1,140   | 1,140   | 93      | 1,140   | 93    |

| Panel C-1: Early-life Health (1933)   | (1) IMR | (2) FDR | (3) FDR | (4) IMR | (5) CMR | (6) CMR |
|---------------------------------------|--------|--------|--------|--------|--------|--------|
| **MineDeposit**                       | 0.025  | 0.065**| 0.001  | 0.001  | 0.001  | 0.001  |
| Control variables                     | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    |
| Observations                          | 93     | 1,140  | 1,140  | 93     | 1,140  | 93     |

| Panel C-2: Early-life Health (1938)   | (1) IMR | (2) FDR | (3) FDR | (4) IMR | (5) CMR | (6) CMR |
|---------------------------------------|--------|--------|--------|--------|--------|--------|
| **MineDeposit**                       | 18.038 | 6.341  | 1.746  | 1.746  | 1.746  | 1.746  |
| Control variables                     | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    |
| Observations                          | 1,364  | 1,364  | 1,364  | 1,364  | 1,364  | 1,364  |

Notes:
- *** *, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors based on the heteroskedasticity-robust covariance matrix estimator are reported in parentheses.
- Panel A shows the results for the local population growth measured in the 1930 and 1935 Population Censuses. Panels A-1 and A-2 show the results for the 1930 and 1956 samples, respectively. Column (1) shows the results for log-transformed population, whereas columns (2) and (3) show the results for mechanism analysis. “Marriage,” “Fertility,” “Size,” and “Sex Ratio” indicate the crude marriage rate, crude birth rate, household size, and adult sex ratio, respectively (Panel B of Table I).
- Panel B shows the results for the labor supplies measured in the 1930 Population Census. Panel B-1 and B-2 show the results for the male and female workers, respectively. Column (1) shows the main result for the labor force participation rate, whereas columns (2)–(5) show the results for the employment share in each industrial sector (Panel C of Table I).
- Panel C shows the results for the early-life health measured in the 1933 and 1938 Vital Statistics. Panel C-1 and C-2 show the results for the 1933 and 1938 samples, respectively. IMR, FDR, and CMR indicate the infant mortality rate, fetal death rate, and child mortality rate, respectively (Panel D of Table I). All the estimates listed are from the IV estimator. First-stage F-statistic values for each regression is similar to those reported in Tables I, II, and III. Control variables include the city and town fixed effects, railway accessibility, port accessibility, river accessibility, and Hokkaido dummy.
Figure C.1: Heterogeneity in the Impact of Mines by Distance from the Mines: The IMRs in 1938 in Fukuoka and Other Prefectures

Notes: This figure shows the results from the expanded regressions of Eq. 1 that includes the five indicator variables for each 5km bin from a mine to 25 km away from the origin. 0–5 km distance from mines indicates the municipalities within 5 km of a mine. 5–10 (10–15, 15–20, 20–25) km distance from mines indicates the municipalities within (5, 10] ((10, 15], (15, 20], (20, 25]) km of a mine. [20–30] km bin is used as a reference group. Figures 4a, 4b, and 4c show the results for the local population, labor force participation rate, and infant mortality rate (IMR), respectively. The dots and solid lines with caps show the estimates and their 95 percent confidence intervals, respectively. The confidence intervals are calculated using the standard errors based on the heteroskedasticity-robust covariance matrix estimator.

Source: Created by the author.

C.6 Mortality Selection before Birth: Theoretical Framework

To analyze the potential health effects of mining, I first illustrate a theoretical framework for mortality selection in utero, which has recently attracted attention in the field of economics (Valente 2015). The biological sorting mechanism in utero suggested by the Trivers-Willard hypothesis (TWH) (Trivers and Willard 1973) implies that there are two possible cases in which fetuses are exposed to health shocks: “scarring” and “selection”.

Let $x \sim \mathcal{N}(\mu, \sigma^2)$ be the initial health endowment of the fetus in utero, and assume that there is a survival threshold $x_s$ below which the fetus is culled before birth. First, the “scarring” mechanism shifts the mean of the distribution ($\mu$) toward the left as $\mu^* < \mu$, such that $x^* \sim \mathcal{N}(\mu^*, \sigma^2)$. As the survival threshold $x_s$ is fixed, this shift implies that the number of culled fetuses must increase as $F^*(x_s) > F(x_s)$, where $F^*(\cdot)$ and $F(\cdot)$ indicate the cumulative distribution functions (CDF) of the normal distributions with means $\mu^*$ and $\mu$, respectively. Similarly, the conditional expectation of the initial health endowment at birth satisfies the following condition:

$$E[x^* | x^* > x_s] < E[x|x > x_s].$$

This means that the health endowment of surviving infants is more likely to decline due to fetal health shocks.

Contrarily, the “selection” mechanism shifts the survival threshold ($x_s^*$) toward the right as $x^*_s > x_s$. As the mean of the distribution is fixed, this shift also increases the number of culled fetuses as $F(x_s^*) > F(x_s)$. Consequently, the conditional expectation of

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56 Veller et al. (2016) examines the TWH mechanism by solving an optimization problem of a simple model of sex allocation by the mother. Ogasawara (2022) provides an intuitive explanation on the TWH mechanism.

57 Let $x \sim \mathcal{N}(\mu, \sigma^2)$ be the initial health endowment of a fetus in utero and $x_s$ be a survival threshold.
Figure C.2: Spatial Distribution of Rivers

Notes: Figure C.2a shows the spatial distribution of all the treatment bins used in Figure C.1. Figure C.2b highlights the location of the 10-15 km bin in Figure C.2a. Figures C.2c and C.2d show the infant mortality rates in 1938 and average altitude in each municipality, respectively.

Source: Created by the author.
endowment at birth satisfies the following condition:

\[ E[x|x > x_s] < E[x|x > x^*_s]. \]  

This implies that the health endowment of surviving infants is more likely to be improved if the “selection” mechanism works.

The propositions can be summarized as follows. First, fetal health shocks may increase the risk of fetal death through both mechanisms. Second, the risk of infant mortality increases (decreases) in the “scarring” (“selection”) mechanism. Third, if both mechanisms work simultaneously, the risk of infant mortality remains unchanged. Both fetal death and IMRs were used to test whether mines had adverse health effects and which mechanism worked in the case of mineral mining exposure.

### C.7 Time-Series Plots of the IMR and FDR

Figure C.3 shows the national average IMR (solid line) and FDRs (dashed line). Both series show secular decreasing trends between 1925 and 1940.

![Figure C.3: The Infant Mortality and Fetal Death Rates between 1925 and 1940](image)

**Note:** This figure shows the national average infant mortality (IMR; solid line) and fetal death rates (FDR; dashed line) in Japan between 1925 and 1940. The IMR is defined as the number of infant deaths per 1,000 live births. The FDR is defined as the number of fetal deaths per 1,000 births.

**Sources:** Created by the author. Data on the number of infant and fetal deaths are from the Statistics Bureau of the Cabinet (1926–1942).

The conditional expectation of the truncated normal distribution can be derived as:

\[
E[x|x > x_s] = \int_{x_s}^{\infty} x \frac{f(x)}{1 - F(x_s)} dx
= \frac{-\sigma^2}{1 - F(x_s)} \int_{x_s}^{\infty} \frac{(x - \mu)}{\sigma^2} f(x) dx + \frac{\mu}{1 - F(x_s)} \int_{x_s}^{\infty} f(x) dx
= \mu + \sigma^2 \frac{f(x_s)}{1 - F(x_s)}.
\]

This implies that while the “scarring” mechanism \((\mu^* < \mu)\) shifts the conditional mean toward the left, the “selection” mechanism \((x^*_s > x_s)\) shifts the conditional mean toward the right.
Figure C.4: Trends in the Two Mining Areas in Iwate and Akita

Notes: This figure shows the time-series plots of the outcomes of the treatment and control groups in Iwate and Akita prefectures used in the regressions shown in Table 6. Figures C.4a, C.4b, C.4c, C.4d, and C.4e show the average number of people, average crude marriage rate, average crude birth rate, average household size, and sex ratio, respectively. The data on the IMR in 1925 are unavailable.

Source: Created by the author.

C.8 Trends in the Two Mining Areas in Iwate and Akita

Figure C.4 shows the time-series plots of the outcome variables used in the DID analysis for the Iwate and Akita subsample in Table 6. Although there are moderate fluctuations due to small sample size in each group, these outcomes do not show peculiar trends but show the materially similar trends in the pretreatment years (i.e., 1925 and 1930). Importantly, the outcomes of the treatment group in the post treatment period (i.e., 1935) show the clear kinks, whereas those for the control group show marginal changes in the post treatment period. Similar check for the IMR is unavailable because the data on the infant deaths in 1925 are not available.

C.9 Heterogeneity with Respect to the Scale of Mines

To assess the potential heterogeneity in the treatment effect with respect to the scale of mine, I first stratiﬁ the treatment group into two subgroups using the median of the number of miners as a threshold. The key treatment indicator variable in equation 1 is then replaced with the two indicator variables for the two subgroups. Table C.5 presents the results for the local population (columns (1) and (2)), labor force participation rates (columns (3) and (4)), and early-life health outcomes (columns (5) and (6)). Columns (1) and (2) suggest that the relatively large scale mines had greater impacts on the local population growth. Column (3) indicates that the impacts on the male labor force
Table C.5: Additional Results: Heterogeneity with Respect to the Scale of Mines

|                          | Dependent Variable |             |             |             |             |             |
|--------------------------|--------------------|-------------|-------------|-------------|-------------|-------------|
|                          | ln(Population)     | LFP Rate in 1930 | IMR         |
|                          | (1) 1930           | (2) 1935    | (3) Male   | (4) Female | (5) 1933    | (6) 1938    |
| MineDeposit (≤ median)   | 0.136**            | 0.176**     | 0.605      | -0.966     | 18.108***   | 7.550       |
|                          | (0.062)            | (0.071)     | (0.420)    | (1.017)    | (5.687)     | (4.875)     |
| MineDeposit (> median)   | 0.674***           | 0.616***    | -0.645     | -7.881***   | 25.848***   | 21.698***   |
|                          | (0.090)            | (0.074)     | (0.408)    | (1.136)    | (4.684)     | (3.512)     |
| City and Town FEs       | Yes                | Yes         | Yes        | Yes        | Yes         | Yes         |
| Railway accessibility    | Yes                | Yes         | Yes        | Yes        | Yes         | Yes         |
| Port accessibility      | Yes                | Yes         | Yes        | Yes        | Yes         | Yes         |
| River accessibility     | Yes                | Yes         | Yes        | Yes        | Yes         | Yes         |
| Observations            | 1,140              | 1,364       | 1,140      | 1,140      | 1,140       | 1,364       |
| Estimator               | OLS                | OLS         | OLS        | OLS        | OLS         | OLS         |

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors based on the heteroskedasticity-robust covariance matrix estimator are reported in parentheses.

Notes: MineDeposit (≤ median) indicates an indicator variable for the municipalities within 5km from a mine, which had the number of miners less than or equals to median. MineDeposit (> median) indicates an indicator variable for the municipalities within 5km from a mine, which had the number of miners more than median. Columns (1) and (2) show the results for the log-transformed population measured in the 1930 and 1935 population censuses, respectively. Columns (3) and (4) show the results for the labor force participation rates of male and female workers, respectively. Columns (5) and (6) show the results for the infant mortality rates measured using the 1933 and 1938 vital statistics, respectively.

participation did not relate to the scale of mines, whereas column (4) suggests that the declines in the female labor force participation were mainly observed in the municipalities with relatively larger scale mines. Column (5) shows that the coal mines increased the risk of infant mortality regardless of the scale of mines in 1933, whereas column (6) indicates that the effects of relatively small scale mines disappeared in 1938 and those of relatively large scale mines also declined from 1933. This result is rather consistent with my baseline finding, which supports the effectiveness of the Revised Miner’s Labor Assistance Regulations of 1933.
References used in the Appendices

Takeshi Abe. Long-term recession in the interwar period and overcoming it. In Matao Miyamoto, editor, Japanese Economic History [in Japanese], pages 98–111. Hosōdaigaku kyōiku shinkōkai, Tokyo, 2008.

Manuel Arellano. Computing standard errors for robust within-groups estimators. *Oxford Bulletin of Economics and Statistics*, 49(4):431–434, November 1987.

Joshua D. Angrist, Guido W. Imbens, and Donald B. Rubin. Identification of Causal Effects using Instrumental Variables. *Journal of the American Statistical Association*, 91(434):444–455, June 1996.

Association for Harmonious Cooperation. Zenkoku köyōkōzan meibo (The lists of factories and mines, 1932 edition). [in Japanese]. Association for Harmonious Cooperation, Tokyo, 1932.

Association for Harmonious Cooperation. Zenkoku köyōkōzan meibo (The lists of factories and mines, 1937 edition). [in Japanese]. Association for Harmonious Cooperation, Tokyo, 1937.

Tuvia Blumenthal. Japanese economy in interwar period: International comparisons. In Takafusa Nakamura, editor, An Analysis of Japanese Economy in Interwar Period [in Japanese], pages 31–51. Tokyo, Tokyo, 1981.

Saburo Fumoto. Mitsubishi iizuka shi (History of Mitsubishi Iizuka Coal Mine). [in Japanese]. Mitsubishi Mining Company, Tokyo, 1961.

Christian B Hansen. Asymptotic properties of a robust variance matrix estimator for panel data when is large. *Journal of Econometrics*, 141(2): 597–620, December 2007.

Susan D Horn, Roger A Horn, and David B Duncan. Estimating Heteroscedastic Variances in Linear Models. *Journal of the American Statistical Association*, 70(350): 380–385, June 1975.

Guido W. Imbens, and Joshua D. Angrist. Identification and Estimation of Local Average Treatment Effects. *Econometrica*, 62(2):467–475, March 1994.

Japan Mining Association. Nihon kōzan kyōkai siryō, dai isshū (Japan Mining Association Materials, volume 1). [in Japanese]. Japan Mining Association, Tokyo, 1928.

Matao Miyamoto. Modern economic growth. In Matao Miyamoto, editor, Japanese Economic History [in Japanese], pages 53–111. Hosōdaigaku kyōiku shinkōkai, Tokyo, 2008.

Mikio Sumiya. Nihon sekitan sangyō bunseki (Study of Japanese Coal Industry). [in Japanese]. Iwanami Shoten, Tokyo, 1968.

Municipal Autonomy Research Association. Zenkoku shichōsonmei hensen sōran (General Survey of Changes in the Names of Municipalities). [in Japanese]. Nihon Kajo Publishing Co., Tokyo, 2006.
Takumi Nagao. Kyūshū ko daisanki sō no sōjyo (Paleogene stratigraphy of Kyūshū). [in Japanese]. Nagasaki Earth Science Association, Nagasaki, 1975.

Yutaka Nishinarita. Jyoshirō no shorniike to sono hen'yō. In Masanori Nakamura, editor, Technological Innovation and Women’s Labor [in Japanese], pages 71–106. Tokyo Daigaku Shuppan Kai, Tokyo, 1985.

Kota Ogasawara. Pandemic influenza and the gender imbalance: Mortality selection before births. Social Science & Medicine, vol. 311, 115299.

Statistics Bureau of the Cabinet. Jinkōdōtaitōkei (The vital statistics of Japan, 1926–1940 editions). [in Japanese]. Statistics Bureau of the Cabinet, Tokyo, 1926–1942.

Statistics Bureau of the Cabinet. Rōdō tōkei jitchi chōsa hōkoku, Taishō jyūsan nen, Kōzan no bu (Labor statistics field survey report, 1924 edition, Mine section). [in Japanese]. Statistics Bureau of the Cabinet, Tokyo, 1926.

Statistics Bureau of the Cabinet. Rōdō tōkei jitchi chōsa hōkoku, Shōwa ni nen dai ikkan, Kijyutsu no bu (Labor statistics field survey report, 1927 edition, volume 1, description). [in Japanese]. Statistics Bureau of the Cabinet, Tokyo, 1932a.

Statistics Bureau of the Cabinet. Rōdō tōkei jitchi chōsa hōkoku, Shōwa ni nen dai yon kan, Kōzan no bu (Labor statistics field survey report, 1927 edition, volume 4, Mine section). [in Japanese]. Statistics Bureau of the Cabinet, Tokyo, 1930.

Statistics Bureau of the Cabinet. Rōdō tōkei jitchi chōsa hōkoku, Shōwa go nen dai ni kan, Kōzan no bu (Labor statistics field survey report, 1930 edition, volume 2, Mine section). [in Japanese]. Statistics Bureau of the Cabinet, Tokyo, 1932b.

Statistics Bureau of the Cabinet. Rōdō tōkei jitchi chōsa hōkoku, Shōwa hachi nen dai ni kan, Kōzan no bu (Labor statistics field survey report, 1933 edition, volume 2, Mine section). [in Japanese]. Statistics Bureau of the Cabinet, Tokyo, 1936.

Statistics Bureau of the Cabinet. Rōdō tōkei jitchi chōsa hōkoku, Shōwa jyūichi nen dai ni kan, dai ichi bu (Labor statistics field survey report, 1936 edition, First section). [in Japanese]. Statistics Bureau of the Cabinet, Tokyo, 1937.

Robert L Trivers and Dan E Willard. Natural Selection of Parental Ability to Vary the Sex Ratio of Offspring. Science, 179(4068): 90–92, January 1973.

Naoki Tanaka and Yoshihiro Ogino. Miners protection issue and rationalization of coal extraction mechanism [in Japanese]. Enerugī-shi kenkyū, 8: 74–82, June 1977.

Christine Valente. Civil conflict, gender-specific fetal loss, and selection: A new test of the Trivers–Willard hypothesis. Journal of Health Economics, 39: 31–50, January 2015.

Carl Veller, David Haig, and Martin A Nowak. The Trivers–Willard hypothesis: sex ratio or investment? Proceedings of the Royal Society B: Biological Sciences, 283(1830): 20160126–9, May 2016.