Urbanization, industrialization, and mortality in modern Japan: a spatio-temporal perspective

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Urbanization, industrialization, and mortality in modern Japan: a spatio-temporal perspective

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The mortality rate in Japan increased from the late nineteenth century until World War I. However, immediately after the influenza pandemic (1918–1920), the Spanish flu, the mortality rate began to decrease. While it is generally recognized that one of the major factors for this phenomenon was the decreasing mortality rate in metropolitan areas such as Tokyo and Osaka, there are a few studies regarding the regional variation of mortality rate in this period. Actually, trends of mortality rate fluctuated with prefecture and cause of death and were obviously different from the trends in metropolitan areas in particular causes of death. Respiratory tuberculosis is a typical example of such a cause of death. Youth accounted for the large part of victims of tuberculosis in the between-war period. The high mortality of youth female factory workers was recognized as an especially serious social problem. Thus, the issue of tuberculosis should be discussed from the viewpoint of not only an individual’s health but also its implications on national efficiency, economic management, and rural life. In this study, we focus on the regional variation of tuberculosis mortality and analyze it by a quantitative approach adopting socioeconomic variables. As a result, we present a risk model of regional variation of tuberculosis mortality. The model suggests that the regional variation can be explained as an effect of urbanization and industrialization. Therefore, it could be concluded that tuberculosis mortality was a proxy variable for human cost of economic growth in modern Japan.

Keywords: mortality; tuberculosis; urbanization; industrialization; modern Japan

1. Introduction

From the beginning of the twentieth century till the end of World War I, the mortality rate in Japan continued to increase. After the influenza pandemic (1918–1920), the Spanish flu, the mortality rate started decreasing immediately. By 1937, the mortality rate was 17 per 10,000 people, which was almost 60% of the rate in 1918. It is widely recognized that one of the major factors for this phenomenon was the decreasing mortality rate in metropolitan areas, such as Tokyo and Osaka. Diarrhea and enteritis, the dominant causes of death in that period, fell remarkably in both the metropolitan areas. However, the trend of mortality rate was not uniform throughout Japan. Outside the metropolitan areas, the descending trend was not decisive and it varied from prefecture to prefecture.

Tuberculosis mortality is a typical example of the issue mentioned above. Many researchers have noted that it is influenced not only by the status of public health or medical service but also by the socioeconomic status of residents, especially factory workers. The death rates from tuberculosis are perhaps the clearest measure of the human costs of an industrial transformation based on the utilization of labor at minimum direct costs in current wages (Taeuber 1958). Therefore, tuberculosis was called a ‘social disease’ in modern Japan. As Hunter suggested, the continual high rates of tuberculosis mortality despite rising national income distinguished Japan from other industrialized countries in the between-war period. The industrialization process in Japan clearly produced substantial changes in the living and disease environment (Hunter 1995). The issue of tuberculosis should, thus, be discussed from the viewpoint of not only individual health but its implications on national efficiency, economic management, and rural life. Although the relationship between tuberculosis and socioeconomic factors has been suggested many times, there have been few quantitative studies intended to examine it. Therefore, exploring that relationship will show us a new viewpoint regarding the modern society of Japan.

In this study, we examine the interaction of mortality rates and socioeconomic factors in modern Japan using cause-specified death statistics and prefectural statistics reports. Especially, we focus on the regional variation of respiratory tuberculosis mortality, because it can be assumed that it reflects the socioeconomic phenomena such as urbanization and industrialization.

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2. Related studies

The most useful, well-organized nationwide survey of tuberculosis infection among youth female factory workers (Joko) was conducted from 1906 to 1910 by the Ministry of Agriculture and Commerce. The survey material, *Kojo Eisei Chosa Shiryo* (The Material of Factory Sanitation Survey) (Seisan Chosa-kai 1910), is one of the reliable data sources for approaching the status of tuberculosis infection in modern Japan. Ishihara, the director of the survey, authored a commentary paper titled *Eiseigaku-jo yori mitaru Joko no Genkyo* (Hygienic review of health status of Joko) (Ishihara 1914). In this work, Ishihara indicated that serious health problems regarding tuberculosis among Joko had been due to not only an infection in factories or dormitories but an infected returnee.

The scenario is as follows: young girls in rural areas were employed by factories located in industrial cities as Joko. The average length of a Joko’s service was approximately 2 years in those days. Say, the Joko had been infected in the workplace with tuberculosis and returned home without the awareness of their infection, because they had quit their job before tuberculosis presented the symptoms. When they went back to their hometowns that were vulnerable areas against tuberculosis, they developed the disease at their home and infected their families also in some cases.

We shall call Ishihara’s scenario the infected returnee case (Taikan Kikyo). It was accepted as a rational scenario to explain an epidemiological process of tuberculosis in modern Japan. However, there were few studies that indicated quantitative evidence about a relationship between labor factors and the tuberculosis mortality rate. Since the tuberculosis mortality rate has decreased, little attention has been given to Ishihara’s work.

Taeuber (1958) mentioned the regional variation of tuberculosis mortality in her master piece, *The Population of Japan*. She suggested that labor migration has been the major answer for the regional variation, as follows:

The great concentrations of tuberculosis deaths were not in the industrial prefectures themselves, but in those prefectures whose youth had been drained off as migrants into the industrial areas. (Taeuber 1958, p. 305)

In the field of disease geography, Momiyama (1971) investigated the spatial variation of post-World War II cause of death at the prefectural level and mentioned that there were remarkable regional variations in the composition of causes. While she suggested that the major source of the epidemic of tuberculosis in the between-war era was terrible labor conditions in the industrial cities and the infection was diffused by labor migration, she did not present any quantitative evidence.

Recently, Hunter (1993, 2009) considered the relationship between female factory workers and tuberculosis in the viewpoint of socioeconomic history. Her major query was how the Japanese nation had been forced to pay for the industrialization. She suggested that the existence of regional concentrations of tuberculosis mortality had been explained by not only regional industrialization and population concentration, but the rate of labor migration occurring in a region. She concluded that youth female workers, especially textile factory workers, had been victimized by the economic efficiency in the rapid industrialization process.

3. Dataset of causes of death

The cause-specific death statistics that was released in the annual report called *Eisei-kyoku Nempo* by The Sanitary Bureau of the Home Department was used to calculate the mortality rates. *Eisei-kyoku Nempo* was revised according to the first International Classification of Diseases, which was adopted by the International Statistical Institute in 1900. Since 1902, the cause-specific death statistics in Japan was compliant with the International Classification of Diseases. The whole period of the published statistics was divided into seven terms as a result of revision of the cause-of-death classification. Thus, to use each cause of death as one time series data, conjunctions between each term are required. We have constructed the Cause-Specified-Death Statistics database which applied the time series adjustment. Fortunately, tuberculosis has been classified almost consistently in the statistics from the beginning to the end. Therefore, we can be fairly certain that there is no discontinuity in the time series.

4. Temporal overview of tuberculosis mortality in modern Japan

In the between-war period, the mortality rate in Japan reached its peak in 1918–1920 caused by the world influenza pandemic. Figure 1 shows the mortality rate in Japan from 1903 to 1937. The dark solid line indicates the tuberculosis mortality and the thin gray line indicates the mortality rate of all causes. It is clear that the time series trends of both mortality rates are almost the same from 1903 to 1918. After the highest peak in 1918, the all-causes mortality rate had another peak which was caused by the second impact of the pandemic in 1920.

On the other hand, the tuberculosis mortality fell rapidly without other peaks after the influenza pandemic. It marked 185/100,000 in 1918 and then decreased to 135/100,000 in 1924. However, after 1930, it began to increase again and grew steadily until the post-war era. In typical Western countries, tuberculosis mortality decreased after the influenza pandemic and did not increase again. Therefore, it can be said that this is a characteristic pattern of Japanese tuberculosis mortality.

Shimao (2008) analyzed the tuberculosis mortality trend between the two World Wars based on national
5. Spatial variation factors of tuberculosis mortality

5.1. Urbanization and tuberculosis

As mentioned already, it is widely accepted that tuberculosis was the most popular cause of death among young laborers, because industrial labor conditions in the between-war period were quite inadequate. However, we consider that more specific inspection is required to agree with this accepted notion, because there are few previous studies which indicate the concrete evidence. Needless to say, Japanese urbanization did not progress simultaneously in all prefectures and differed according to the conditions in each prefecture. Therefore, it is supposed that Ishihara’s scenario, the infected returnee case, reflects an interaction between industrial prefectures and rural prefectures. To verify the relationship between urbanization and tuberculosis mortality rate, we should examine the regional variation of both variables.

Figure 1. Temporal trend of mortality rate of all causes and tuberculosis in Japan, 1903–1937.

5.2. Industry and tuberculosis

Although the industrialization process in modern Japan was deeply involved with the urbanization, both processes were not simultaneous. Needless to say, industrial concentrations proceeded in urbanized areas; additionally there were several industrial centers in rural areas also. That the production output of the textile industry was greater than that of the heavy industry was a remarkable feature of
Japanese industry in the between-war era. Textile industry formed several industrial centers, such as in Osaka, Hyogo, Aichi, Nagano, and Gunma prefectures; however, some of them were not in metropolitan areas (see Figure 3).

Another characteristic of the industry in modern Japan was a high dependency on female labor; this tendency was especially obvious in the textile industry. In 1924, 82% of the female factory workers were employed by the textile...
industry. Therefore, female factory workers, Joko, immediately meant textile industry workers. For example, in Nagano prefecture, almost 90% of all factory workers were youth female workers. Therefore, it can be assumed that the distribution of Joko indicated spatial variation of textile industry in modern Japan.

Figure 4a is a map of the number of female factory workers per 10,000 people sorted by prefectures. The

Figure 5. Scatter diagram of tuberculosis mortality rate and female factory workers: (a) includes all prefectures, (b) excludes Nagano prefecture.
high-scored prefectures concentrated in the middle part of Honshu Island; among them, the score of Nagano prefecture was extremely high. In the field of industrial epidemiology in Japan, the health problem of Joko was one of the major issues; above all, tuberculosis was recognized as a serious health problem which affected the productivity of the textile factory. If the relationship between Joko and tuberculosis was so close, it can be assumed that the distribution of tuberculosis mortality rate was correlated with the spatial distribution of Joko. Figure 4b shows the tuberculosis mortality rate of youth (10–25 years) females per 100,000 people in 1924. High-mortality prefectures were located mainly in the middle and west parts of Japan; however, the pattern was not identical with the spatial distribution of Joko. Although Ishikawa prefecture indicated the highest tuberculosis mortality, the number of Joko was in the middle range. On the other hand, Nagano indicated the largest number of Joko, but the mortality rate was rather low.

To clarify the overall tendency of correlation between Joko and tuberculosis mortality, we applied a regression analysis. Figure 5a is a scatter diagram of the number of Joko and tuberculosis mortality rate of youth females. It is obvious that Nagano’s is a peculiar case. $R^2$ is 0.16; however, the diagram shows positive relationship between both variables. This tendency becomes clear if Nagano is excluded (see Figure 5b). In this case, the $R^2$ is modified to 0.27; though the correlation is not so obvious, it should not be ignored (see Table 1). Therefore, although several exceptional prefectures other than Nagano exist, it seems reasonable to suppose that a prefecture having the large number of Joko can be regarded as a high tuberculosis mortality prefecture.

Now that we have made the overall tendency clear, we should further examine meanings of existence of the exceptional prefectures. This is because it can be assumed that the exceptional prefectures which widely diverged from the regression line indicate any regional variation in the relationship of tuberculosis mortality and Joko. For the present, let us examine two exceptional prefectures, Nagano and Ishikawa.

### 5.3. Nagano, the center of silk-reeling industry

Nagano was the largest center of silk industry in modern Japan. The remarkable features of the silk industry in Nagano were as follows: (1) they were specialized in silk-reeling; (2) almost all factories were located in the center of the prefecture, especially the area of Suwa lakeside; (3) over 50% of the factories were under private management until the World Depression; and (4) 80–90% of Joko lived in dormitories. Silk-reeling in Nagano began to grow from the late 1800s by the introduction of yarn-making machines and reached a peak in 1930. The largest agglomeration area of silk factories was Hirano village (Okaya city, present) and its surrounding area; in 1927, almost 10% of the female factory workers of Japan were employed in this area. Therefore, the proportion of youth female population (10–25 years old) reached approximately 50% of the total population of Hirano village in 1925 (Osako 1987).

Tuberculosis mortality rate (all ages) in Nagano was almost 140–150 (per 100,000 people) from 1905 to 1917; after the influenza pandemic it decreased rapidly to 96 in 1921 (see Figure 6). After 1921, the mortality rate did not fluctuate so much and stayed around 100; it was rather low in comparison with Japan’s mortality rate.

It is difficult to clarify the reason for such low-level mortality in Nagano by quantitative evidence; however, we suppose that the rational factors are as follows:

1. Infection risk in the working environment of the silk-reeling factory was relatively low against other textile industries, especially cotton spinning. Following are the major reasons for this assumption:
   - Most of the factories closed during winter season, because the supply of cocoon is usually cut off after late autumn. While 75% of Joko in Nagano were local inhabitants, others came from Niigata and Yamanashi which were neighborhood prefectures. Therefore, they were able to return home with less effort than Joko who worked in other prefectures, such as

| Variable                        | Estimate | Standard error | t-value | Pr(>|t|)         | Significance |
|---------------------------------|----------|----------------|---------|-----------------|--------------|
| (Intercept)                     | 25.0333  | 1.8909         | 13.239  | <2e–16          | <0.001       |
| Female factory workers¹         | 0.0632   | 0.0156         | 4.0660  | 0.000195        | <0.001       |
| $R^2$                           | 0.2731, 44 degrees of freedom | 0.5226 |
| Correlation coefficient         | 0.5226   |                |         |                 |              |

Note: ¹Per 10,000 people.
Osaka and Aichi. This ‘winter closing’ was not holidays, but it is supposed to have some effect in reducing the infection risk.

- The working hour of Joko in silk-reeling factory was 12–14 hours a day; of course, it was a terribly long time, but it was slightly better than a double-shift working system in cotton-spinning factory. At least they were not forced to work through night; hence orderly working hours might have reduced any infection risk.

- The air in silk factory was generally too warm and too humid, but it was less dusty than the air in cotton factory. The dust of cotton fiber often damages respiratory organs. On the other hand, being biodegradable, silk fiber does not damage human organs. Although the air in silk factory was quite unacceptable, we are not able to reject a possibility that the infection risk was slightly lower than in cotton-spinning factory.

- The skills of silk-reeling required more training time to workers than cotton spinning. Therefore, the average service period of silk mill workers was longer than that of cotton mill workers. It means that the cycle time of labor migration was longer in silk industries than in cotton industries. The longer cycle time possibly reduced the frequency of exposure in the home towns of Joko.

(2) Due to the collapse of silk market price in 1921, many of the privately managed factories closed or were acquired by large capital companies. Consequently, the silk industry shifted to oligopolistic situation. Although the total number of Joko did not decrease, the competitive situation between the cotton industry and the silk industry in the labor market got more severe. Major large silk companies spent more effort to improve working conditions in order to keep employing fresh Joko. As a result, the working environments in silk-reeling factories including sanitary conditions of dormitories were improved to a more adequate level. The purpose of these activities was not the welfare of the employees, but as an advertisement for recruitment; however, it is likely that these activities had some effect in the reduction of the infection risk.

It seems reasonable to suppose, from what has been said above, that the low tuberculosis mortality in Nagano had been caused by the features of silk-reeling industry; above all, working environment and working pattern might be dominant factors. It should also be added that agglomerations of silk industries in Nagano were located in rather rural areas and not in urban areas. It is likely that the geographic characteristics contributed in reducing
the infection risk by isolating Joko from the infectious environment of urban areas.

5.4. *Ishikawa, the highest tuberculosis mortality prefecture*

Tuberculosis mortality rate in Ishikawa began to increase from 1905 and reached a peak in 1918. After 1918, the mortality rate rapidly fell to 165.4 in 1925; then it started increasing and continued to rise (see Figure 7). The rank of mortality rate of Ishikawa was fifth in 1917, but rose to third in 1924 and then reached first in 1930. Moreover, in the case of mortality rate of youth females, Ishikawa was almost always the top-ranked. The prefecture government and medical agencies suffered from this fact and struggled to resolve it. Although they executed some anti-tuberculosis projects, they could not get remarkable improvement.

Researchers of Kanazawa Medical College, led by Yoshio Koya, authored a detailed research report regarding tuberculosis in Ishikawa and Fukui in 1938. Subsequently, in 1941, another research paper was released by Muneo Arima (1941), a scientific officer of Ishikawa. It is remarkable that both researches suggested that tuberculosis mortality had been higher in rural areas than in city areas. They also suggested that youth accounted for a high proportion of deaths from tuberculosis in the rural areas. Arima considered the factors for this trend and concluded that the large proportion of youth dekasegi (migrant) workers had caused the high tuberculosis mortality in the rural areas of Ishikawa. His conclusion can be summarized as follows:

1. The proportion of dekasegi workers in the rural areas of Ishikawa was the highest of all prefectures. Most of the destinations of dekasegi workers were metropolitan areas such as Osaka, Kyoto, and Kobe. The ratio of dekasegi workers in those destinations to all dekasegi workers from Ishikawa was extremely high in comparison to other prefectures. It means that the distribution of dekasegi workers from Ishikawa was concentrated in metropolitan areas that were high-risk areas of tuberculosis infection. Thus, many of the returnees had been infected with the disease. Consequently, this situation caused a high infection rate of tuberculosis among returnees.

2. Destinations of dekasegi workers were not only outside of Ishikawa. Kanazawa, the prefecture capital, was the most urbanized city in Hokuriku district. Because of its high infection rate of tuberculosis, Kanazawa was one of the infection sources as well as other metropolitan areas. In Kanazawa, dekasegi workers were exposed to infectious environments during their service.

![Figure 7. Trend of tuberculosis mortality rate: Ishikawa, Toyama, and Fukui, 1903–1937.](image-url)
(3) Most of the dekasegi workers worked in factories that were sorted as high infection risk industries, such as cotton spinning. Therefore, the proportion of infected returnees was inevitably high. When an infected returnee developed tuberculosis at home, other family members were exposed to high risk of infection.

(4) From what has been said above, it should be concluded that the high tuberculosis mortality in the rural areas of Ishikawa was caused by labor immigration (dekasegi) to metropolitan areas and the high infection risk in dekasegi workers' destinations.

According to Arima’s view, Ishikawa seems a typical example of the infected returnee case. However, his research paper was published in 1941; thus it must be worth examining whether Arima’s view was fit for 1924. The number of total female migrant workers (dekasegi Joko), in 1924, from Ishikawa in Osaka, Hyogo, Kyoto, Aichi, and Tokyo was 55.5 per 10,000 (see Table 2). It was ranked 11th within all prefectures and most of the high-ranked prefectures were located in remote areas of the five industrial centers. Some of the high-ranked prefectures such as Kagoshima and Kochi indicated relatively low mortality rate. It is supposed that those prefectures were too far for sick Joko to return home. Additionally, Toyama’s mortality rate was low in comparison to Ishikawa, although the number of dekasegi Joko was extremely high. While the reason for Toyama’s low mortality rate has not been clarified yet, it is possible to assume that Toyama did not have an internal infection source like Kanazawa. Due to space constraints, we have concentrated on Ishikawa’s case; however, Toyama’s case should be discussed later.

From Ishikawa’s case discussed above, it seems reasonable to conclude that tuberculosis mortality rate of youth females was obviously influenced by the number of dekasegi Joko and the infection risk of their destination areas. One of the major factors of tuberculosis infection risk was the sort of factories; along with Nagano’s case, it is supposed that the risk in cotton-spinning factory was greater than the risk in silk-reeling factory. With these considerations, we may examine, as the next step, a more general relationship between urbanization and tuberculosis mortality.

6. Discussion: an experimental model for the tuberculosis mortality risk

Let us now discuss a model that explains the regional variation of tuberculosis mortality. According to the considerations in the previous section, we shall introduce a working hypothesis.

<table>
<thead>
<tr>
<th>No.</th>
<th>Prefecture</th>
<th>Migrant female worker (per 10,000)</th>
<th>Rank</th>
<th>No.</th>
<th>Prefecture</th>
<th>Migrant female worker (per 10,000)</th>
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*Source: Rodo Tokei Jicchi Chosa Hokoku (the Actual Condition Statistical Survey of Factories) in 1924.*
In Section 5.1, we discussed urbanization and tuberculosis mortality and examined a regression analysis adopting UPR as the explanatory variable. It was not possible to explain the regional variations of tuberculosis mortality by UPR alone; however, a positive correlation was recognized among the metropolitan areas. Because we considered that the influence of urbanization on tuberculosis mortality should not be neglected, we included the following statement in the working hypothesis:

- The urbanization process increased the risk of tuberculosis mainly in the metropolitan areas.

In Section 5.2, we inspected the correlation between the number of female factory workers and tuberculosis mortality. As a result, it seemed that a positive correlation was recognized between both variables; however, there were several exceptional prefectures such as Nagano and Ishikawa. Because the number of Joko per capita in Nagano was the highest in Japan at that time, a rational explanation regarding the singularity of Nagano’s tuberculosis mortality was required. Through the considerations regarding textile industries in Nagano (in Section 5.3), we assumed that the dominant situation of the silk-reeling industry had influenced tuberculosis mortality. Although the working environment in silk-reeling factories was obviously not adequate for Joko’s health, it is supposed that in comparison with cotton-spinning factories, there were some factors that suppressed the infection risk of tuberculosis. Therefore, we include the following statement:

- The regional variation of tuberculosis mortality rate of youth females depended on the distribution of female factory workers.
- The industrial categories which should be concerned are textile industries, with cotton-spinning being the important.
- Silk-reeling had less effect on mortality than cotton-spinning.

Based on the discussions above, we considered in Section 5.4 the fact that while Ishikawa was neither an urbanized prefecture nor the center of cotton industries, it had the highest tuberculosis mortality. By referring to previous studies, it is supposed that the major factor of Ishikawa’s high mortality was the ‘infected returnee case’ from the centers of cotton industries, which had been caused by dekasegi (labor migration). Therefore, we append this assumption to the working hypothesis as follows:

- The labor migration of Joko between the industrial area and the home town expanded tuberculosis infection among the non-industrial prefectures (the infected returnee case).

- Therefore, it can be assumed that the regional variation of tuberculosis mortality rate was formed by the composite effect of urbanization, industrialization, and labor migration.

Based on the above hypothesis, three items can be selected as explanatory variables of the regional variation of tuberculosis mortality rate (female, age 10–25 years, per 100,000; ‘TBYF’).

1. ‘UPR’: Urban population ratio in 1924; calculated from the census population in 1920 and 1925 adopting linear interpolation.
2. ‘JOKO’: The number of female factory workers (per 10,000) in textile industries excluding silk-reeling in 1924; calculated from Rodo Tokei Jicchi Chosa Hokoku (the Actual Condition Statistical Survey of Factories) in 1924.
3. ‘DEKASEGI’: The number of dekasegi Joko (per 10,000) in the five major industrial prefectures (Osaka, Kyoto, Hyogo, Tokyo, Aichi) in 1924.

UPR has already been explained. It represents an index of urbanization. The definition of JOKO is based on the hypothesis shown above. We considered that to clarify the influence of industrialization on tuberculosis mortality, silk-reeling industry should be excluded. The last one, DEKASEGI, should represent not only labor migrations of JOKO to the industrial areas but the effects of infected returnees. As we have mentioned in the consideration of Ishikawa’s case, the most important point of the infected returnee case is that migrant workers return from industrial areas with tuberculosis infection. In the between-war period, while railway networks had developed well in Japan, long-distance trip was still not easy for young girls. It was frequently observed that Joko who had quit the factory had stayed in the urban area offering various job opportunities rather than returning to home town (Ishihara 1914). At this point, it is supposed that the distances between their home towns and industrial areas contributed to the probability of infected returnees. The effect of distance can be described by applying the concept of distance-decay model (King and Golledge 1978). We assume that the decay factor is defined as a negative exponential function of the distance between home prefecture and industrial prefecture. Above all, the experimental model is described as follows:

\[
TBYF_p = a_1 UPR_p + a_2 JOKO_p + a_3 \sum_{i=1}^{5} \left( \frac{DEKASEGI_i}{\log (d_{im})} \right)
\]
Table 3. The results of multiple regression of the experimental model for tuberculosis mortality.

| Variable                      | Partial coefficient | Standard error | t-value | Pr(>|t|) | Significance |
|-------------------------------|---------------------|----------------|---------|---------|--------------|
| UPR (urban population ratio)  | 0.3547              | 0.1486         | 2.3870  | 0.02146 | <0.05        |
| JOKO (excluding silk-reeling) | 0.4514              | 0.1320         | 3.4200  | 0.00138 | <0.01        |
| DEKASEGI (distance decayed)   | 0.2798              | 0.1322         | 2.1170  | 0.04007 | <0.05        |

Adjusted multiple $R^2$: 0.4405, 43 degrees of freedom

$F$-statistic: 13.07 on 3 and 43 degrees of freedom

$P$-value: 0.00000334

Residual standard error: 0.748 on 43 degrees of freedom

Note: *All variables are standardized.

where $p = 1$ to 47, the index of subject prefecture and $d_{pi}$ is the distance between subject prefecture $p$ and destination prefecture $i$.

$\text{Destination prefecture}_i \in \overline{D} = \{\text{Osaka, Kyoto, Hyogo, Tokyo, Aichi}\}$

The results of multiple regression are shown in Table 3. Although the determination coefficient (adjusted multiple $R^2$) is not so high, the significance of partial coefficients $a_1$, $a_2$, and $a_3$ is acceptable. Figure 8 shows diagnostic plots; it can be assumed that almost no particular distribution is recognized regarding residuals. From the diagnostic information, the model should be judged as significant.

Figure 9 shows maps of estimated TBYF (a) and residuals (b). Prefectures which indicate positive residuals correspond to high mortality prefectures such as Gunma, Niigata, Ishikawa, Tokushima, Kagawa, Ehime, Shimane, and Hokkaido. Excluding Hokkaido, the other prefectures were sources of dekasegi Joko or centers of textile industries. Thus, it means that these prefectures were affected by some factors other than the variables implemented in the model. In the case of Hokkaido, it is possible that the factors of actual high tuberculosis mortality were different from other prefectures, because this area was still in the developing period. On the other hand, prefectures in Tohoku district (northeast Japan) such as Iwate, Miyagi, Akita, and Yamagata indicate negative residuals. Prefectures in Kanto district (surrounding area of Tokyo) also indicate the same results. The reason for negative residuals in these prefectures is not clear. It is possible to suppose that the infected returnee risk was reduced because the distance-decay effect in Tohoku district was stronger than in the other parts of Japan. Another possibility is that the estimation errors are amplified by leverage effect because tuberculosis mortalities in these prefectures are in the lowest rank.

As the examination above suggests, there is room for improvement in the performance of the model; nevertheless, it would be reasonable to assume that the estimated mortality approximately corresponds to the overall tendency of the regional variation of actual mortality, as shown by the comparison of Figures 4b and 9a. Thus, we may conclude that the experimental model is sufficiently significant to verify the working hypothesis. Let us call the working hypothesis ‘Tb-Joko hypothesis’, tentatively. According to the hypothesis, it is supposed that the model represents the theoretical composition of regional variation of tuberculosis mortality rate of youth females; more specifically,
it is composed of the urbanization factor (UPR), the industrialization factor (JOKO), and the infected returnee factor (DEKASEGI adjusted by the distance-decay effect). If we explain the estimated tuberculosis mortality as a risk of tuberculosis infection, we may assume each factor of the model as infection hazard. Thus, the conceptual model of Tb-Joko hypothesis is described as follows:

\[
T_b(p) = \alpha U(p) + \beta I(p) + \gamma R(p)
\]

where \(T_b\) is the tuberculosis infection risk in the given prefecture \(p\), \(U\) is the urbanization hazard in the given prefecture \(p\), \(I\) is the industrialization hazard in the given prefecture \(p\), \(R\) is the infected returnee hazard in the given prefecture \(p\), and \(\alpha\), \(\beta\), \(\gamma\) are the coefficients.

It is supposed that the above conceptual model suggests that tuberculosis mortality represents the negative effect of the modernization process of Japan. In this viewpoint, tuberculosis mortality can be assumed as the human cost that each region was forced to pay for the modernization. If this assumption is appropriate, the conceptual model can be expanded to apply to the whole industrialization process in modern Japan.

7. Conclusion
Tuberculosis mortality in Japan in the between-war era is distinguished from other Western countries by several factors. First, although in Western countries tuberculosis mortality never rose after decreasing in the 1920s, in Japan it continuously increased until the post-World War II years. Second, in Japan, it is difficult to explain the regional difference of tuberculosis mortality by a simple hypothesis such as ‘urban penalty.’ Finally, youth females dominated a large share of deaths from tuberculosis. Although it is understood intuitively that these features were involved with industrialization and urbanization, there have been few studies that indicated the specific model of relationship. We have examined how these three features could be explained in a socioeconomic process of industrialization and urbanization.

In the previous section, we have discussed the experimental model of tuberculosis mortality risk. By applying multiple regression analysis to the three variables, the experimental model was evaluated as acceptable. We have explained each factor of the model as urbanization hazard, industrialization hazard, and infected returnee hazard. The model reflects considerations regarding Nagano and
Ishikawa, which we have mentioned in the previous section. It can be assumed that urbanization hazard reflects exposure incidents to tuberculosis such as the high population density of living environment. On the other hand, it can be assumed that industrialization hazard implies influences of inadequate working conditions of textile industries, especially cotton-spinning factories. Infected returnee hazard implies more complicated socioeconomic factors. The labor migration that caused the infected returnee case can be explained as the socioeconomic interaction between the industrialized areas and the rural areas. The geographical factor is absolutely essential in the model, because the labor migration and the return home are restricted by geographical distance. Therefore, infected returnee hazard involves a spatial factor as well as a socioeconomic factor.

In Taeuber’s view, if tuberculosis mortality rate had been a measure of the human cost of industrialization, the estimated mortality rate can be interpreted as forced expenditure of human resource for keeping the national economic growth. In this sense, it can be assumed that tuberculosis mortality was a proxy variable of negative effect of economic growth in modern Japan. Our model is estimated as a snapshot in 1924, thus further temporal analysis is required. However, we consider that the conceptual framework can be applied throughout the between-war period. The nexus of industrialization, urbanization, and mortality is obviously a key to explain the regional variations of modern Japan. Moreover, further inspections regarding exceptional prefectures such as Ishikawa, Tokushima (high mortality), Nagano, and Yamanashi (low mortality) are required. These inspections will need more detailed historical materials such as at city level or town level. Currently, we have such historical materials regarding Ishikawa, and we intend to explore them regarding other prefectures. Lastly, we have some implications of the effect of industrialization on mortality, especially in the context of cottage industrialization of modern Japan. In rural modern Japan, the rural industrialization brought to peasant household not only additional monetary income but the total reduction of labor intensity for peasant women by replacement of agricultural work by home industrial activities. As Table 4 shows, in the case of Aomori prefecture, northeastern Japan, the introduction of cottage industry into household productive activities brought the reduction of women’s labor intensity and made their infant mortality lower; moreover, both variables, cottage industry and labor intensity, independently did the role of reducing infant mortality significantly. Theoretically, the transformation of women’s workload first reduced infertility, stillbirth, and infant mortality and then drastically raised their fertility similar to the process of raising marital fertility in the British population in the eighteenth century (Wrigley 2004). The effect of industrialization in modern Japan on mortality truly depended on the regional context and human behaviors.

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Notes
1. While we have tested several types of distance-decay functions, the results of estimation were not so different. Thus, we adopt the negative exponential functions as they are simple.
2. Although we examined Geographically Weighted Regression (GWR) using the same explanatory variables (DEKASEGI before the distance decay effect is applied), the result was almost the same. Therefore, we chose the current model that described our concept more clearly.

Table 4. Regression analysis of effects of cottage industrial production, agricultural productivity, and labor intensity on infant mortality rates in Aomori prefecture, 1913–1917.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model (1)</th>
<th></th>
<th>Model (2)</th>
<th></th>
<th>Model (3)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>(t-Value)</td>
<td>Coefficient</td>
<td>(t-Value)</td>
<td>Coefficient</td>
<td>(t-Value)</td>
</tr>
<tr>
<td>(Intercept)</td>
<td>169.73</td>
<td>(18.18)*</td>
<td>203.60</td>
<td>(21.31)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor intensity</td>
<td>3.65</td>
<td>(4.50)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cottage production</td>
<td></td>
<td></td>
<td>−0.40</td>
<td>(2.11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standardized labor intensity</td>
<td>−0.40</td>
<td>(2.11)</td>
<td>0.49</td>
<td>(3.75)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standardized cottage industry</td>
<td></td>
<td></td>
<td>−0.38</td>
<td>(2.86)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.38</td>
<td></td>
<td>0.08</td>
<td></td>
<td>0.32</td>
<td></td>
</tr>
<tr>
<td>Number of GUN (county)</td>
<td>32</td>
<td></td>
<td>40</td>
<td></td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Unit of observation: county; labor intensity: rice acreage/number of agricultural household; cottage production: non-agricultural production/number of agricultural household.
*Significance level, <0.01.
Source: Tomobe (2010).
References