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The Role of Structural Transformation in Regional Convergence in Japan: 1874-2008

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Abstract

Extending the literature on productivity convergence to a multi-sector growth framework, we show that σ-convergence in regional productivity growth can be decomposed into σ-convergence in sectoral productivity growth and σ-convergence in structural transformation-led productivity growth. Empirical support is provided using novel historical datasets at the Japanese prefecture level from 1874 to 2008. In pre-war Japan (1874–1940), regional convergence was primarily driven by productivity growth in the secondary sector. The rapid productivity convergence within the secondary and tertiary sectors relative to that in the primary sector between 1890 and 1940 provided an important base for the large convergence effects of structural transformation in the post-war years through a larger sectoral productivity gap in the lagging regions compared to the leading regions. However, the pace of regional convergence gradually slowed down and since the early 1970s the σ-convergence of structural transformation has been offset by the σ-divergence of within-sector productivity growth and vice versa, thwarting the pace of convergence in aggregate productivity.

JEL Classifications: O40, O10
Keywords: Structural transformation, Labor productivity, Regional convergence, Japan

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I. Introduction

Structural transformation[1] has been regarded as a key mechanism for growth and convergence in regional labor productivity (Caselli and Coleman, 2001; Duarte and Restuccia, 2010; Hnatkovska and Lahiri, 2012). In a multi-sector growth framework, a standard shift-share analysis decomposes labor productivity growth into the contribution of structural transformation (between-sector effect) and the contribution of sectoral productivity (within-sector effect). Extending this decomposition framework, we show that convergence in regional aggregate productivity can also be decomposed into (1) the contribution of convergence in sectoral productivity growth and (2) the contribution of convergence in structural transformation-led productivity growth. Closest to ours in spirit are the papers by Bernard and Jones (1996a, 1996b, 1996c). However, their studies decompose productivity convergence into industry productivity gains and changing sectoral shares of output. To the best of our knowledge, this is the first study to estimate the contribution of structural transformation to convergence in regional productivity. Using our novel decomposition framework, we examine this relationship focusing on Japan's economic development since the early Meiji period. For this purpose, we employ novel historical datasets at the regional level spanning a period of 135 years, from 1874 to 2008.

Studies on the US show a divergent trend of regional income from 1840 to 1900 and convergence thereafter (Easterlin, 1960; Williamson, 1965; Barro and Sala-i-Martin, 1992; Kim, 1998).[2] Turning to the case of Japan, it was the first Asian country to industrialize following the Western model and its remarkable growth in the 20th century is a well-known story.[3] In a recent study, Fukao et al. (2015) have shown that after the divergence in per capita gross prefectural domestic product (GPDP) during the period 1874–1910, Japan's regional income gap continued to be large during the inter-war period. Only in the early post-war era did Japan experience rapid regional convergence, especially in the high-growth period from 1955 to 1970. From the 1970s, the pace of regional convergence slowed and has almost come to a standstill since the early 1990s.[4] Using our new decomposition framework, we analyze these dynamics in regional convergence from the viewpoint of structural transformation and sectoral productivity growth. In a related study, Hayashi and Prescott (2008) show that

[1] Structural transformation through resource allocation can significantly impact on growth and convergence as labor and other resources move from less productive to more productive sectors (Kuznets, 1955).

[2] Similar trends in regional economic performance have been found in Britain (Crafts, 2005), France (Combes et al., 2011), Italy (Felice, 2011), Spain (Martinez-Galarraga Roses and Tirado, 2013) and Portugal (Baidia-Miro et al., 2012).

[3] Early modernization since the 1860s (Meiji era) led to steady growth in the first half of the 20th century. Japan's real per capita GDP relative to the US rose from 30% in 1870 to 41% in 1940. After the devastation of World War II, in merely 45 years, Japan achieved 85% of US per capita GDP.

[4] On this issue, also see Davis and Weinstein (2002), Kataoka and Akita (2003), Higashikata (2013), and Kakamu and Fukushige (2005).

institutional barriers kept agricultural employment almost constant, bottlenecking output growth in the pre-war period. Removal of such barriers in the post-war period resulted in high growth. Our findings also provide evidence of the key role that structural transformation played in output growth between 1955 and 1970; additionally, we show that structural transformation also contributed to the rapid regional convergence during this period.

Hayashi and Prescott (2008) used a two-sector framework (consisting of a primary and a non-primary sector). In this study, we use more disaggregated sectoral data. Based on this approach, we can also examine which sectors played a key role in the structural transformation and analyze sectoral productivity growth. We study productivity convergence using the notion of σ-convergence and measure σ-convergence in terms of changes in the Gini coefficient for aggregate productivity over time (O'Neill and Van Kerm, 2008). As a first step, we show that σ-convergence in aggregate productivity growth can be decomposed into σ-convergence in sectoral productivity growth and σ-convergence in the growth effect of structural transformation. Using a theoretical framework, we the derive conditions under which changes in the Gini coefficient for aggregate productivity can be closely approximated by a summation of changes in the Gini coefficient for productivity growth through the within-sector effect and changes in the Gini coefficient for productivity growth through the between-sector effect. Next, we combine the features of the two decomposition frameworks[5] to estimate the role of productivity catch-up (β-convergence) in productivity convergence (σ-convergence). This enables us to derive the respective contributions of the growth components, i.e., the within-sector and between-sector growth effects, to both productivity catch-up and productivity convergence. We apply this framework to novel historical data across 47 Japanese prefectures. We first apply our method to a dataset on sectoral productivity and employment shares over nine benchmarks years (1874–2008)[6] and across three broad sectors (primary, secondary, and tertiary). Since the decomposition results might be affected by the aggregation level of sectors, we also apply our method to a more disaggregated dataset for seven benchmark years (1909–2008) and across a more disaggregated 12 sectors. To gain more insights into the role of each sector at an even more disaggregated level, we also use another 23-sector dataset consisting of yearly data available for the period from 1955 to 2008.

The empirical findings provide evidence that convergence in regional productivity is closely approximated by the sum total of σ-convergence through sectoral productivity growth and σ-convergence through the growth through structural transformation. We find the

[5] We combine (a) the shift-share decomposition of labor productivity growth (Fabricant, 1942; de Vries et al., 2013) and (b) the decomposition of changes in the Gini into a re-ranking of prefectures and income growth (Jenkins and Van Kerm, 2006; O'Neill and Van Kerm, 2008).

[6] 1874, 1890, 1909, 1925, 1935, 1940, 1955, 1970, 1990 and 2008 (Fukao et al., 2016).

following two clear patterns. In the pre-WWII period (1874–1940), regional convergence is led by the within-sector effect, mainly through increased productivity in manufacturing (cotton in particular). On the other hand, the between-sector effect was the dominant force behind regional convergence in the post-WWII period (1955–2008), reflecting large sectoral productivity differences and the rapid move of labor to non-primary sectors (mainly private services) from the primary sector. If we look at the average for the entire period, the between-sector effect explains about 20% of aggregate productivity growth. However, prefectures with faster reallocation of labor across sectors and larger sectoral productivity gaps experienced a stronger between-sector growth effect. The contribution of structural transformation to regional convergence accelerated in the high-growth era (1955–70) along with σ-convergence in the within-sector growth effect. However, the pace of regional convergence gradually slowed down and since the early 1970s the σ-convergence of structural transformation has been offset by σ-divergence of within-sector productivity growth and vice versa, thwarting the pace of convergence in aggregate productivity.

Our study mainly contributes to the sectoral study of regional convergence. Despite a recent increase in the literature on structural transformation, studies which combine structural transformation and regional convergence are still scarce.[7] Our study is also related to the literature on the role of specific sectors in regional convergence in productivity. Bernard and Jones (1996a, 1996b, 1996c) show that productivity convergence in services was the key to GDP per capita convergence at the macro level in the US. In a similar vein, wholesale and retail trade played the key role in structural transformation-led regional convergence in Japan, particularly in the second half of the 20th century. Another important aspect of this study is that we examine the link between structural transformation and regional income inequality over a long period of time. The need for studies on inequality histories has been repeatedly emphasized by Williamson (1991). In a recent analysis, Herrendorf et al. (2014) voice similar concerns by highlighting the usefulness of documenting the historical process of structural transformation along with development and growth. Difficulties in putting together long time series data especially at the subnational level have remained the main obstacle, which we overcome to a large extent with the help of novel datasets available for the period from 1874 to 2008.

The rest of the paper is organized as follows. In Section 2, we explain the data and data sources and also describe the methodological framework. Section 3 provides some stylized facts and the main findings on the relationship between structural transformation and

[7] See Herrendorf et al. (2014) for a recent literature survey on this topic.

regional convergence. In Section 4, we discuss the mechanisms behind the role of structural transformation in regional convergence. Finally, Section 5 concludes.

2. Data and Methodology

2.1. Description of data

We use three datasets for this study. The first dataset on sectoral producivity and employment shares comprises of nine benchmark years (1874, 1890, 1909, 1925, 1940, 1955, 1970, 1990, and 2008) spanning a period of almost 135 years. We use three broad sectors of production: primary, secondary and tertiary, which cover the whole economy. The primary sector consists of agriculture, forestry, and fishery, while the secondary sector consists of mining, manufacturing, and construction. The tertiary sector covers all other sectors. The data on real aggregate labor productitivity (calculated as the gross prefectural domestic product over the number of workers) for the period from 1874–1940 (in yen) is measured in 1934–36 prices and for the period from 1955–2008 (in 1,000 yen) is measured in 2000 prices. For this reason, we do not compare the figures on productivity between 1940 and 1955. By-employment is considered while calculating sectoral employment shares in the post-war period. See Fukao et al. (2015) for a detailed discussion of the data estimation methodology.[8]

The starting year of the dataset, 1874 is chosen because of data availability. In this year, Japan's first modern statistical survey on the output of all non-service activities of almost all the prefectures was conducted and published as the Fuken Bussan Hyo (Table of Prefectural Products). The survey took place only six years after the Meiji Restoration (1868). Therefore, our dataset covers the entire period for which reliable data are available. In 1874, Japan was an agrarian economy and per capita income was only 1,011 international 1990 Geary-Khamis dollars (GK$) (Settsu et al., 2016; Bassino et al., 2016), which is almost the same level as that of the US in 1820 (1,133 GK$, Maddison Project Database). Mainly because of the proto-industrialization in the Edo period (Saito and Takashima, 2016), Japan's per capita GDP in 1874 was already more than 50% higher than that of most other Asian countries such as India and China (Broadberry, 2016) and almost at the same level as the poorest European countries such as Portugal and Finland (Maddison Project Database). In 1874, Japan had only one commercial railroad of 29 km between Tokyo and Yokohama (one of Japan's major sea ports), which started operating in 1872. Therefore, we can study Japan's

[8] Detailed descriptions of the data and estimation techniques are available in Fukao et al. (2016). Note that data for Okinawa for the period 1955 to 1970 are not available.

regional convergence and changes in industrial structure from the very beginning of its modern economic growth.

The second dataset[9] consists of 12 sectors (agriculture, mining, food, textiles, chemicals, ceramics, metals, machinery, miscellaneous manufacturing, construction including utilities, commerce including services, and transport & communication).[10] This dataset is available for the period from 1909 to 2008. Our third dataset, known as the Regional-Level Japan Industrial Productivity (R-JIP) database,[11] consists of 23 sectors (agriculture, mining, food, textiles, pulp, chemicals, petroleum, non-metallic minerals, primary metals, fabricated metals, machinery, electrical machinery, transport equipment, precision instruments, other manufacturing, construction, utilities (electricity, gas, and water supply), wholesale and retail trade, finance and insurance, real estate, transport and communication, private services, and government services). This data set is available for the period 1955–2008.[12] Since the last two datasets are available for certain sub-periods, we only use them to supplement the main findings.

2.2. Methodological framework

Consider a framework with three production sectors, primary (*P*), secondary (*S*), and tertiary (*T*), as well as two regions, *H* (high productivity) and *L* (low productivity).[13] In the context of Japan, *H* can be thought of as Tokyo, while *L* represents the other prefectures. Production in P, S, and T takes place in both regions. Labor is reallocated across sectors within each of the regions between two points in time, t and $t+1$, and θ_{ki}^{t} denotes the sectoral labor share of sector i in region k and period t. Following a variant of the canonical shift-share decomposition methodology (see Fabricant, 1942, for the original decomposition and de Vries et al., 2013, and Foster-McGregor and Verspagen, 2016, for the variant) we write changes in aggregate labor productivity between t and $t+1$ as follows:

(1) $$\Delta V_k = \sum_{i=P,S,T}(\theta_{ki}^{t})(\Delta V_{ki}) + \sum_{i=P,S,T}(\Delta\theta_{ki})(V_{ki}^{t}) + \sum_{i=P,S,T}(\Delta\theta_{ki})(\Delta V_{ki})$$

[9] This novel dataset is constructed based on the *Census of Manufactures* starting from 1909 (Fukao et al., 2016). See http://www.ier.hit-u.ac.jp/histatdb/stats/view/299).
[10] Japan's *Census of Manufactures* started in 1909.
[11] http://www.rieti.go.jp/en/database/r-jip.html (To note, data is missing for Okinawa for the period 1955 to 1970.
[12] 1955 is chosen because Japan's official GPDP statistics are available from this year.
[13] To convey the main idea, we simplify the framework by considering only two regions. In our empirical analysis, we consider 47 regions (prefectures).

where V_{ki} is the log of labor productivity in sector i (primary, secondary, or tertiary) and region k, and θ_{ki} denotes the labor share in sector i in region k. On the right-hand side of equation (1), we have three terms. The first term shows the contribution of own-sector productivity growth due to capital acumulation, technological progress, or a reduction in the misallocation of resources among firms within a sector. The second term represents the static effect of the reallocation of labor through differences in the sectoral productivity level at the beginning of each period. Finally, the third term measures the covariance effect between the reallocation of labor across sectors and changes in sectoral productivity. The last two terms together measure the contribution of structural transformation to changes in aggregate labor productivity. Thus, productivity growth in region k (as well as aggregate productivity growth) can be decomposed as follows:

(2) $$V_k{}^{t+1} - V_k{}^{t} = \Phi(WS)_k + \Phi(ST)_k,$$

where $\Phi(WS)_k$ and $\Phi(ST)_k$ represent labor productivity growth in region k due to within-sector productivity growth and due to structural transformation, respectively.

Next, to examine the mechanism through which structural transformation is linked with productivity growth, we consider the term $\Phi(ST)_k$ from equation (1). By adding a time suffix to $V(x)_k$, and after some simple algebraic manipulations, the structural transformation effect is transformed into the sum of two factors:

(3) $$\Phi(ST)_k = (\theta_{kT}^{t+1} - \theta_{kT}^{t})(V_{kT}^{t+1} - V_{kP}^{t+1}) + (\theta_{kS}^{t+1} - \theta_{kS}^{t})(V_{kS}^{t+1} - V_{kP}^{t+1}).$$

The first term on the right-hand side of equation (3) shows the change in the tertiary sector employment share multiplied by the productivity gap between the tertiary and the primary sector in region k. Meanwhile, the second term shows the same relationship between the secondary and the primary sector in region k. Using vector notation, the equation can be rewritten as $\boldsymbol{V_k}^{\boldsymbol{ST}} = [\Delta\boldsymbol{\theta_k}] \times [\boldsymbol{PG_k}]$, where $\Delta\boldsymbol{\theta_k}$ and $\boldsymbol{PG_k}$ represent the change in the non-primary sector labor share and the productivity gap between the non-primary and the primary sector in region k. If both of these vectors are either positive or negative, the contribution of structural transformation to productivity growth is positive.[14] However, reallocation of labor from the primary sector may lower the aggregate labor productivity level if labor productivity in the primary sector is higher than in the other two sectors. Moreover, if the sectoral

[14] McMillan et al. (2014) distinguish between growth-enhancing structural transformation (mostly in Asia) and growth-reducing structural transformation (as seen in many countries in Africa and Latin America).

productivities are equal, then labor reallocation does not lead to any change in aggregate productivity. The poor region (k') catches up with the rich region through structural transformation (k) if $[\Delta\theta_{k'}] \times [PG_{k'}] > [\Delta\theta_k] \times [PG_k]$, which shows regional convergence.

As suggested by equation (2), in the context of a multi-sector model for each region or for the whole economy, structural transformation makes a partial contribution to aggregate productivity growth. The contribution of the within-sector effect to aggregate productivity growth is typically larger than that of the between-sector effect (Kaldor, 1967; Syrquin, 1986; Kucera and Roncolato, 2014; Timmer and de Vries, 2009).[15] Moreover, structural transformation may not lead to convergence if the degree and contribution of structural transformation to economic growth varies across regions (McMillan et al., 2014). This implies that even if sectoral productivity growth and structural transformation both make a positive contribution to productivity growth, they could work in opposite directions in terms of regional convergence or divergence and hence (partially) offset each other.[16]

Next, let us construct a framework to decompose convergence in regional aggregate productivity into (1) the contribution of convergence in sectoral productivity growth and (2) the contribution of convergence in the growth effect of the reallocation of labor across sectors (structural transformation). To do so, we define $V_{WS}^{t+1} = V^t + \Phi(WS)$, where V^t represents productivity in period t, $\Phi(WS)$ represents the change in productivity due to the within-sector effect, and V_{WS}^{t+1} represents the hypothetical productivity level in period $t+1$ if productivity growth is driven only by the within-sector effect. To simplify our notation, we omit suffix k when this does not result in confusion. In a similar manner, we define $V_{ST}^{t+1} = V^t + \Phi(ST)$ when productivity growth is driven only by the between-sector effect (structural transformation). Using the definitions of V_{WS}^{t+1} and V_{ST}^{t+1} and equation (2), we can write

[15] These studies show that 75%–79% of aggregate labor productivity growth is explained by the within-sector effect.

[16]

One-sector model

σ-conv	
Yes	No

Multi-sector model

<table>
<tr><td colspan="3" rowspan="3"></td><td colspan="2">Sectoral productivity growth (within-sector)</td></tr>
<tr><td colspan="2">σ-conv</td></tr>
<tr><td>Yes</td><td>No</td></tr>
<tr><td rowspan="2">Structural transformation (between-sector)</td><td rowspan="2">σ-conv</td><td>Yes</td><td>Yes</td><td>?</td></tr>
<tr><td>No</td><td>?</td><td>No</td></tr>
</table>

This table compares the link between productivity growth and regional convergence in a one-sector and a multi-sector model. The left-hand panel shows regional convergence in a one-sector model, while the right-hand panel shows the same in a multi-sector model (with two sources of productivity growth). The shaded cells show that the net impact on σ-convergence is jointly determined by σ-convergence in sectoral productivity growth and growth from structural transformation when the σ-convergence based on these two factors has the opposite sign.

(4) $$V^{t+1} - V^t = V_{WS}^{t+1} - V^t + V_{ST}^{t+1} - V^t.$$

We use the Gini coefficient of regional labor productivity to measure regional disparities in labor productivity. In many studies, measures of income inequality are the coefficient of variation of GDP (Friedman, 1992) or the standard deviation of log GDP (e.g., Sala-i-Martin, 1996). The Gini coefficient is most similar to the variance and shares many properties with it (Yitzhtaki, 2003). In addition, as Yitzhaki (2003) shows, the Gini mean difference[17] can be more informative about the properties of distributions that are nearly normal, such as stochastic dominance between two distributions and stratification (when the overall distribution is decomposed into sub-populations). The Gini coefficient of regional labor productivity, written as

(5) $$G(V) = 1 - 2\int_{\alpha}^{\beta}[1 - F(V)]\frac{V}{\mu}f(V)dx$$

where μ is the mean value of labor productivity (V), α and β are the lower and upper bounds of V, F *is* the cumulative distribution of V, and f *is* the density function of V. The Gini coefficient represents the weighted average of mean-normalized productivity $(\frac{V}{\mu})$, where the weights, $1 - F(V)$, are determined by the relative rank of each region's labor productivity. By adding a time suffix to $G(V)$, changes in inequality between t and $t+1$ can be written as

(6) $$\Delta G(V) = G^{t+1}(V^{t+1}) - G^t(V^t).$$

From equation (4), we can write $V^{t+1} = V_{WS}^{t+1} + V_{ST}^{t+1} - V^t$. Based on the properties of the Gini coefficient of the sum of two or more random variables (Yitzhaki, 2003), $G^{t+1}(V^{t+1})$ can be approximated as

(7) $$G^{t+1}(V^{t+1}) = G^{t+1}(V_{WS}^{t+1}) + G^{t+1}(V_{ST}^{t+1}) - G^t(V^t) + \varphi^t,$$

[17] The Gini mean difference and the Gini coefficient are defined as $G_{MD} = 4Cov(x, F(x)$ and $G(x) = \frac{Cov\,(x,\ F(x))}{E(x)}$, respectively (where x is a random variable and F is the cumulative distribution of x). Thus, the relationship between these two terms becomes $G_{MD} = 4\,G(x)E(x)$.

where φ^t denotes the adjustment term of this approximation. The detailed derivation of equation (7) is provided in Appendix 1. If we subtract $G^t(V^t)$ from both sides of equation (7), we obtain

(7') $$G^{t+1}(V^{t+1}) - G^t(V^t) = \{G^{t+1}(V_{WS}^{t+1}) - G^t(V^t)\} + \{(G^{t+1}(V_{ST}^{t+1}) - G^t(V^t)\} + \varphi^t.$$

Equation (7') implies that given a smaller value of φ^t, σ-convergence in labor productivity (a drop in the left-hand side of equation (7')) can be approximated by the net sum of σ-convergence due to the within-sector effect (a drop in the difference in the first two terms on the right-hand side of equation (7')) and σ-convergence due to structural transformation (a drop in the difference in the last two terms on the right-hand side of equation (7')). Figure 1 provides a graphical representation of this argument using some hypothetical Lorenz curves and assuming that the value of φ^t is equal to zero. Using the Lorenz curves of labor productivity, σ-convergence in labor productivity is represented by the area between L(V[t+1]) and L(V[t]). σ-convergence due to the within-sector effect is represented by the area between L(V_WS[t+1]) and L(V[t]), and σ-convergence due to structural transformation is represented by the area between L(V_ST[t+1]) and L(V[t]).

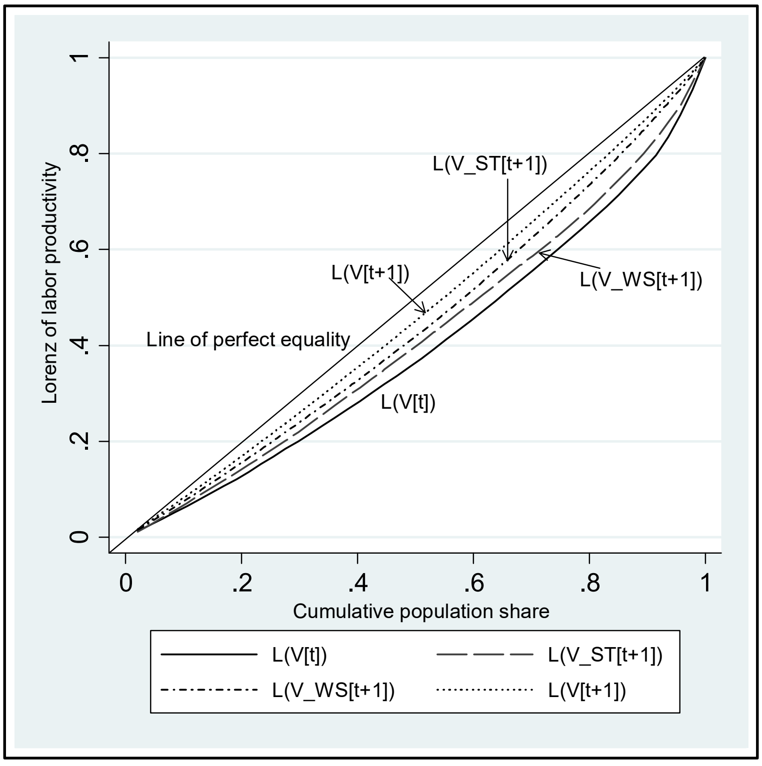


Figure 1. Lorenz curves illustrating the decomposition of labor productivity growth

We next provide a theoretical explanation of the size of the approximation error, φ. In Appendix 1, we show that the magnitude of the approximation error φ becomes large if the Gini correlation coefficients are far from 1. In addition, the size of φ becomes small if the expected values of the four key variables, $E(V^{t+1})$, $E(V_{WS}^{t+1})$, $E(V_{ST}^{t+1})$, and $E(V^t)$ are similar in magnitude. If these terms differ greatly, then the magnitude of φ becomes large. In order to check how the stochastic dynamic process of these factors affects the distribution of φ across different periods, we perform a *t*-test of the null hypothesis that $\varphi = 0$. Empirically, the value of φ for each period can be calculated for any time period as long as $G^{t+1}(V^{t+1}) - G^t(V^t)$, $[G^{t+1}(V_{WS}^{t+1}) - G^t(V^t)]$, and $[G^{t+1}(V_{ST}^{t+1}) - G^t(V^t)]$ are measured separately. We use these values to test the above hypothesis about φ using the benchmark years from 1874 to 1955 and then annual figures for the rest of the period from 1955 to 2008.

Until this point, we have mainly focused on σ-convergence. However, as many studies on convergence have shown (e.g., Barro and Sala-i-Martin, 1992), analysis based on β-convergence is also useful and provides important insights on the dynamic process of convergence. As a next step, we incorporate the mechanism of β-convergence into our decomposition framework of structural transformation and productivity convergence. Following the lead of Jenkins and Van Kerm (2006) and O'Neill and Van Kerm (2008), we extend the relationship between σ-convergence and β-convergence in the context of a multi-sector model. We rewrite equation (6) as

$$(8) \qquad G^{t+1}(V^{t+1}) - G^t(V^t) = [G^{t+1}(V^{t+1}) - C_t^{t+1}(V^{t+1}, V^t)] - [G^t(V) - C_t^{t+1}(V^{t+1}, V^t)],$$

where $C_t^{t+1}(V^{t+1}, V^t) = 1 - 2\int_\alpha^\beta \int_\alpha^\beta [1 - F^t(V^t)] \frac{V^{t+1}}{\mu^{t+1}} h(V^{t+1}, V^t) dV^{t+1} dV^t$ is the concentration index (Schechtman and Yitzhaki, 2003; Lambert, 2001) indicating the distribution of regional productivity levels in period $t+1$, with the regions being arranged according to the productivity ranking in period *t*, where h is the bivariate density function of productivity in periods t and $t+1$. In general, the concentration index reveals the relationship between two random variables. Unlike the Gini coefficient, which measures the cumulative shares of a variable plotted against the cumulative frequencies of that variable, the concentration coefficient shows the degree of association between two variables, and its value lies in the range [-1, 1]. Equation (8) shows that changes in the Gini index between two periods can be decomposed into two factors. The last two terms on the right-hand side of equation (8) show the change in the Gini index caused by productivity catch-up between t and $t+1$ keeping the ranking of the regions as in period *t*. We express this part by

$Progress(V^{t+1}, V^t)$. If productivity growth of a poorer region is higher than that of a richer region, then the value of $Progress(V^{t+1}, V^t)$ becomes negative. The first two terms show the change in the Gini index caused by the re-ranking of regions in terms of the aggregate productivity level. We express this part by $Rank(V^{t+1}, V^t)$. If there is no change in the ranking of regions between *t* and *t*+1, then the value of $Rank(V^{t+1}, V^t)$ becomes zero. If there is a change in the ranking, then it has a positive value. Therefore, $Rank(V^{t+1}, V^t) \geq 0$, implying that the re-ranking of regions dampens the pace of σ-convergence.

Thus, a change in the inequality of labor productivity (σ-convergence) between two points in time can be decomposed into the effect of productivity catch-up (β-convergence) and the effect of re-ranking:

(8') $$G^{t+1}(V^{t+1}) - G^t(V^t) = Rank(V^{t+1}, V^t) - Progress(V^{t+1}, V^t).$$

O'Neill and Van Kerm (2008) have shown that $[G^{t+1}(V^{t+1}) - G^t(V^t)]$ can be interpreted as an indicator of the magnitude of σ-convergence and the term $Progress(V^{t+1}, V^t)$ can be interpreted as an indicator of the magnitude of β-convergence.[18] Using this decomposition framework, we can find the contribution of β-convergence to σ-convergence net of the re-ranking of regions.

In a similar manner, we define the concentration index for V_{WS}^{t+1} as

(9) $$C_t^{t+1}(V_{WS}^{t+1}, V^t) = 1 - 2\int_\alpha^\beta \int_\alpha^\beta [1 - F^t(V^t)] \frac{V_{WS}^{t+1}}{\mu_{WS}^{t+1}} h(V_{WS}^{t+1}, V^t) dV_{WS}^{t+1} dV^t,$$

where μ_{WS}^{t+1} is the mean of labor productivity (V_{WS}^{t+1}), α and β are the lower and upper bounds of V_{WS}^{t+1} and V^t, *F is* the cumulative distribution of V, and *f is* the density function of V. The concentration index is a weighted average of mean-normalized productivity ($\frac{V_{WS}^{t+1}}{\mu_{WS}^{t+1}}$), where the weights, $1 - F^t(V^t)$, are determined by the relative rank of each region's labor productivity in period *t*. Moreover, h is the bivariate density function of productivity in periods t and $t+1$.

[18] In the growth literature, β-convergence represents the catching-up by poorer regions and σ-convergence shows changes in the dispersion of income across regions. Thus, β-convergence is a necessary but not a sufficient condition for σ-convergence to occur. Using our framework, this can be shown as follows:

- No β-convergence & no σ-convergence $\begin{cases} if\ \Delta G(x) = 0\ \&\ Progress(x) = 0 \\ if\ \Delta G(x) > 0\ \&\ Progress(x) < 0 \end{cases}$
- β-convergence but no σ-convergence $if\ \Delta G(x) < 0\ \&\ Progress(x) > 0\ \&\ |Rank(x)| > |Progress(x)|$
- β-convergence & σ-convergence $\begin{cases} if\ \Delta G(x) < 0\ \&\ Progress(x) > 0\ \&\ Rank(x) = 0 \\ if\ \Delta G(x) < 0\ \&\ Progress(x) > 0\ \&\ |Rank(x)| < |Progress(x)| \end{cases}$

We use $C_t^{t+1}(V_{WS}^{t+1}, V^t)$ to replicate the decomposition shown in equation (8) for $G^{t+1}(V_{WS}^{t+1}) - G^t(V^t)$:

(10) $$G^{t+1}(V_{WS}^{t+1}) - G^t(V^t) = Rank(V_{WS}^{t+1}, V^t) - Progress(V_{WS}^{t+1}, V^t).$$

Intuitively, equation (10) shows the relationship between σ-convergence and β-convergence when $\Phi(ST) = 0$. In a similar manner, when $\Phi(WS) = 0$, the relationship between σ-convergence and β-convergence can be written as

(11) $$G^{t+1}(V_{ST}^{t+1}) - G^t(V^t) = Rank(V_{ST}^{t+1}, V^t) - Progress(V_{ST}^{t+1}, V^t).$$

With the help of equations (10) and (11), we can separately analyze the contribution of sectoral productivity growth and structural transformation to β-convergence and σ-convergence.

3. Stylized facts on structural transformation and regional convergence in Japan

3.1. Structural transformation, 1874–2008

The process of structural transformation in Japan started during the Meiji era (1868–1912). A number of early initiatives helped the reallocation of labor across sectors. There were the abolition of barrier stations and the caste system (in which society was divided into four classes: samurai, farmers, merchants, and craftsmen) in 1868 and the granting of official permission in 1872 to farmers to engage in commercial activities. Restrictions on the selection of occupation and residence from the Tokugawa period were also removed. In the period from 1874 to 1890, the share of manufacturing activities increased substantially in all prefectures. As we will show later, national average labor productivity in the secondary sector remained at almost the same level as that in the primary sector. Therefore, it seems that the expansion of the manufacturing sector during this period was mainly driven by the expansion of traditional manufacturing activities such as food processing, wood products, labor-intensive textile production, etc. An important exception was Osaka, where capital-intensive industries such as the heavy chemical industry and the machinery industry started. During the Edo period, Osaka had been the hub of nationwide wholesale and banking networks. In addition, Osaka borders on Kyoto and Hyogo. Kyoto had been Japan's capital until the Meiji Restoration and the center of traditional manufacturing activities. Hyogo had the most important seaport for

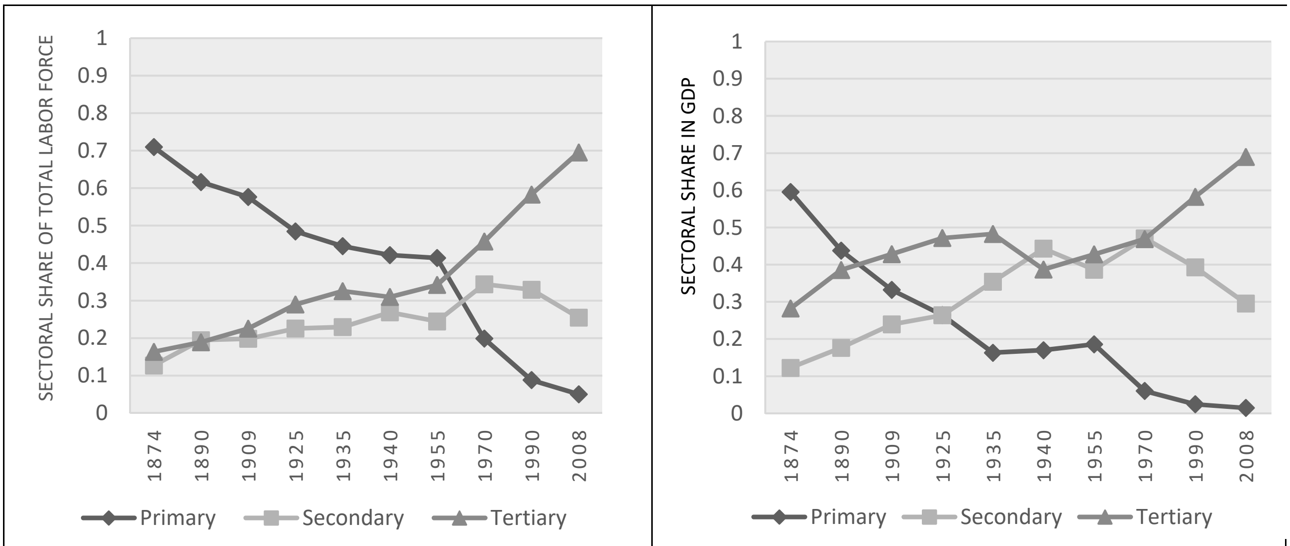
Japan's imports, Kobe, and import substitution activities developed around this area. In the case of East Japan, manufacturing activities expanded particularly in the silk-reeling prefectures of eastern Japan (Gunma, Nagano, and Yamanashi).[19] Around this time, new industrialized areas also arose with specializations in heavy industry, machinery, shipbuilding, etc., in Fukuoka, Nagasaki, and Akita, which had international seaports (Fukao et al., 2015).

In addition, traditional manufacturing activities expanded throughout Japan through the abolition of protectionist measures introduced by feudal clans during the Edo period, the expansion of nationwide trade activities, and international trade without tariff autonomy. For example, traditional production of candle, paper, and salt in Yamaguchi, which was governed by an influential feudal clan during the Edo period, declined substantially through domestic and international competition (Nishikawa, 1985). Later on, the turn of the 20th century saw further expansion of high-productivity manufacturing sectors, which were located mainly in the urbanized areas (Tanimoto, 1998; Nakabayashi, 2003; Nakamura, 2010). Heavy manufacturing-based industrialization evolved with the extensive use of electricity, chemicals, metals, and machinery (Fukao et al., 2015b). The labor force in the primary sector declined from 15.4 million in 1874 to 13.1 million in 1909. At the same time, the dependency ratio (the ratio of non-working to working people) rose from 60% in 1874 to 92% in 1909 as a result of significant population growth from 40 million in 1874 to 49 million in 1909.

As depicted in Figure 2(a), employment shares in Japan based on labor input data show a steady fall for the primary sector, a steady increase for the tertiary sector, and a hump shape for the secondary sector. Over the 135 years from 1874, the employment share of the primary sector fell from 72% to 5%, whereas that of the tertiary sector rose from 16% to 69%. During the same period, the secondary sector's employment share grew from 14%, peaked at 34% in the 1970s, and then eventually dropped to 26% in 2008. The value-added trends in sectoral shares in GDP (Figure 2(b)) are consistent with the literature on growth and structural transformation in early industrialized countries.[20]

[19] After the abolition of strict regulations on international trade in 1954, Japan enjoyed comparative advantage in silk products and suffered from a disadvantage in cotton products. Consequently, prefectures that specialized in cotton products – such as Aichi and Osaka – suffered.

[20] See the recent survey by Herrendorf et al. (2014)



(a) Employment shares

(b) Value-added shares

Figure 2. Structural Transformation in Japan

Note: By-employment is considered while calculating man-hour input shares. See Fukao et al. (2015) for a detailed discussion on the data estimation methodology. Sectoral shares in GDP are calculated using real GDP in constant 1934–36 prices for 1874–1940 and constant 2000 prices for 1955–2008.

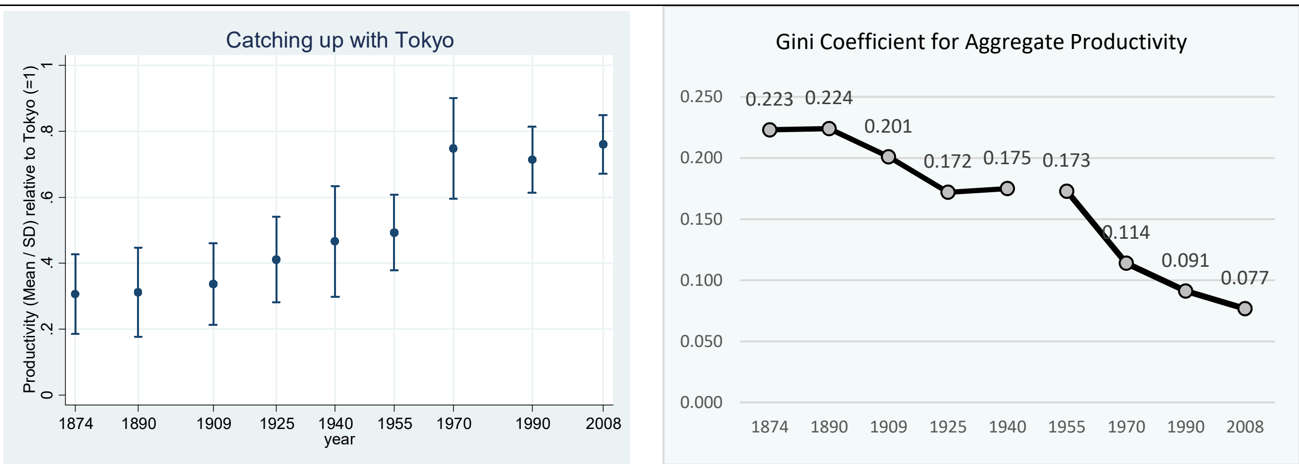
Before we conclude this section, we briefly mention a few factors that have slowed down the labor reallocation process in Japan. One of the factors partly responsible for the slowdown, according to Nakamura (1983), is the opening of new foreign markets for Japanese silk and tea. Saito (1998) showed that the level of income across peasant households wielded a decisive influence on migration as peasants were able to earn from both agriculture and cottage industries that had sprung up in the course of proto-industrialization[21] during the Tokugawa period, which provided less incentive for agricultural workers to reallocate to non-agricultural activities. Other factors that perhaps also contributed to the slow process of structural transformation include institutional barriers related to agriculture (Hayashi and Prescott, 2008), the reallocation of capital to war industries and labor to the munitions industry (Okazaki, 2016), and cost linkages between inputs and suppliers of inputs between prefectures (Davis and Weinstein, 2001).

3.2. Convergence of labor productivity, 1874–2008

Both regional convergence in productivity and the decline in the employment share in agriculture in Japan[22] started in the late 19th century (Fukao et al., 2016) when the process of industrialization gained momentum (see Figure 3(a)). The average labor productivity (over 46 prefectures) benchmarked to the level of Tokyo increased from 32% in 1874 to almost 77% in

[21] Proto-industrialization refers to pre-modern industrialization without energy and capital intensive modern factories. See Saito (1983) and Smith (1988) for details on proto-industrialization in Japan.
[22] For developments in the United States, see Easterlin (1960), Barro and Sala-i-Martin (1992), Kim (1998) and Mitchener and McLean (1999).

1970. During the period of the post-war growth miracle from 1955 to 1970, Japan's aggregate productivity rose remarkably, but the regional disparity in productivity also narrowed to an unprecedented level in this phase. Since the 1970s, the average prefectural labor productivity level (excluding Tokyo) remained in the vicinity of 75% of that of Tokyo. The Gini coefficient for labor productivity also continued to drop in the second half of the 20th century, and did so at a faster rate than in the pre-WWII period (Figure 3(b)).



(a) Average prefectural aggregate labor productivity (relative to Tokyo)

(b) Regional disparity in aggregate labor productivity

Figure 3. Convergence of aggregate labor productivity, 1874-2008

Notes: In both figures, real GDP figures are in constant 1934–36 prices for 1874–1940 and constant 2000 prices for 1955–2008. In panel (a), the points indicate the average and the vertical range represents the spread (2 standard deviations) around the mean.

3.3. Productivity catch-up and convergence through structural transformation

In this section, we examine the role of structural transformation in productivity convergence. Figure 4 provides a graphic summary of the main results and indicates that there were two distinct patterns of regional convergence. Specifically, during the pre-war period, it was primarily the within-sector effect that led to regional convergence, while during the post-war period it was the between-sector effect (i.e., structural transformation). In other words, convergence was the result of two countervailing forces: within-sector productivity growth and productivity growth driven by structural transformation. Appendix Figure 1 shows that except in a few periods the distribution of the adjustment term is close to zero. We conduct a t-test which accepts the null hypothesis that $\varphi = 0$ at the 10% significance level.

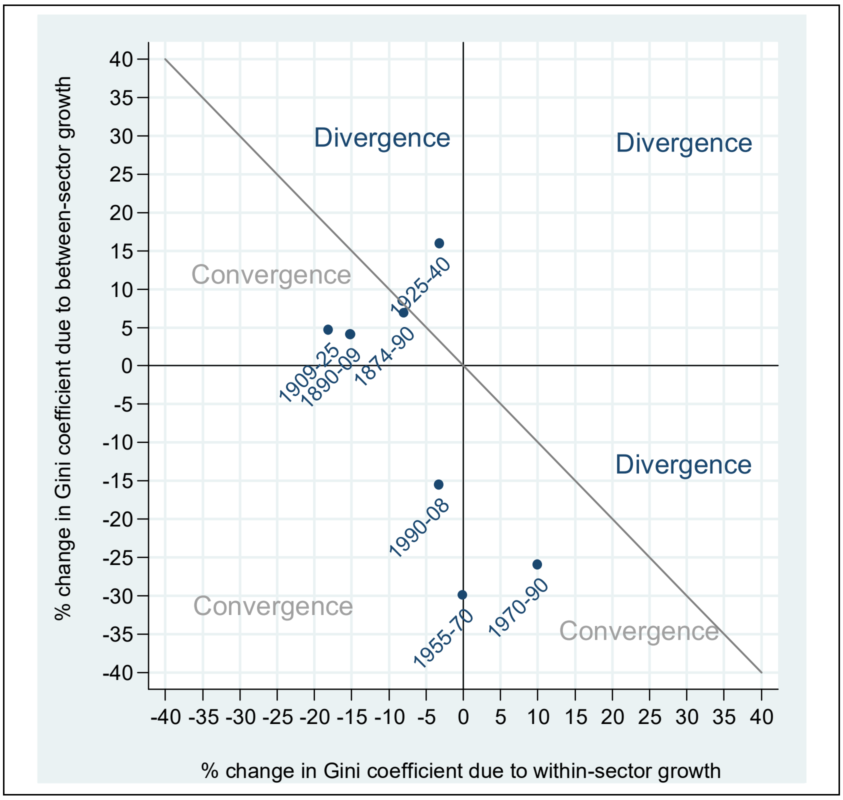


Figure 4. Contribution of structural transformation and the within-sector effect to regional convergence (σ) in labor productivity

Note: This figure only shows the sign of the σ-convergence of aggregate productivity (resulting from the magnitudes and signs of σ-convergence of the within-sector and the between-sector effects). It does not show the actual measure of σ-convergence of aggregate productivity. The vertical and horizontal axes represent the percentage change in the Gini coefficient (of the initial year of each period) in regional labor productivity due to the between-sector and within-sector effects, respectively.

Table 1 reports the detailed empirical results of the decomposition of the change in the Gini coefficient. The top panel shows the results for the decomposition for σ-convergence in labor productivity, while the second and third panels show the results for the decomposition of σ-convergence in the between-sector and within-sector effects. Labor productivity converged across regions in all periods except in 1874–1890[23] and 1925–1940. The second column in each of the panels shows the change in productivity in terms of the percentage change in the Gini coefficient from the starting year of each period to the end year. Panel A suggests that β-convergence in the post-war era was much larger than in the pre-war era. Our estimates show that the Gini coefficient, on average, dropped by almost 35% in the post-war periods compared to only 10% in the pre-war periods. The highest rate of productivity catch-up was observed in the high-speed growth era from 1955 to 1970. The estimates for Rank (the

[23] This is the only period for which the change in the Gini index and the sum total of the decomposed factors have the opposite sign. This is because the magnitude of the approximation error was relatively large. However, the magnitude of convergence in labor productivity was negligible (only 0.5 percent of the Gini coefficient of labor productivity in 1874).

re-ranking of prefectures) were also higher for the post-war era, but the difference is less pronounced than in the case of β-convergence.

Table 1. Evidence on productivity catch-up and convergence

	Change in Gini index	Rank	(-) Progress	*β*-convergence	σ-convergence
A. Decomposition results for σ-convergence in labor productivity					
1874–1890	0.5	9.3	-8.8	Yes	No
1890–1909	-11.6	3.7	-15.4	Yes	Yes
1909–1925	-14.4	3.2	-17.6	Yes	Yes
1925–1940	1.3	5.4	-4.1	Yes	No
1955–1970	-36.8	11.6	-48.4	Yes	Yes
1970–1990	-19.5	12.5	-32	Yes	Yes
1990–2008	-14.1	19.0	-33.2	Yes	Yes
B. Decomposition results for σ-convergence in the structural transformation effect					
1874–1890	6.9	1.2	5.7	No	No
1890–1909	4.1	0.5	3.6	No	No
1909–1925	4.7	0.3	4.4	No	No
1925–1940	16.0	3.5	12.6	No	No
1955–1970	-29.9	8.3	-38.2	Yes	Yes
1970–1990	-25.9	2.9	-28.7	Yes	Yes
1990–2008	-15.5	0.6	-16	Yes	Yes
C. Decomposition results for σ-convergence in the within-sector effect					
1874–1890	-8.0	9.2	-17.2	Yes	Yes
1890–1909	-15.2	3.6	-18.8	Yes	Yes
1909–1925	-18.1	3.8	-21.9	Yes	Yes
1925–1940	-3.2	15.3	-18.5	Yes	Yes
1955–1970	-0.1	8.0	-8.1	Yes	Yes
1970–1990	10.0	11.8	-1.9	Yes	No
1990–2008	-3.3	13.8	-17.2	Yes	Yes

Note: All figures are given as a percentage of the Gini index in the initial year of each period.

Next, panel B shows the decomposition results for the structural transformation effect. Here, let us focus on the column labeled "(-) Progress," which represents productivity catch-up or β-convergence. The figures indicate that while there was β-divergence (positive figures) in the pre-war period, the post-war period is characterized by β-convergence (negative figures). The estimates for Rank (the re-ranking of prefectures) show slightly higher values in the post-war period than in the pre-war period. The results on regional convergence (σ-convergence) closely follow the productivity catch-up trend (β-convergence). Between 1955 and 1970, structural transformation-led growth alone contributed almost 30% to the drop in the Gini coefficient for aggregate productivity.

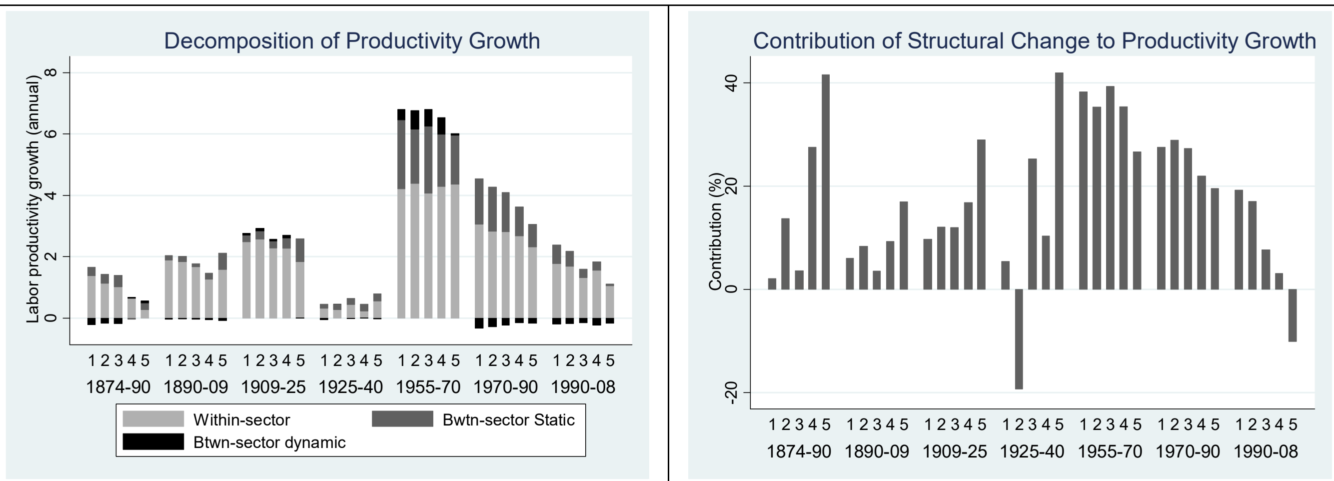
Finally, panel C presents the decomposition results for the within-sector effect. The figures indicate that Japan experienced a productivity catch-up of lagging regions through within-sector productivity growth in all periods. However, the pattern is the opposite of that observed for the between-sector effect, namely, the high rate of productivity catch-up was observed only in the post-war period. The within-sector effect made a particularly prominent contribution to regional convergence (σ-convergence) during the pre-war era. This was driven by many factors. These include the introduction of motors at small factories in rural Japan (Minami, 1976) as well as the transfer of management skills through mergers and acquisitions (Braguinsky et al., 2015). Overall, the sum total of σ-convergence in the within-sector effect (sectoral productivity growth) and σ-convergence in the reallocation effect (structural transformation-led productivity growth) provides a good approximation of the regional convergence in labor productivity.

Our results suggest that the contribution of structural transformation to regional convergence varies over time, as already highlighted by McMillan et al. (2014). In addition, depending on the period, the contributions of the between-sector effect on growth and within-sector growth to regional convergence potentially offset each other. To examine this process in more detail, we employ a more disaggregated dataset containing annual figures on sectoral productivity and employment levels for the post-war period (1955–2008). We find that after the pace of regional convergence initially gained momentum between 1955 and 1965, it then slowed down between 1965 and 1990 (Appendix Figure 2). Further, the two sources of productivity growth – within-sector productivity growth and structural transformation – often worked in opposite directions in terms of regional differences in productivity, slowing the pace of convergence.

4. The mechanisms underlying the role of structural transformation in convergence

4.1. Aggregate productivity catch-up

In this section, we examine the mechanisms underlying the role of structural transformation in convergence. We start by decomposing aggregate (national average) labor productivity growth (measured as log differences in real aggregate productivity) by productivity quintile across the benchmark years. To obtain the annual average figures, we divide the productivity growth in each period by the length of the period (measured in years). The results are shown in Figure 5(a). (Detailed results are provided in the last column of Appendix Table 4.) The annual average labor productivity growth in the period from 1955 to 1970 (measured at roughly 6% based on logarithmic approximation) outpaced the growth rates in the other periods. The contributions of within-sector productivity growth and between-sector static productivity growth (equation 1, section 2.2) to aggregate labor productivity growth were positive throughout; however, the magnitudes varied over time (Figure 5(b)). Until 1925, more than 80% of increases in productivity were due to within-sector growth. The contribution of structural transformation became larger in the post-war era. In the high-speed growth era from 1955 to 1970, the contribution of structural transformation to annual average growth rose to about 35%. In the 1980s and 1990s, structural transformation continued to contribute about one-third of aggregate labor productivity growth. Within the contribution of structural transformation, the dynamic structural transformation-led productivity effect (equation 1, Section 2.2) was positive in only two periods: 1909–1925 and 1955-1970.



Panel (a)	Panel (b)

Figure 5. Decomposition of aggregate labor productivity growth by productivity quintile

Comparing the decomposition results across the productivity quintiles suggests that productivity catch-up became more pronounced in the post-war period. Prefectures in the bottom quintile showed the highest rate of productivity growth. Productivity catch-up was evident in the phase from 1874–1890, but the relationship between structural transformation and productivity catch-up is unclear in the years between 1890 and 1940. In the first three periods – 1874–1890, 1890–1909, and 1909–1925 – the contribution of structural transformation to productivity growth suggests regional divergence. Overall, in the pre-war period, between-sector growth (structural transformation) did not make any clear contribution to convergence, whereas in the post-war period, there was a clear link between structural transformation-led growth and productivity catch-up. Structural transformation contributed to aggregate productivity catch-up in the post-war period.[24]

Since the Meiji Restoration in the 1860s, productivity growth followed an upward trend over the next 50 years, mainly driven by industrialization and modernization in the secondary and tertiary sectors. Capital accumulation clearly played an important role in this growth surge (until 1925). The capital stock increased more than seven-fold between 1878 and 1940 (Nakamura, 1971). In 1874, about 74% of the capital stock was in the primary sector, but this share dropped to only 17% in 1940. The large increase in the capital stock in the secondary sector fueled its remarkable growth in the early 20th century, especially in heavy manufacturing and related industries. In addition, as highlighted by Nakamura (1983), the Meiji central government and local authorities played a vital role in the establishment of railway networks, the modernization of maritime transportation, the introduction of postal and telegraphic systems, and a national banking system. The growth rate of productivity faltered in the inter-war period, 1925–40. A possible explanation for this might be the reallocation of capital to war industries and of labor to the munitions industry (Okazaki, 2016). Also playing an important role were the industrial boom during WWI and the scarcity of final demand caused by a difficult international environment and inappropriate foreign exchange policies from 1918 to the early 1930s (Cha, 2003).

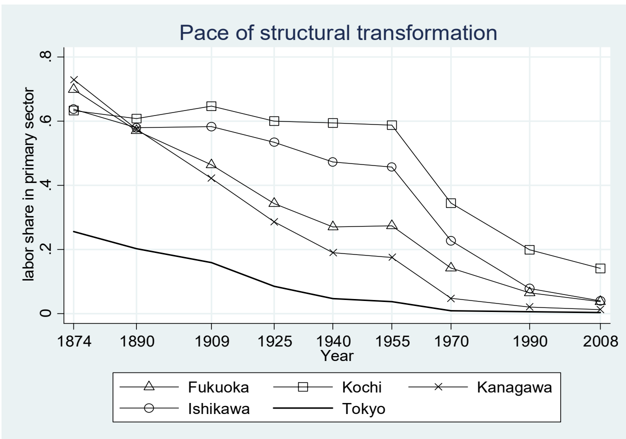
4.2. The pace of structural transformation and sectoral productivity gaps

McMillan et al. (2014) argue that the speed with which structural transformation takes place is the key factor that distinguishes leading countries from lagging countries. A similar argument can be made for the 47 prefectures in Japan, as we find regional differences in the pace of structural transformation (Figure 6(a)). While in most prefectures the agricultural employment share had dropped, there were some prefectures (like Kochi) in which agriculture still accounted for more than a quarter of total labor hours until 1970. Also, there were considerable differences in productivity growth across prefectures. Compared to Tokyo's aggregate labor productivity level, some prefectures experienced a process of sustained catch-up, while others followed a rollercoaster path of convergence (Figure 6(b)) throughout study period, 1874 – 2008. For example, in 1874, Hokkaido was among the top three prefectures (the other two being Tokyo and Osaka) in terms of productivity, and its aggregate labor productivity level was about 70% of Tokyo's. Almost 135 years later, the gap in aggregate

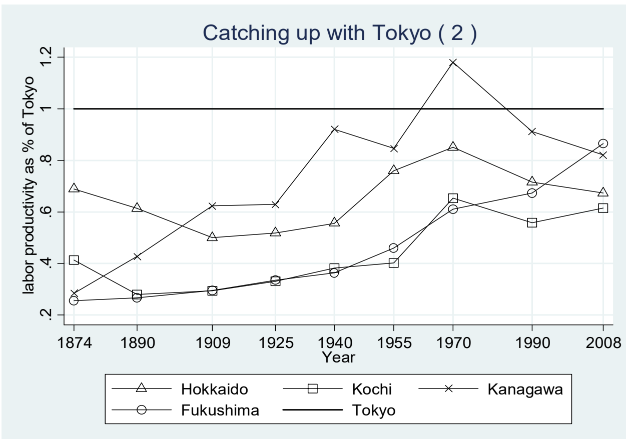
[24] The negative contribution of between-sector growth in the second quintile in 1925–40 is mainly due to one prefecture, Fukushima.

productivity in 2008 was almost identical, albeit after a substantial increase between 1874 and 1890, a decrease from 1890 to 1970, and another increase between 1970 and 2008. On the other hand, Fukushima followed a path of sustained productivity catch-up, with its productivity level relative to Tokyo's increasing from 26% in 1874 to 87% in 2008.

Heterogeneity in productivity catch-up patterns has also been associated with frequent changes in the productivity ranking of prefectures. Appendix Table 2 shows the full ranking of prefectures for the nine benchmark years. In the pre-war period, structural transformation was slow partly because of the lack of technology spillovers, capital stock, and markets for new non-agricultural industries. Proto-industrialization, which emerged during the Edo period (Saito, 1983; Smith, 1988) and the growing overseas demand for Japanese products (silk, tea, etc.) in the early 20th century made agricultural activities profitable for some prefectures (Gunma, Yamanashi). Only major cities like Osaka, Kyoto, and Tokyo benefited from slow but steady growth of heavy manufacturing industries (Fukao et al., 2015b). Since the northern part of Japan was less attractive as a sailing route, Yokohama, Kobe, Osaka, and Fukuoka became prominent ports as hubs for trade and commerce (Nakamura, 1983; Fujita and Tabuchi, 1997). Other prefectures followed a different pattern of economic development, characterized by various reversals of fortune. For instance, many prefectures – such as Yamaguchi and Ehime – that specialized in indigenous industries (salt, paper, wax candles, etc.) in the 19th century lost their competitiveness with changes in the nationwide economic environment (such as growing demand for other types of agricultural commodities) and international competition (Nishikawa, 1985). As a result, in the post-war period, the relative productivity level of a sizable number of prefectures (19 out of 46) fluctuated considerably without a clear catch-up with Tokyo. In summary, we find very diverse patterns in relative productivity growth across prefectures.



(a) Primary sector employment share in selected prefectures, 1874–2008



(b) Labor productivity (relative to Tokyo) in selected prefectures, 1874–2008

Figure 6. Convergence and structural transformation in selected prefectures

Notes: Labor productivity relative to Tokyo is calculated using real GDP in constant 1934–36 prices for 1874–1940 and constant 2000 prices for 1955–2008. In panel (b), by-employment is considered when calculating man-hour input shares. See Fukao et al. (2015) for a detailed discussion of the data estimation methodology. The primary sector consists of agriculture, forestry, and fisheries.

Focusing on Japan's long-run economic growth, Hayashi and Prescott (2008) examine why Japan's growth miracle did not take place until after World War II and, based on a two-sector growth model (consisting of agriculture and non-agriculture), argue that output growth in the pre-war period was depressed due to an institutional barrier that kept pre-war agricultural employment constant. They suggest that high output growth had to wait until the post-war period mainly because of the negligible rate of structural transformation in the pre-war period, i.e., the slow move out of agriculture. We also find that the pace of structural transformation in the pre-war period was quite slow, as shown in Figure 7. However, even if the reallocation of labor across sectors had occurred at a faster pace, this still would not have led to higher growth, because the productivity gap across sectors was relatively small. As shown in Section 2.2, a larger productivity gap across sectors leads to a higher contribution of structural transformation to productivity growth, even when there is limited movement of labor out of agriculture. In the post-war period, both the movement of labor out of agriculture accelerated and the productivity gaps across sectors widened substantially, giving rise to high output growth. In addition, in the pre-war period, regions in the bottom quintile had a lower rate of structural transformation and smaller sectoral productivity gaps than regions in the top quintile. However, this patterns completely reversed in the post-war era. On average, lagging regions showed a more rapid process of structural transformation along with higher sectoral productivity gaps, especially during the high-speed growth period from 1955 to 1970. This implies that sectoral productivity gaps contributed to regional convergence through productivity catch-up.

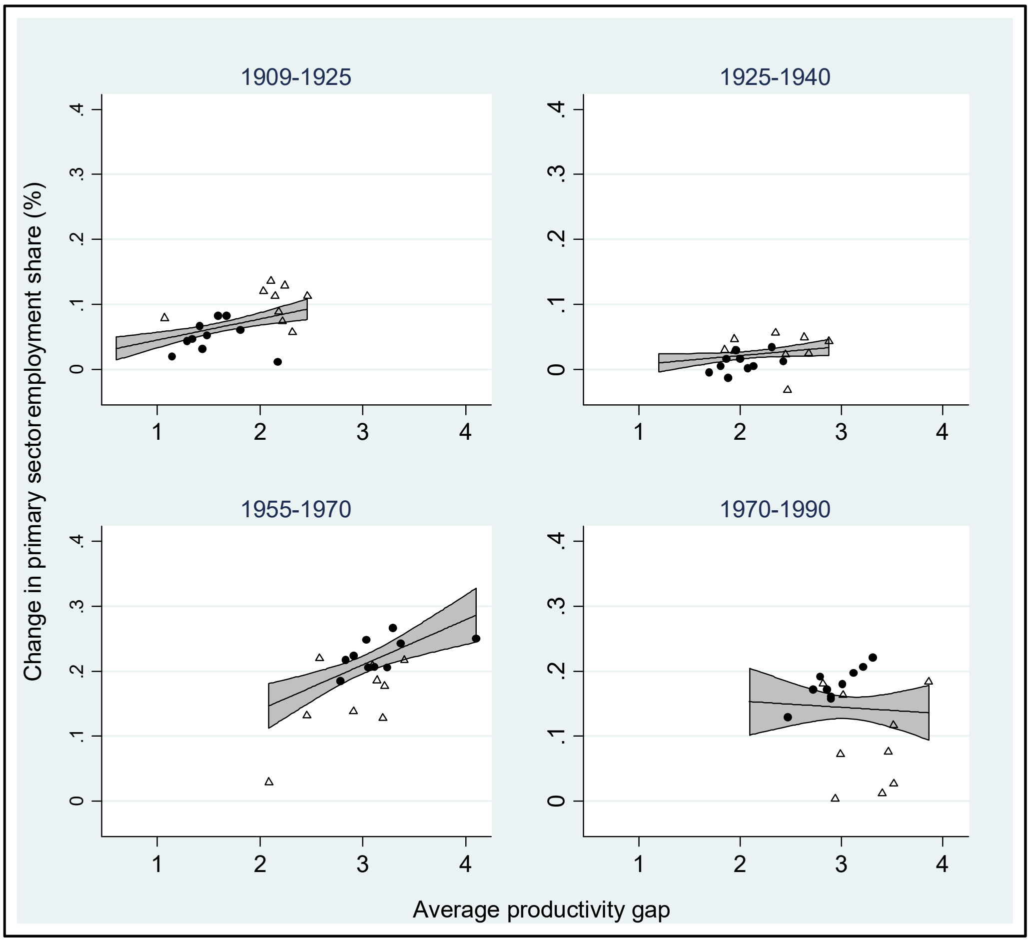


Figure 7. Structural transformation and sectoral productivity gaps

Notes: The average productivity gap is calculated in two steps. First, we estimate the arithmetic mean of the tertiary-primary sector gap and the secondary-primary sector gap in both the initial and the final year in each period. Second, we take the average of the initial and the final year to obtain the average productivity gap for the period. The fitted line is based on regressions with a confidence interval of 95%. The vertical axis shows the shift of labor out of the primary sector in terms of the employment share percentage point difference. The dots represent regions in the bottom 20% and triangles represent regions in the top 20% based on the labor productivity in the initial year in each period.

As a final step, we show how the ratio of the sectoral productivity gap in the top 20% prefectures to the sectoral productivity gap in the bottom 20% prefectures changed over time. We separately calculate this ratio for both the secondary and the tertiary sector. The results are shown in Figure 8, which indicates that these ratios almost always were greater than one. Intuitively, if the pace of structural transformation is the same across regions, then it may not contribute to convergence in regional productivity. A smaller ratio will make the convergence effects of structural transformation larger given that the pace of structural transformation in the lagging regions (the bottom quintile) is greater than or equal to that in the leading regions (the top quintile). The ratios for both the secondary and the tertiary sector are lower in the first half of the post-war era (1955–1970), suggesting that structural transformation had a strong influence on regional convergence. However, we find a somewhat reverse trend thereafter. This reversal must have contributed to the slowdown in regional convergence through the process of structural transformation from the early 1970s. To sum up, the rapid productivity convergence within the secondary and tertiary sectors relative to the productivity convergence within the primary sector during the period 1890–1955 prepared an important basis for the large convergence effects of structural transformation in the post-war years, especially the high-speed growth era.

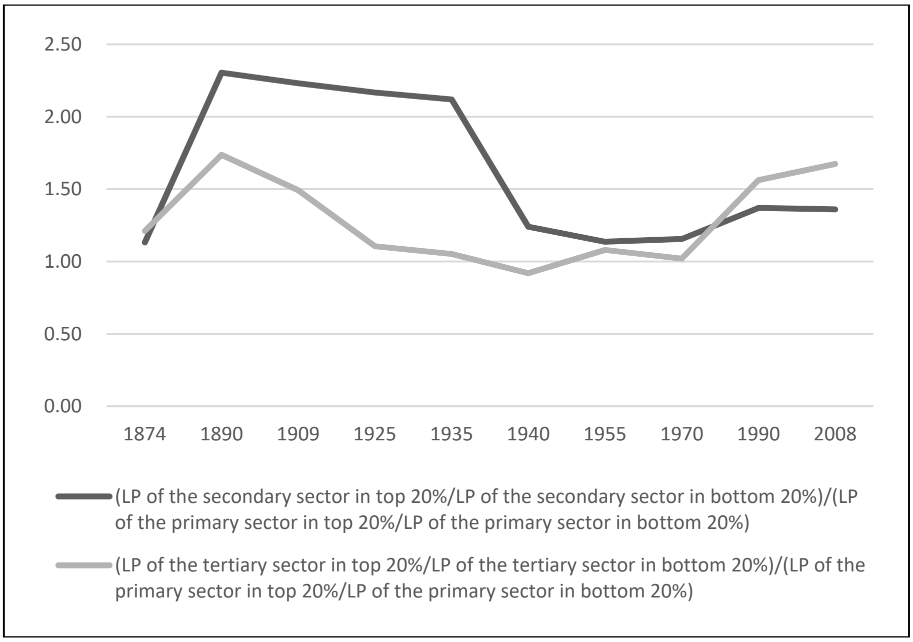


Figure 7. Ratio of sectoral productivity gap between the top and the bottom quintile

4.3. Sectoral productivity (at a more disaggregated level)

We now examine the role of structural transformation in regional convergence looking at a more detailed sectoral classification using the second dataset consisting of benchmark years 1909, 1925, 1940, 1955, 1970, 1990, and 2008. Regional convergence in productivity within a sector plays a key role in regional aggregate productivity convergence (Bernard and Jones, 1996a, 1996b, 1996c). In Japan, manufacturing has been the leading sector in regional convergence within a sector, followed by construction and transport (Appendix Figure 3). In the period from 1909–1925, regional convergence was achieved mainly through the within-sector effect. In contrast, the between-sector effect worked in the direction of divergence (Table 1). Productivity growth in agriculture and manufacturing (particularly in textiles) made the greatest contribution to within-sector productivity growth (Figure 8). This finding is in line with the results obtained by Chenery, et al (1962). Almost all prefectures experienced productivity growth in textile manufacturing (the leading prefectures were Aomori, Kochi, Miyazaki, Mie, and Niigata). Structural transformation occurred mainly through the reallocation of labor from agriculture and construction (in most prefectures) to machinery (in the manufacturing sector), commerce and services, and transport and communication.

Between 1925 and 1940, there was a divergence in regional productivity. While within-sector productivity growth worked in the direction of convergence, this effect was outweighed by the divergence effect of the structural-transformation effect. This was also the only period when productivity growth in agriculture was negative,[25] which in turn reduced the contribution of within-sector growth. Labor reallocation out of agriculture continued to take place. Within manufacturing, the food and textile industries also experienced a drop in their labor shares. Within manufacturing, the employment shares of the chemical and machinery industries registered increases, possibly reflecting war-time needs.

After World War II, Japan achieved remarkable growth in the period from 1955 to 1970 (the high-speed growth era). This is the only period when productivity growth was positive for all sectors in all prefectures. In the high-speed growth era, the contribution of the dynamic between-sector effect also became positive, suggesting that resources moved from low-productivity to high-productivity sectors. Labor continued to move out of agriculture and mining, while the employment shares of most secondary and tertiary sectors increased. Sectors whose labor shares increased in all regions were ceramics, metal, machinery, construction, commerce and services, and transport and communication. In this period, the within-sector effect was driven by agriculture, manufacturing, and commerce and services, while the between-sector effect was driven by commerce and services. Wholesale and retail trade (WRT), private sector services,[26] and transport and communication were the main drivers of between-sector growth (Figure 9).

[25] During this period, Japan's agricultural sector experienced serious demand shocks and a decline in the terms of trade. In the 1930s, exports of raw silk to the United States fell due to the Great Depression and the invention of nylon and other synthetic fiber products, which began to replace silk items (Hatase, 2002). Moreover, probably reflecting the development of Japan's manufacturing sector (boosting exports of light industry products and import-substitution in the heavy-chemical industry), Japan's agricultural sector was losing comparative advantage and imports of agricultural products such as rice increased (Yukizawa and Maeda, 1978). These demand shocks may have slowed down productivity growth in the agricultural sector.

[26] Private services include private medical services, private education services, private hygiene services, private research services, information and internet-based services, work in eating and drinking places, automobile maintenance, etc.

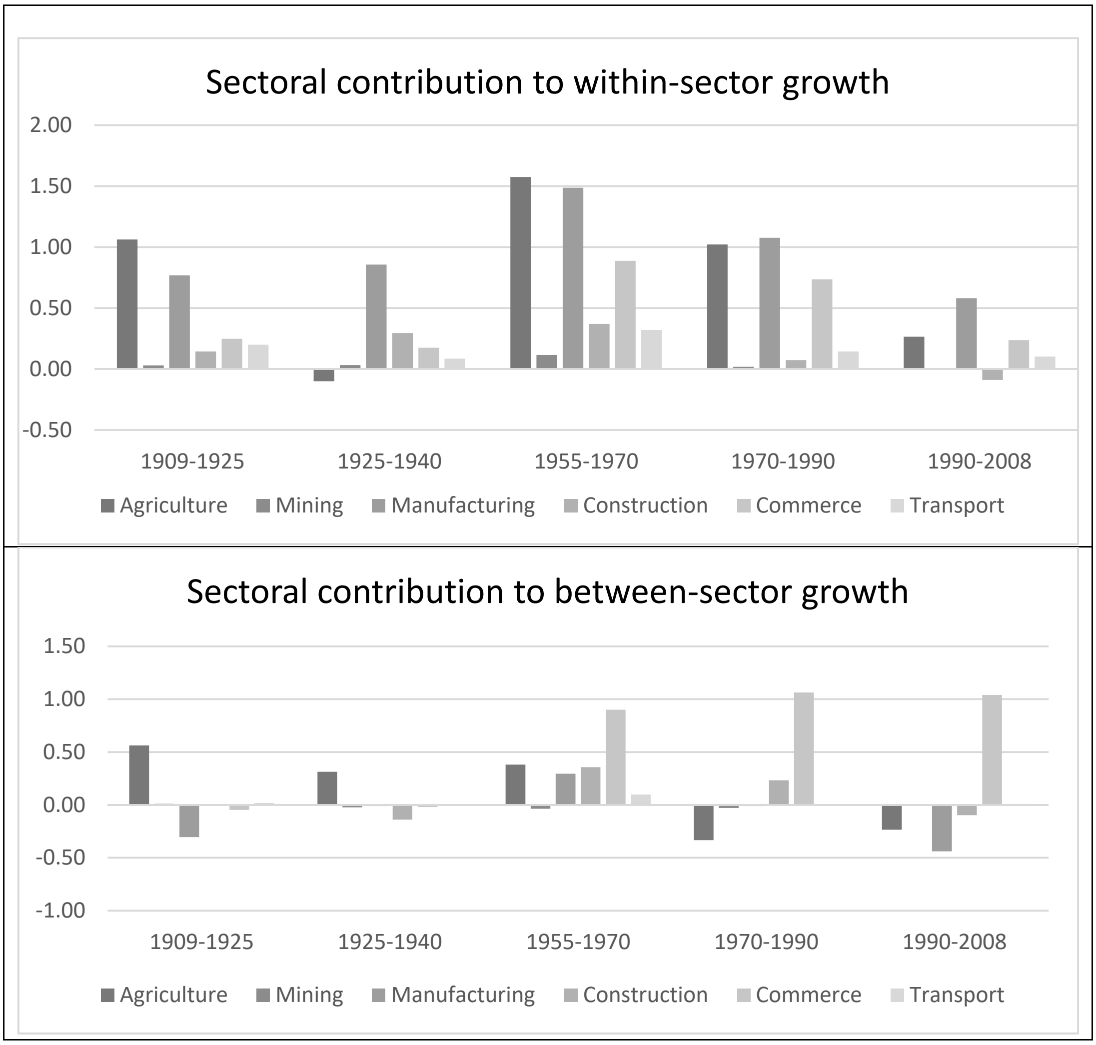


Figure 8. Sectoral contributions to aggregate productivity growth

Note: The vertical axis measures productivity growth (approximated by the log difference in productivity levels)

Next, using the third dataset, which provides even more disaggregated data for the period 1955–2008, we find that in the next two periods, 1970–1990 and 1990–2008, regional convergence in aggregate productivity was mainly achieved through the process of structural transformation.[27] The commerce and services sectors (mainly WRT and private sector services) provided the main thrust to between-sector growth. Between 1970 and 1990, the primary winners in employment shares were construction, commerce and services, and machinery (only in certain prefectures). Another important point to note here is that the rate of productivity growth slowed down compared to the previous period in all sectors including commerce and services. Average productivity growth between 1990 and 2008 was the lowest in the post-war period, with productivity growth actually turning negative in mining, food, textiles, metal, and construction. Moreover, for the first time in Japan's history, labor was moving out of most manufacturing sector industries (along with primary sectors) to private sector services.

[27] We calculate the sectoral composition of the growth effect of structural transformation based on equation (1).

To sum up, we observe two secular trends of convergence: regional convergence in the pre-war period was driven by within-sector productivity growth through agriculture and manufacturing (cotton), while regional convergence in the post-war period was mainly driven by the between-sector reallocation effect through commerce and services. The between-sector reallocation effect can be further divided into two distinct phases: until 1990, both WRT and private sector services contributed to this reallocation effect, while from 1990 onward it was only private sector services.

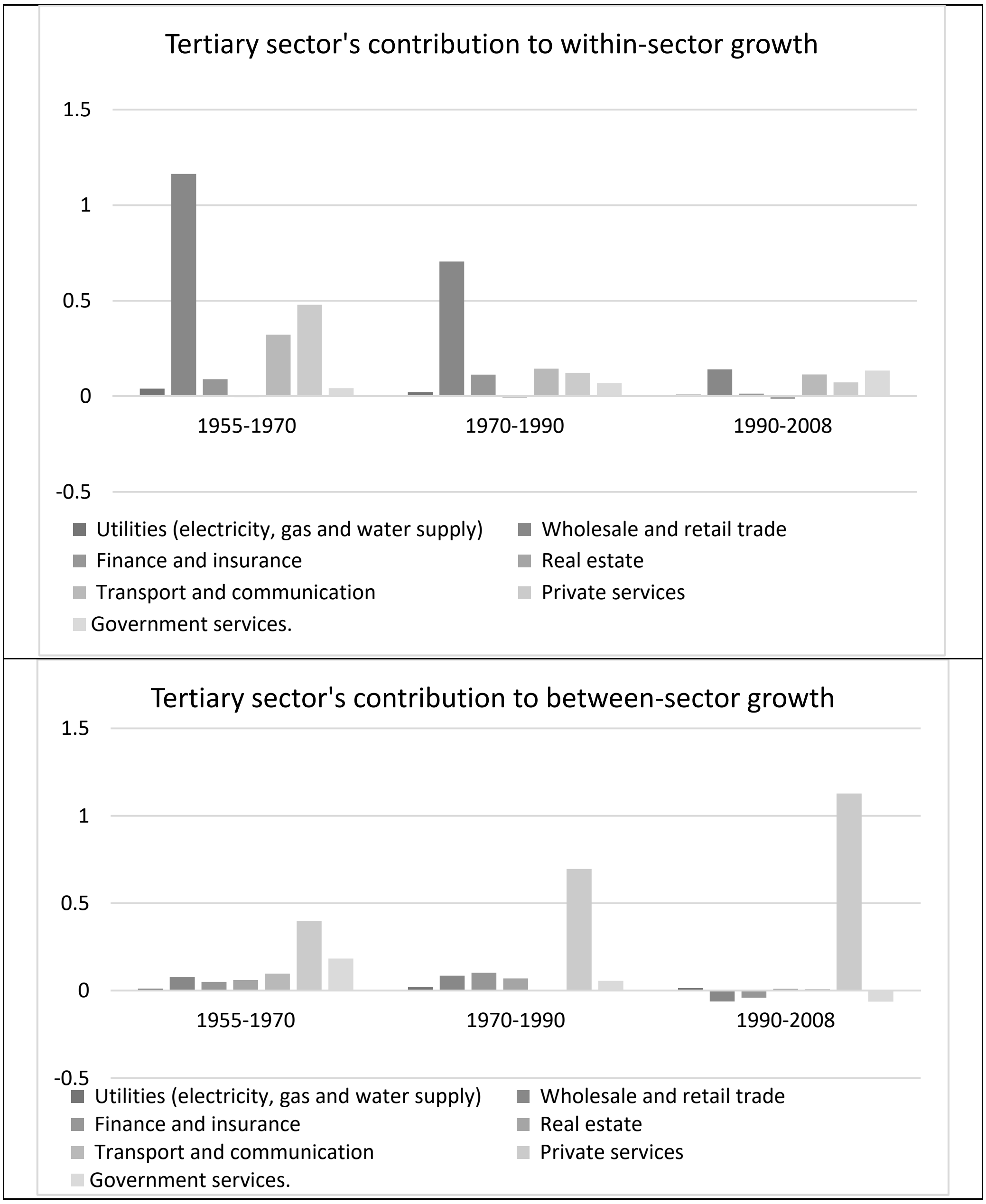


Figure 9. Tertiary sector contributions to aggregate productivity growth

Note: The vertical axis measure the productivity growth (approximated by the log difference in productivity levels)

5. Conclusion

The main purpose of this study was to estimate the potential role that the process of structural transformation played in regional productivity convergence in Japan. Using a novel dataset for 47 Japanese prefectures spanning a period of nearly 135 years (from 1874 to 2008), and based on a simple theoretical framework, we find that the process of structural transformation played a crucial role (mainly through commerce and the services sector) in aggregate productivity growth, productivity catch-up, and regional convergence, especially in the second half of the 20th century. In addition, regions with a faster reallocation of labor across sectors and larger sectoral productivity gaps showed a stronger effect. However, since the early 1970s, the pace of convergence slowed down as convergence in the growth effect of structural transformation was frequently offset by the divergence effect of within-sector productivity growth.

This study has a number of implications. First, it provides novel insights for understanding regional convergence in a multi-sectoral set up. The framework is easy to implement and can be extended to any country where regional data on sectoral labor shares and value added are available. We did a quick test using the historical data available for the US for the period from 1840 to 1987, covering five benchmark years (1840, 1880, 1900, 1954, and 1987) and nine regions, i.e., NE, MA, ENC, WNC, SA, ESC, WSC, MT, and PC,[28] and two sectors, agriculture and non-agriculture. The results are shown in Figure 10. We find that regional divergence in labor productivity in the period from 1840 to 1880 was primarily driven by the within-sector growth effect. Both within-sector and between-sector growth effects contributed to regional convergence in the next period, 1880–1900. However, regional convergence in the next two periods, 1900–1954 and 1954–1987, was mainly driven by σ-convergence in structural transformation-led growth. This supports the empirical findings provided in Caselli and Coleman II (2001). The results for the post-WWII period for Japan and the US are quite similar. With the growing literature on structural transformation in less developed countries (Dekle and Vandenbroucke (2012) on China, Verma (2012) on India, and Ungor (2011) on Latin America and East Asia, among others), we hope that the decomposition framework built in this study will be useful for analyzing regional growth dynamics and related factors in developing countries.

[28] See Kim (1998) for a detailed description of the data. The regions are: NE=New England, MA=Middle Atlantic, ENC=East North Central, WNC=West North Central, SA=South Atlantic, ESC=East South Central, WSC=West South Central, MT=Mountain, and PC=Pacific. Labor productivity is computed based on labor shares by sector and sectoral earnings data based on personal income.

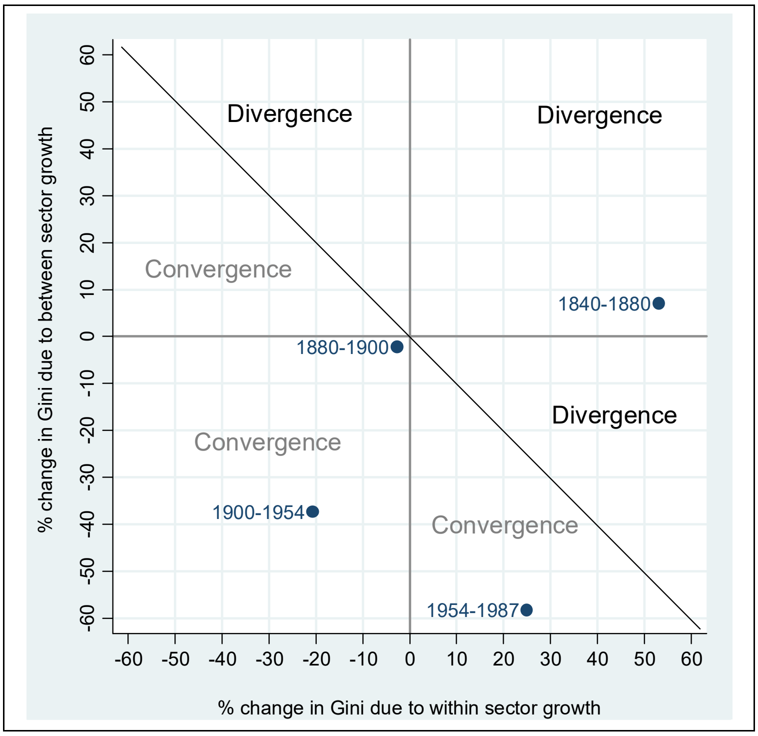


Figure 10. Contribution of structural transformation to regional convergence (σ) in labor productivity in the US, 1880–1987

Note: This figure only shows the sign of the σ-convergence of aggregate productivity (resulting from the magnitudes and signs of σ-convergence of the within-sector and the between-sector effects). It does not show the actual measure of σ-convergence of aggregate productivity. The vertical and horizontal axes measure the percentage change in the Gini index[29] (initial year of each period) in regional labor productivity due to the between-sector and within-sector effects, respectively. The diagonal line demarcates the areas that indicate convergence and divergence.

Second, the fact that within-sector and between-sector growth effects can have opposing effects on σ-convergence in aggregate productivity growth has direct implications for industrial performance and allocative efficiency. Among other factors, such opposing effects could be driven by barriers to resource allocation and/or a disproportionate increase in input factor shares. In Japan, average sectoral productivity growth slowed down during the early 1990s and became negligible or even negative in many sectors, leading us to suspect that the misallocation of factor inputs across sectors and regions[30] contributed to this. Examining the potential role of resource misallocation represents a promising area for future research. Finally, we observe two distinct phases of structural transformation. In the pre-WWII period, labor moved from the primary to the secondary and tertiary sectors, while in the post-war period, labor moved from the secondary to the tertiary sector (in particular

[29] The Gini index as a measure of inequality in regional productivity in the US was 0.16 in 1840, 0.22, in 1880, 0.20 in 1900, 0.08 in 1954, and 0.06 in 1987. Average annual labor productivity growth was 0.80 in 1840–80, 0.70 in 1880–1900, 3.9 in 1900–54, and 6.1 in 1954–87. Finally, the contribution of structural transformation to labor productivity growth was 19% in 1840–80, 43% in 1880–1900, 16% in 1900–54, and 10% in 1954–87.

[30] In a recent study, Tombe and Zhu (2015) find that the decline in internal trade and migration costs accounts for roughly two-fifths of aggregate labor productivity growth in China between 2000 and 2005.

private sector services). We do not investigate the factors[31] that led to the process of structural transformation in Japan, particularly in the second half of the 20th century. Last but not least, capital movements across regions as well as the effect of capital accumulation and changes in total factor productivity are other potential factors playing a role in differences in productivity performance that it would be worthwhile to examine. We leave these tasks for future research.

[31] A growing literature addresses these issues. See, for example, Herrendorf et al. (2014) for a literature survey. In a recent study, Herrendorf et al. (2015) find that differences in technical progress across sectors play a much greater role in structural transformation than other factors.

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Appendix 1

For the sum of two random variables, it is straightforward to decompose the variance. However, it is practically impossible to decompose the Gini index of the sum of two random variables unless certain assumptions are met (Yitzhaki, 2003). Following Yitzhaki (2003), we define two additional terms: the Gini mean difference, $G_{MD} = 4Cov(x, F(x))$, where x is a random variable that represents labor productivity (x) and F is the cumulative distribution of x, and the Gini correlation coefficient between two random variables, $\Upsilon_{xy} = \frac{Cov\,(x,\ F(y))}{Cov(y,\ F(y))}$, where x and y are two random variables.

Lemma 1. A necessary and sufficient condition for two Gini correlation coefficients to be equal, i.e., $\Upsilon_{xy} = \Upsilon_{yx}$, is $C_x^y = C_y^x$, where C_x^y represents the area enclosed by the concentration curve of x with respect to y, and similarly C_y^x represents the area enclosed by the concentration curve of y with respect to x (Yitzhaki, 2003).

Since by construction $V^{t+1} = V^t + \Phi(WS) + \Phi(ST)$, using the definitions of $V_{WS}^{t+1}$and V_{ST}^{t+1}, we can write the linear relationship $V^{t+1} = V_{WS}^{t+1} + V_{ST}^{t+1} - V^t$.

Assuming that Lemma 1 holds, we can express the Gini mean difference of V^{t+1} in the following manner:

(1) $$[G_{MD}(V^{t+1})]^2 = [G_{MD}(V_{WS}^{t+1})]^2 + [G_{MD}(V_{ST}^{t+1})]^2 + [G_{MD}(V^t)]^2 + 2G_{MD}(V_{WS}^{t+1})G_{MD}(V_{ST}^{t+1})\Upsilon_{V_{WS}^{t+1}V_{ST}^{t+1}} - 2G_{MD}(V_{WS}^{t+1})G_{MD}(V^t)\Upsilon_{V_{WS}^{t+1}V^t} - 2G_{MD}(V_{ST}^{t+1})G_{MD}(V^t)\Upsilon_{V_{ST}^{t+1}V^t}.$$

Equation (1) closely resembles the variation decomposition expression for the sum of three random variables. Using the covariance definition (Lerman and Yitzhaki, 1985), we can write the Gini coefficient of V^t as $G^t(V^t) = \frac{Cov\,(V^t,\ F(V^t))}{E(V^t)}$, where V^t is labor productivity in period t, F is the cumulative distribution of V^t, and $E(V^t)$ is the expectation of V^t. This yields the following relationship between G_{MD} and $G^t(V^t)$: $G_{MD} = 4E(V^t)G^t(V^t)$. Plugging this back into equation (1), we obtain an expression for equation (1) in terms of the Gini indices:

(2) $$[E(V^{t+1})G^{t+1}(V^{t+1})]^2 = [E(V_{WS}^{t+1})G^{t+1}(V_{WS}^{t+1})]^2 + [E(V_{ST}^{t+1})G^{t+1}(V_{ST}^{t+1})]^2 + [E(V^t)G^t(V^t)]^2 + 2E(V_{WS}^{t+1})G^{t+1}(V_{WS}^{t+1})E(V_{ST}^{t+1})G^{t+1}(V_{ST}^{t+1})\Upsilon_{V_{WS}^{t+1}V_{ST}^{t+1}} - 2E(V_{WS}^{t+1})G^{t+1}(V_{WS}^{t+1})E(V^t)G^t(V^t)\Upsilon_{V_{WS}^{t+1}V^t} - 2E(V_{ST}^{t+1})G^{t+1}(V_{ST}^{t+1})E(V^t)G^t(V^t)\Upsilon_{V_{ST}^{t+1}V^t}.$$

If we assume that the Υs are equal to 1, then equation (2) can be transformed into

(3) $$[E(V^{t+1})G^{t+1}(V^{t+1})]^2 = [E(V_{WS}^{t+1})G^{t+1}(V_{WS}^{t+1}) + E(V_{ST}^{t+1})G^{t+1}(V_{ST}^{t+1}) - E(V^t)G^t(V^t)]^2,$$

where the right-hand side becomes a squared term of a linear relationship with three variables. Depending on whether the square-root term is positive or negative, we get two expressions for equation $G^{t+1}(V^{t+1})$. Since the value of the Gini coefficient lies between 0 and 1 and it can be plausibly assumed that $|G^{t+1}(V_{WS}^{t+1}) + G^{t+1}(V_{ST}^{t+1})| > |G^t(V^t)|$, we consider only the positive root and express equation (3) with an approximation error term (φ), written in implicit form as

(4) $G^{t+1}(V^{t+1}) = G^{t+1}(V_{WS}^{t+1}) + G^{t+1}(V_{ST}^{t+1}) - G^t(V^t) + \varphi.$

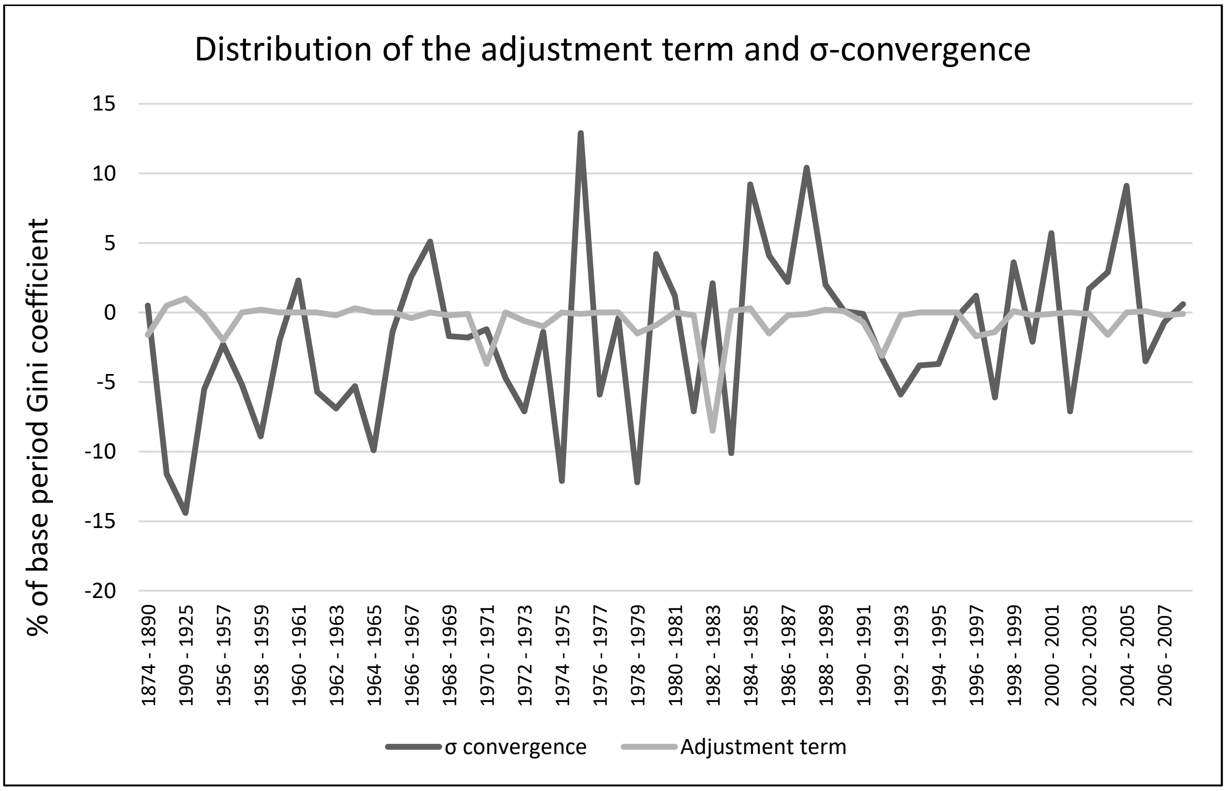
Subtracting $G^t(V^t)$ from both sides, we get

(5) $\varphi = [G^{t+1}(V^{t+1}) - G^t(V^t)] - [G^{t+1}(V_{WS}^{t+1}) - G^t(V^t)] + [G^{t+1}(V_{ST}^{t+1}) - G^t(V^t)]$

Since we can only approximate the value of $G^{t+1}(V^{t+1}) - G^t(V^t)$ based on certain assumptions, it is imperative that we provide some theoretical justification. The size of φ essentially depends on two factors. The first is the extent to which Lemma 1 is violated, i.e., when $2\Upsilon_{xy}(or\ \Upsilon_{yx}) \neq \Upsilon_{yx} + \Upsilon_{xy}$. The linear relationship in equation (1) depends on how closely $\Upsilon_{yx} + \Upsilon_{xy}$ approximates to 2. In this sense, Lemma 1 is a more binding condition, as it requires each Υ_{xy} to be sufficiently close to 1. If the ϒs are close to 1, then the magnitude of φ is small. Second, the size of φ also depends on the extent to which the expectation terms $E(V^{t+1})$, $E(V_{WS}^{t+1})$, $E(V_{ST}^{t+1})$, and $E(V^t)$ differ in magnitude. The implicit form of φ assumes this fact. If these terms differ to a large extent, then the magnitude of φ becomes large. On the empirical side, the value of φ can be estimated for any time period, since $Gini(V)$, $\Delta Gini(V_{WS})$, and $\Delta Gini(V_{ST})$ are separately calculated. We conduct a *t*-test to check whether the distribution of φ across periods is sufficiently close to zero.

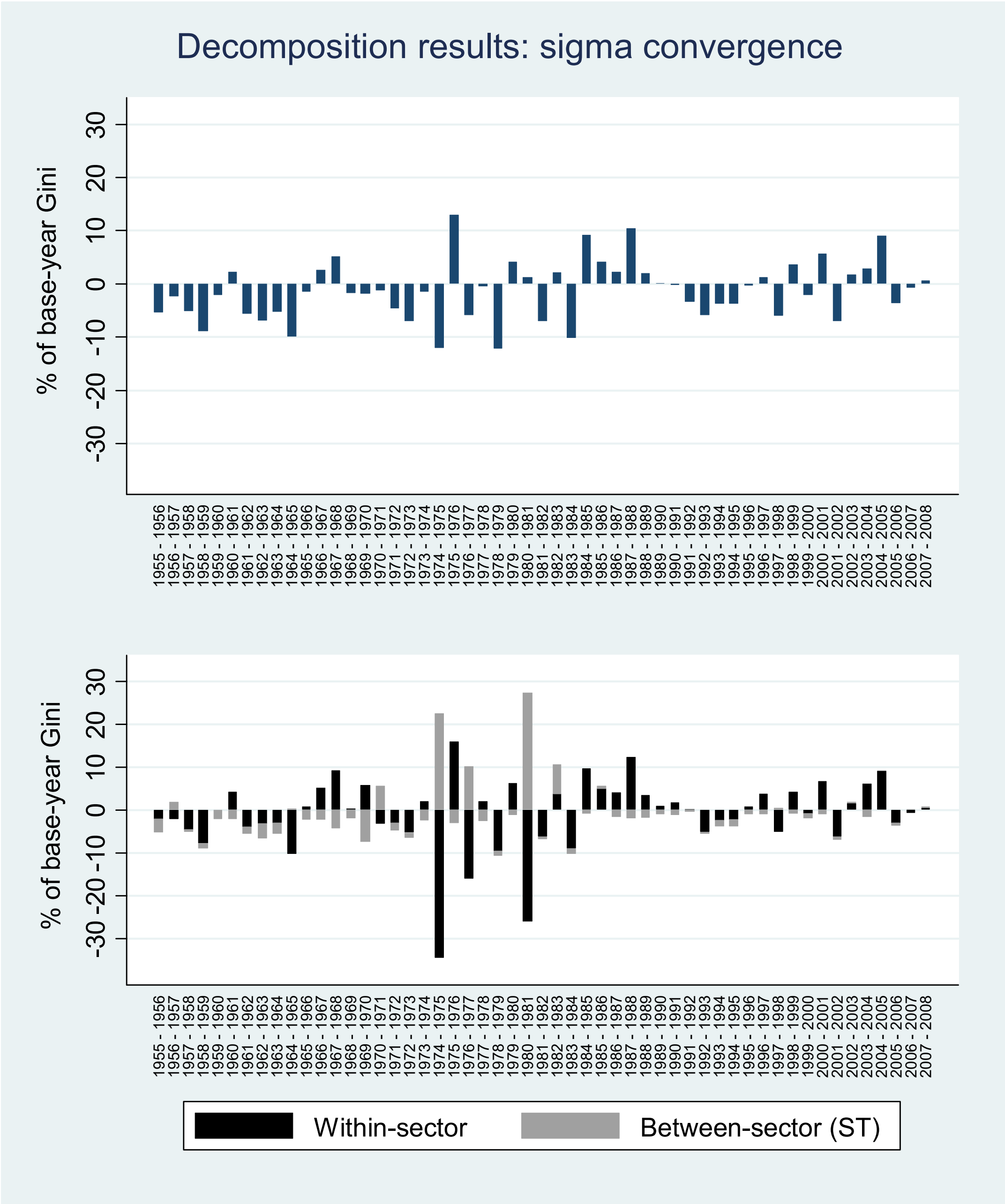
Appendix Figures and Tables

Appendix Figure 1. Distribution of the adjustment term



Note: The figure shows that the distribution of the adjustment term is close to zero except in a few periods. A t-test accepts the null hypothesis that $\varphi = 0$ at the 10% significance level.

Appendix Figure 2. Decomposition of changes in the Gini coefficient for aggregate productivity: 1955–2008



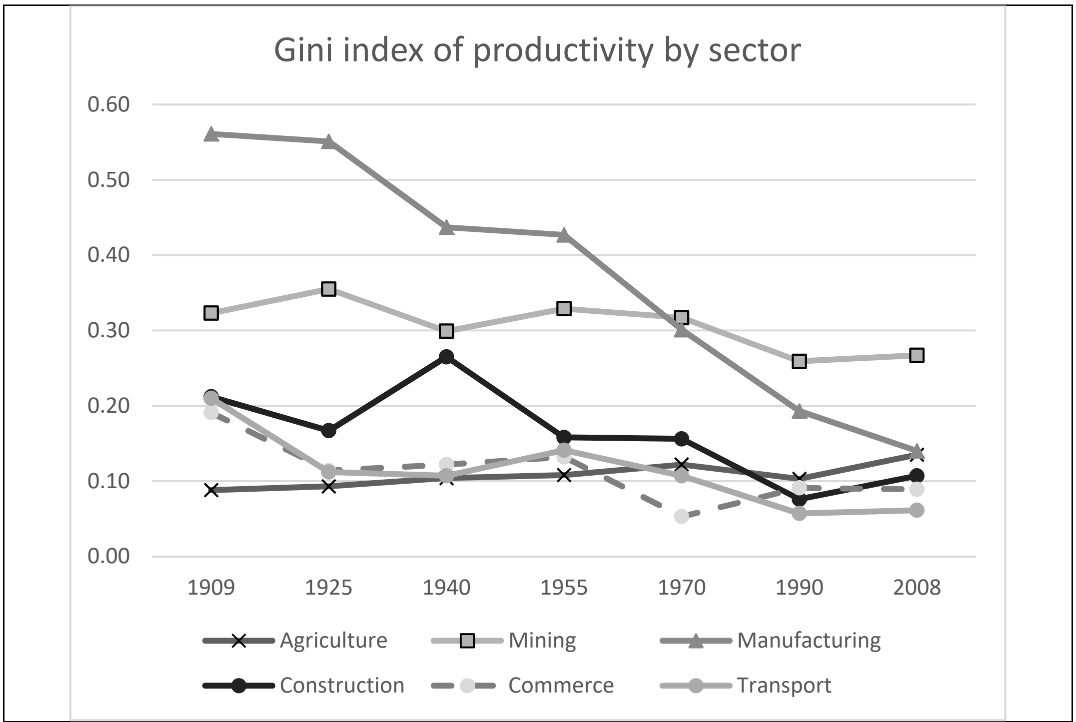
Appendix Table 1. Detailed growth decomposition results

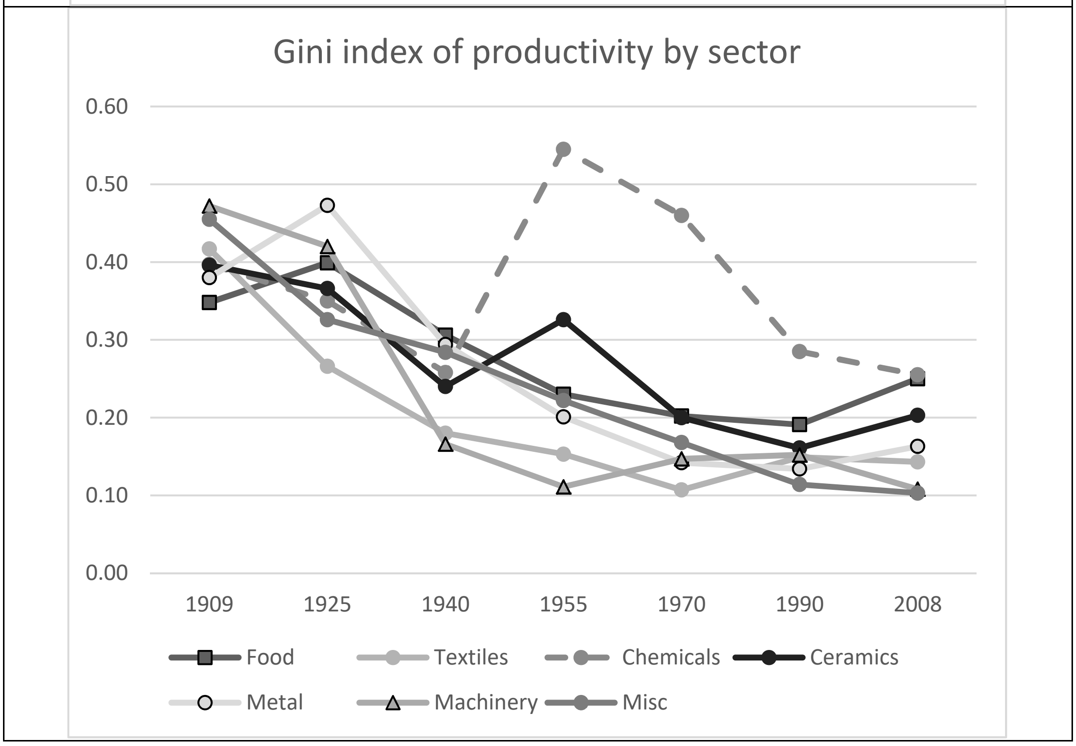
			Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	**Total**
1874-90	Annual Growth		0.852	1.317	1.259	0.138	1.631	**1.040**
	Within-sector	Primary	0.678	1.158	0.954	-0.032	0.656	**0.688**
		Secondary	0.136	-0.013	0.085	0.181	0.310	**0.139**
		Tertiary	0.069	0.050	0.060	0.071	0.079	**0.066**
	Between-sector	Static	0.066	0.341	0.295	-0.074	0.582	**0.239**
		Dynamic	-0.097	-0.219	-0.135	-0.008	0.005	**-0.092**
1890-09	Annual Growth		1.581	1.764	1.618	2.013	2.261	**1.837**
	Within-sector	Primary	0.970	0.946	0.862	1.019	0.975	**0.953**
		Secondary	0.390	0.676	0.564	0.567	0.798	**0.594**
		Tertiary	0.152	0.090	0.136	0.161	0.004	**0.110**
	Between-sector	Static	0.097	0.103	0.077	0.292	0.597	**0.227**
		Dynamic	-0.028	-0.050	-0.021	-0.026	-0.112	**-0.047**
1909-25	Annual Growth		2.671	2.775	2.880	2.619	2.593	**2.711**
	Within-sector	Primary	1.092	1.179	1.173	1.071	0.785	**1.063**
		Secondary	0.695	0.734	0.746	0.726	0.834	**0.746**
		Tertiary	0.621	0.498	0.593	0.414	0.243	**0.480**
	Between-sector	Static	0.171	0.275	0.271	0.351	0.757	**0.359**
		Dynamic	0.092	0.089	0.096	0.057	-0.027	**0.063**
1925-40	Annual Growth		0.610	0.515	0.198	0.802	0.623	**0.543**
	Within-sector	Primary	-0.156	-0.342	-0.341	-0.053	-0.207	**-0.221**
		Secondary	0.750	0.812	0.599	0.812	0.863	**0.763**
		Tertiary	-0.146	-0.129	-0.228	-0.175	-0.267	**-0.189**
	Between-sector	Static	0.178	0.167	0.184	0.264	0.251	**0.208**
		Dynamic	-0.016	0.007	-0.016	-0.046	-0.017	**-0.018**
1955-70	Annual Growth		6.539	6.571	6.709	6.829	6.279	**6.588**
	Within-sector	Primary	1.805	1.834	1.770	1.517	0.947	**1.579**
		Secondary	1.199	1.211	1.470	1.282	2.210	**1.474**
		Tertiary	1.127	1.120	1.123	1.098	1.566	**1.205**
	Between-sector	Static	1.995	2.007	1.838	2.338	1.343	**1.903**
		Dynamic	0.414	0.400	0.507	0.593	0.213	**0.427**
1970-90	Annual Growth		3.884	3.907	3.894	3.738	3.060	**3.701**
	Within-sector	Primary	1.228	1.314	1.183	0.930	0.435	**1.022**
		Secondary	0.695	0.526	0.773	0.868	1.081	**0.788**
		Tertiary	0.887	0.924	0.876	0.875	1.103	**0.932**
	Between-sector	Static	1.326	1.459	1.303	1.304	0.562	**1.193**
		Dynamic	-0.252	-0.316	-0.241	-0.239	-0.120	**-0.234**
1990-08	Annual Growth		1.910	1.912	1.751	1.733	0.898	**1.649**
	Within-sector	Primary	0.361	0.398	0.277	0.298	0.136	**0.295**
		Secondary	0.785	0.683	0.883	1.043	0.517	**0.784**
		Tertiary	0.473	0.499	0.382	0.313	0.311	**0.397**
	Between-sector	Static	0.471	0.479	0.386	0.337	0.086	**0.355**
		Dynamic	-0.181	-0.147	-0.177	-0.257	-0.153	**-0.183**

Appendix Table 2. Ranking of prefectures based on real aggregate labor productivity

Prefecture	1874	1890	1909	1925	1935	1940	1955	1970	1990	2008
Aichi	28	12	7	10	8	8	17	12	7	5
Akita	41	29	16	24	27	29	20	35	39	25
Aomori	19	13	37	39	45	44	41	37	45	44
Chiba	47	45	42	43	41	45	26	3	4	22
Ehime	21	32	21	21	19	14	31	28	30	37
Fukui	8	17	35	32	20	25	21	38	21	9
Fukuoka	13	8	9	6	4	4	8	17	20	33
Fukushima	31	27	26	35	39	35	23	40	31	7
Gifu	42	37	38	36	30	26	32	27	23	32
Gumma	20	36	34	14	35	32	30	33	25	30
Hiroshima	34	34	19	28	15	13	14	10	8	8
Hokkaido	3	3	6	7	12	10	3	11	24	39
Hyogo	7	5	5	3	5	5	7	7	5	17
Ibaragi	33	15	12	23	26	31	22	26	12	6
Ishikawa	25	18	32	26	23	20	15	21	18	21
Iwate	30	30	31	31	28	19	46	44	46	43
Kagawa	12	21	14	22	21	16	33	20	22	29
Kagoshima	32	42	40	46	46	46	43	45	42	36
Kanagawa	23	6	3	5	3	3	2	1	2	12
Kochi	6	24	27	37	34	33	38	31	47	46
Kumamoto	35	22	23	19	29	28	39	39	38	40
Kyoto	4	4	4	4	6	6	9	13	16	19
Mie	17	20	18	12	17	23	16	9	11	2
Miyagi	29	26	13	17	33	34	18	23	29	31
Myazaki	26	23	28	30	22	21	45	42	43	45
Nagano	45	41	41	29	44	38	37	34	36	18
Nagasaki	14	19	33	15	18	18	29	41	41	42
Nara	11	7	8	8	10	11	5	8	9	34
Niigata	39	33	29	38	24	24	34	32	35	28
Oita	44	43	43	34	31	30	25	22	28	20
Okayama	27	31	24	33	16	22	35	18	17	23
Okinawa	38	47	47	47	47	47	n.a.	n.a.	33	47
Osaka	2	2	2	2	1	1	10	4	6	15
Saga	22	16	30	20	25	27	24	30	37	27
Saitama	24	35	25	42	40	39	27	19	19	38
Shiga	9	14	22	25	11	15	12	14	3	3
Shimane	40	46	46	41	36	40	42	46	40	41
Shizuoka	36	39	17	13	14	17	6	15	14	4
Tochigi	43	44	45	44	43	42	44	29	15	10
Tokushima	10	28	36	40	32	36	28	24	32	13
Tokyo	1	1	1	1	2	2	1	5	1	1
Tottori	46	38	39	45	42	41	13	25	34	24
Toyama	16	11	11	18	13	9	19	16	13	16
Wakayama	5	9	10	9	9	12	4	2	26	35
Yamagata	18	10	20	16	38	43	36	43	44	26
Yamaguchi	15	25	15	11	7	7	11	6	10	11
Yamanashi	37	40	44	27	37	37	40	36	27	14

Appendix Figure 3. Gini index of productivity by sector





Appendix Figure 4. Contribution of manufacturing sector to growth