RIETI Discussion Paper Series 15-E-089

Industry-level Factor Inputs and TFP and Regional Convergence: 1970-2008

TOKUI Joji
RIETI

MAKINO Tatsuji
Hitotsubashi University

FUKAO Kyoji
RIETI

Research Institute of Economy, Trade & Industry, IAA

The Research Institute of Economy, Trade and Industry
http://www.rieti.go.jp/en/

RIETI Discussion Paper Series 15-E-089

July 2015

Industry-level Factor Inputs and TFP and Regional Convergence: 1970–2008*

TOKUI Joji

RIETI, Shinshu University

MAKINO Tatsuji

Hitotsubashi University

FUKAO Kyoji

RIETI, Hitotsubashi University

Abstract

Using the Regional-Level Japan Industrial Productivity (R-JIP) Database, we examined prefectural differences in labor productivity from 1970 to 2008 from various angles by looking at prefectural differences in industrial structure and prefectural and industry differences in factor inputs and productivity. First, in section 2, we decomposed prefectural labor productivity differences into the contribution of differences in industrial structure and the contribution of within-industry differences in labor productivity, and further decomposed the latter into the contribution of capital-labor ratio, labor quality, and total factor productivity (TFP). Next, in section 3, we decomposed prefectural differences in productivity and factor inputs into the share effect due to prefectural differences in industrial structure and the within effect due to prefectural differences in productivity or factor intensity within the same industry. Finally, in section 4, we examined which industries make the largest contribution to prefectural differences in productivity and how they do so—namely, through differences in capital-labor ratio, labor quality, or TFP, and through the share effect or the within effect.

The results of these analyses show that industrial structures among prefectures became increasingly similar over the roughly four decades, and that this greatly contributed to the decline in labor productivity differences overall. In contrast, within-industry differences in labor productivity among prefectures declined only marginally over the same period and therefore hardly contributed to the reduction in prefectural labor productivity differences. The decomposition of within-industry labor productivity differences shows that although such within-industry differences show relatively little change over time, the factors contributing to them did shift considerably. That is, while regional differences in capital-labor ratios decreased substantially, regional within-industry differences in TFP increased. Therefore, the increase in within-industry differences in TFP is the main cause of the recent slowdown of the convergence of regional labor productivity differences. By decomposing the covariance between within-industry TFP differences and labor productivity differences among prefectures into each industry's contribution, we find vital contribution of service industries, especially wholesale and retail trade, and other non-government services, suggesting the important role of these service industries in recent increase of within-industry differences in TFP, and thereby in the recent slowdown of the convergence of regional labor productivity differences.

Keywords: Regional economy, Productivity, Industrial Structure, Factor Intensity

JEL classification: O18, D24, L16

*This study is conducted as a part of the Project "Regional-Level Japan Industrial Productivity Database: Database Refinement and Its Analysis" undertaken at Research Institute of Economy, Trade and Industry (RIETI). We would like to thank Dr. Masahisa Fujita (President and CRO of the Research Institute of Economy, Trade and Industry), Dr. Masayuki Morikawa (Vice-Chairman and Vice-President of Research Institute of Economy, Trade and Industry) and other participants of the workshop held at RIETI for helpful comments on earlier versions of this paper.

1. Introduction

Focusing on the period from 1955 to 2008, Fukao, Makino, and Tokui (2015) examined developments in prefectural factor inputs and their role in the convergence of prefectural labor productivity. It was shown that prefectural differences in the capital–labor ratio, labor quality, and total factor productivity (TFP) to different degrees all contributed to regional inequality in labor productivity at the start of the period in 1955. However, over time, prefectural differences in all three determinants of regional inequality in labor productivity declined, so that by 2008, the productivity gap between leading and lagging prefectures had shrunk considerably.

A shortcoming of this analysis, however, was that the data available for that period were aggregated at the prefectural level; that is, for all industries together. Yet, capital–labor ratios and human-capital intensity differ considerably across industries. This means that the mechanism underlying the convergence in capital–labor ratios, etc., which in turn drove the convergence in labor productivity, remained unclear. One possibility, for example, is that physical and human capital-intensive industries with high labor productivity may have been concentrated in certain prefectures at the start of the period, but became more evenly dispersed across Japan over time, thus resulting in labor productivity convergence. Another possibility, however, is that there were substantial differences in physical and human capital-intensity within the *same* industry at the start of the period, but these within-industry differences declined over time. Of course, it is also possible that the labor productivity convergence was driven by a combination of the two mechanisms.

Thus, in order to gain a better understanding of the mechanisms driving labor productivity convergence, it is necessary to examine the determinants of labor productivity at the industry level for each prefecture. The data necessary for such an analysis have recently become available in the form of the Regional-Level Japan Industrial Productivity (R-JIP) Database jointly compiled by the Research Institute of Economy, Trade and Industry (RIETI) and Hitotsubashi University. Covering the period from 1970 to 2008, the R-JIP Database comprises annual output and factor input data for Japan's 47 prefectures classified into 23 industries.[1] Using the R-JIP data, this paper attempts to obtain a more detailed picture of the forces driving productivity convergence in Japan by examining the role of changes in prefectural industry structures and industry-level factor intensities[2].

The remainder of this paper is organized as follows. Section 2 presents a decomposition of prefectural differences in labor productivity into the contribution of differences in prefectural industrial structures and the contribution of within-industry differences in labor productivity in order to examine the mechanism underlying the observed convergence in prefectural labor productivity.

[1] Specifically, the R-JIP Database contains data on nominal and real value added, capital stock, labor input, social capital stock, estimates of the TFP level and TFP growth, etc., broken down into 23 industries for each of the 47 prefectures. (Data for Okinawa prefecture are available from 1972.) Further details on the R-JIP Database can be found in Tokui et al. (2013).

[2] This paper is the extension of our previous research repoted as Tokui et al. (2013) and forms part of our research at the Research Institute of Economy, Trade and Industry (RIETI).

Moreover, within-industry differences in labor productivity are further decomposed into the contribution of capital–labor ratios, labor quality, and TFP in order to examine their respective contributions to labor productivity differences within the same industry across prefectures. Next, Section 3 focuses on prefectural differences in capital–labor ratios, labor quality, and TFP and decomposes these into the share effect due to differences in industry structures and the within-industry effect due to prefectural differences in factor intensities within the same industry. Based on the decomposition in Section 3, Section 4 then focuses on the correlation between the share and within-industry effects on the one hand and prefectural differences in labor productivity on the other in order to investigate for the different industries how the share and within-industry effects are related to differences in labor productivity.

2 Decomposition of labor productivity differences

When we look at labor productivity in very broadly defined industry categories indicated that the concentration of industries with high labor productivity in prefectures with high per capita income was a key factor underlying differences in prefectural per capita incomes overall. Moreover, the contribution of such differences in industrial structure to prefectural income inequality overall followed an inverted U-curve, generally increasing during the prewar period and decreasing during the postwar period. On the other hand, labor productivity differences within these broad industry categories declined over time and thus worked in the direction of reducing prefectural income inequality. However, when the analysis does not include information on capital input and, for labor input, only include the number of employed persons, but not information on working hours and labor quality, the contributions of prefectural differences in capital input, working hours, labor quality, and TFP are all included in the contribution of differences in labor productivity within the same industry. In other words, such differences in labor productivity within the same industry remained a black box.

In order to open this black box, we use the information on factor inputs and TFP provided in the R-JIP Database and focus on three benchmark years, 1970, 1990, and 2008. We begin our analysis by decomposing differences in labor productivity between the top and bottom 20% of prefectures in terms of labor productivity (where the top and bottom 20% are counted in terms of their cumulative population) into differences in industrial structure and differences in within-industry productivity. Moreover, we decompose the latter – that is, differences in within-industry productivity – into the contribution of differences in capital–labor ratios, differences in labor quality, and differences in TFP, and examine how these factors contributed to developments in prefectural labor productivity differences.[3] As a start, instead of looking at the 23 industry categories in the R-JIP Database, we aggregate the data for these industries into the four broad industry categories (i.e., agriculture, forestry and fisheries; mining, manufacturing, and construction; domestic trade and services; and transport and communication).

Let us describe how we decompose prefectural differences in labor productivity. By definition, prefectural labor productivity consists of the product of the labor productivity in a particular industry in that prefecture and the labor input share (measured in man-hours) in that industry in that prefecture, aggregated over all industries. To start with, equation (1) below shows the decomposition of prefectural differences in labor productivity between the top 20% of prefectures and the national average, where subscript *J* denotes the national average, *T* denotes the top 20% of prefectures (in terms of their cumulative population) with the highest labor productivity for all industries, *v* denotes labor productivity for all industries, θ_n denotes the labor input share of industry *n*, and a_n denotes labor productivity in industry *n*:

$$\ln\left(\frac{v_T}{v_J}\right) = \ln\left(\frac{\sum_n \theta_{n,T} a_{n,T}}{\sum_n \theta_{n,J} a_{n,J}}\right) = \ln\left(\frac{\sum_n \theta_{n,T} a_{n,T}}{\sum_n \theta_{n,J} a_{n,T}}\right) + \ln\left(\frac{\sum_n \theta_{n,J} a_{n,T}}{\sum_n \theta_{n,J} a_{n,J}}\right) \quad (1)$$

In equation (1), the expression after the first equal sign shows the difference between the top 20% of prefectures and the national average for the labor productivity for all industries decomposed into labor productivity by industry and labor input share by industry. This is further decomposed into the two terms in the expression after the second equal sign by first dividing by the aggregated industry-level labor productivity levels in the top 20% of prefectures weighted by the national average industry-level labor input shares and then multiplying again by the same term.

The first term to the right of the second equal sign shows prefectural differences in labor productivity for all industries due to prefectural differences in the labor input share for each industry based on the industry-level labor productivity levels in the top 20% of prefectures. Put differently, the term represents that part of prefectural labor productivity differences caused by relative differences in industrial structure across prefectures. On the other hand, the second term represents the labor productivity difference between the top 20% of prefectures and the national average due to prefectural labor productivity differences within the same industry assuming that the industrial structure measured in terms of labor input shares was the same as the national average.

[3] It should be noted that labor productivity in this paperr is measured not in terms of the number of employed persons (i.e., value added/number of employed persons), but in terms of total man-hours (i.e., value added/man-hours).

Using the value-added share ($S^V_{n,J}$), the last term in equation (1) can be rewritten as follows:

$$\ln\left(\frac{\sum_n \theta_{n,J} a_{n,T}}{\sum_n \theta_{n,J} a_{n,J}}\right) = \ln\left(\sum_n S^V_{n,J}\left(\frac{a_{n,T}}{a_{n,J}}\right)\right) \qquad (2)$$

Further, using linear approximation of equation (2) around $a_{n,T}/a_{n,J} = 1$, the following relationship is obtained:[4]

$$\ln\left(\sum_n S^V_{n,J}\left(\frac{a_{n,T}}{a_{n,J}}\right)\right) \approx \sum_n S^V_{n,J} \ln\left(\frac{a_{n,T}}{a_{n,J}}\right) \qquad (3)$$

Using labor productivity decomposition equations from Fukao, Makino, and Tokui (2015), each $\ln(a_{n,T}/a_{n,J})$ in equation (3), which is the logarithm of the relative labor productivity in the top 20% of prefectures in a particular industry to the national average labor productivity in that industry, can be decomposed into three components: the TFP level, the capital–labor ratio, and labor quality (all relative to the national average). Replacing the last term in equation (1) above with these three components, equation (1) can be rewritten as follows,[5] where the approximation error from equation (3) is explicitly taken into account and represented by the last term:

$$\ln\left(\frac{v_T}{v_J}\right) = \ln\left(\frac{\sum_n \theta_{n,T} a_{n,T}}{\sum_n \theta_{n,J} a_{n,T}}\right) \qquad (4)$$
$$+\sum_n S^V_{n,J} RTFP_{n,T} + \sum_n S^V_{n,J} \frac{1}{2}\left(S^K_{n,T} + S^K_{n,J}\right)\ln\left(\frac{Z_{n,T}}{Z_{n,J}}\right) + \sum_n S^V_{n,J} \frac{1}{2}\left(S^L_{n,T} + S^L_{n,J}\right)\ln\left(\frac{Q_{n,T}}{Q_{n,J}}\right) + \varepsilon'_{T,J}$$

---

4 To derive the right hand side of (3), we apply the first-order Taylor approximation to the left hand side of the equation and then use the approximation $\mathrm{a_{n,T}/a_{n,J}} - 1 \approx \ln(\mathrm{a_{n,T}/a_{n,J}})$ assuming that each $\mathrm{a_{n,T}/a_{n,J}}$ does not greatly differ from 1.

5 In equation (4), S^K stands for the capital cost share, S^L for the labor cost share, *RTFP* for relative TFP, *Z* for the capital stock, and *Q* for labor quality. The concept of relative TFP over cross-sectional data is first formally introduced by Caves, Christensen and Diewert (1982).

Finally, because the same relationship as in equation (4) also holds for the prefectures with the lowest labor productivity (referred to as the bottom 20% of prefectures hereafter), the difference in labor productivity between the top and bottom 20% of prefectures can be expressed as follows:

$$
\begin{aligned}
&\ln\left(\frac{v_T}{v_B}\right) \\
&= \sum_n S^V_{n,J}\left(RTFP_{n,T} - RTFP_{n,B}\right) \\
&+ \sum_n S^V_{n,J}\left(\frac{1}{2}\left(S^K_{n,T} + S^K_{n,J}\right)\ln\left(\frac{Z_{n,T}}{Z_{n,J}}\right) - \frac{1}{2}\left(S^K_{n,B} + S^K_{n,J}\right)\ln\left(\frac{Z_{n,B}}{Z_{n,J}}\right)\right) \\
&+ \sum_n S^V_{n,J}\left(\frac{1}{2}\left(S^L_{n,T} + S^L_{n,J}\right)\ln\left(\frac{Q_{n,T}}{Q_{n,J}}\right) - \frac{1}{2}\left(S^L_{n,B} + S^L_{n,J}\right)\ln\left(\frac{Q_{n,B}}{Q_{n,J}}\right)\right) \qquad (5) \\
&+ \ln\left(\frac{\sum_n \theta_{n,T} a_{n,T}}{\sum_n \theta_{n,J} a_{n,T}}\right) - \ln\left(\frac{\sum_n \theta_{n,B} a_{n,B}}{\sum_n \theta_{n,J} a_{n,B}}\right) \\
&+ \varepsilon'_{T,J} - \varepsilon'_{B,J}
\end{aligned}
$$

where the first term on the right-hand side is the weighted TFP difference within each industry between the top and bottom 20% of prefectures, the second term is the weighted capital–labor ratio difference within each industry, the third term is the weighted labor quality difference within each industry, the fourth and fifth terms are prefectural differences in labor productivity due to differences in industrial structure, and the last two terms are approximation errors. The analysis in this section focuses on the first three terms representing prefectural differences within each industry.

The results of the factor decomposition of prefectural differences in labor productivity using equation (5) for the years 1970, 1990, and 2008 employing the R-JIP Database are shown in Table 1.

Table 1 Factor decomposition of labor productivity differences between the top and bottom 20% of prefectures

	1970	1990	2008
Differences in labor productivity	0.642	0.454	0.435
	(100.0)	(100.0)	(100.0)
Differences in industrial structure	0.275	0.119	0.102
	(42.8)	(26.3)	(23.5)
Within-industry differences in labor productivity	0.367	0.335	0.333
	(57.2)	(73.7)	(76.5)
Contribution of TFP	0.162	0.205	0.299
	(25.3)	(45.2)	(68.7)
Contribution of capital-labor ratio	0.149	0.067	0.010
	(23.2)	(14.7)	(2.3)
Contribution of labor quality	0.109	0.103	0.069
	(16.9)	(22.7)	(15.9)
Measurement error	-0.053	-0.040	-0.045
	(-8.2)	(-8.8)	(-10.4)

Note: All differences are expressed in logarithm. Figures in parentheses show the percentage contribution.

The table indicates that labor productivity differences between the top and bottom 20% of prefectures declined rapidly between 1970 and 1990 and continued to do so thereafter, albeit at a slower pace. This is in line with the results obtained in other research. However, since we are using industry-level data, we can now examine the reasons for the decline, which was not possible with the aggregate data used in Fukao, Makino, and Tokui (2015).

Thus, looking at the factors underlying the observed decline in labor productivity differences, we find that this is more or less in line with the trend in differences in industry structure, indicating that industrial structures in the top and bottom prefectures became increasingly similar over the roughly four decades we are examining here, and that this greatly contributed to the decline in labor productivity differences overall. In contrast, within-industry differences in labor productivity across prefectures declined only marginally over the same period and therefore hardly contributed at all to the reduction in prefectural labor productivity differences. In fact, within-industry differences in labor productivity explain more than half (57.2%) of the overall difference in labor productivity in 1970 and an even greater proportion thereafter (76.5% in 2008), meaning that within-industry labor productivity across prefectures are the main reason for regional differences in labor productivity overall.

The decomposition of within-industry labor productivity differences into difference in TFP, capital–labor ratios, and labor quality differences shows that although such within-industry differences show relatively little change over time, the factors contributing to them did shift considerably. Specifically, the contribution of TFP differences to differences in labor productivity overall increased by about 14 percentage points from 0.162 in 1970 to 0.299 in 2008, while the contribution of differences in capital–labor ratios declined by an almost equal margin of about 14 percentage points from 0.149 to 0.010. In other words, the two moved in opposite directions and more or less offset each other. In contrast, although labor quality differences show a slight declining trend, the change is relatively small compared to the other two factors. (That being said, in 2008, the contribution of differences in labor quality is greater than that of differences in capital–labor ratios.) Thus, given these developments in the three different factors, within-industry differences in labor quality remained largely unchanged between 1970 and 2008.

In other words, over the four decades covered in the analysis, regional differences in capital–labor ratios decreased substantially, thereby greatly contributing to the decrease in prefectural differences in labor productivity. At the same time, however, regional within-industry differences in TPF increased, more or less cancelling out the former effect. This is also shown by the fact that whereas in 1970, the contribution of TFP differences to labor productivity differences, at 25.3%, was more or less the same as that of differences in capital–labor ratios (23.2%), in 2008, with 68.7%, it greatly exceeded the contribution of differences in capital–labor ratios.

Next, let us compare the results obtained here with those in Fukao, Mkino, and Tokui (2015). The aggregate of value added-weighted industry-level TFP differences in this paper more or less corresponds to the differences in prefecture-level TFP for all industries in Fukao, Mkino, and Tokui (2015). The analysis of prefecture-level TFP differences in Fukao, Mkino, and Tokui (2015) suggested that such differences declined substantially between 1955 and 2008. Moreover, looking at the dispersion of labor productivity from a cross-section perspective, Fukao, Mkino, and Tokui (2015) found that the contribution of TFP differences declined consistently from 1955 to 1970, 1990, and 2008. On the other hand, Table 1 in this paper suggests that the contribution of within-industry TFP differences to labor productivity differences between the top and bottom 20% of prefectures consistently increased from 1970 onward. The difference in the results for TFP in Fukao, Mkino, and Tokui (2015) and in this paper are likely due to the following three factors.

The first factor is the difference in periods being analyzed. Because capital stock data by industry are available only from 1970, the starting point for the analysis here is 1970. However, it is between 1955 and 1970, i.e., before the period examined in this paper, that the largest decline in prefectural TFP differences took place, while the decline between 1970 and 2008 was much more moderate.

The second factor is the choice of prefectures that are being used for the comparison. Table 1 in this paper compares the industry aggregate labor productivity of the top and bottom 20% of prefectures, and Tokyo makes up an overwhelming share of the top 20% of prefectures. Recall that the top 20% of prefectures are chosen based on their cumulative population. Given Tokyo's large share in Japan's population overall, the results in Table 1 can be seen as essentially a comparison of Tokyo with prefectures with low labor productivity such as Okinawa, Kagoshima, Yamanashi, and Shimane. On the other hand, the decomposition of the dispersion of labor productivity in Fukao, Mkino, and Tokui (2015) is for all prefectures. Since TFP growth was much higher in Tokyo than in the other prefectures, it is possible that this is the reason that we obtained different results in the two approaches.

The third factor is related to the method of aggregation. If we assume, for example, that the share of industries in which Tokyo's TFP is much higher than that of other prefectures contracts only in Tokyo, prefecture-level TFP differences between Tokyo and the bottom 20% of prefectures would shrink. However, in the decomposition in Table 1, such a development would not manifest itself in a change in the contribution of TFP to within-industry labor productivity differences, but in a change in labor productivity differences due to differences in industry structure. We will return to this issue regarding the method of aggregation later.

Let us summarize the results obtained thus far. Regarding prefectural differences in labor productivity within the same industry, we found that differences in capital–labor ratios worked in the direction of reducing within-industry differences, while TFP differences worked in the opposite direction. As a result, the two more or less cancelled each other out, so that hardly any change in within-industry labor productivity differences was observed. On the other hand, differences in prefectural industrial structures decreased substantially, thus considerably reducing prefectural differences in labor productivity.

The approach employed for the analysis in this section consisted of first decomposing changes in industry structure and prefectural within-industry differences and then used information on factor inputs solely for analysis of prefectural within-industry differences. However, there should also be a close relationship between changes in prefectural industrial structures and factor inputs such that, for example, an increase in capital-intensive industries in a prefecture should push up the capital–labor ratio. The approach in this section does not really allow us to capture such interaction between the industrial structure and the composition of factor inputs. In the next section we therefore use a different approach to examine the relationship between changes in prefectural industrial structures and factor intensities.

3 The effect of changes in industrial structure on prefectural differences in factor intensity

The analysis in Fukao, Mkino, and Tokui (2015) using aggregate prefecture-level data suggested that the decline in prefectural differences in the capital–labor ratio was one of the principal driving forces underlying the fall in prefectural differences in labor productivity. Specifically, at the prefectural level, i.e., for all industries together, the capital–labor ratio in the top 20% of prefectures in 1970 was 1.72 times as high as that in the bottom 20% of prefectures, but by 2008 this difference had shrunk to only a factor of 1.02. Moreover, as seen in the preceding section, one of the reasons for this decline in prefectural differences in the capital–labor ratio was the decline in within-industry differences in capital–labor ratios. However, since factor intensities differ substantially across industries, a further reason may have been changes in prefectures' industrial structures. For example, if capital-intensive industries agglomerate in particular prefectures, this will raise the prefecture-level capital–labor ratio of that prefecture. The aim of this section therefore is to examine how changes in prefectures' industrial structure affected their factor intensities. In addition to physical capital-intensity, we will also focus on human capital-intensity.

We start by looking at differences in factor intensity by industry. In contrast with the previous section, in our analysis here, we focus on the 23 industry categories in the R-JIP Database. The national average factor intensities for the 23 industries are presented in Table 2.

Table 2 Capital–labor ratio, labor quality, and man-hour share by industry (national average)

	Capital-labor ratio Capital stick/man hours Unit: Yen (in 2000 prices)/hour			Labor quality Unit: 2000 national average for all industries=1			Man-hour share Unit: %		
	1970	1990	2008	1970	1990	2008	1970	1990	2008
Agriculture, forestry, and fisheries	1,809	7,140	16,363	0.40	0.63	0.77	16.39	6.83	4.37
Mining	3,206	8,489	18,867	0.78	1.07	0.97	0.47	0.17	0.07
Food and beverages	1,742	4,101	6,885	0.50	0.79	0.90	2.43	2.40	2.40
Textile mill products	1,137	2,293	7,032	0.46	0.70	0.81	3.74	2.48	0.82
Pulp and paper	2,894	6,847	13,928	0.53	0.86	0.95	0.76	0.61	0.44
Chemicals	7,448	16,628	32,716	0.57	0.96	1.06	1.01	0.74	0.66
Petroleum and coal products	27,129	52,522	135,870	0.57	0.99	1.05	0.09	0.06	0.05
Ceramics, stone and clay	2,473	4,592	8,842	0.54	0.89	0.98	1.30	0.97	0.59
Basic metals	5,979	17,650	24,658	0.57	0.95	1.01	2.01	1.10	0.92
Processed metals	1,525	2,373	4,242	0.54	0.88	0.96	2.14	1.96	1.47
General machinery	2,159	4,482	8,615	0.57	0.93	1.03	2.51	2.68	2.50
Electrical machinery	1,497	5,044	14,040	0.49	0.81	1.00	2.62	3.71	2.90
Transport equipment	1,969	9,655	13,108	0.56	0.90	1.00	2.12	2.02	2.36
Precision instruments	915	4,143	12,158	0.50	0.82	0.96	0.53	0.52	0.31
Other manufacturing	1,055	3,185	6,933	0.53	0.86	0.97	5.56	4.87	3.38
Construction	985	1,450	2,384	0.57	0.94	1.05	9.06	10.37	9.32
Electricity, gas and water utilities	35,541	109,985	156,664	0.66	0.98	1.19	0.51	0.62	0.68
Wholesale and retail trade	689	2,574	3,708	0.54	0.89	0.94	16.55	16.12	13.53
Finance and insurance	2,776	3,153	6,610	0.55	0.87	1.01	2.26	3.04	2.98
Real estate	13,705	50,768	68,734	0.78	1.04	1.12	0.59	1.37	1.47
Transport and communications	5,393	14,011	25,888	0.60	0.97	1.08	5.89	6.40	6.53
Other non-government services	1,039	3,599	4,534	0.61	0.99	1.10	16.12	25.34	37.05
Government service activities	3,141	9,315	20,858	0.80	1.25	1.41	5.33	5.63	5.20
Average	2,083	6,184	10,299	0.57	0.94	1.07	-	-	-

Table 2 shows that factor intensities do indeed differ considerably across industries. Starting with the capital–labor ratio, this is far above the average in the electricity, gas, and water utilities, petroleum and coal products, real estate, chemical, and basic metals industries, while it is more or less in line with the average in the three machinery-related industries (general machinery, electrical machinery, and transport equipment). Meanwhile, it is far below the average in construction, wholesale and retail trade, other non-government services, which all account for large man-hour shares.[6] These patterns can be observed throughout the period. On the other hand, labor quality does not differ as much across industries as the capital–labor ratio, but a closer look reveals a slight decrease in differences across industries over time.

Next, the man-hour shares in Table 2 provide an indication of how Japan's industrial structure overall developed over time. We find that the share of industries with a high capital–labor ratio – such as the petroleum and coal products, chemical, and basic metals industries – has generally declined, although the electricity, gas, and water utilities and real estate industries have seen an increase. On the other hand, the man-hour share of other non-government services, which have a low capital–labor ratio and even in 1970 already accounted for a large share, more than doubled over the roughly four decades covered by our data. Many of the industries with a high capital–labor ratio are what the Japanese call "heavy, high, long, large-type" industries, which require space and transport links, so that potential locations for these industries are limited. This is not the case for other non-government services, so that the growth of such services is likely a key factor underlying the decline in differences in prefecture-level capital–labor ratios.

Before examining the effect of structural change on prefectural factor intensities, let us compare the capital–labor ratio, labor quality, and TFP trends between the top and bottom 20% of prefectures. It should be noted that the top and bottom 20% of industries are not ranked in terms of their input factor intensity or TFP level but in terms prefecture-level labor productivity. The results are shown in Table 3.[7]

[6] Other non-government services include both "for profit activities" and "not for profit activities" such as entertainment, eating and drinking places, education, and health services.

[7] It should be noted that we cannot compare TFP across industries, but can only compare TFP within industries between the top and bottom 20% of prefectures or between two points in time.

Table 3 Factor-intensity and TFP level of the top and bottom 20% of prefectures

(a) Capital–labor ratio (Unit: Yen (in 2000 prices) / hour)

	1970			1990			2008		
	Top 20%	Bottom 20%	Top/Bottom	Top 20%	Bottom 20%	Top/Bottom	Top 20%	Bottom 20%	Top/Bottom
Agriculture, forestry, and fisheries	2,216	1,631	1.36	12,262	6,408	1.91	12,517	15,491	0.81
Mining	3,378	3,319	1.02	12,622	8,029	1.57	9,883	17,665	0.56
Food and beverages	2,203	979	2.25	4,487	3,223	1.39	6,328	5,647	1.12
Textile mill products	816	851	0.96	1,829	1,672	1.09	3,346	6,992	0.48
Pulp and paper	1,166	3,987	0.29	3,825	12,472	0.31	5,678	18,552	0.31
Chemicals	4,148	7,738	0.54	10,419	20,859	0.50	18,661	34,859	0.54
Petroleum and coal products	19,759	17,448	1.13	31,119	59,844	0.52	97,407	122,120	0.80
Ceramics, stone and clay	2,071	2,190	0.95	5,623	3,463	1.62	6,637	6,965	0.95
Basic metals	4,219	4,160	1.01	16,564	19,458	0.85	19,838	20,085	0.99
Processed metals	1,555	978	1.59	2,367	2,034	1.16	3,616	4,268	0.85
General machinery	1,890	1,622	1.17	4,634	4,077	1.14	5,658	7,634	0.74
Electrical machinery	1,665	988	1.68	5,642	4,266	1.32	8,995	15,036	0.60
Transport equipment	2,313	878	2.63	9,548	5,959	1.60	9,131	9,155	1.00
Precision instruments	1,218	319	3.82	4,214	3,424	1.23	10,218	11,398	0.90
Other manufacturing	1,426	532	2.68	3,251	2,031	1.60	4,635	6,064	0.76
Construction	1,351	866	1.56	1,425	1,218	1.17	2,051	2,327	0.88
Electricity, gas and water utilities	31,272	33,865	0.92	133,048	95,469	1.39	217,715	134,529	1.62
Wholesale and retail trade	1,008	463	2.18	3,199	1,900	1.68	5,246	2,941	1.78
Finance and insurance	3,421	1,712	2.00	3,524	2,234	1.58	7,036	6,187	1.14
Real estate	16,408	7,768	2.11	43,998	63,540	0.69	51,640	97,357	0.53
Transport and communications	8,655	1,838	4.71	18,360	12,199	1.51	32,986	20,665	1.60
Other non-government services	1,630	580	2.81	3,285	3,518	0.93	4,160	4,695	0.89
Government service activities	3,335	2,823	1.18	7,838	9,934	0.79	15,904	23,326	0.68
Average	2,563	1,486	1.72	6,705	5,482	1.22	9,988	9,761	1.02

(b) Labor quality (Unit: 2000 national average for all industries)

	1970			1990			2008		
	Top 20%	Bottom 20%	Top/Bottom	Top 20%	Bottom 20%	Top/Bottom	Top 20%	Bottom 20%	Top/Bottom
Agriculture, forestry, and fisheries	0.50	0.38	1.32	0.71	0.61	1.18	0.87	0.74	1.17
Mining	0.87	0.75	1.15	1.17	1.09	1.07	1.08	1.00	1.08
Food and beverages	0.58	0.46	1.25	0.91	0.73	1.25	1.00	0.84	1.18
Textile mill products	0.52	0.42	1.22	0.81	0.64	1.25	0.91	0.76	1.20
Pulp and paper	0.59	0.48	1.24	0.96	0.79	1.22	1.02	0.92	1.11
Chemicals	0.62	0.51	1.21	1.04	0.86	1.22	1.12	1.00	1.11
Petroleum and coal products	0.62	0.52	1.18	1.07	0.90	1.19	1.11	0.98	1.13
Ceramics, stone and clay	0.60	0.51	1.16	0.97	0.84	1.16	1.08	0.95	1.13
Basic metals	0.61	0.54	1.12	1.02	0.89	1.15	1.07	0.96	1.12
Processed metals	0.57	0.50	1.14	0.95	0.81	1.17	1.01	0.92	1.10
General machinery	0.60	0.53	1.13	1.01	0.86	1.17	1.11	0.98	1.13
Electrical machinery	0.53	0.43	1.24	0.91	0.71	1.28	1.14	0.93	1.23
Transport equipment	0.59	0.55	1.08	0.96	0.85	1.13	1.10	0.96	1.14
Precision instruments	0.54	0.45	1.21	0.93	0.71	1.31	1.05	0.89	1.19
Other manufacturing	0.60	0.47	1.27	0.99	0.76	1.29	1.07	0.91	1.17
Construction	0.62	0.53	1.17	1.02	0.89	1.14	1.11	1.02	1.09
Electricity, gas and water utilities	0.67	0.71	0.95	1.02	0.96	1.06	1.19	1.20	0.99
Wholesale and retail trade	0.60	0.49	1.22	0.97	0.81	1.20	1.02	0.88	1.16
Finance and insurance	0.58	0.55	1.06	0.89	0.85	1.05	1.05	0.98	1.07
Real estate	0.87	0.79	1.09	1.09	0.99	1.10	1.18	1.10	1.07
Transport and communications	0.63	0.59	1.06	1.01	0.95	1.06	1.13	1.04	1.10
Other non-government services	0.68	0.57	1.20	1.06	0.93	1.15	1.16	1.06	1.10
Government service activities	0.89	0.78	1.14	1.35	1.19	1.13	1.50	1.35	1.11
Average	0.63	0.54	1.16	1.02	0.89	1.14	1.13	1.03	1.09

(c) TFP (Unit: 2000 national average in each industry = 1)

	1970			1990			2008		
	Top 20%	Bottom 20%	Top/Bottom	Top 20%	Bottom 20%	Top/Bottom	Top 20%	Bottom 20%	Top/Bottom
Agriculture, forestry, and fisheries	0.87	0.80	1.09	0.66	1.28	0.52	1.11	1.05	1.06
Mining	0.42	0.48	0.88	1.36	0.94	1.44	0.93	0.77	1.20
Food and beverages	1.23	0.89	1.38	1.03	0.78	1.33	0.78	0.73	1.07
Textile mill products	0.73	0.61	1.20	1.18	1.21	0.97	1.45	0.98	1.49
Pulp and paper	0.68	0.53	1.28	1.10	1.14	0.97	0.87	1.07	0.82
Chemicals	0.24	0.12	2.07	1.00	0.67	1.48	1.06	0.83	1.28
Petroleum and coal products	1.32	0.85	1.56	1.20	0.93	1.29	0.98	0.12	7.82
Ceramics, stone and clay	0.77	0.42	1.85	1.00	0.72	1.40	1.27	0.94	1.35
Basic metals	0.62	0.47	1.34	0.93	0.78	1.18	0.81	0.84	0.96
Processed metals	0.55	0.40	1.37	0.85	0.82	1.04	0.79	0.82	0.96
General machinery	0.51	0.38	1.34	1.14	1.01	1.13	1.12	1.36	0.82
Electrical machinery	0.06	0.03	1.82	0.66	0.38	1.74	2.30	2.51	0.92
Transport equipment	0.39	0.24	1.64	0.99	0.63	1.58	1.73	1.21	1.44
Precision instruments	0.43	0.27	1.56	1.09	0.88	1.24	1.10	1.39	0.79
Other manufacturing	0.96	0.68	1.40	1.24	0.95	1.31	1.25	0.94	1.32
Construction	1.12	1.34	0.83	1.42	1.26	1.13	1.15	0.82	1.40
Electricity, gas and water utilities	0.86	0.76	1.14	0.86	1.12	0.76	1.00	1.12	0.90
Wholesale and retail trade	0.40	0.28	1.43	0.83	0.58	1.43	1.38	0.75	1.84
Finance and insurance	0.29	0.27	1.08	1.31	0.73	1.81	0.99	0.61	1.63
Real estate	3.42	13.25	0.26	1.52	1.77	0.86	1.01	1.13	0.89
Transport and communications	0.68	0.92	0.74	0.83	0.91	0.91	1.05	1.15	0.91
Other non-government services	1.20	1.30	0.93	1.28	0.95	1.35	1.31	0.86	1.51
Government service activities	0.94	0.92	1.02	1.01	0.92	1.10	1.31	1.13	1.16
Average	0.63	0.65	0.97	1.07	0.89	1.20	1.23	0.93	1.31

Starting with Table 3(a), we find that in 1970 the top 20% of prefectures in terms of prefecture-level labor productivity across all industries had a considerably higher average capital–labor ratio than the bottom 20% of prefectures. However, the relative gap between the two groups shrank over the years, so that by 2008 the capital–labor ratio in the bottom 20% of prefectures no longer lagged far behind that of the top 20%. In fact, looking at individual industries reveals that in capital-intensive industries, the bottom 20% of prefectures in 1970 were already either not far behind the top 20% (petroleum and coal products, basic metals) or even ahead (chemicals; electricity, gas, and water utilities), and that by 2008, they had a higher capital–labor ratio in these industries than the top 20% of prefectures, with the exception of electricity, gas, and water utilities. Moreover, in the real estate industry, the pattern more or less reversed over the roughly four decades: whereas in 1970, the capital–labor ratio in the top 20% was almost twice as high as in the bottom 20%, the opposite was the case in 2008. Further, looking at industries with a comparatively low capital–labor ratio, the relative gap between the two groups shrank considerably over the period or reversed as well (such as the machinery industries and other manufacturing as well as finance and insurance, other non-government services, and government service activities). Overall, therefore, the table shows that whereas in 1970 capital investment tended to be concentrated in prefectures with a high labor productivity overall, by 2008 it had become much more evenly distributed across prefectures.

Turning to Table 3(b), we find that, with the exception of the electricity, gas, and water utilities industry, labor quality is higher in the top 20% of prefectures in all industries and years. Finally, Table 3(c) for TFP shows that this tends to be higher in the top 20% of prefectures in most industries and on average as well. (The notable exception to this pattern is the average for 1970, which is largely due to the extremely high TFP value in the real estate industry of the bottom 20% of prefectures. This, in turn, likely is a statistical artefact. In this period, large real estate companies from major cities such as Tokyo were setting up branches in rural prefectures to oversee major real estate investment projects in these prefectures in anticipation of high-speed rail links and other transportation infrastructure improvements. In this case, service input from headquarters is not properly counted in the estimation of local branches' value added, thus overstating their TFP.)

Let us now turn to the examination of the link between prefectures' industrial structure and factor intensities. To do so, we use the following equation to decompose the difference between the capital–labor ratio in prefecture *r* and the national average of the capital labor ratio (i.e., the left-hand side of the equation) into the part due to differences in prefectures' industrial structure (the first term on the right-hand side of the equation) and the part due to prefectural differences in factor inputs within the same industry (the second term on the right-hand side of the equation):[8]

---

[8] Equation (6) is derived as follows. The prefecture-level capital–labor ratio (i.e., for all industries together) in prefecture, z_r, can be represented as the weighted average of the capital–labor ratio in each industry z_{ir}, where the weights are given by industries' labor input share l_{ir} measured in terms of man-hours:

$$z_r \equiv \sum_i l_{ir} z_{ir}$$

Next, the national average of the capital–labor ratio in industry *i*, denoted by $\bar{z}_i$, and the national average of the labor input share in that industry, denoted by $\bar{l}_i$, are obtained by taking the simple average across all prefectures:

$$\bar{z}_i \equiv \frac{1}{47}\sum_r z_{ir} \text{、} \quad \bar{l}_i \equiv \frac{1}{47}\sum_r l_{ir}$$

Further, the capital–labor ratio for Japan as a whole across all industries, denoted by $\bar{z}$, is obtained as the weighted average of the national average capital–labor ratio in each industry $\bar{z}_i$ using the national average labor input share in each industry $\bar{l}_i$, as weights:

$$\bar{z} \equiv \sum_i \bar{l}_i \bar{z}_i$$

The difference between the capital–labor ratio for each prefecture as a whole and the capital–labor ratio for Japan as a whole can then be decomposed as shown below by regarding the product $l_{ir}z_i$ as a non-linear function of l_{ir} and z_{ir} and linearly approximating in the neighborhood of $l_{ir}=\bar{l}_I$ and $z_{ir}=\bar{z}_i$:

$$\begin{aligned}\sum_i l_{ir} z_{ir} - \sum_i \bar{l}_i \bar{z}_i &\approx \sum_i \left(l_{ir} - \bar{l}_i\right)\bar{z}_i + \sum_i \left(z_{ir} - \bar{z}_i\right)\bar{l}_i \\ &= \sum_i \left(l_{ir} - \bar{l}_i\right)\left(\bar{z}_i - \bar{z}\right) + \sum_i \left(l_{ir} - \bar{l}_i\right)\bar{z} + \sum_i \left(z_{ir} - \bar{z}_i\right)\bar{l}_i\end{aligned}$$

$$\sum_{i=1}^{I} l_{i,r} z_{i,r} - \sum_{i=1}^{I} \bar{l}_i \bar{z}_i \approx \sum_{i=1}^{I} \left(l_{i,r} - \bar{l}_i \right)\left(\bar{z}_i - \bar{z} \right) + \sum_{i=1}^{I} \left(z_{i,r} - \bar{z}_i \right) \bar{l}_i \qquad (6)$$

Equation (6) allows us to do the following. If we find, for example, that the capital–labor ratio of prefecture *r* is higher than the national average, we can decompose this difference into the sum of two effects: the fact prefecture *r* has a high concentration of industries with a high capital–labor ratio; and the fact that the capital–labor ratio in many industries in prefecture *r* is higher than the national average for those industries We will refer to the former as the share effect and to the latter as the within effect.[9]

Based on this approach, Table 4 shows the decomposition of the differences in prefectures' capital–labor ratios, labor quality, and TFP from the national average into the share effect and the within effect for the top and bottom 20% of prefectures in terms of labor productivity for 1970, 1990, and 2008. Note that (as mentioned in footnote 6) it is not possible to compare TFP levels across industries, so that in the case of TFP we can only calculate the within effect, but not the share effect. Therefore, for TFP, the difference from the average for Japan shown in Table 4 captures only the within effect.

Given that the second term on the right-hand side equals zero, we obtain the following relationship (where we use the fact that the sum total of the labor input shares in each prefecture has to be equal to 1):

$$\sum_{i} l_{ir} z_{ir} - \sum_{i} \bar{l}_i \bar{z}_i \approx \sum_{i} \left(l_{ir} - \bar{l}_i \right)\left(\bar{z}_i - \bar{z} \right) + \sum_{i} \left(z_{ir} - \bar{z}_i \right) \bar{l}_i$$

where the first term on the right-hand side represents the contribution of the fact that a prefecture has, e.g., above-average labor input shares in industries with a capital–labor ratio that is above the national average, while the second term represents the contribution of differences between the capital–labor ratios of the industries in a particular prefecture and the national average capital–labor ratios for those industries.

[9] Note that in definitions of the "share effect" and "within effect" here differ from those used in Section 6.4, where we focus on each industry's contribution to the covariance between the two terms on the right-hand side of equation (6) and labor productivity in each of the prefectures.

Table 4 Decomposition of prefecture-level factor input differences between the top and bottom 20% of prefectures

(a) 1970

	Top 20%	Bottom 20%	Japan average
Capital labor ratio (Unit: Yen (in 2000 prices) / hour)	2,563	1,486	2,083
Difference from Japan average (%)	23.1	-28.6	
Share effect	4.1	-5.1	
Within effect	18.9	-29.1	
Approximation error	0.1	5.6	
Labor quality (Unit: (Unit: 2000 national average for all industries)	0.63	0.54	0.57
Difference from Japan average (%)	9.3	-5.6	
Share effect	0.0	0.4	
Within effect	10.0	-15.6	
Approximation error	-0.7	9.7	
TFP (Unit: 2000 = 1)	0.63	0.65	0.65
Difference from Japan average (%)	-2.2	1.3	

(b) 1990

	Top 20%	Bottom 20%	Japan average
Capital labor ratio (Unit: Yen (in 2000 prices) / hour)	6,705	5,482	6,184
Difference from Japan average (%)	8.4	-11.3	
Share effect	4.6	-4.4	
Within effect	9.3	-5.9	
Approximation error	-5.5	-1.0	
Labor quality (Unit: (Unit: 2000 national average for all industries)	1.02	0.89	0.94
Difference from Japan average (%)	8.1	-5.1	
Share effect	0.1	1.0	
Within effect	8.2	-8.1	
Approximation error	-0.2	2.1	
TFP (Unit: 2000 = 1)	1.07	0.89	1.00
Difference from Japan average (%)	7.0	-11.1	

(c) 2008

	Top 20%	Bottom 20%	Japan average
Capital labor ratio (Unit: Yen (in 2000 prices) / hour)	9,988	9,761	10,299
Difference from Japan average (%)	-3.0	-5.2	
Share effect	0.1	-1.9	
Within effect	-4.0	-2.1	
Approximation error	0.9	-1.2	
Labor quality (Unit: (Unit: 2000 national average for all industries)	1.13	1.03	1.07
Difference from Japan average (%)	5.7	-3.4	
Share effect	-0.5	1.0	
Within effect	6.6	-5.0	
Approximation error	-0.3	0.7	
TFP (Unit: 2000 = 1)	1.23	0.93	1.08
Difference from Japan average (%)	13.1	-13.8	

The results in the table show that the difference in the capital–labor ratios between the top and bottom prefectures declined rapidly during our observation period (from 51.7 percentage points in 1970 to 19.7 percentage points in 1990 and 2.2 percentage points in 2008), so that by 2008 the difference had almost disappeared. Moreover, we find that at the beginning of our observation period in 1970 most of the difference in capital–labor ratios was due to the within effect, while the share effect played only a minimal role. Consequently, the contribution of the share effect to the decline in the difference in the labor ratio was also small and it was primarily the within effect that drove the overall trend.

Turning to the results on labor quality, it is again the within effect that was more important than the share effect. However, because the decline in the within effect was less pronounced than in the case of the capital–labor ratio, the difference in labor quality in 2008 between the top and bottom prefectures when adding up the two effects was still about 9 percentage points, meaning that the difference was larger than that for the capital–labor ratio. Finally, the difference in TFP between the top and bottom prefectures increased throughout the period and in 2008 stood at about 27 percentage points.

Comparing the results in Table 4 with those in the preceding section, the share effect and the within effect can be considered to respectively correspond to the contribution of differences in industrial structure and the contribution of within-industry differences in labor productivity. The analysis in this section showed that over the four decades that we focus on, within-industry differences in capital–labor ratios tended to decline and that within-industry differences in TFP tended to increase, which is more or less consistent with the result in the preceding section based on decomposing prefectural within-industry differences in labor productivity into the contribution of the capital–labor ratio, labor quality, and TFP. On the other hand, the factor decomposition in the preceding section indicated that differences in industrial structure made a considerable contribution to prefectural labor productivity differences, whereas the analysis in this section on prefectural differences in capital–labor ratios and labor quality suggests that the share effect did not play a particularly large role. Since the decomposition equation employed for the analysis in this section does not allow us to calculate the share effect for TFP, we therefore suspect that there must be a share effect with regard to TFP that we were not able to pick up. Returning to the example given above, if the share of industries in which Tokyo has a much higher TFP than other prefectures contracts in Tokyo, the difference in aggregate TFP for all industries between Tokyo and the bottom 20% of prefectures would decline. However, this kind of effect is not included in the change in the TFP contribution in Table 4. How to measure this TFP share effect is an issue that we have to leave for future research.

The analytical approach in this section allowed us to break down factor inputs into the capital–labor ratio, labor quality, and TFP and decompose prefectural differences in these into the contribution of the share effect and the industry effect. However, in order to understand how the growth or decline of individual industries contributed to developments in labor productivity differences, and trends in which industries made the largest contribution, a different approach is necessary. The next section seeks to tackle this issue by examining the correlation between the share and industry effects obtained in this section and differences in prefecture-level aggregate labor productivity.

4 Industry contributions to the decline in regional differences in labor productivity

Examining how prefectural differences in industrial structure give rise to differences in prefectural labor productivity, the analysis so far highlighted two mechanisms: the share effect and the within effect. The first referred to the fact that if, for example, the share of industries with an above-average capital–labor ratio increases in a prefecture, the capital–labor ratio for the prefecture as a whole and, as a result, labor productivity will increase. On the other hand, the second referred to the fact that if the capital–labor ratio in a particular industry in a prefecture rises relative to the capital–labor ratio in that industry in other prefectures, this will also result in an increase in the capital–labor ratio and hence in labor productivity. In this section, we investigate the contribution of each of the different industries to these two effects. In conducting this analysis we take account of differences in factor intensity and productivity among all the prefectures, whereas in previous sections of this paper we mainly focus on the differences between top 20% and bottom 20% of prefectures.

We do so by first taking the covariance between the left-hand side of equation (6) and the prefectural-level labor productivity, $v_{r.}$, that is the covariance between prefecture-level capital intensities relative to the national average and the prefecture-level labor productivities. This covariance can be decomposed using the right-hand side of equation (6). The calculation is shown in the following equation:

$$Cov\left(\sum_{i=1}^{I} l_{i,r} z_{i,r} - \sum_{i=1}^{I} \bar{l}_i \bar{z}_i , v_r\right)$$
$$= \sum_{i=1}^{I} Cov\left(\left(l_{i,r} - \bar{l}_i\right)\left(\bar{z}_i - \bar{z}\right), v_r\right) + \sum_{i=1}^{I} Cov\left(\left(z_{i,r} - \bar{z}_i\right)\bar{l}_i , v_r\right)$$

In the right-hand side of the above equation, the first term is the sum of the covariances between the share effect of each industry and prefectures' labor productivity, while the second term is the sum of the covariances between the within-effect of each industry and prefectures' labor productivity.

Next, we divide the covariance for each industry in the first term on the right-hand side by the total covariance between prefecture-level capital intensities and labor productivity levels.

$$\frac{Cov\left(\left(l_{i,r}-\overline{l}_i\right)\left(\overline{z}_i-\overline{z}\right),v_r\right)}{\sum_{i=1}^{I}Cov\left(\left(l_{i,r}-\overline{l}_i\right)\left(\overline{z}_i-\overline{z}\right),v_r\right)+\sum_{i=1}^{I}Cov\left(\left(z_{i,r}-\overline{z}_i\right)\overline{l}_i,v_r\right)}$$

We refer to this as the contribution of the share effect for industry *i*.

Similarly, we divide the covariance for each industry in the second term by the total covariance between prefecture-level capital intensities and labor productivity levels.

$$\frac{Cov\left(\left(z_{i,r}-\overline{z}_i\right)\overline{l}_i,v_r\right)}{\sum_{i=1}^{I}Cov\left(\left(l_{i,r}-\overline{l}_i\right)\left(\overline{z}_i-\overline{z}\right),v_r\right)+\sum_{i=1}^{I}Cov\left(\left(z_{i,r}-\overline{z}_i\right)\overline{l}_i,v_r\right)}$$

We refer to this as the contribution of the within effect for industry *i*.

Similarly, regarding labor quality and TFP, we can decompose the difference between prefecture *r*'s labor quality or TFP and the average for Japan as a whole as in equation (6). The only difference is that, for labor quality, we use not the man-hour share but the labor cost share, while for TFP, we use the nominal value added share. Just as in the case of the capital-labor ratio, we follow the same procedure to calculate the contribution of the share effect and the within effect to the total covariance between prefecture-level labor quality or TFP and labor productivity levels. The results of for 1970, 1990, and 2008 are shown in Table 6.5.

Table 6.5 Industries' contribution to the decline in prefectural labor productivity differences

(a) 1970

	Capital-labor ratio		Labor quality		TFP
	Share effect	Within effect	Share effect	Within effect	Within effect
Agriculture, forestry, and fisheries	-0.18	6.60	30.30	26.72	4.33
Mining	-0.71	-0.09	-10.22	3.46	2.30
Food and beverages	0.14	3.04	-0.35	4.53	12.91
Textile mill products	-1.37	1.87	-1.37	7.22	8.07
Pulp and paper	0.30	-1.27	0.57	1.35	1.25
Chemicals	5.48	2.77	6.81	2.00	13.43
Petroleum and coal products	4.28	0.15	1.07	0.14	9.28
Ceramics, stone and clay	0.18	0.96	0.77	2.04	4.32
Basic metals	6.05	3.92	14.86	1.91	0.00
Processed metals	-0.85	1.09	3.90	1.73	3.74
General machinery	0.67	1.59	9.65	2.07	7.60
Electrical machinery	-1.22	1.07	1.04	5.12	6.36
Transport equipment	-1.11	1.26	8.55	1.50	5.81
Precision instruments	-0.30	0.23	0.22	0.57	0.29
Other manufacturing	-2.13	3.61	5.01	8.99	3.55
Construction	-0.50	1.91	4.01	13.48	8.81
Electricity, gas and water utilities	1.01	5.00	-2.19	-4.05	2.39
Wholesale and retail trade	-1.01	3.25	-2.93	23.23	19.86
Finance and insurance	0.23	2.31	1.08	-4.37	0.80
Real estate	2.73	1.61	2.71	-1.84	-5.73
Transport and communications	2.29	33.69	-4.70	-0.65	-10.08
Other non-government services	-0.31	9.94	-16.62	17.25	3.38
Government service activities	-1.89	3.70	-73.92	9.37	-2.69
Primary sector subtotal	-0.89	6.51	20.08	30.18	6.63
Manufacturing subtotal	10.12	20.30	50.72	39.16	76.61
Services subtotal	2.54	61.42	-92.57	52.42	16.76
Total	11.77	88.23	-21.76	121.76	100.00

(b) 1990

	Capital-labor ratio		Labor quality		TFP
	Share effect	Within effect	Share effect	Within effect	Within effect
Agriculture, forestry, and fisheries	-7.96	20.33	13.35	8.06	-15.93
Mining	-0.46	1.06	-1.64	0.80	0.40
Food and beverages	0.98	2.21	-0.09	4.49	10.57
Textile mill products	1.16	2.00	0.18	4.44	3.61
Pulp and paper	0.07	-0.89	0.33	1.29	0.76
Chemicals	5.17	2.62	5.06	2.01	11.96
Petroleum and coal products	2.38	0.56	0.82	0.17	0.76
Ceramics, stone and clay	0.11	1.12	0.02	1.92	4.00
Basic metals	6.06	2.96	6.43	2.21	-0.67
Processed metals	-2.76	0.41	2.57	2.36	2.32
General machinery	-1.83	1.35	6.69	4.02	6.01
Electrical machinery	-0.11	0.59	0.38	9.09	10.34
Transport equipment	0.67	3.22	5.32	2.46	7.54
Precision instruments	0.05	0.37	0.01	1.05	1.40
Other manufacturing	-3.38	4.53	3.57	8.49	4.52
Construction	1.91	2.01	-0.64	9.28	13.69
Electricity, gas and water utilities	0.20	7.55	-1.40	0.24	-4.55
Wholesale and retail trade	0.91	8.02	-3.88	13.25	23.83
Finance and insurance	-1.04	1.23	0.22	0.00	9.52
Real estate	27.60	-7.60	2.73	-1.00	-2.02
Transport and communications	4.34	12.08	0.60	0.64	-1.68
Other non-government services	-2.23	5.10	-6.50	18.09	14.44
Government service activities	-2.28	-0.38	-39.09	11.58	-0.83
Primary sector subtotal	-8.42	21.40	11.72	8.86	-15.52
Manufacturing subtotal	8.56	21.05	31.29	44.00	63.14
Services subtotal	29.41	28.01	-47.95	52.08	52.39
Total	29.55	70.45	-4.94	104.94	100.00

(c) 2008

	Capital–labor ratio		Labor quality		TFP
	Share effect	Within effect	Share effect	Within effect	Within effect
Agriculture, forestry, and fisheries	-30.47	13.10	7.07	4.92	-7.18
Mining	-1.05	1.37	-0.27	0.73	-0.07
Food and beverages	2.95	5.30	-0.19	5.09	7.01
Textile mill products	0.39	3.35	0.13	2.07	0.00
Pulp and paper	0.28	-2.62	0.22	0.87	0.57
Chemicals	11.85	6.32	5.28	1.93	1.25
Petroleum and coal products	5.67	2.99	0.78	0.20	13.43
Ceramics, stone and clay	-0.01	1.29	0.15	1.33	2.59
Basic metals	6.19	7.13	3.89	2.47	1.81
Processed metals	-3.82	0.62	1.67	2.05	0.97
General machinery	-1.93	3.72	6.06	5.31	3.77
Electrical machinery	-2.26	-10.52	-1.02	10.90	-0.95
Transport equipment	-1.09	5.52	6.64	4.69	6.84
Precision instruments	0.00	0.45	0.03	0.96	-0.30
Other manufacturing	-4.00	7.42	3.75	6.55	1.95
Construction	9.28	1.10	-5.43	7.10	11.72
Electricity, gas and water utilities	-8.78	24.96	-3.24	-1.42	-2.57
Wholesale and retail trade	-1.69	8.43	0.77	13.63	25.27
Finance and insurance	-1.71	1.07	0.96	0.91	8.12
Real estate	54.77	-15.92	3.39	-1.81	-0.64
Transport and communications	11.82	21.76	4.72	2.97	0.87
Other non-government services	-5.72	-2.31	-5.23	36.71	25.09
Government service activities	-13.27	-11.96	-62.59	24.28	0.44
Primary sector subtotal	-31.51	14.48	6.80	5.65	-7.25
Manufacturing subtotal	14.23	30.99	27.40	44.43	38.95
Services subtotal	44.70	27.13	-66.65	82.37	68.29
Total	27.41	72.59	-32.45	132.45	100.00

Let us start by looking at the results for the capital–labor ratio. In the manufacturing sector, the share effect was positive throughout the observation period in the heavy and chemical industries, whereas it was negative in the machinery industries. This shows that the capital-intensive heavy and chemical industries are concentrated in prefectures with high prefecture-level labor productivity, and that the machinery industries, which are not very capital-intensive, are not necessarily concentrated in prefectures with high labor productivity. Turning to the within-industry effect, this is generally positive in all industries with the exception of the large negative value for the contribution of the electrical machinery industry in 2008, and we find that in prefectures with a higher prefecture-level labor productivity, the capital–labor ratio of manufacturing industries tends to be higher than within the same industry in other prefectures. For the service sector, we find that the share effect overall made a large positive contribution, although in government services it made a large negative contribution. A notable development is that the share effect increased greatly over time in the real estate and transport and communications industries. The within effect in the service sector generally tended to decline, with particularly pronounced falls seen in the real estate industry and government services, so that the contribution in the service sector overall fell by about half from 1970 to 2008.

Next, looking at the results for labor quality, we find that, as in the case of the capital–labor ratio, the share effect in the manufacturing sector is positive in many industries, indicating that human capital-intensive industries are concentrated in prefectures with high labor productivity. The results further show that labor quality in agriculture, forestry, and fisheries is comparatively low, and because these activities are concentrated in prefectures with low labor productivity, the share effect is positive and considerable, although it fell substantially in 2008. On the other hand, labor quality in government services is high, and because government services are concentrated in prefectures with low productivity, the share effect is large and negative, i.e., the opposite to agriculture, forestry, and fisheries. Turning to the within effect, this is positive in almost all industries, showing that the higher prefectural labor productivity within a particular industry is compared to the same industry in other prefectures, the more human capital-intensive is that industry.

Finally, let us look at the results for TFP. Again, due to data limitations, we can only look at the within effect. We find that for 1970, the TFP within effect is generally positively correlated with prefectural labor productivity. Exceptions are the real estate and transport and communications industries as well as government services, where the correlation was negative, and these were joined in the following four decades by agriculture, forestry, and fisheries and parts of the manufacturing sector. Nevertheless, in the majority of industries, the correlation between the TFP of those industries and prefectural labor productivity is positive. Moreover, the relative shares of the manufacturing and service sectors in the covariance for all industries more or less reversed over the roughly four decades examined, with the share of the manufacturing sector falling from about 77% in 1970 to 39% in 2008 and that of the service sector increasing from 17% to 68%.

As highlighted by, for example, Fujita and Tabuchi (1997), from the 1970s onward, Japan's industrial structure changed from one dominated by the heavy and chemical industries to one dominated by high-tech and service industries. They further pointed out that this change in industrial structure over the last four decades led economic activity in Japan to become heavily concentrated in Tokyo. Our analysis confirms this pattern, indicating that physical capital-intensive service industries such as real estate and transport and communications are concentrated in prefectures with high labor productivity, and that human capital-intensive service industries such as other non-government services and transport and communications are also concentrated in prefectures with high labor productivity, with Tokyo first among them. These factors are the main reason for the remaining differences in prefectural labor productivity. Looking at the correlation between TFP and prefectural labor productivity, we find that such non-manufacturing industries as construction, wholesale and retail, and other non-government services make a particularly large contribution to the remaining differences in labor productivity across prefectures.

On the other hand, in the manufacturing sector, the share effect of labor quality and the within effect of TFP have declined markedly. Specifically, we found that in the manufacturing sector prefectural labor productivity differences declined through the growing concentration of human capital-intensive industries in non-metropolitan regions and the relocation of factories with high within-industry TFP toward such regions.

It should be noted, however, that when interpreting the results reported above, we need to be careful when considering the direction of causality involved in the contribution of individual industries to prefectural differences in labor productivity. For instance, the fact that prefectures with high labor productivity have a higher concentration of physical and human capital-intensive industries could reflect that such prefectures had more abundant physical and human-capital resources to start with and, based on the Heckscher-Ohlin mechanism, specialized in physical and human capital-intensive industries.[10]

On the other hand, because of high domestic factor mobility, the regional distribution of production factors is determined endogenously, so that the distribution of industries depends on a variety of factors. These include firms' locational choices reflecting, for instance, agglomeration effects and factor prices, transportation costs of inputs and outputs, and infrastructure. They also include changes in Japan's comparative advantage over time; for example, Japan's comparative advantage in the transportation machinery industry resulted in the agglomeration of that industry in Aichi prefecture. And they include changes in Japan's industrial structure overall through, for instance, the shift to a post-industrial economy and through population aging, which does not affect all regions in the same way, so that sectors such as the healthcare industry expand much more in some prefectures than in others. Under these circumstance, physical and human capital will move to prefectures where physical and human capital-intensive industries are concentrated, so that the labor productivity of these prefectures will increase relative to that of other prefectures.

Given the high factor mobility in Japan during the postwar period, it can be conjectured that probably the latter mechanism was more important than the former; that is, Japan's industrial structure likely determined the distribution of factors of production rather than the other way around. However, to confirm this, further empirical analysis from a spatial economics perspective focusing on the location of firms and the advantages of agglomeration is necessary. Unfortunately, such an analysis is beyond the scope of the current study, but we hope to conduct further research on this issue using the R-JIP Database in the future.[11]

[10] Empirical studies that support the Heckscher-Ohlin interpretation of regional specialization include those by Kim (1995) and Yue (1998). Kim (1995) finds that the long-run trends in U.S. regional specialization supports explanations based on the Heckscher-Ohlin model, or production scale economies, but is inconsistent with explanations based on external economies. Yue's (1998) analysis on Japanese case finds that regional specialization is consistent with Heckscher-Ohlin explanation, but its effect tends to become lower in recent years.

[11] In fact, research along these lines is already underway, with Ikeuchi et al. (2013) partly addressing this issue.

5 Conclusion

Using the R-JIP Database, this paper examined prefectural difference in labor productivity from 1970 to 2008 from various angles by looking at prefectural differences in industrial structure and prefectural and industry differences in factor inputs and productivity. In Section 2, we decomposed prefectural labor productivity differences into the contribution differences in industrial structure and the contribution of within-industry differences in labor productivity, and further decomposed the latter into the contribution of the capital–labor ratio, labor quality, and TFP. The results indicated that during roughly four decades prefectural differences in labor productivity declined and that most of this decline is explained by the decline in differences in industrial structure. On the other hand, within-industry labor productivity played a minor role, since decline in regional differences in capital–labor ratios and the increase in regional differences in TFP more or less cancelled each other out.

Next, in Section 3, we decomposed prefectural differences in productivity and factor inputs into the share effect due to prefectural differences in industry structure and the within effect due to prefectural differences in productivity or factor intensity within the same industry. The results showed that much of the difference in prefectural capital–labor ratios and labor quality in 1970 can be explained by the within and that the largest part of the decline in prefectural differences in capital–labor ratios during the subsequent four decades is also explained by the within effect.

Finally, in Section 4 we examined which industries make the largest contribution to prefectural differences in productivity and how – that is, through differences in the capital-labor ratio, labor quality, or TFP, and through the share effect or the within effect. For this analysis, we decomposed the covariance between prefectures' capital-labor ratio and their labor productivity into the covariance for each industry, which was further decomposed into the share effect and the within effect. Moreover, we applied the same approach to examine the role of labor quality and TFP. We found that no clear pattern for the 23 industries can be observed, with the share and within effects of factor intensities showing positive correlations with prefectural labor productivity in some cases and negative correlations in others. However, for the manufacturing sector as a whole and for the service sector as whole, we find that both the share and within effects of factor intensities show generally positive correlations with prefectural labor productivity, with the share effect for labor quality in the service sector being the only exception. In other words, from a broad perspective, we find that prefectures with a high share of industries that have a high capital–labor ratio, high labor quality, and high TFP relative to the national average for those industries and prefectures have higher labor productivity than other prefectures. The only result that does not fit this pattern is that the share effect of labor quality in service sector is negative in all years. The main reason for this result is that labor quality in government service activities is high and prefectures in which government service activities account for a large share of economic activity also tend to be the prefectures in which there is relatively little private sector activity and labor productivity is low.

Overall, the results from the three different analyses are generally consistent with each other. However, one puzzle remains, which is that Section 6.2 suggested that almost all of the decline in prefectural labor productivity differences since 1970 can be explained by the decline in differences in industrial structure, while the analysis in Section 6.3, which focused on prefectural differences in factor inputs, indicated that the share effect, which can be thought of as being caused by prefectural differences in industrial structure, had very little explanatory power. As pointed out in that section, due to data limitations we cannot grasp the share effect of TFP. Whether it is possible to resolve this remaining puzzle by figuring out a way to measure the share effect with regard to TFP is a task we would like to tackle in the future.

References

Caves, Douglas, Laurits Christensen, and Walter Erwin Diewert (1982) "Multilateral Comparisons of Output, Input and Productivity Using Superlative Index Numbers," *Economic Journal*, 92(365): 73–86.

Fujita, Masahisa, and Takatoshi Tabuchi (1997) "Regional Growth in Postwar Japan," *Regional Science and Urban Economics*, 27(6): 643–670.

Fukao, Kyoji, Tatsuji Makino and Joji Tokui (2015) "Regional Factor Inputs and Concergence in Japan: A Macro-Level Analysis, 1955-2008," to be prepared for RIETI discussion paper.

Ikeuchi Kenta, YoungGak Kim, Hyeog Ug Kwon, and Kyoji Fukao (2013) "Seizogyo ni okeru seisansei dogaku to R&D spillovers – Microdata ni yoru jissho bunseki [Productivity Dynamics and R&D Spillovers in the Japanese Manufacturing Industry: An Empirical Analysis Based on Micro-level Data," *Keizai Kenkyu [The Economic Review]*, 64(3): 269–285 (in Japanese).

Kim, Sukkoo (1995) "Expansion of Markets and the Geographic Distribution of Economic Activities: The Trends in U. S. Regional Manufacturing Structure, 1860–1987," *The Quarterly Journal of Economics*, 110(4): 881–908.

Tokui, Joji, Tatsuji Makino, Kyoji Fukao, Tsutomu Miyagawa, Nobuyuki Arai, Sonoe Arai, Tomohiko Inui, Kazuyasu Kawasaki, Naomi Kodama and Naohiro Noguchi (2013)

“Todofuken-betsu sangyo seisansei (R-JIP) Database no kochiku to chiiki-kan seisensei kakusa no bunseki [Compilation of the Regional-Level Japan Industrial Productivity Database (R-JIP) and Analyses of Productivity Differences across Prefectures],” *Keizai Kenkyu [The Economic Review]*, 64(3): 218–239 (in Japanese).

Yue, Ximing (1998) “Nihon ni okeru seisan yoso fuson to sangyo kozo no chiiki-kan kakusa [Regional Differences in Factors of Production and Industrial Structure in Japan],” *Nihon Keizai Kenkyu [JCER Economic Journal]*, 37: 142–164 (in Japanese).