RIETI Discussion Paper Series 17-E-021

Factor Intensity Reversals Redux

KIYOTA Kozo
RIETI

KUROKAWA Yoshinori
University of Tsukuba

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 17-E-021

March 2017

Factor Intensity Reversals Redux*

KIYOTA Kozo
Keio University and Research Institute of Economy, Trade and Industry
KUROKAWA Yoshinori
University of Tsukuba

Abstract

Little evidence for factor intensity reversals (i.e., reversals of capital/labor ratios) among countries or regions has been found in previous empirical studies. This supports Samuelson's (1951) view that factor intensity reversals are of theoretical interest rather than empirical importance. Using newly developed region-level data, however, we argue that the abandonment of factor intensity reversals in the empirical analysis has been premature. Specifically, we find that the degree of the factor intensity reversals is higher than that found in previous studies on average. Moreover, the degree of the factor intensity reversals has increased over the last two decades. Finally, the degree of the factor intensity reversals is higher when we use disaggregated industry-level data, weakening a possible criticism that several factor intensity reversals may be a result of the aggregation of industries.

Keywords: Factor intensity reversals, Capital, Labor, Region, Japan
JEL classification: F11, F14

* We are very grateful to Ichiro Daitoh, Kyoji Fukao, Taiji Furusawa, Makoto Hasegawa, Kaoru Hosono, Tomohiko Inui, Arata Ito, Hayato Kato, Fukunari Kimura, Gang Li, Kiyoshi Matsubara, Daisuke Miyakawa, Masayuki Morikawa, Hiroshi Mukunoki, Yasusada Murata, Kentaro Nakajima, Ryo Nakajima, Eiichi Nakazawa, Michio Naoi, Masao Ogaki, Michihiro Ohyama, Hisamitsu Saito, Yukiko Saito, Chisato Shibayama, Yoshimasa Shirai, Michio Suzuki, Miho Takizawa, Kimiko Terai, Eiichi Tomiura, Makoto Yano, and Lianming Zhu for their useful comments. We also thank the participants in seminars and conferences at Keio, RIETI, and the Japan Society of International Economics KANTO. This study was conducted as part of the Project "Microeconomic Analysis of Firm Growth" undertaken at the Research Institute of Economy, Trade and Industry (RIETI). The study uses the micro data from the questionnaire in the Census of Manufacture, which is conducted by the Ministry of Economy, Trade and Industry (METI). The usual disclaimers apply.

"In connection with the two factor case, I have the impression that the phenomenon of goods that interchange their roles of being more labor intensive is much less important empirically than it is interesting theoretically" (Samuelson, 1951, pp. 121–22).

1 Introduction

Samuelson's (1951) well-known view is that factor intensity reversals—reversals of the capital/labor ratio—are of theoretical interest rather than empirical importance. Factor intensity reversal means that a good/industry is relatively capital intensive compared with other goods/industries within a country/region but relatively labor intensive compared with other goods/industries within another country/region. In fact, little evidence for factor intensity reversals among countries or regions has been found in previous empirical studies (e.g., Fuchs, 1963; Leontief, 1964; Ball, 1966; Moroney, 1967).[1] Therefore, factor intensity reversals have been abandoned in empirical analysis for a long time.

This issue of whether factor intensity reversals exist or not is an important issue particularly in the analysis of the Heckscher–Ohlin model. This is because all of the major four theorems of the standard Heckscher–Ohlin model (i.e., the Stolper–Samuelson theorem, the Rybczynski theorem, the factor price equalization theorem, and the Heckscher–Ohlin theorem) assume no factor intensity reversals. Although some trade economists, such as Deardorff (1986) and Bhagwati and Dehejia (1994), have questioned this assumption and taken seriously the possibility of factor intensity reversals, so far the empirical studies on the Heckscher–Ohlin model have ruled out the possibility of factor intensity reversals because little evidence has been found as mentioned above.[2]

Recently, however, some studies such as Kurokawa (2011) and Sampson (2016) have documented empirically that there exist skill intensity reversals: a good/industry is relatively high-skill intensive within a country but relatively low-skill intensive within another country.[3] Note that these studies focused on skill intensity rather than capital intensity. These studies thus did not tackle the issue of factor intensity reversals, which were controversial in the 1960s, directly.[4] Noting that the availability of the data on capital and labor has recently been improved significantly compared with that in the 1960s, it is worth revisiting the issue of the factor intensity reversal controversy from the

[1] At first sight, Minhas (1962) seemed to show evidence of factor intensity reversals using both parametric tests (i.e., estimates of elasticity and distribution parameters of production functions) and nonparametric tests (i.e., examination of the rank correlation of capital intensities). However, his parametric test was criticized by Fuchs (1963) and Leontief (1964) because the test results are sensitive to the ratio of the distribution parameters and the specification of the production function. For example, Fuchs (1963) showed that the estimated elasticities of substitution were less dispersed if the production function includes a dummy variable that allows for the differences between developed and developing countries. The nonparametric test was also criticized by Ball (1966) and Moroney (1967). For example, Ball (1966) showed that the test results were sensitive to whether or not the agricultural industry is included.

[2] For example, Tomiura (2005), Bernard, Redding, Schott, and Simpson (2008), and Bernard, Redding, and Schott (2013) examined whether factor price equalization exists in Japan, the United Kingdom, and the United States, respectively. These studies found that factor price equalization did not exist even within a country. Similarly, Kiyota (2012) confirmed that in Japan, the average manufacturing wage rate in Kanagawa prefecture is almost twice as high as that in Aomori prefecture. However, all of these studies ignored the possibility of factor intensity or skill intensity reversals.

[3] Reshef (2007) also seriously considered the possibility of skill intensity reversals.

[4] In this paper, the expression "factor intensity reversal" refers to a capital intensity reversal and is distinguished from a skill intensity reversal. Of course, there are factors of production other than capital and labor, such as land, but we focus on capital and labor, as in neoclassical trade models such as the Heckscher–Ohlin model. We note, however, that even in the case of more than two factors, we can still define capital intensity as the capital/labor ratio, as in the case of two factors. Moreover, the meaning of factor intensity reversal in such a case remains the same as that in the case of two factors: the ranking of capital intensity among sectors is not the same among countries/regions. For example, see Wong (1990) for factor intensity reversals in the case of multiple factors.

1960s with new data on capital and labor.

In fact, Table 1, which shows the capital/labor ratios for the manufacturing industries in 47 Japanese prefectures in 2005, indicates that several factor intensity reversals might have existed in these industries.[5] Note that a Japanese "prefecture" corresponds to a US "state." The industries and the prefectures are sorted in order of capital intensity and relative capital abundance, respectively. The color of each cell indicates the capital intensity of a given industry in a given prefecture. Light gray, gray, dark gray, and black mean that the capital intensity is in the first, second, third, and fourth quartiles, respectively. If there is no factor intensity reversal, cells will become darker from left to right in the same way in all prefectures. That is, the order of industry capital intensities will be the same in all prefectures.[6] As can be seen, however, Table 1 indicates the existence of factor intensity reversals. For example, transportation machinery was more capital intensive than were pulp and paper in Aichi, where Toyota is located. In contrast, pulp and paper were more capital intensive than was transportation machinery in Ehime, where the plants of Daio Paper Corporation are located. Similarly, general machinery was more capital intensive than was transportation machinery in Nagasaki, whereas transportation machinery was more capital intensive than was general machinery in Kyoto.

=== Table 1 ===

This paper now examines whether or not factor intensity reversals indeed existed, using prefecture-level data in Japan over the period 1973–2009. An advantage of using Japanese prefecture-level data is that identical technology across prefectures is plausible within a country as compared with the situation across countries. One of the key assumptions in the Heckscher–Ohlin model is that technology is identical across countries or regions. If one industry in a country/region employs different production technology from an industry in another country/region, it is impossible to classify the industry as the same industry. Indeed, Harrigan (1997) found that technology differences as well as factor supplies were important determinants of the international specialization of production. Bernstein and Weinstein (2002) pointed out that the use of international data was sometimes subject to problems such as measurement error and government policy. The use of national data can overcome some of these problems. Bernstein and Weinstein (2002) and Kiyota (2012) used Japanese regional data to test the empirical validity of the Heckscher–Ohlin model. Indeed, Moroney (1967) also used US regional data in 1957 in examining the existence of factor intensity reversal. Another advantage of the use of Japanese prefecture data is that, as we will see in Section 2, real capital stock and labor inputs data are available at the prefecture-industry level in Japan. While such data are available at the country level, to the best of our knowledge, they are not available at the state or prefecture level in many countries.[7] This study thus focuses on Japan.

In contrast, there is a disadvantage in that the factors are more mobile in a cross-region analysis than in a cross-country analysis. One of the key assumptions in the Heckscher–Ohlin model is that there is no mobility of factors across countries or regions.

[5] In Section 2, we present a more detailed description of the data. Kiyota (2012) also showed a similar table for Japan in 2000, although his focus was not on factor intensity reversals but on the existence of multiple cones of diversification.

[6] See Table A1 for a hypothetical example of no factor intensity reversal.

[7] Note that because the US Bureau of Economic Analysis provides data on the net capital stock for the nation but not for individual states, Garofalo and Yamarik (2002) and Yamarik (2013) estimated state-level capital stock. Their estimates, however, are not at the state-industry level but at the state-aggregate-level.

It is fortunate, however, that domestic labor mobility is relatively low in Japan.[8] According to the Ministry of Internal Affairs and Communications (2000), the migration rate of manufacturing workers among prefectures was 6.6 percent from 1995 to 2000.[9] This implies that the annual domestic migration rate in Japan was about 1 percent, which is almost the same as the international migration rates of some OECD countries, such as Switzerland.[10]

The contribution of our paper is as follows. We revive and add to the factor intensity reversal literature. Minhas (1962) seemed to show evidence of reversals, but his results have been criticized and rejected.[11] We present strong evidence that weakens these criticisms. We also perform several robustness checks: 1) the sample includes agriculture and mining industries; 2) 47 prefectures are aggregated into eight regions; 3) the analysis takes human capital into account; 4) we compare different years; and 5) the industries are disaggregated at the four-digit level. In particular, we emphasize that the factor intensity reversals are stronger when we use the disaggregated industry-level data than when we use the aggregated data. We can thus weaken the possible criticism that several factor intensity reversals may be a result of the aggregation of industries.

The rest of this paper is organized as follows. Section 2 describes the data and methodology used in this paper. Section 3 presents the results, and Section 4 uses more disaggregated data. Section 5 concludes the paper and discusses opportunities for future research.

2 Data and Methodology

2.1 Data

We use the Regional-Level Japan Industrial Productivity (R-JIP) Database 2014 for real capital stock and labor data.[12] It provides us with annual information on capital and labor inputs, as does the National Bureau of Economic Research manufacturing database. One of the notable features of the database is that the information is available at the prefecture-industry level. The data cover 47 prefectures in Japan for the period from 1970 to 2009. Note again that a "prefecture" in Japan corresponds to a "state" in the United States. The data include 13 manufacturing industries and the agriculture and mining industries.[13] The 47 prefectures are aggregated into eight regions.[14]

In the R-JIP Database 2014, capital stock is defined as the net real capital stock. The unit of measurement is one million Japanese yen (2000 constant prices). Labor is measured as man-hours (i.e., number of workers times working-hours per worker divided by 1,000).[15] Section 3.1 will focus on the year 2005 as in Table 1. In Section 3.2, we

[8] We acknowledge that capital mobility is not low compared with labor mobility in Japan. Using Japanese prefecture-level data, however, can still be compatible with the Heckscher–Ohlin model assuming factor intensity reversals. In such a model, the isoquant curves of two sectors have more than one intersection, and multiple diversification cones exist. Then the rental/wage ratios differ among countries/regions that are located in different cones. In that case, even if we allow capital mobility across countries/regions, as long as labor mobility is low, it is possible that the countries/regions remain in different cones and thus differences in the rental/wage ratios remain. In fact, the standard deviation of the capital/labor ratios for 47 prefectures in Japan increased over 1975–2005.

[9] The migration rate refers to the inflows divided by the total labor force in manufacturing.

[10] For more details, see OECD (2006, p.32, Chart I.1.).

[11] For criticisms of Minhas's (1962) results, see footnote 1.

[12] The data are available at http://www.rieti.go.jp/jp/database/R-JIP2014/index.html. The Japan Industrial Productivity (JIP) Database has been widely used in several studies (e.g., Dekle et al., 2010; Dekle et al., 2015).

[13] See Table A2 for the classifications of prefectures and industries.

[14] See Table A2 for the region classification.

[15] For more detailed explanations on how to measure capital and labor, see Tokui et al. (2013).

examine the period 1973–2009. Note that the reason that we use the data from 1973 is that Okinawa prefecture was returned to Japan in 1972.

2.2 Methodology

Using the data on capital and labor from the R-JIP Database 2014, we first calculate capital intensity by industry and by prefecture.[16] We then calculate Spearman's rank correlations of industry capital intensity, ρ, for all prefecture pairs, and their mean, $\overline{\rho}$. Spearman's rank correlation presents the correlation of rankings of capital intensity between two different prefectures, which is defined as:

$$\rho = 1 - \frac{6 \sum d^2}{n(n^2 - 1)}, \tag{1}$$

where d is the difference between the two ranks of each observation, and n is the number of observations.[17] It takes values from -1 to 1. The value 1 indicates a perfect agreement among rankings of capital intensity between two prefectures, whereas the value 0 indicates no agreement; and the value -1 indicates a perfect negative association. In other words, the smaller the value of ρ, the stronger the factor intensity reversals between two prefectures.

Following Moroney (1967), we also calculate Kendall's coefficient of concordance, W. Kendall's W is another useful statistic for measuring the uniformity of rankings among m ($m > 2$) sets of rankings. It takes values from 0 (no agreement among ranks) to 1 (perfect agreement). It can easily be calculated by using the following linear relationship with the mean of the Spearman's rank correlations, $\overline{\rho}$:[18]

$$\overline{\rho} = \frac{mW - 1}{m - 1}. \tag{2}$$

It should be noted that instead of a parametric approach, this paper takes a nonparametric approach—Spearman's rank correlations—to measure the degree of the factor intensity reversals. There are two main reasons for this. First, we ensure the comparability of our findings with previous studies by following the nonparametric approach taken by Minhas (1962) and Moroney (1967). Minhas (1962) showed that Spearman's rank correlation of capital intensities for 20 industries between Japan and the United States was 0.730. Moroney (1967) analyzed factor intensity reversals among regions in the United States and found higher rank correlations (0.8774–0.9074) than those of Minhas (1962). As can be seen, as in our paper, Moroney (1967) also analyzed factor intensity reversals at the region level. While he focused on US regions, we focus on Japan's prefectures. Second, by taking a nonparametric approach, our results do not depend on the specification of the production function.

Note also that there is no single criterion for the correlations regarding whether factor intensity reversals exist or not. Because the previous studies often referred to the correlations reported by Minhas (1962) (i.e., 0.730) and Moroney (1967) (i.e., 0.8774–0.9074), we also consider these values as reference values.[19]

[16] As we have noted in footnote 4 in Section 1, even if we add factors other than capital and labor to our analysis, we can similarly define/calculate capital intensity as the capital/labor ratio, and discuss capital intensity reversals among prefectures.

[17] Note that this formula assumes that all ranks are distinct in both observations. We use a modified version when ties are present.

[18] See p. 315 in Agarwal (2007).

[19] Minhas (1962) argued that "the difference between unity and .730 is large enough to suggest that reversals in relative capital intensity do exist" (p.148).

3 Empirical Results

3.1 Evidence for 2005

As we have seen in Section 1, Table 1 indicates that several factor intensity reversals might have existed among the manufacturing industries of the 47 prefectures in Japan in 2005. To determine the degree of the factor intensity reversals, we calculate Spearman's rank correlations, ρ, for all prefecture pairs. Here, the number of prefecture pairs is 1,081 ($= 46 + 45 + \ldots + 1$). We then obtain the mean of Spearman's rank correlations, $\overline{\rho}$, of 0.645 (the standard deviation is 0.186). This is much lower than the values obtained by Moroney (1967), who concluded that few factor intensity reversals existed among regions in the US manufacturing industries in 1957: 0.8774 (six regions & 14 industries) and 0.9074 (five regions & 16 industries). Note that the lower the value of $\overline{\rho}$, the stronger the factor intensity reversals.

This value of 0.645 indicates that several reversals existed in 2005 because the value is even lower than the value obtained by Minhas (1962) (i.e., 0.730), who argued that several reversals existed.[20]

While his results have been criticized and rejected as mentioned in Section 1, our results can withstand such criticisms. Thus, we can no longer say that few factor intensity reversals existed among the manufacturing industries in the 47 prefectures of Japan in 2005. We also calculate Kendall's W of 0.652, which is also much lower than the values obtained by Moroney (1967) (i.e., 0.8955–0.9228). This reconfirms our above argument based on $\overline{\rho}$.

One may argue that as shown in Table 1, factor intensity reversals seem to be observed mainly in the four machinery industries (general machinery, electrical machinery, transportation machinery, and precision machinery) and thus our results might be driven by these machinery industries. To address this concern, we aggregate these four machinery industries into one industry (the total number of industries is now 10) and calculate the rank correlations for the 47 prefectures. The mean of Spearman's rank correlations, $\overline{\rho}$, for 2005 increases to 0.753 (the standard deviation is 0.171). Although higher than the value before aggregation, it is still comparable to that of Minhas (1962) and lower than the values obtained by Moroney (1967). Our main messages therefore are not changed by the aggregation of the machinery industries.

3.1.1 Inclusion of the agriculture and mining industries

Ball (1966) found that the factor intensity reversals estimates of Minhas (1962) were sensitive to whether or not the agricultural industry is included. Specifically, the rank correlation increased considerably if the analysis excluded one agricultural industry (i.e., from 0.732 for all industries to 0.833 for manufacturing). One may thus be concerned that our results are sensitive to the inclusion of agricultural and mining industries. To address this concern, we add the agriculture and mining industries to the previous analysis that focused only on the manufacturing industries in 47 prefectures in 2005.

Table 2 shows the capital intensities for all industries including agriculture and mining in 47 prefectures in 2005. The mean of Spearman's rank correlations, $\overline{\rho}$, is now 0.649 (the standard deviation is 0.171), which is slightly higher than the previous value of 0.645, with the focus only on the manufacturing industries. In other words, $\overline{\rho}$ for the case of only the manufacturing industries is lower than that for the case including the agriculture and

[20] We also compute the 95 percent confidence interval, assuming that ρ follows a normal distribution. The 95 percent confidence interval is between 0.634 and 0.656 (the number of observations is 1,081, and the standard error is 0.006), implying that the rank correlation obtained in this study is significantly lower than that of the previous studies.

mining industries. This lower value of Spearman's rank correlation implies that factor intensity reversals are more prevalent when we focus only on the manufacturing industries than when we include the agriculture and mining industries.

=== Table 2 ===

Moreover, Kendall's W is now 0.657, which is also slightly higher than the value of 0.652 when the analysis focuses only on the manufacturing industries. This again indicates that focusing only on the manufacturing industries does not show fewer factor intensity reversals. Interestingly, while previous studies such as Ball (1966) showed that the case of only the manufacturing industries showed fewer factor intensity reversals, our Japanese data indicate the opposite pattern.

3.1.2 Aggregation of prefectures

Another concern may be that our results are sensitive to the aggregation of prefectures. For example, Moroney (1967) focused on five or six aggregated regions in the United States, whereas our study focuses on 47 disaggregated prefectures. The aggregation of the prefectures may affect the results. To address this concern, we repeat the analysis in the previous sections, with eight aggregated regions. Here, the number of region pairs is 28 $(= 7 + 6 + \ldots + 1)$.

Tables 3 and 4 present the results for the aggregated eight-region counterparts of Tables 1 and 2, respectively. Tables 3 and 4 indicate that few factor intensity reversals might have existed among the eight regions in 2005. In fact, the mean of Spearman's rank correlations, $\overline{\rho}$, is now 0.831 (the standard deviation is 0.097) for the case of only the manufacturing industries; it is 0.844 (the standard deviation is 0.079) for the case including the agriculture and mining industries. These values are higher than those in Minhas (1962) and are close to those in Moroney (1967), although still smaller. The results indicate that in 2005, the degree of the factor intensity reversals was lower at the aggregated-eight-region level than at the 47-prefecture level but still not negligibly small. Kendall's W also indicates similar patterns. It is 0.853 for the case of only the manufacturing industries, while it is 0.864 for the case including the agriculture and mining industries. These values are also close to those in Moroney (1967), although still smaller.

=== Tables 3 & 4 ===

3.1.3 Human capital

One may be also concerned that our results are driven by the differences in human capital across prefectures because man-hours, which is our measure of labor input, does not take into account the differences in skill level (human capital). For example, consider the case in which the capital/labor ratio of an industry is relatively large within prefecture A but relatively small within prefecture B. If, however, the skill level of labor used in prefecture A is higher and thus the labor productivity is higher, then it is possible that for the industry in prefecture A, man-hours employed is smaller and thus the capital/labor ratio is larger. This indicates that the same number of man-hours does not necessarily mean the same level of skill (human capital).

Therefore, to take into account crudely the differences in human capital across prefectures, here we use total wages rather than man-hours as the measure of labor input. This approach is also employed by Hsieh and Klenow (2009) to take into account the differences in hours worked and human capital. The data on total wages by prefecture and industry are also available in the R-JIP Database. The unit of measurement of total wages is millions of Japanese yen.

Table 5 presents the results for the manufacturing industries in the 47 prefectures for 2005. As in Table 1, actual capital intensities are different from the pattern presented in Table A1. This suggests the existence of factor intensity reversals. The mean of Spearman's rank correlations, $\overline{\rho}$, is 0.503 (the standard deviation is 0.231), which is lower than that in Table 1. These results together suggest that our main results hold even when we take into account the differences in human capital.

=== Table 5 ===

3.2 Evidence for 1973–2009

In Section 3.1, we found that in 2005, factor intensity reversals were less severe among the eight aggregated regions of Japan, focusing only on the manufacturing industries and in the case including the agriculture and mining industries. However, factor intensity reversals were prevalent among the 47 prefectures in the same year in both cases, but more existed in the former case. In this section, to determine whether the above results also hold for other years, we construct a table that shows the mean of Spearman's rank correlations, $\overline{\rho}$, and its standard deviation for each of the years 1973–2009 as well as Kendall's W.

The analysis consists of 47-prefectures level and eight-aggregated-regions level analyses. In each analysis, we compare two cases: (1) only the manufacturing industries and (2) the manufacturing plus agriculture and mining industries.

We first present the 47-prefectures level analysis. Table 6 shows that $\overline{\rho}$ ranges from 0.603 to 0.750 for the case focusing only on manufacturing and from 0.612 to 0.753 for the case including agriculture and mining, over the period 1973–2009. The table also shows that Kendall's W ranges from 0.611 to 0.755 for the former case and from 0.620 to 0.759 for the latter case, over the same period. The values of $\overline{\rho}$ and W are much smaller than those obtained by Moroney (1967) and even smaller than those obtained by Minhas (1962). Thus, the results indicate that several factor intensity reversals existed among the 47 prefectures in both cases during 1973–2009, but more existed in the case of only manufacturing. Moreover, the degree of the factor intensity reversals among the 47 prefectures has increased in the last two decades as indicated by both $\overline{\rho}$ and W, which have decreased since 1985.

=== Table 6 ===

We next present the eight-aggregated-regions level analysis. Table 7 shows that both $\overline{\rho}$ and W exceeded 0.8 in both cases during the period 1973–2009, and they even exceeded 0.9 in some years. These values are close to those obtained by Moroney (1967). Thus, like previous studies, our results indicate that factor intensity reversals were less severe among the eight aggregated regions over 1973–2009.

=== Table 7 ===

It is worth pointing out that as shown in Table 6, the standard deviation of Spearman's rank correlations for all prefecture pairs has also increased recently, as has the mean of ρ, both in the case focusing only on manufacturing and in the case including agriculture and mining. Figure 1 shows the distribution of Spearman's rank correlations for all prefecture pairs for the years 1975, 1985, 1995, and 2005, with the focus on the manufacturing industries. As can be seen, the distribution across prefecture pairs was concentrated from 1975 to 1985, but it was dispersed from 1985 to 2005. This indicates that differences in the degree of the factor intensity reversals between prefecture pairs have increased recently. Figure 2 shows similar changes in the distribution for the case including the agriculture and mining industries.

=== Figures 1 & 2 ===

4 Intra-industry Heterogeneity

One may also be concerned about intra-industry heterogeneity because our 13 manufacturing industry classifications might be too aggregated to address the issue of identical technology across prefectures. For example, transportation machinery includes not only automobiles but also other transportation machines such as trains, ships, and airplanes. If different prefectures specialize in different products within an industry, it may be natural to find differences in factor intensity.[21] Thus, a possible criticism is that factor intensity reversals among prefectures may be found because of the aggregation of industries; in other words, if industries are disaggregated, then fewer factor intensity reversals among prefectures may be found.

We want to address this concern; however, a problem exists with the availability of data for Japan. Other than the R-JIP Database, there are no time-series data on real capital stock and labor that use the same industry classifications over time at the prefecture-industry level. Therefore, here we use confidential plant-level data from the Census of Manufacture published by the Japanese Ministry of Economy, Trade and Industry. These data come from an annual census that is compulsory for plants with more than three employees. For plants that have at least 30 workers, it records information on tangible assets and number of workers.[22] Although it is an annual census, we cannot trace the same industry throughout the period because of the revisions of the industry classifications.[23] We thus focus on the year 2005. The industry classifications are available at the four-digit industry level: 560 manufacturing industries in 2005. Note that the information on tangible assets in an industry in a prefecture is not available if none of the plants in the industry in the prefecture have more than 30 workers. As a result, information on tangible assets and the number of workers is available for 552 manufacturing industries in 2005.

Table 8 presents the results. Capital stock is measured as nominal tangible assets measured in millions of yen. Labor is measured as number of workers. As in Table 1, the industries and the prefectures are sorted in order of capital intensity and relative capital abundance, respectively. Note that there are 552 manufacturing industries, which prevents us from reporting the name of each industry.

=== Table 8 ===

The color of each cell indicates the capital intensity of a given industry in a given prefecture. Note that some prefectures report no production at the four-digit industry level. Accordingly, we now have some white cells, which means no production. As in the previous tables, light gray, gray, dark gray, and black mean that the capital intensity is in the first, second, third, and fourth quartiles, respectively.

[21] In a similar context, using detailed product-level import data for the United States, Schott (2004) found that US imports were inconsistent with factor-proportion specializations across products but were consistent with such specialization within products.

[22] For plants that have fewer than 30 workers, the information on tangible assets is not available.

[23] Another concern in the use of the Census of Manufacture data is that tangible assets are reported as a nominal book value rather than a market value.

Similar to Table 1, several factor intensity reversals exist among the 47 prefectures even if we use plant-level data. We also computed the mean of Spearman's rank correlations, $\overline{\rho}$. The correlations are calculated using pairwise deletion of observations with missing values. The mean of the correlations is 0.360 (the standard deviation is 0.108), which is significantly smaller than that of Moroney (1967) and even smaller than that of Minhas (1962).[24] Our results show that our main results hold even when we use a disaggregated industry classification. In fact, the degree of the factor intensity reversals is higher when we use the disaggregated industry-level data than when we use the aggregated data. Thus, we weaken any possible criticism that factor intensity reversals may be a result of the aggregation of industries.[25]

We note that as indicated by equation (1) in Section 2.2, Spearman's rank correlation, ρ, depends on the number of observations, n. Thus, one may be concerned that the correlation decreases from 0.645 (the benchmark case in Section 3.1) to 0.360 primarily because the number of manufacturing industries, n, increases substantially from 13 to 552. However, equation (1) indicates that the correlation should become larger as n becomes larger, other things unchanged. Therefore, the decreased correlation (0.360) is not because of the increased n (552) but because of the increased factor intensity reversals.

One may also be concerned that if the number of plants in each cell in Table 8 is small, the capital intensity will be affected by the small number of large (or small) plants. To address this concern, we exclude cells whose number of observations is fewer than 10. The results indicate that the mean of the correlations is 0.473 (the standard deviation is 0.569).[26] Although the rank correlation is slightly higher, this result is similar to the result that includes all plants in that the mean correlation is significantly smaller than that of Moroney (1967) and even smaller than that of Minhas (1962).

Moreover, regardless of the number of plants in each cell in Table 8, the capital intensity may be affected by very large plants. To address this concern, we exclude plants that are in the top 1 percent of capital intensity in each cell. The results indicate that the mean of the correlations is 0.335 (the standard deviation is 0.107).[27] This result is also similar to the result that includes all plants. Another concern may be that, as we confirmed in Section 3, the correlation increases if prefectures are aggregated at the region level. To address this concern, we compute the rank correlation, aggregating 47 prefectures to eight regions while using the same detailed four-digit industry level data. The results indicate that the mean of the rank correlation is 0.567 (the standard deviation is 0.045).[28] This is higher than that for the prefecture-level results, but it is still smaller than that in the previous studies. In sum, our main results hold even when we take into account intra-industry heterogeneity (i.e., even when we use detailed industry-level data).

---

[24] We also compute the 95 percent confidence interval, as in the previous section, which is from 0.354 to 0.367 (the number of observations is 1,081, and the standard error is 0.003).

[25] It may be worth mentioning an aggregation problem associated with the so-called "lens conditions." Debaere (2004) showed theoretically that with more disaggregation of sectors, the goods lens becomes even wider, making a violation even less likely. Thus a possible criticism of empirical studies that documents the satisfaction of the lens condition is that the lens condition may be satisfied because of the disaggregation of industries. Evidence indeed supports this criticism. Bernard et al. (2005) empirically showed that lenses created with more disaggregated data are wider than lenses created with more aggregate data and that the satisfaction of the lens condition is more likely when industries are relatively disaggregated compared with countries or regions.

[26] The 95 percent confidence interval is from 0.435 to 0.511 (the number of observations is 867, and the standard error is 0.019).

[27] The 95 percent confidence interval is from 0.329 to 0.342 (the number of observations is 1,081, and the standard error is 0.003).

[28] The 95 percent confidence interval is from 0.550 to 0.584 (the number of observations is 28, and the standard error is 0.008).

5 Conclusion

Based on newly developed Japanese prefecture-level data, we argue that the abandonment of factor intensity reversals in empirical analysis has been premature. Specifically, we have found that the degree of factor intensity reversals is higher than that found in previous studies on average. Our empirical results have shown that while factor intensity reversals are less severe at the aggregated eight-region level, they are prevalent at the 47-prefecture level. Furthermore, the degree of the factor intensity reversals has increased in the last two decades. We have also performed several robustness checks: 1) the sample includes agriculture and mining industries, 2) 47 prefectures are aggregated into eight regions, 3) the analysis takes into account human capital, 4) we compare different years, and 5) the industries are disaggregated at the four-digit level. In particular, we have found that the degree of the factor intensity reversals is higher when we use disaggregated industry-level data than when we use aggregated data. Thus we have successfully weakened any possible criticism that factor intensity reversals may be a result of the aggregation of industries.

The implications of our study are threefold. First, the "standard" industry classifications may not be appropriate for testing the empirical validity of the Heckscher–Ohlin model. As was pointed out by Schott (2003) and Kiyota (2012), the "standard" industry classification groups output loosely, according to the similarity of end use (e.g., electrical machinery, transportation machinery) rather than actual factor use (e.g., capital-intensive goods, labor-intensive goods). However, our results show that the same industry can be relatively capital intensive in one prefecture but relatively labor intensive in another prefecture. This indicates that the "standard" industry classifications may not be able to capture the actual capital intensity differences among countries or regions. It thus may be important to adapt a theoretically appropriate aggregation method such as the "Heckscher–Ohlin aggregates" developed by Schott (2003).

Second, it is important for policy makers to understand the intra-industry capital-intensity heterogeneity. A capital-intensive industry in one country or one region may not necessarily be capital intensive in the same industry in another country or region because of the intraindustry capital-intensity heterogeneity. This in turn implies that industry-specific policies may not work effectively because of the intra-industry heterogeneity. Before designing industrial policies, policy makers need to examine the heterogeneity across countries and/or regions.

Third, the theoretical studies on international trade need to place more importance on the empirical validity of the factor intensity reversals. As long as we rely on the end-use industry classifications, factor intensity reversals can be expected to exist. It may be appropriate to relax the assumption of no factor intensity reversals.

Of course, room for future research still exists. First, it is important to investigate the possible factors that have recently increased factor intensity reversals among the 47 prefectures in Japan, and the quantitative importance of each. Second, the four-digit level industry classifications may not be disaggregated enough to control for technology differences. In other words, the use of more detailed prefecture-industry-level data may weaken the degree of factor intensity reversals, although it may also further strengthen them. To address this issue, the quality and coverage of the prefecture-industry-level data must be improved and further disaggregated.

References

Agarwal, B.L. 2007. *Programmed Statistics: Questions–Answers.* New Delhi: New Age International.

Ball, David S. 1966. “Factor-Intensity Reversals in International Comparison of Factor Costs and Factor Use.” *Journal of Political Economy*, 74(1): 77–80.

Bernard, Andrew B., Stephen J. Redding, Peter K. Schott, and Helen Simpson. 2008. “Relative Wage Variation and Industry Location in the United Kingdom.” *Oxford Bulletin of Economics and Statistics*, 70(4): 431–59.

Bernard, Andrew B., Stephen J. Redding, and Peter K. Schott. 2013. “Testing for Factor Price Equality with Unobserved Differences in Factor Quality or Productivity.” *American Economic Journal: Microeconomics*, 5(2): 135–63.

Bernard, Andrew B., Raymond Robertson, and Peter K. Schott. 2005. “A Note on the Empirical Implementation of the Lens Condition.” NBER Working Paper Series, No. 11448, National Bureau of Economic Research (NBER).

Bernstein, Jeffrey R. and David E. Weinstein. 2002. “Do Endowments Predict the Location of Production? Evidence from National and International Data.” *Journal of International Economics*, 56(1): 55–76.

Bhagwati, Jagdish, and Vivek H. Dehejia. 1994. “Freer Trade and Wages of the Unskilled–Is Marx Striking Again?” In Jagdish Bhagwati and Marvin H. Kosters, eds., *Trade and Wages: Leveling Wages Down?* Washington, D.C.: The American Enterprise Institute Press, pp. 36–75.

Debaere, Peter. 2004. “Does Lumpiness Matter in an Open Economy? Studying International Economics with Regional Data.” *Journal of International Economics*, 64(2): 485-501.

Deardorff, Alan V. 1986. “Firless Firwoes: How Preferences Can Interfere with the Theorems of International Trade.” *Journal of International Economics*, 20(1–2): 131–42.

Dekle, Robert, Kyoji Fukao and Murat Ungor. 2010. “The Japan-US Exchange Rate, Productivity, and the Competitiveness of Japanese Industries.” In Koichi Hamada, Anil K Kashyap, and David E. Weinstein, eds., *Japan’s Bubble, Deflation, and Long-term Stagnation*. Cambridge: The MIT Press, pp. 105–28.

Dekle, Robert, Atsushi Kawakami, Nobuhiro Kiyotaki, and Tsutomu Miyagawa. 2015. “Product Dynamics and Aggregate Shocks: Evidence from Japanese Product and Firm Level Data.” RIETI Discussion Paper Series, 15-E-137, Research Institute of Economy, Trade and Industry (RIETI).

Fuchs, Victor R. 1963. “Capital–Labor Substitution: A Note.” *Review of Economics and Statistics*, 45(4): 436–38.

Garofalo, Gasper A. and Steven Yamarik. 2002. “Regional Convergence: Evidence from a New State-by-State Capital Stock Series.” *Review of Economics and Statistics*, 84(2): 316–23.

Harrigan, James. 1997. “Technology, Factor Supplies, and International Specialization: Estimating the Neoclassical Model.” *American Economic Review*, 87(4): 475–94.

Hsieh, Chang-Tai and Peter J. Klenow. 2009. “Misallocation and Manufacturing TFP in China and India.” *Quarterly Journal of Economics*, 124(4): 1403–48.

Kiyota, Kozo. 2012. “A Many-cone World?” *Journal of International Economics*, 86(2): 345–54.

Kurokawa, Yoshinori. 2011. "Is A Skill Intensity Reversal A Mere Theoretical Curiosum? Evidence from the US and Mexico." *Economics Letters*, 112(2): 151–54.

Leontief, Wassily. 1964. "An International Comparison of Factor Costs and Factor Use: A Review Article." *American Economic Review*, 54(4): 335–45.

Minhas, Bagicha S. 1962. "The Homohypallagic Production Function, Factor-Intensity Reversals, and the Heckscher–Ohlin Theorem." *Journal of Political Economy*, 70(2): 138–56.

Ministry of Internal Affairs and Communications (MIC). 2000. *Kokusei Chousa: Heisei 12 Nen (2000 Population Census of Japan)*, Tokyo: Nihon Tokei Kyokai. (In Japanese)

Moroney, John R. 1967. "The Strong-Factor-Intensity Hypothesis: A Multisectoral Test." *Journal of Political Economy*, 75(3): 241–49.

Organization for Economic Corporation and Development (OECD). 2006. *International Migration Outlook, 2006*, Paris: OECD.

Reshef, Ariell. 2007. "Heckscher–Ohlin and the Global Increase of Skill Premia: Factor Intensity Reversals to the Rescue." Working Paper, New York University.

Sampson, Thomas. 2016. "Assignment Reversals: Trade, Skill Allocation and Wage Inequality." *Journal of Economic Theory*, 163: 365–409.

Samuelson, Paul A. 1951. "A Comment on Factor Price Equalisation." *Review of Economic Studies*, 19(2): 121–22.

Schott, Peter K. 2003. "One Size Fits All? Heckscher-Ohlin Specialization in Global Production." *American Economic Review*, 93(3): 686–708.

Schott, Peter K. 2004. "Across-Product versus Within-Product Specializaion in International Trade." *Quarterly Journal of Economics*, 119(2): 647–78.

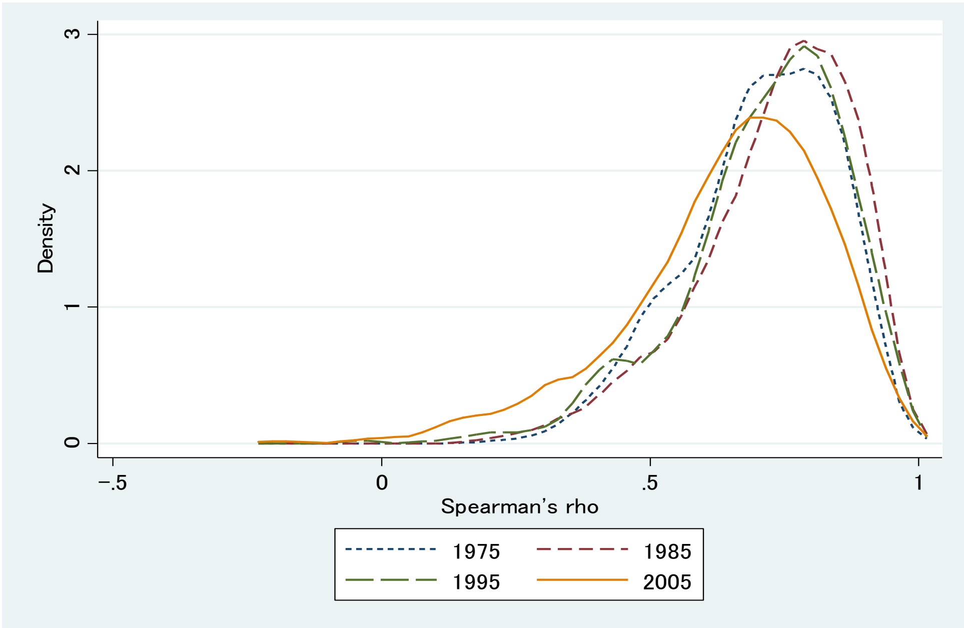
Tokui, Joji, Tatsuji Makino, Kyoji Fukao, Tsutomu Miyagawa, Nobuyuki Arai, Sonoe Arai, Tomohiko Inui, Kazuyasu Kawasaki, Naomi Kodama, and Naohiro Noguchi. 2013. "Compilation of the Regional-Level Japan Industrial Productivity Database." RIETI Discussion Paper Series, 13-J-037, Research Institute of Economy, Trade and Industry (RIETI).

Tomiura, Eiichi. 2005. "Factor Price Equalization in Japanese Regions." *Japanese Economic Review*, 56(4): 441–56.

Wong, Kar-yiu. 1990. "Factor Intensity Reversal in A Multi-Factor, Two-good Economy." *Journal of Economic Theory*, 51(2): 434–42.

Yamarik, Steven. 2013. "State-Level Capital and Investment: Updates and Implicatioms." *Contemporary Economic Policy*, 31(1): 62–72.

Figure 1: Distribution of ρ, Prefecture Level, Manufacturing



Note: Kernel density function.

Figure 2: Distribution of ρ, Prefecture Level, Including Agriculture and Mining

Note: Kernel density function.

Table 1: Prefecture–Industry Capital Intensity, Manufacturing, 2005

Prefecture	Endowment: prefecture capital-labor ratio (manufacturing total)	Metal products	Other manufacturing	Textile products	Food products	Ceramic, stone and clay products	General machinery	Precision machinery	Pulp and paper	Transportation machinery	Electrical machinery	Primary metal	Chemical products	Petroleum and coal products
Industry average capital labor ratio	10.55	3.86	6.13	6.26	7.12	7.83	8.12	11.55	12.76	13.06	13.14	25.53	27.99	123.48
Tokyo	4.82													
Okinawa	6.09													145.74
Kochi	6.32					13.51					14.62			
Gifu	7.04								13.77				21.41	69.75
Shimane	7.16							14.02						25.70
Akita	7.36							18.62	33.11			16.84	34.17	85.19
Kagoshima	7.53								17.62		13.81		16.54	32.72
Ishikawa	7.74										13.15		19.28	63.42
Yamagata	7.91											14.18	24.08	29.78
Osaka	7.97											18.61	18.15	123.86
Tottori	8.06								25.24					37.98
Kyoto	8.12									19.36			17.34	29.59
Saitama	8.15												18.46	45.91
Iwate	8.17								18.16		13.60	28.08	33.43	59.78
Kagawa	8.55											22.52	23.57	146.45
Niigata	8.61								15.41		13.22	15.32	50.93	129.25
Miyazaki	8.63							17.09	23.40				40.85	65.69
Saga	8.90										16.77	18.87	16.60	50.63
Nara	9.01						15.49				16.14			26.91
Fukui	9.19											24.28	21.63	58.61
Miyagi	9.32								25.00			22.75		174.98
Yamanashi	9.56							14.63			16.72		21.48	
Nagano	9.98							19.60			14.41		14.22	39.76
Hokkaido	10.01								39.16	17.59	15.25	33.94	22.98	227.11
Aomori	10.10								28.90			62.50	31.75	64.52
Gumma	10.12											14.30	30.30	38.16
Shizuoka	10.65			22.18				13.53	18.06			14.84	31.81	35.50
Fukuoka	10.65									16.66		36.32	38.74	95.13
Kumamoto	10.73								24.32		23.76	15.33	23.03	63.34
Fukushima	10.80								13.74		15.07	14.85	45.46	210.63
Toyama	11.27								20.03		17.16	27.10	27.54	128.87
Tokushima	11.49								22.71		17.50	23.52	31.80	241.57
Nagasaki	11.55						14.64				59.39		20.59	216.21
Tochigi	11.62							14.25	16.14		13.18	19.01	25.75	19.93
Aichi	11.98									16.96		22.04	26.33	164.39
Hyogo	12.79								15.83		14.08	33.85	26.04	122.89
Hiroshima	12.86								18.21		30.48	37.19	32.73	22.05
Shiga	12.97		13.68	13.98		15.17		13.73		17.51	14.53	17.86	18.75	63.78
Okayama	14.00							18.96				45.54	45.28	179.37
Ehime	14.09			17.76					18.07		25.53	43.21	51.32	154.74
Ibaraki	14.87						15.33					36.97	44.60	139.30
Kanagawa	14.98					13.45				15.00	14.06	36.14	38.47	152.91
Mie	15.49									16.05	20.71	16.49	48.90	194.24
Wakayama	16.36							30.20				53.98	38.66	235.07
Chiba	16.61										19.85	39.79	50.66	145.67
Oita	17.58							17.87	22.53		28.08	61.49	61.64	148.65
Yamaguchi	20.52			15.08		14.75			27.93		20.28	30.80	61.86	141.21

Notes: The color of each cell indicates the capital intensity of a given industry in a given prefecture. Light gray, gray, dark gray, and black mean that the capital intensity is in the first, second, third, and fourth quartiles, respectively. The industries and the prefectures are sorted in order of capital intensity and relative capital abundance, respectively.

Source: RIETI (2014) R-JIP Database 2014.

Table 2: Prefecture–Industry Capital Intensity, Including Agriculture and Mining, 2005

Prefecture	Endowment: prefecture capital-labor ratio (all tradables)	Metal products	Other manufacturing	Textile products	Food products	Ceramic, stone and clay products	General machinery	Precision machinery	Pulp and paper	Transportation machinery	Electrical machinery	Agriculture, forestry and fisheries	Mining	Primary metal	Chemical products	Petroleum and coal products
Industry average capital labor ratio	11.56	3.86	6.13	6.26	7.12	7.83	8.12	11.55	12.76	13.06	13.14	15.61	16.72	25.53	27.99	123.48
Tokyo	5.14											16.40				
Kochi	7.80															
Osaka	8.16													18.61	18.15	123.86
Gifu	8.27											16.62	23.10		21.41	69.75
Yamanashi	8.84										16.72				21.48	
Saitama	8.88														18.46	45.91
Kyoto	9.00									19.36					17.34	29.59
Saga	9.53										16.77		25.59	18.87	16.60	50.63
Yamagata	9.61												19.05		24.08	29.78
Kagawa	9.85												18.96	22.52	23.57	146.45
Nara	9.94												26.10			26.91
Shimane	10.18															25.70
Ishikawa	10.45											25.90	27.89		19.28	63.42
Kagoshima	10.51								17.62				19.07		16.54	32.72
Kumamoto	10.53								24.32		23.76		19.84		23.03	63.34
Miyazaki	10.53							17.09	23.40						40.85	65.69
Nagano	10.79							19.60					18.46			39.76
Akita	10.95							18.62	33.11			16.58	16.41	16.84	34.17	85.19
Iwate	11.00								18.16					28.08	33.43	59.78
Fukushima	11.09														45.46	210.63
Niigata	11.18											18.45			50.93	129.25
Gumma	11.25											16.30			30.30	38.16
Shizuoka	11.26			22.18					18.06						31.81	35.50
Tottori	11.51								25.24			16.83	30.71			37.98
Aomori	11.59								28.90				20.53	62.50	31.75	64.52
Tochigi	12.12													19.01	25.75	19.93
Fukuoka	12.12									16.66		17.37	36.21	36.32	38.74	95.13
Aichi	12.17									16.96				22.04	26.33	164.39
Nagasaki	12.17										59.39		21.45		20.59	216.21
Fukui	12.19											26.65		24.28	21.63	58.61
Okinawa	12.62											18.86				145.74
Hiroshima	12.88								18.21		30.48		17.52	37.19	32.73	22.05
Miyagi	13.09								25.00			22.41		22.75		174.98
Ehime	13.19			17.76					18.07		25.53			43.21	51.32	154.74
Tokushima	13.44								22.71		17.50	16.92		23.52	31.80	241.57
Okayama	13.63							18.96					17.36	45.54	45.28	179.37
Hyogo	13.97											21.63	107.47	33.85	26.04	122.89
Toyama	14.72								20.03		17.16	37.83	20.40	27.10	27.54	128.87
Kanagawa	14.92													36.14	38.47	152.91
Chiba	15.28										19.85		24.45	39.79	50.66	145.67
Ibaraki	15.42											17.12	29.80	36.97	44.60	139.30
Wakayama	15.50							30.20					145.60	53.98	38.66	235.07
Shiga	15.83									17.51		38.59	17.60	17.86	18.75	63.78
Hokkaido	16.16								39.16	17.59		23.84		33.94	22.98	227.11
Oita	16.22							17.87	22.53		28.08			61.49	61.64	148.65
Mie	16.41										20.71	21.72	16.53	16.49	48.90	194.24
Yamaguchi	17.81								27.93		20.28			30.80	61.86	141.21

Notes and source: See Table 1.

Table 3: Region–Industry Capital Intensity, Manufacturing, 2005

	Endowment: prefecture capital-labor retio (manufacturing total)	Metal products	Other manufacturing	Textile products	Food products	Ceramic, stone and clay products	General machinery	Precision machinery	Pulp and paper	Transportation machinery	Electrical machinery	Primary metal	Chemical products	Petroleum and coal products
Industry average capital labor ratio	10.55	3.86	6.13	6.26	7.12	7.83	8.12	11.55	12.76	13.06	13.14	25.53	27.99	123.48
Region														
Tohoku	9.17								20.01			26.23	34.86	135.80
Hokkaido	10.01								39.16	17.59	15.25	33.94	22.98	227.11
Kanto	10.19											25.31	23.72	100.43
Chubu	10.42								13.50	14.74		18.37	29.18	113.02
Kyushu	10.60										20.43	35.36	35.35	109.94
Kinki	10.73									13.47	13.52	25.25	23.73	151.20
Shikoku	10.96								16.39		17.46	29.22	37.00	145.63
Chugoku	13.75								16.80		17.74	34.49	49.13	143.06

Notes: Prefectures are aggregated into eight regions. For other notes and source, see Table 1.

Table 4: Region–Industry Capital Intensity, Including Agriculture and Mining, 2005

	Endowment: prefecture capital-labor retio (manufacturing total)	Metal products	Other manufacturing	Textile products	Food products	Ceramic, stone and clay products	General machinery	Precision machinery	Pulp and paper	Transportation machinery	Electrical machinery	Agriculture, forestry and fisheries	Mining	Primary metal	Chemical products	Petroleum and coal products
Industry average capital labor ratio	11.56	3.86	6.13	6.26	7.12	7.83	8.12	11.55	12.76	13.06	13.14	15.61	16.72	25.53	27.99	123.48
Region																
Kanto	10.74													25.31	23.72	100.43
Tohoku	11.24								20.01					26.23	34.86	135.80
Chubu	11.33											16.34		18.37	29.18	113.02
Shikoku	11.44								16.39		17.46			29.22	37.00	145.63
Kyushu	11.70										20.43		19.81	35.36	35.35	109.94
Kinki	11.74											19.70	42.86	25.25	23.73	151.20
Chugoku	13.61								16.80		17.74			34.49	49.13	143.06
Hokkaido	16.16								39.16	17.59		23.84		33.94	22.98	227.11

Notes: Prefectures are aggregated into eight regions. For other notes and source, see Table 1.

Table 5: Prefecture–Industry Capital Intensity, Alternative Measure of Labor Input, 2005

	Industry average capital labor ratio													
	3.79	1.53	2.46	2.65	3.00	3.68	3.73	3.81	3.90	4.29	4.57	6.88	6.97	25.41
	Endowment: prefecture capital-labor ratio (manufacturing total)	Metal products	Other manufacturing	General machinery	Ceramic, stone and clay products	Precision machinery	Textile products	Transportation machinery	Food products	Electrical machinery	Pulp and paper	Primary metal	Chemical products	Petroleum and coal products
Tokyo	1.28													
Osaka	2.44													
Gifu	3.01													
Nara	3.13													
Kyoto	3.13													
Ishikawa	3.28													
Kochi	3.47													
Shimane	3.49													
Gumma	3.51													
Nagano	3.55													
Aichi	3.62													
Shizuoka	3.63													
Saitama	3.76													
Tochigi	3.85													
Yamagata	3.88													
Niigata	3.97													
Kagawa	4.10													
Hyogo	4.13													
Fukui	4.19													
Kagoshima	4.20													
Yamanashi	4.28													
Tottori	4.29													
Akita	4.32													
Miyagi	4.34													
Iwate	4.37													
Fukuoka	4.41													
Fukushima	4.43													
Kumamoto	4.50													
Tokushima	4.51													
Hiroshima	4.55													
Saga	4.60													
Toyama	4.71													
Okinawa	4.73													
Mie	4.83													
Shiga	4.95													
Miyazaki	5.02													
Ibaraki	5.14													
Okayama	5.32													
Nagasaki	5.33													
Chiba	5.37													
Kanagawa	5.44													
Ehime	5.74													
Aomori	6.18													
Hokkaido	6.38													
Wakayama	6.50													
Yamaguchi	6.95													
Oita	7.24													

Notes and source: See Table 1.

Table 6: Rank Correlation of Industry Capital Intensities, 1973–2009: Prefecture-Level Results

	Manufacturing only				Includes agriculture and mining			
Year	Mean	S.D.	N	Kendall's W	Mean	S.D.	N	Kendall's W
1973	0.679	0.150	1,081	0.686	0.691	0.140	1,081	0.697
1974	0.682	0.146	1,081	0.689	0.681	0.143	1,081	0.688
1975	0.706	0.139	1,081	0.712	0.697	0.138	1,081	0.704
1976	0.716	0.138	1,081	0.722	0.708	0.138	1,081	0.715
1977	0.728	0.136	1,081	0.734	0.720	0.131	1,081	0.726
1978	0.734	0.140	1,081	0.740	0.731	0.132	1,081	0.736
1979	0.735	0.146	1,081	0.740	0.736	0.134	1,081	0.741
1980	0.727	0.142	1,081	0.733	0.733	0.127	1,081	0.738
1981	0.731	0.137	1,081	0.736	0.740	0.124	1,081	0.745
1982	0.735	0.135	1,081	0.740	0.736	0.123	1,081	0.741
1983	0.750	0.127	1,081	0.755	0.753	0.113	1,081	0.759
1984	0.727	0.144	1,081	0.733	0.734	0.128	1,081	0.740
1985	0.734	0.145	1,081	0.739	0.739	0.131	1,081	0.745
1986	0.726	0.141	1,081	0.732	0.727	0.130	1,081	0.733
1987	0.720	0.145	1,081	0.726	0.725	0.129	1,081	0.731
1988	0.711	0.154	1,081	0.717	0.723	0.136	1,081	0.729
1989	0.697	0.168	1,081	0.704	0.707	0.149	1,081	0.713
1990	0.709	0.156	1,081	0.715	0.709	0.147	1,081	0.716
1991	0.719	0.144	1,081	0.724	0.714	0.138	1,081	0.720
1992	0.716	0.147	1,081	0.722	0.700	0.140	1,081	0.707
1993	0.705	0.152	1,081	0.711	0.685	0.144	1,081	0.692
1994	0.705	0.157	1,081	0.711	0.694	0.146	1,081	0.700
1995	0.712	0.155	1,081	0.718	0.695	0.147	1,081	0.701
1996	0.712	0.151	1,081	0.718	0.692	0.145	1,081	0.699
1997	0.700	0.150	1,081	0.706	0.685	0.144	1,081	0.692
1998	0.697	0.151	1,081	0.703	0.681	0.143	1,081	0.688
1999	0.693	0.151	1,081	0.700	0.677	0.143	1,081	0.684
2000	0.678	0.163	1,081	0.685	0.665	0.152	1,081	0.673
2001	0.657	0.181	1,081	0.664	0.649	0.163	1,081	0.657
2002	0.654	0.180	1,081	0.661	0.649	0.162	1,081	0.657
2003	0.649	0.186	1,081	0.656	0.651	0.170	1,081	0.658
2004	0.659	0.181	1,081	0.666	0.664	0.165	1,081	0.671
2005	0.645	0.186	1,081	0.652	0.649	0.171	1,081	0.657
2006	0.625	0.197	1,081	0.633	0.638	0.177	1,081	0.645
2007	0.622	0.189	1,081	0.630	0.635	0.174	1,081	0.643
2008	0.603	0.199	1,081	0.611	0.612	0.189	1,081	0.620
2009	0.618	0.184	1,081	0.626	0.615	0.180	1,081	0.624

Notes: Rank correlation of capital intensities is calculated for different prefecture pairs. The number of correlations is 1,081 (= the number of prefecture pairs (46 + 45 + ... + 1)).

Source: RIETI (2014) R-JIP Database 2014.

Table 7: Rank Correlation of Industry Capital Intensities, 1973–2009: Region-Level Results

	Manufacturing only				Includes agriculture and mining			
	Mean	S.D.	N	Kendall's W	Mean	S.D.	N	Kendall's W
Year								
1973	0.827	0.083	28	0.848	0.821	0.084	28	0.843
1974	0.823	0.086	28	0.845	0.818	0.083	28	0.841
1975	0.839	0.082	28	0.859	0.828	0.084	28	0.849
1976	0.840	0.084	28	0.860	0.827	0.083	28	0.848
1977	0.853	0.076	28	0.872	0.850	0.073	28	0.869
1978	0.874	0.062	28	0.890	0.861	0.065	28	0.878
1979	0.871	0.064	28	0.887	0.863	0.067	28	0.880
1980	0.867	0.068	28	0.884	0.861	0.069	28	0.878
1981	0.891	0.057	28	0.905	0.877	0.069	28	0.892
1982	0.888	0.067	28	0.902	0.873	0.075	28	0.889
1983	0.887	0.070	28	0.901	0.881	0.068	28	0.896
1984	0.892	0.055	28	0.905	0.883	0.057	28	0.898
1985	0.898	0.059	28	0.911	0.894	0.057	28	0.907
1986	0.890	0.059	28	0.904	0.890	0.057	28	0.904
1987	0.882	0.061	28	0.897	0.885	0.054	28	0.900
1988	0.880	0.056	28	0.895	0.882	0.056	28	0.897
1989	0.884	0.061	28	0.899	0.886	0.059	28	0.900
1990	0.892	0.053	28	0.906	0.895	0.053	28	0.908
1991	0.898	0.055	28	0.910	0.897	0.054	28	0.910
1992	0.905	0.055	28	0.917	0.899	0.059	28	0.912
1993	0.898	0.054	28	0.911	0.887	0.061	28	0.901
1994	0.896	0.059	28	0.909	0.888	0.061	28	0.902
1995	0.890	0.063	28	0.904	0.886	0.064	28	0.900
1996	0.871	0.080	28	0.887	0.881	0.071	28	0.896
1997	0.862	0.081	28	0.880	0.870	0.074	28	0.886
1998	0.860	0.083	28	0.878	0.855	0.085	28	0.873
1999	0.853	0.086	28	0.872	0.853	0.084	28	0.871
2000	0.850	0.086	28	0.869	0.834	0.085	28	0.855
2001	0.847	0.083	28	0.866	0.832	0.075	28	0.853
2002	0.828	0.090	28	0.850	0.821	0.077	28	0.843
2003	0.825	0.102	28	0.847	0.831	0.082	28	0.852
2004	0.827	0.109	28	0.849	0.832	0.094	28	0.853
2005	0.831	0.097	28	0.853	0.844	0.079	28	0.864
2006	0.826	0.099	28	0.848	0.842	0.084	28	0.861
2007	0.827	0.104	28	0.849	0.817	0.104	28	0.840
2008	0.821	0.101	28	0.843	0.829	0.090	28	0.851
2009	0.818	0.094	28	0.840	0.825	0.086	28	0.847

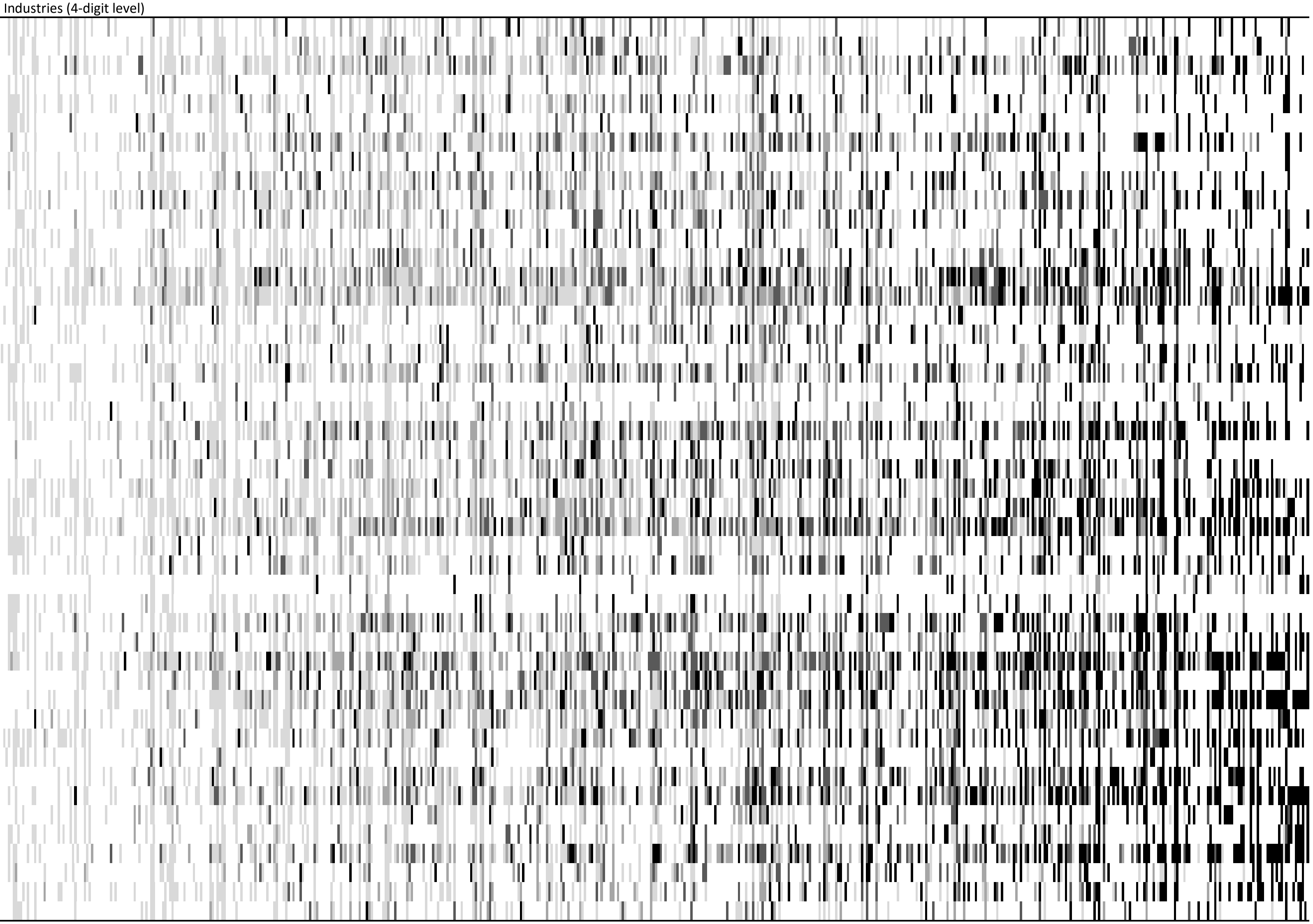
Notes: Rank correlation of capital intensities is calculated for different region pairs. The number of correlations is 28 (= the number of region pairs (7 + 6 + ... + 1)).

Source: RIETI (2014) R-JIP Database 2014.

Table 8: Prefecture-Industry Capital Intensity, 4-Digit Industry Level, 2005

Prefecture	Endowment
Akita	510.5
Yamagata	575.3
Tokyo	583.2
Kagoshima	598.9
Iwate	614.7
Shimane	618.7
Gifu	635.1
Tottori	636.9
Nagano	641.3
Kyoto	659.0
Ishikawa	668.7
Saga	679.0
Miyagi	692.4
Saitama	705.4
Osaka	706.3
Fukui	727.6
Nara	740.2
Kagawa	746.3
Niigata	767.2
Kochi	771.2
Miyazaki	776.7
Shizuoka	780.9
Yamanashi	805.0
Gumma	805.1
Fukuoka	819.2
Fukushima	822.8
Aichi	828.4
Kumamoto	839.3
Toyama	855.4
Okinawa	883.3
Nagasaki	908.8
Tochigi	913.6
Hokkaido	933.7
Hyogo	958.8
Shiga	964.3
Kanagawa	976.0
Hiroshima	1081.7
Okayama	1093.8
Tokushima	1102.7
Mie	1167.8
Ibaraki	1196.5
Ehime	1232.2
Oita	1363.5
Chiba	1380.6
Wakayama	1415.9
Yamaguchi	1558.5
Aomori	1579.8

Industries (4-digit level)



Notes: The color of each cell indicates the capital intensity of a given industry in a given prefecture. White means no production. Light gray, gray, dark gray, and black mean that the capital intensity is in the first, second, third, and fourth quartiles, respectively. The industries and the prefectures are sorted in order of capital intensity and relative capital abundance, respectively.

Source: Ministry of Economy, Trade and Industry (2007) Census of Manufacture, 2005.

Table A1: Hypothetical Prefecture–Industry Capital Intensities

	Industry average capital labor ratio													
	164	100	103	106	109	112	115	118	121	124	127	130	133	136
Prefecture	Endowment: prefecture capital-labor ratio (manufacturing total)	Food products	Textile products	Pulp and paper	Chemical products	Petroleum and coal products	Ceramic, stone and clay products	Primary metal	Metal products	General machinery	Electrical machinery	Transportation machinery	Precision machinery	Other manufacturing
Hokkaido	118	100	103	106	109	112	115	118	121	124	127	130	133	136
Aomori	120	100	103	106	109	112	115	118	121	124	127	130	133	136
Iwate	122	100	103	106	109	112	115	118	121	124	127	130	133	136
Miyagi	124	100	103	106	109	112	115	118	121	124	127	130	133	136
Akita	126	100	103	106	109	112	115	118	121	124	127	130	133	136
Yamagata	128	100	103	106	109	112	115	118	121	124	127	130	133	136
Fukushima	130	100	103	106	109	112	115	118	121	124	127	130	133	136
Ibaraki	132	100	103	106	109	112	115	118	121	124	127	130	133	136
Tochigi	134	100	103	106	109	112	115	118	121	124	127	130	133	136
Gumma	136	100	103	106	109	112	115	118	121	124	127	130	133	136
Saitama	138	100	103	106	109	112	115	118	121	124	127	130	133	136
Chiba	140	100	103	106	109	112	115	118	121	124	127	130	133	136
Tokyo	142	100	103	106	109	112	115	118	121	124	127	130	133	136
Kanagawa	144	100	103	106	109	112	115	118	121	124	127	130	133	136
Niigata	146	100	103	106	109	112	115	118	121	124	127	130	133	136
Toyama	148	100	103	106	109	112	115	118	121	124	127	130	133	136
Ishikawa	150	100	103	106	109	112	115	118	121	124	127	130	133	136
Fukui	152	100	103	106	109	112	115	118	121	124	127	130	133	136
Yamanashi	154	100	103	106	109	112	115	118	121	124	127	130	133	136
Nagano	156	100	103	106	109	112	115	118	121	124	127	130	133	136
Gifu	158	100	103	106	109	112	115	118	121	124	127	130	133	136
Shizuoka	160	100	103	106	109	112	115	118	121	124	127	130	133	136
Aichi	162	100	103	106	109	112	115	118	121	124	127	130	133	136
Mie	164	100	103	106	109	112	115	118	121	124	127	130	133	136
Shiga	166	100	103	106	109	112	115	118	121	124	127	130	133	136
Kyoto	168	100	103	106	109	112	115	118	121	124	127	130	133	136
Osaka	170	100	103	106	109	112	115	118	121	124	127	130	133	136
Hyogo	172	100	103	106	109	112	115	118	121	124	127	130	133	136
Nara	174	100	103	106	109	112	115	118	121	124	127	130	133	136
Wakayama	176	100	103	106	109	112	115	118	121	124	127	130	133	136
Tottori	178	100	103	106	109	112	115	118	121	124	127	130	133	136
Shimane	180	100	103	106	109	112	115	118	121	124	127	130	133	136
Okayama	182	100	103	106	109	112	115	118	121	124	127	130	133	136
Hiroshima	184	100	103	106	109	112	115	118	121	124	127	130	133	136
Yamaguchi	186	100	103	106	109	112	115	118	121	124	127	130	133	136
Tokushima	188	100	103	106	109	112	115	118	121	124	127	130	133	136
Kagawa	190	100	103	106	109	112	115	118	121	124	127	130	133	136
Ehime	192	100	103	106	109	112	115	118	121	124	127	130	133	136
Kochi	194	100	103	106	109	112	115	118	121	124	127	130	133	136
Fukuoka	196	100	103	106	109	112	115	118	121	124	127	130	133	136
Saga	198	100	103	106	109	112	115	118	121	124	127	130	133	136
Nagasaki	200	100	103	106	109	112	115	118	121	124	127	130	133	136
Kumamoto	202	100	103	106	109	112	115	118	121	124	127	130	133	136
Oita	204	100	103	106	109	112	115	118	121	124	127	130	133	136
Miyazaki	206	100	103	106	109	112	115	118	121	124	127	130	133	136
Kagoshima	208	100	103	106	109	112	115	118	121	124	127	130	133	136
Okinawa	210	100	103	106	109	112	115	118	121	124	127	130	133	136

Notes: Hypothetical capital–labor ratio is presented in each cell. Light gray, gray, dark gray, and black mean that the capital intensity is in the first, second, third, and fourth quartiles, respectively.

Table A2: Prefecture and Industry Classification

Panel A. Region and prefecture classification

Region ID	Region	Prefecture ID	Prefecture
1	Hokkaido	1	Hokkaido
2	Tohoku	2	Aomori
		3	Iwate
		4	Miyagi
		5	Akita
		6	Yamagata
		7	Fukushima
3	Kanto	8	Ibaraki
		9	Tochigi
		10	Gumma
		11	Saitama
		12	Chiba
		13	Tokyo
		14	Kanagawa
4	Chubu	15	Niigata
		16	Toyama
		17	Ishikawa
		18	Fukui
		19	Yamanashi
		20	Nagano
		21	Gifu
		22	Shizuoka
		23	Aichi
5	Kinki	24	Mie
		25	Shiga
		26	Kyoto
		27	Osaka
		28	Hyogo
		29	Nara
		30	Wakayama
6	Chugoku	31	Tottori
		32	Shimane
		33	Okayama
		34	Hiroshima
		35	Yamaguchi
7	Shikoku	36	Tokushima
		37	Kagawa
		38	Ehime
		39	Kochi
8	Kyushu	40	Fukuoka
		41	Saga
		42	Nagasaki
		43	Kumamoto
		44	Oita
		45	Miyazaki
		46	Kagoshima
		47	Okinawa

Panel B. Industry classification

Industry ID	Industry
1	Agriculture, forestry and fisheries
2	Mining
3	Food products
4	Textile products
5	Pulp and paper
6	Chemical products
7	Petroleum and coal products
8	Ceramic, stone and clay products
9	Primary metal
10	Metal products
11	General machinery
12	Electrical machinery
13	Transportation machinery
14	Precision machinery
15	Other manufacturing

Source: RIETI (2014) R-JIP Database 2014.