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Kazumi Asako
(Institute of Economic Research, Hitotsubashi University)
Takashi Onodera
(Japan Center for Economic Research)
and
Atsuko Ueda
(Faculty of Political Science & Economics, Waseda University)

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Institute of Economic Research
Hitotsubashi University
Kunitachi, Tokyo, 186-8603 Japan

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Kazumi Asako,[a] Takashi Onodera,[b] and Atsuko Ueda[c*]

[a] IER, Hitotsubashi University, 2-1 Naka, Kunitachi-shi, Tokyo 186-8603, Japan
(E-mail) kasako@ier.hit-u.ac.jp

[b] Japan Center for Economic Research, 1-3-7 Otemachi, Chiyoda-ku, Tokyo 100-8066, Japan
(E-mail) onodera@jcer.or.jp

[c] Faculty of Political Science & Economics, Waseda University, 1-6-1 Nishi-waseda, Shinjuku-ku, Tokyo 169-8050, Japan (Phone/Fax) +81-3-3204-9189 (E-mail) aueda@waseda.jp

* Corresponding author

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Abstract

The purpose of this paper is to analyze regional business cycle movements in Japan. We construct regional monthly composite indexes by 47 prefectures over the period 1985–2010. In order to characterize the deviation of regional economies from the nationwide economy, we propose a method to match each prefectural composite index sequence to the national composite index sequence. High performance of the matching analysis indicates that regional deviations involve leads and lags in both the timing of the business cycle and time trends, although certain disparities remain for some prefectures. The analysis also suggests that there is a structural change between the post-bubble era of the 1990s and the long expansion phase of 2002–2008. Only a limited number of prefectures show better performance than the national average, while the majority tend to fall behind during the expansion phase. Also, we investigate the factors that exert influence on prefectural economies, and find that fiscal and monetary measures possibly help stimulate regional economies.

JEL classification: E32, R11

Keywords: regional business cycle; composite index; structural change; public investment.

1. Introduction

International co-movements of business cycles have been studied widely from the viewpoint of worldwide factors that commonly influence national business cycles (e.g., Kose et al., 2003). Similarly, *intra*-national business cycles might not be unified, although they show similar movements under common social systems and economic policies within a country. However, studies on intra-national co-movements of business cycles seem to be rather limited compared to international studies.

In the case of the United States, Hess and Shin (1998) examine cross-correlations of business cycles across states, applying Hodrick–Prescott filters. Hamilton and Owyang (2012) and Owyang et al. (2005) apply regime-switching models and find differences in the timing of peaks and troughs (i.e., turning points between expansion and contraction phases) as well as economic growth rates across states. They also investigate factors that affect the timing of business cycles.

Regarding studies in Japan, Wall (2007) examines eight-region quarterly data for 1976–2005, and finds a structural break across the collapse of the asset price bubble around 1990. Hayashida and Hewings (2009) examine nine-region monthly data for 1986–2006, and find regional differences in the timing of peaks and troughs. Artis and Okubo (2011) examine data from 47 prefectures for 1955–1995, applying the gravity-model approach to explain co-movements of regional business cycles.

The objective of this paper is to examine prefectural-specific business cycles compared to the nationwide business cycle, and also to investigate influential factors that affect prefectural business cycles in the case of Japan. The analysis applies different approaches from previous studies in the following respects. First, we examine monthly business cycle data of 47 prefectures from 1985 to 2010. The prefectural business cycle index used in this study is a composite index (CI) constructed originally from prefectural economic indicators following Asako and Onodera (2009), Onodera (2008), and Onodera et al. (2011).[1] The utilization of monthly prefectural CIs enables us to successively ascertain the spatial and temporal spread of business conditions across Japan.

Second, we apply a matching method to characterize deviations of prefectural business cycles from the national business cycle, considering leads and lags in timing as well as synchronous disparity of business cycles. The reason we consider leads and lags is that some regional economies drive, while others follow, the national business cycle, and these relations might change over time. Asako and Onodera (2009), Onodera (2008), and Onodera et al. (2011) suggest that prefectural peaks and troughs show at most several months' lead and lag, scattered almost randomly in the neighborhood of nationwide peaks and troughs. In other words, there

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1 Asako (2012, chapter 10) also reviews previous analyses and discussions.

does not seem to be any specific pattern in observing leads and lags in prefectural peaks and troughs. In this regard, we utilize the dynamic programing matching (DPM) algorithm employed by Asako et al. (2007) in identifying leads and lags in the timing of each prefectural business cycle.

The analysis results indicate that prefectural deviations in business cycles involve leads and lags of timing and also time trends; yet certain unexplained disparities remain for some prefectures. The analysis also suggests that there is a structural change between the post-bubble era of the 1990s and the long expansion phase in 2002–2008. Only a limited number of prefectures show better performance than the national average while the majority tend to fall behind the expansion.

Third, we investigate factors that exert influence on deviations of prefectural CIs from the national CI. For potential influencing factors that affect prefectural economies, we examine fiscal measures, monetary conditions, and export demand for each prefecture. We examine prefectural panel data during 1990–2008 on an annual basis. The result indicates that public investment rates, as a measure of fiscal policy, and growth of money lending, as a measure of monetary conditions, help stimulate regional economies. We do not find any evidence to indicate that export demand drives regional economies.

The rest of the paper is organized as follows. In Section 2, we construct prefectural CIs from four common economic indicators, and explain characteristics according to prefecture. In Section 3, we propose a matching method by transforming prefectural CIs, and examine characteristics of prefectural CIs vis-à-vis the national CI. Section 4 presents panel data analysis to explain the deviation of prefectural CIs from the national CI. Section 5 concludes the paper.

2. Prefectural composite index

2.1 Constructing the monthly prefectural index

Some official regional business cycle indexes are published in Japan. However, in the case of the Regional Economic Conditions Index published by the Cabinet Office of the government of Japan, regions are grouped into 11 blocks with quarterly periodicity. Prefectural indexes of business conditions are compiled independently by each local government in some prefectures, but not others. For the purpose of capturing detailed differences in regional economies, we construct monthly prefectural CIs using common economic indicators for all 47 prefectures by applying the calculation method developed by Asako and Onodera (2009), Onodera (2008), and Onodera et al. (2011).[2]

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[2] We apply NEEDS-CIDIc, a software with a database compiled with main monthly economic indicators for all 47 prefectures in Japan. The software is provided by the Nikkei Economic Electronic Databank System (NEEDS), Nikkei Digital Media Inc. It enables us to calculate a variety of ready-made prefectural CI-type indexes with the same methodology employed by the Cabinet Office.

In constructing monthly prefectural CIs, four economic indicators are selected through procedures explained in detail in these aforementioned studies. Specifically, we narrow candidate indicators down to components representing four aspects of the macro economy: production, retail sales, income, and employment. Data sources and variable definitions are provided in Appendix A. The selected four indicators have been published continuously and these components have often been adopted in similar indexes such as the current indexes of business conditions of prefectures.

The nationwide coincident CIs published by the Cabinet Office are compiled from 11 components whereas our CIs are compiled from four components. In this regard, we confirm that official coincident CIs and our constructed CI at the national level are quite similar in respect of overall business cycle movement and the timing of peaks and troughs.[3]

The constructed CIs include all of the prefectures for the period from December 1985 to December 2010. The CIs are standardized to be 100 for an average of 12 months in 2005 for each prefecture. The sample period includes a total of five expansion phases (from the 11th cycle to the 15th cycle) and four contraction phases (from the 11th cycle to the 14th cycle).

2.2 Prefectures with larger deviations

Time-series movements of prefectural CIs seem to vary according to prefecture. Some prefectures, such as, Fukuoka, Mie, Saitama, and Tochigi, appear to co-move fairly well in accordance with the national CI over time, while some other prefectures show considerably large deviations. Figure 1 illustrates the CI movements of Japan and Tottori prefecture, as an example; it shows that prefectural CI movements clearly deviate from the national CI, and did so particularly in the early 2000s. CI movements for all prefectures are found in Appendix D.

[Figure 1 here]

Let *JCI(t)* denote a CI at the national level at period *t* and *PCI(t)* denote a CI of each prefecture at period *t*. The difference between a prefectural CI vis-à-vis the national CI is defined as {*PCI(t)*-*JCI(t)*} for each prefecture at period *t*. As a measure of deviation between prefectural and national CIs, the standard deviation of {*PCI(t)*-*JCI(t)*} in each prefecture ranges between [1.9, 12.7] with an average of 5.2, or a median of 4.8 for 47 prefectures. Figure 2 illustrates the geographic distribution of prefectures with larger disparity from the nationwide CI than the average, using reference points of 5 (nearly average), 7, and 9. Prefectures in the highest rank include Nagano, Shimane, and Tottori; those in the next highest rank include Akita, Miyazaki, Nara, Wakayama, and Yamanashi. Standard deviation of each prefecture is reported in Appendix C, column (1).

3 For example, Onodera (2008, Figure 2), and Onodera et al. (2011, Figure 5-1).

[Figure 2 here]

3. Deviations of prefectural CIs from the national CI

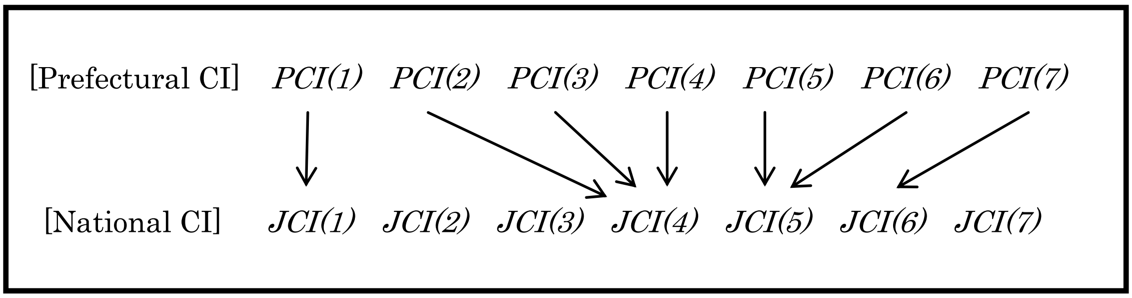
3.1 An analysis method by matching prefectural CIs to the national CI

This section proposes an analysis method to examine deviation of prefectural CIs from national CI, by matching two CI sequences while controlling for two different aspects: first, leads and lags in the timing of business cycles and second, synchronous disparity in corresponding CIs. When there are leads and lags in the timing of business cycles, the duration period of each business cycle phase could vary for each prefecture. Regarding disparity in corresponding CI levels, it should be remembered that constructed prefectural CIs are standardized to be 100 in 2005 for all prefectures. As a result of this standardization, many prefectural CIs appear to be much higher than the corresponding national CI in the 1980s–1990s. Therefore, prefectural CI levels need to be adjusted to be compared to the national CI.

Leads and Lags

Differences in the timing of business cycles are captured by DPM, following Kamisaka and Ozeki (1990). DPM is a method of pattern recognition to examine similarities between two sets consisting of a sequence of elements, by matching one sequence to the other through the expansion and contraction of the relevant sequence.[4]

Consider the following example to match a prefectural CI sequence to the national CI sequence.



In this example, a prefectural CI leads in periods 2 and 3 and lags in periods 6 and 7 compared to the national CI. Then, with DPM, sequential points of correspondence between the two CIs are rearranged one by one in an order as follows:

[Prefecture] *PCI(1), PCI(2), PCI(3), PCI(4), PCI(5), PCI(6), PCI(7)*, …

[4] For example, DPM is applied in linguistics along with a language analysis and in biology along with an alignment analysis of DNA.

[Japan] *JCI(1), JCI(4), JCI(4), JCI(4), JCI(5), JCI(5), JCI(6), …*

Let *CCI(t)* represent a rearranged national CI of *JCI(t)* corresponding to the prefectural *PCI(t)*. In our example, a sequence of *CCI(t)*, {*CCI(1), CCI(2), …*} equals to {*JCI(1), JCI(4), JCI(4), JCI(4), JCI(5), JCI(5), JCI(6), …*}.

An advantage of the DPM method is that peaks and troughs are not required to determine even when multiple candidates for a turning point (i.e., a peak or a trough) are not unique. A detailed description of the underlying assumptions, computational algorithm, and procedure in executing the DPM procedure is summarized in Appendix B.

Linear transformation

The best correspondence sequence by the DPM method is obtained to minimize a distance between sequences, which is defined here by the sum of squared residuals:

$$\sum_{t=1}^{T}[\ \varepsilon(t)\ ]^2 \qquad (1)$$

for T time-periods, where $\varepsilon(t)$ denotes a residual at period t of the following equation model:

$$CCI(t) = \beta_0 + \beta_1 \cdot PCI(t) + \beta_2 \cdot t + \varepsilon(t) \qquad (2)$$

where parameters β_0, β_1, and β_2 are coefficients. The constant term β_0 adjusts the overall prefectural CI level, and β_1 adjusts the magnitude of variation of prefectural CI. β_2 captures the time trend movement of deviation. This formulation is introduced to meet the following observations: first, CIs in some prefectures appear consistently higher or lower than the national CI; second, peaks and troughs in some prefectures appear more magnified than those of the national CI; and third, CI movements in some prefectures appear to show time trends against national CI movement.

Equation (2) and leads and lags are estimated simultaneously by a non-linear optimization technique. Each of the 47 prefectural CI sequences is matched independently to the national CI over the sample period of 301. That is, Equation (2) is estimated for each prefecture with adjustment of leads and lags to the national CI.

Structural change

For some prefectures, such as, Tottori in Figure 1, the linear transformation of Equation (2) with DPM is not very successful at matching to the national CI. A possible reason might be found in a change in CI movements from the 1990s to the 2000s for these prefectures. Prefectural CI movements drop in the early 2000s but subsequently show different trends, especially in the 14th expansion phase of 73 months from January 2002 to a peak in February 2008, which is the longest expansion in the history of Japan's post-war business cycle. Hence, Equation (2) is also estimated separately for the period up to December 2001, and again from January 2002. The Chow-tests confirm possible structural change at the 5% significance level for most prefectures.

3.2 Characteristics of prefectures with large deviation

[Figure 3 here]

The matching analysis applying DPM and linear transformation with a structural change shows high performance in matching prefectural CI to the national CI. The average R^2 of 47 prefectures is 0.96. R^2 for each prefecture is reported in Appendix C, column (5). Original prefectural CI, fitted CI, and leads and lags are illustrated in Appendix D for all prefectures.

Figure 3 designates the worst eight prefectures, with R^2 of 0.92 or below, out of 14 prefectures that are below the average. Compared to Figure 2, which illustrates prefectures with large deviation, the matching attempt seems to work well for some prefectures, such as, Nagano and Yamanashi in central Japan. Meanwhile, the rest of the prefectures shown in Figure 2 still have unexplained disparity from the national business cycle.[5] The lowest R^2 is reported for Okinawa, whose peaks and troughs are not observed clearly and, therefore, expansions and contractions do not seem to correspond to the nationwide business cycle phases. Other prefectures with low goodness of fit include, from north to south, Iwate, Akita, Niigata, Tottori, Shimane, Ehime, and Kochi. These prefectures with low goodness of fit seem to be located away from the Tokyo metropolitan area.

Prefectures with low goodness of fit seem to share common features in business cycle movements. They appear to have relatively low peaks in February 1991 at the end of the bubble economy of the 11th expansion phase (in particular, Iwate, Akita, Tottori, and Ehime), and then experience a post-bubble contraction with smaller amplitude and shorter duration than the national average (Iwate, Akita, Niigata, Tottori, Shimane, and Kochi). After the trough in October 1993, they appear to show a good recovery until the next peak in May 1997, which is higher than even the bubble peak (Iwate, Akita, Tottori, and Ehime). Afterwards, they appear to fail to expand in the long lasting 14th expansionary phase in the early 2000s (Iwate, Akita, Tottori, Shimane, Ehime, and Kochi).

3.3 Performance of DPM and structural change

Table 1 reports average and minimum R^2, with and without DPM, together with and without the structural change for Equation (2), for the purpose of evaluating the relative importance of DPM and structural change to improve the goodness of fit of the linear transformation of Equation (2).

5 We also examine patterns of leads and lags, but do not find any specific tendency.

The dependent variable is *JCI(t)* without DPM and *CCI(t)* with DPM, respectively. R^2 for each prefecture is reported in Appendix C, columns (2)–(4).

[Table 1 here]

Overall, the matching method appears to perform fairly well as an explanation for deviations in prefectural CI to the national CI. Average R^2 rises 0.118 (from 0.784 to 0.902) by introducing DPM alone, while it rises 0.101 (from 0.784 to 0.885) by considering the structural change alone. Applying both DPM and the structural change, the partial contribution of DPM is 0.076 (from 0.885 to 0.961), and that of the structural change is 0.059 (from 0.902 to 0.961).

As we note that deviations of CI movements appear to vary across prefectures, an improvement of fit for prefectures with large deviations is also of importance. Minimum R^2 rises 0.194 (from 0.330 to 0.524) by introducing DPM alone, and 0.476 (from 0.330 to 0.706) by considering the structural change alone. Applying both DPM and the structural change, the partial contribution of DPM is 0.121 (from 0.706 to 0.827), and that of the structural change is 0.303 (from 0.524 to 0.827).

An overall assessment would imply that both DPM and the structural change should be considered for the matching. From the perspective of explaining large deviations for specific prefectures, the structural change looks to be even more important than that ascribed to the timing of the business cycle.

Figure 4 compares the R^2 of each prefecture with and without allowing the structural change. Some prefectures, such as, Akita, Ehime, Kagoshima, Shimane, and Tottori, experience the structural change more seriously than others, as they are located relatively far from the 45-degree line horizontally, indicating that their R^2 improves considerably by introducing the structural change.[6]

[Figure 4 here]

Regional business cycles appear to be influenced by the change in economic conditions from the stagnation of the 1990s after the bubble burst to the 14th expansionary phase starting in 2002, albeit the extent of influence might vary across prefectures. Such structural change might have been induced by globalization and structural reforms in Japan to recover from the stagnant economy in the aftermath of the bubble.[7] However, the penetration of these structural reforms

6 Even if the distance is measured not horizontally but perpendicular to the 45-degree line, the relative ranking is unchanged. However, the relative ranking would be altered once the distance is normalized, for instance, by the absolute level of R^2.

7 Structural reforms were the main political objectives of several governments, first the Ryutaro Hashimoto Cabinet (1996–1998), which set six major structural reforms and, second, the Junichiro Koizumi Cabinet (2001–2006), which aimed for smaller government and private sector efficiency, such as, the privatization of Japan Post. In addition, certain public sector activities, as well as taxes and subsidies, were shifted from the

might vary across prefectures. The reasons could lie in differences in policy measures conducted by local governments, or in the different industrial structures of prefectures. In the next section, we seek factors that are important determinants of this issue.

3.4 Time trend against national CI

[Table 2 here]

For the linear transformation using Equation (2), Table 2 summarizes estimates of time trend coefficients of β_2 before and after the structural change; estimates for each prefecture are reported in Appendix C, columns (6)–(7). A negative time trend estimate indicates that the national CI sequence becomes lower than the prefectural CI sequence as time passes by. That is, the prefectural economy performs better than the nationwide economy over time, in the sense that CI declines slower in a contraction phase and increases faster in an expansion phase than the national CI. A positive time trend indicates the opposite. Up to 2001, before the structural change, 19 (28) prefectures show negative (positive) trends; it appears that time trend estimates distribute rather symmetrically.[8] Meanwhile, during the long expansion phase after the structural change, only nine prefectures show negative trends, or better performance than the national average.

Figure 5 illustrates the geographical distribution of time trends before and after the structural change. For example, a positive-positive trend indicates a decreasing trend for prefectures against the national average over the sample period. After the structural change, prefectures with an increasing trend locate to the Nagoya area, including Aichi, Gifue, Mie, and Wakayama, and also the Kyushu area, including Fukuoka, Kagoshima, Miyazaki, and Oita. The rest of the prefectures seem to show lower performance than the national average. In particular, prefectures such as Tottori, Okinawa, and Hokkaido, experience considerable decline after the structural change, but do not show this tendency before the structural change.

[Figure 5 here]

4. Policy effects and regional economies

In the previous section, the matching analysis reveals that deviations of prefectural CIs from the national CI involve leads and lags of the timing in the business cycle and time trends with a structural change. This section examines whether these deviations are explained by factors that exert influences on regional economies. Factors we consider are fiscal measures, monetary

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jurisdiction of the central government to local governments in order to give them more fiscal autonomy, known as the Trinity Reform on local public finance.

[8] A non-parametric statistical test cannot reject the symmetry hypothesis at standard significance levels.

conditions, and export demand.

4.1 Influential factors on regional economies

Factor 1: Public investment rate as a fiscal measure

We presume that each prefecture maneuvers fiscal measures with discretion in order to stabilize local business conditions. A local government possibly intends to stimulate its regional economy by means of fiscal policy during periods of contraction and slumps; it is expected that appropriately executed fiscal policy activates regional economies. As a measure of fiscal policy, we focus on the public investment rate compared to gross prefectural products (total value added). Since the data on Japan's public investment is observed for the fiscal year basis from April to March, annual frequency data is utilized in the following analysis.[9]

Factor 2: Growth rate of outstanding lending as a monetary condition

In addition to fiscal measures, monetary conditions such as financial environments are likely to influence regional economies (Noma, 2007). However, monetary policy in principle applies uniformly nationwide and is indistinguishable across prefectures. Therefore, we capture its effective position in each prefecture by the growth rate of outstanding lending by financial institutions at the end of the fiscal year. The role of monetary policy and thereby of monetary conditions in regional economies is expected to be reflected in this monetary measure.[10]

Factor 3: Exports of the machinery industry as export demand

We consider differences in export demand across prefectures.[11] Since regional economies differ with respect to underlying basic industrial structure, some prefectures produce more while others produce less than an average amount of exports. Thus, local business cycles might be amplified in those regions where exporting industries are concentrated more densely than others. In examining the role of export demand according to prefecture, we focus on the machinery industry and consider a possible multiplier effect from export demand of the machinery industry to business conditions as a whole.[12] Due to a limitation of data availability, we employ export

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9 We have also considered other fiscal measures, such as, the index of fiscal power, the current account ratio, and the local government debt expenditure ratio. However, they do not seem to be stable influencing factors.

10 We have also considered the growth rate of savings accounts, but the result appears similar and less clear.

11 Although it is often pointed out that business cycles in Japan are led mostly by the twin engines of private investment and exports, we focus only on export activity here as the latter exceeds the former from the perspective of involved impact over at least a couple of recent business cycles. For instance, see Chapter 4 of Asako (2012). We have also tried to include differences in industrial structure, but find no evidence for these as influencing factors.

12 We have also considered the whole manufacturing sector, but the effect looks less clear possibly because of the inclusion of processing primary materials. The export ratio of the machinery industry was on average 30% while that of the manufacturing sector was 19% during 1990–2008. We have also tried an industry specialization coefficient, but the result is inconclusive.

demand to the machinery industry for prefecture *i* by

(National export rate out of total output of the machinery industry at time *t*)

× (Proportion of the machinery industry out of products in a prefecture *i* at time *t*).

Nationwide transition of three factors

Figure 6 presents the nationwide transition of the public investment rate compared to gross domestic product (GDP), the growth rate of outstanding lending by financial institutions, and the rate of exports to total output in the machinery industry. Regarding public investment, the rate rose from 6.5% in the late 1980s to beyond 8% in the early 1990s, because traditional Keynesian fiscal measures were called for during the contraction phase after the collapse of the bubble economy. However, an increase in fiscal expenditure inevitably resulted in an increase in budget deficits. The public investment rate began to decline in consecutive years from the late 1990s, and in due course, the discretionary policy portfolio shifted to rely more heavily on monetary policy and structural reforms. The public investment rate declined to 4% in the late 2000s, which is less than half that of the immediate post-bubble period.

Regarding growth of outstanding lending, the rate declined in consecutive years in the 1990s, and even became negative in the late 1990s and early 2000s. This might be explained by the credit crunch in Japan in the 1990s and early 2000s. A reluctance to lend and a cutback in lending (*kashi-shiburi* and *kashi-hagashi*, respectively, in Japanese) by financial institutions prevailed widely in this time, especially toward small and medium-sized firms. The growth rate then turned upward and recovered to become positive during the expansion phase from 2002.

Regarding export demand for the machinery industry, the proportion was approximately 25% until the mid-1990s, then started to rise from the late 1990s, and reached nearly 40% in the late 2000s. Export demand appears to have increased in importance during the 2000s alongside globalization.

[Figure 6 here]

4.2 Empirical framework

Now we examine the effects of the three factors on the deviation of a prefectural CI compared to the national CI. The equation to be estimated is proposed as

$$PCI(i,t) - JCI(t) = \beta_0(i) + \beta_1 Pub(i,t) + \beta_2 Loan(i,t) + \beta_3 Export(i,t) + u(i,t), \qquad (3)$$

where a suffix notation (*i,t*) indicates the pair of prefecture index *i* and the fiscal year index *t*, *Pub(i,t)* denotes the public investment rate, *Loan(i,t)* denotes the growth rate of lending, *Export(i,t)* denotes export demand in the machinery industry, and *u(i,t)* denotes other unobservables.[13] The constant term $\beta_0(i)$ might vary according to prefecture, because of the standardization of CI to be 100 in 2005. For the estimation method, we apply panel data analysis.

A problem in pursuing our proposed influencing factors is that public investment is observed only by the fiscal year basis from April to the following March, and not monthly, as noted. Therefore, *JCI(t)* and *PCI(i,t)* are converted into 12-month averages, and other explanatory variables are also prepared in this manner for the fiscal year.[14] The sample is restricted to the period from 1990 to 2008 due to data availability. The entire sample consists of 47 prefectures for the fiscal years of 1990–2008. Data sources for three factors are described in Appendix A.

Table 3 summarizes the means and standard deviations of both dependent and explanatory variables. Standard deviations are reported for those between prefectures and within prefectures, in addition to overall deviation for the entire sample. Variation in the growth rate of lending within prefectures is larger than that between prefectures, and vice versa for machinery exports.

Figure 7 illustrates the geographical distribution of the public investment rate averaged over the sample period; the rate for each prefecture is reported in Appendix C, column (8). The rate ranges from 3% in the case of Tokyo to 14.9% in the case of Shimane, with an average of 8.2% for the 47 prefectures.[15] Prefectures with high public investment rates of 10% or more also appear in Figure 2 as those with large disparity from the national CIs, or in Figure 3 as those with low fit by the matching analysis.

[Table 3 here] [Figure 7 here]

4.3 Estimation results of the panel data analysis

[Table 4 here]

Table 4 reports the estimation results using the fixed-effects model.[16] Also, a dynamic panel estimation result is reported, because business conditions might not be independent from those in the previous year.[17] A dynamic model assumes that explanatory variables are *strictly exogenous*,

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13 Since the time of a dispute about the Federal Reserve St. Louis reduced form equation, which regresses the increment of nominal gross national product (GNP) on both fiscal and monetary policy variables, there has been a debate on the interpretation of policy effectiveness centering on insignificant coefficient estimates. That is, perfectly successful stabilization of GNP should bring about zero coefficient estimates as GNP stays constant while the policy instrument varies by whatever amount is necessary. A single reduced form equation such as Equation (3) might be subject to a similar identification problem (McCallum, 1984, surveys this issue).

14 We also consider [*PCI(i,t)* - *CCI(i,t)*] as the prefectural CI deviation after timing adjustment of at most six months, but the result looks fairly similar to using *JCI(t)*.

15 The average across prefectures is higher than the national average of 6.3% in Figure 6 because small-sized prefectures in local areas tend to mark higher rates.

16 Our choice is the fixed-effects model, because the random-effects model cannot be applied from the Hausman test in some cases. The basic results look similar between the two estimation methods.

17 Over-identifying restrictions are tested by the Hansen J-statistic.

that is, independent from unobserved terms in whole periods. However, fiscal and monetary policies may be determined depending on previous business conditions that are affected by unobservables in the previous periods. For this respect, these two explanatory variables may be considered as *predetermined*, that is, independent from current and future unobserved terms but not previous ones. Dynamic models are estimated by the generalized method of moments (GMM).[18]

The estimation results in Table 4 indicate that fiscal and monetary conditions are influencing factors. Because both the effects of public investment and lending growth are estimated with a positive sign, an increase in each explanatory variable has the impact of improving the prefectural economy compared to the national economy. Regarding public investment, the decline in public investment in the 21st century could be a serious blow to regional economies, especially for prefectures with relatively high dependence on public investment. The same is true for the decline in lending in the 1990s.

The effect of export demand is estimated as positive, but is not statistically significant in model (A) with three factors in Table 4.[19] One reason might be that export demand has only limited influence on regional economies. However, data limitation could have affected our measure of exports and influenced this result. Model (B) excludes machinery exports from the explanatory variables, which indicates that the effects of fiscal and monetary policies appear robust.

4.4 Estimation results of sub-periods

To examine whether the effects of fiscal and monetary policies are stable throughout the sample period, we divide the sample period into two sub-periods of 1990–2001 (hereafter called the 1990s) and 2002–2008 (hereafter called the 2000s). Although distinguishing between 2001 and 2002 is by no means symmetrical in terms of the number of sample years, we separate the entire sample period in this way for reasons outlined in Section 3. Also, the three influencing factors have witnessed certain changes in Japanese national policies and recent globalization with almost the same timing.

Table 5 reports the estimation results using all three factors in the sub-periods. Again, the effect of public investment is estimated as positive, and the estimates seem to become somewhat larger in the 2000s compared to the 1990s. However, estimates may not be statistically significant when applying the dynamic model. A positive effect of fiscal measures might be found over the decline in public investment throughout the period, that is, from the 1990s to the 2000s, but not within each sub-period.

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[18] System-GMM is applied.

[19] It is possible that public investment affects a local economy with a time lag. However, the effect of public investment in the previous fiscal year turns out not to be robust.

Regarding monetary conditions, an effect of the growth rate of lending is not statistically significant using the fixed-effects model for sub-periods, but is positive and statistically significant in the 1990s applying the dynamic model. Declining lending is likely to have depressed regional economies in the 1990s, while the effect of a recovery in the 2000s is not confirmed. Again, we do not find significant effects of export demand in the sub-periods.

4.5 An evaluation of panel data analysis performance

In order to evaluate to what degree the panel data model of Equation (3) explains prefectural CI disparity, we calculate explained variation of CI disparity, similar to R^2, as 1-{(residual sum of squares) / (total sum of squares)} for each prefecture.[20] Using an estimate of the dynamic panel model in the predetermined case of model (A) with three explanatory factors in Table 4, the explained variation is 0.895 for the whole sample; by prefecture, the average is 0.678, and the median is 0.740. Explained variation for each prefecture is reported in Appendix C, column (9).

In comparison to the prefectural standard deviation of {*PCI(i,t)-JCI(t)*}, the correlation coefficient is 0.579. This suggests that the model explains CI disparity for prefectures with larger CI deviation better than others. Figure 8 illustrates the geographical distribution of the explained variation of CI disparity for each prefecture. In this figure, eight designated prefectures, which appear in Figure 2 as those with large CI deviation, show comparatively good fit of at least 0.835. Among prefectures with large CI deviation, an exception is Okinawa prefecture; the model explains only 0.753 of disparity variation, which is around the median.

[Figure 8 here]

5. Concluding remarks

During the last two decades, Japan has experienced a stagnant economy after the burst of the asset price bubble of the early 1990s. Under such economic conditions, stagnating local economies have been an important political issue in Japan. Our original CIs showed that there are certain disparities in business cycle movements across prefectures.

The analysis considered a structural change between the post-bubble era in the 1990s and the long expansion phase of the 2000s. Prefectural CI movements suggested that the long expansion phase during 2002–2008 could have been led by only a limited number of prefectures, while the majority of others displayed a relatively low performance. In fact, some prefectures failed in an economic recovery during the long expansion phase.

The matching analysis suggested that leads and lags in the timing of business cycles, time trends, and a structural change can characterize the regional deviations fairly well. Such

[20] In the case of Fukuoka prefecture, which has the smallest deviation from national CIs, R^2 is not calculated because the standard error of the residual is larger than the deviation, which leads R^2 to be negative.

deviations were also explained by fiscal measures and monetary conditions as influencing factors that contribute to regional economies. The analysis result suggested that the downturn in monetary conditions in the 1990s and the considerable cutback of public investment in the 2000s might have delivered a serious blow to regional economies. However, we do not find any evidence of an effect from export demand; this might require further examination.

Acknowledgements

The authors are grateful to the discussants of a 2013 meeting of the Japanese section of Regional Science Association International for their valuable comments. The research was supported by Grant-in-Aid from the Institute of Economic Research, a Joint Usage and Research Center at Hitotsubashi University.

Figure 1. Example of CI movements

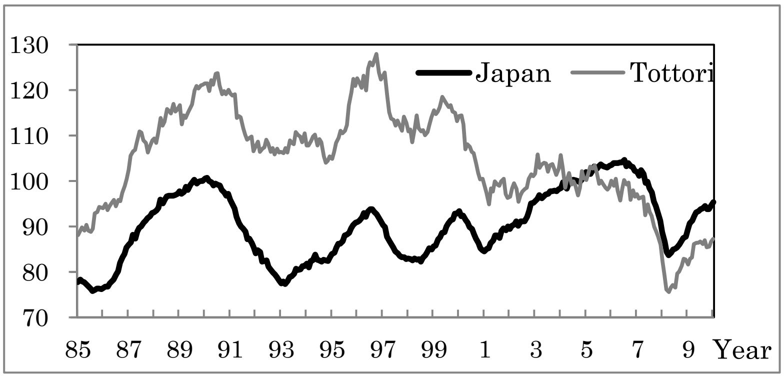
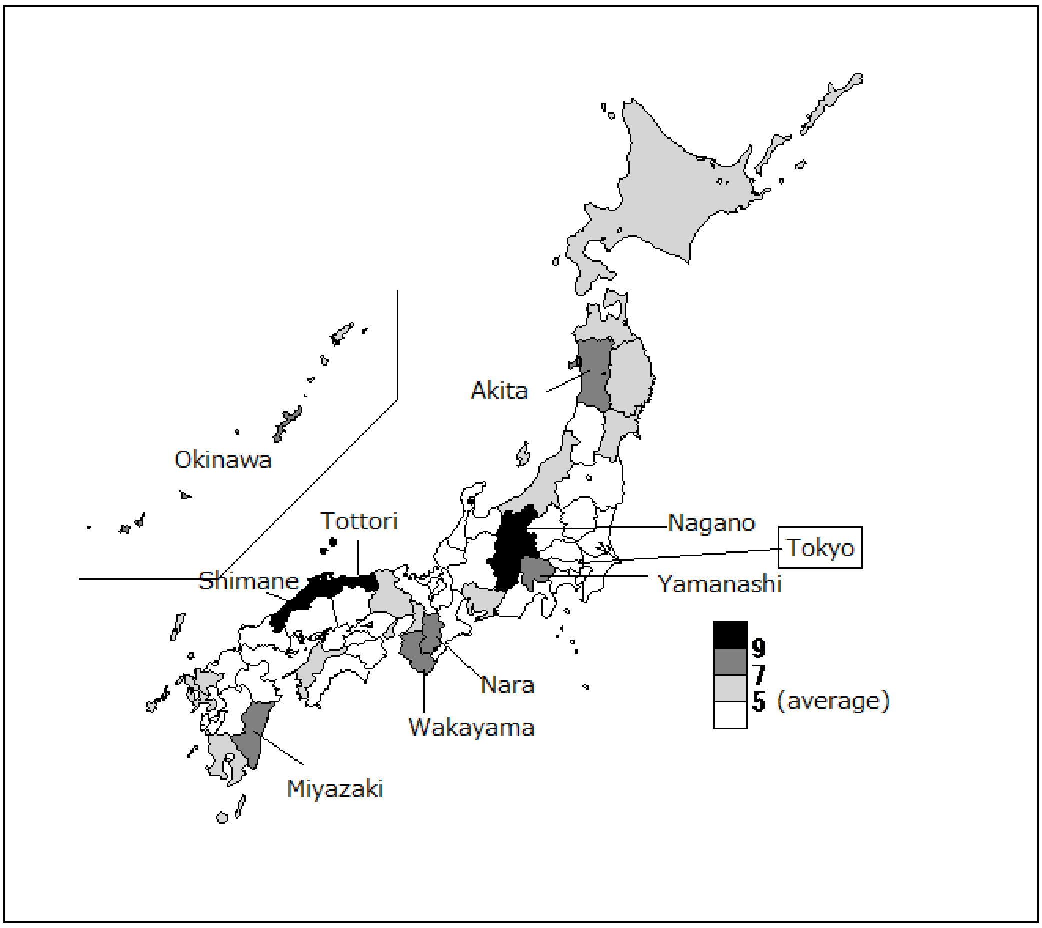


Figure 2. Geographical distribution of regional deviation



Note: Standard deviation of *PCI(t)-JCI(t)*.

Figure 3. R^2 for matching with DPM and structural change

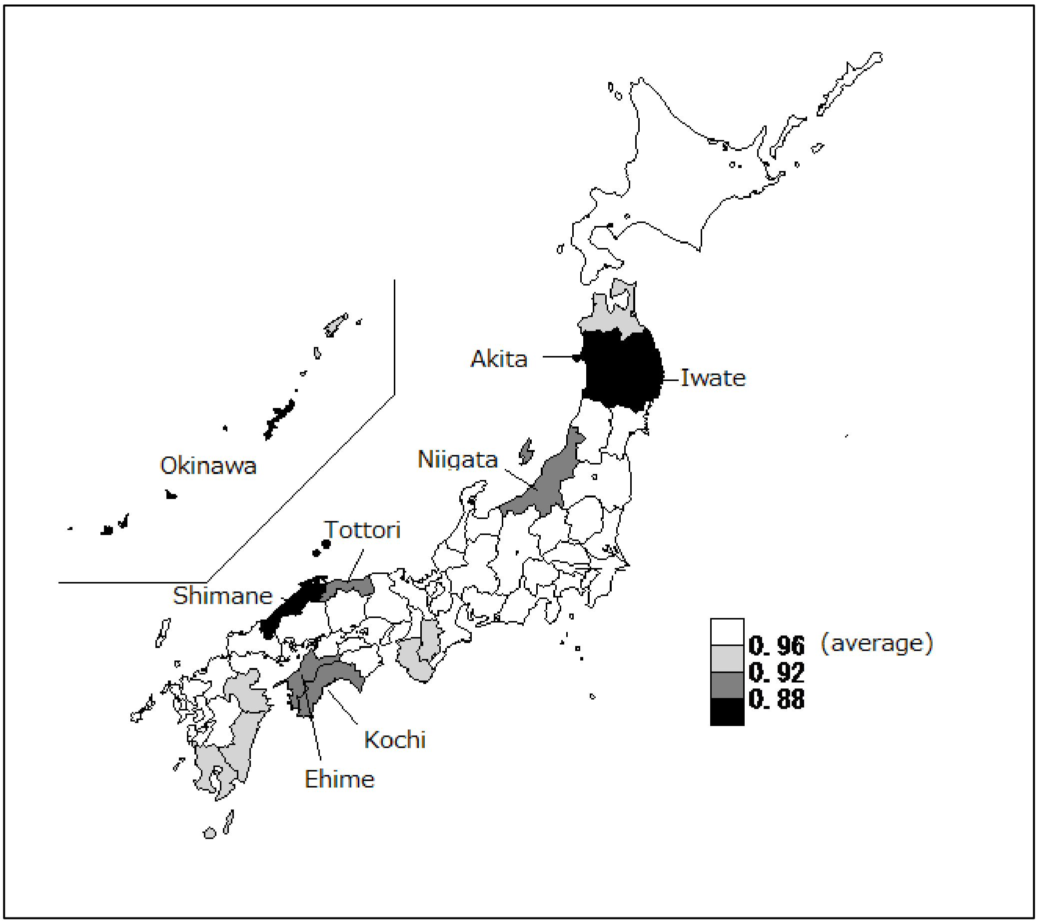


Table 1. Minimum and average R^2 for 47 prefectures

	Without structural change		With structural change	
	Minimum R^2	Average R^2	Minimum R^2	Average R^2
Without DPM	0.330	0.784	0.706	0.885
With DPM	0.524	0.902	0.827	0.961

Figure 4. Comparison of R^2 with and without the structural change

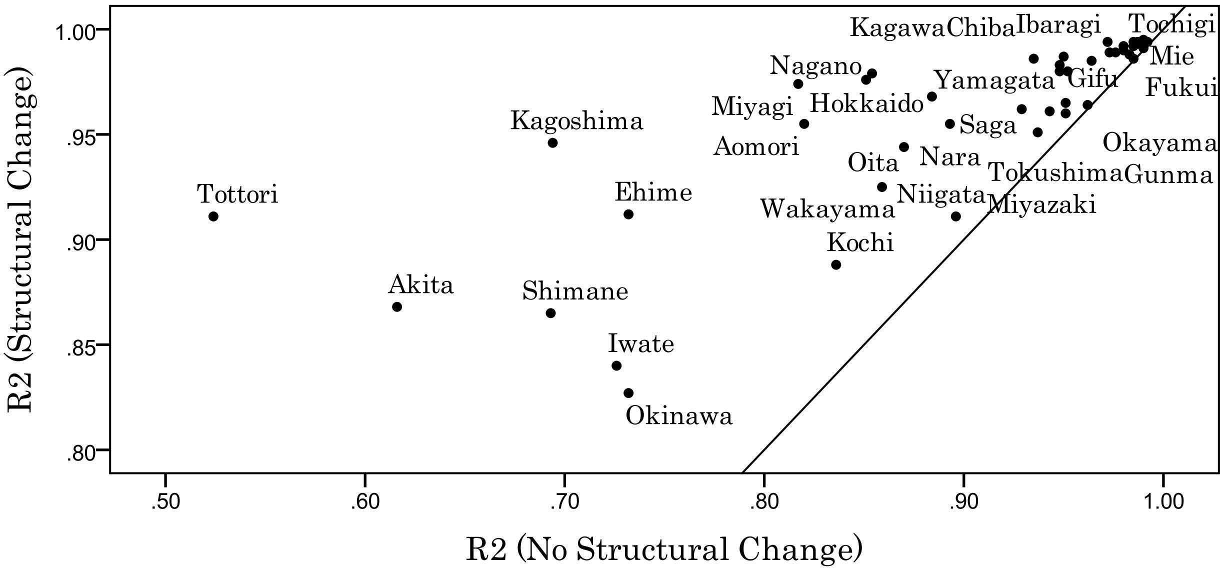


Table 2. Summary of time trend estimate

	Average	Median	Minimum	Maximum	No. of prefectures	
					Negative	Positive
Up to Dec 2001	0.000	0.012	-0.160	0.080	19 (18)	28 (26)
Jan 2002 and after	0.050	0.037	-0.046	0.194	9 (8)	38 (37)

Note: Numbers in parentheses indicate the number of prefectures whose estimates are statistically significant at the 5% level.

Figure 5. Time trend before and after structural change

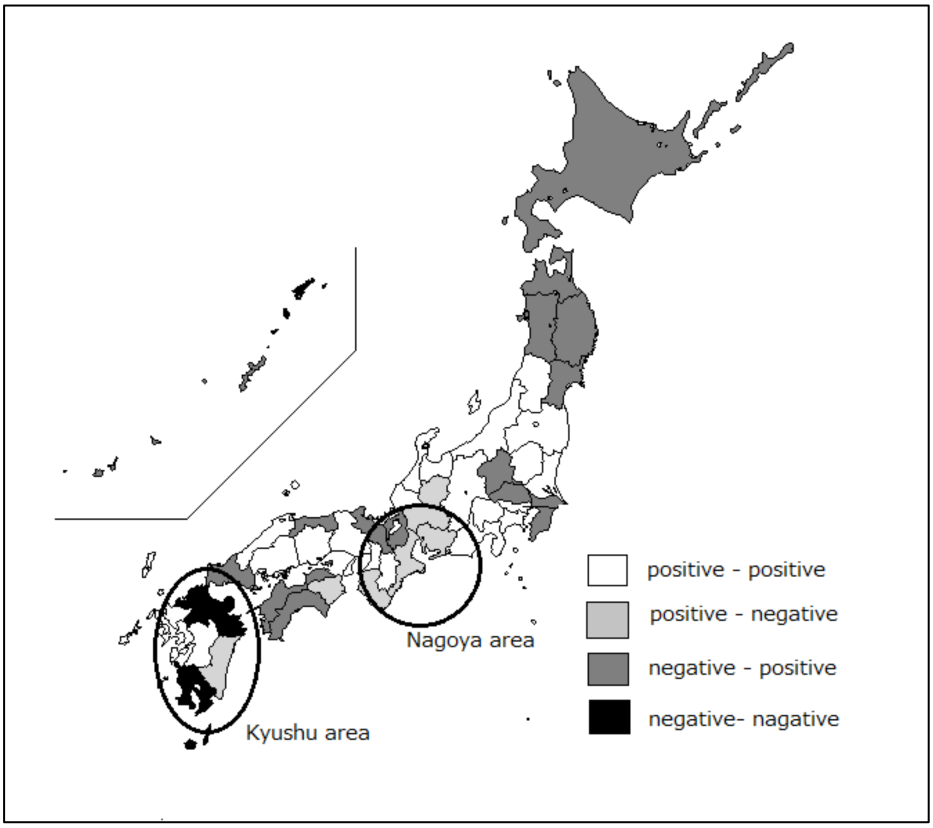


Figure 6. Transition of three factors at the national level

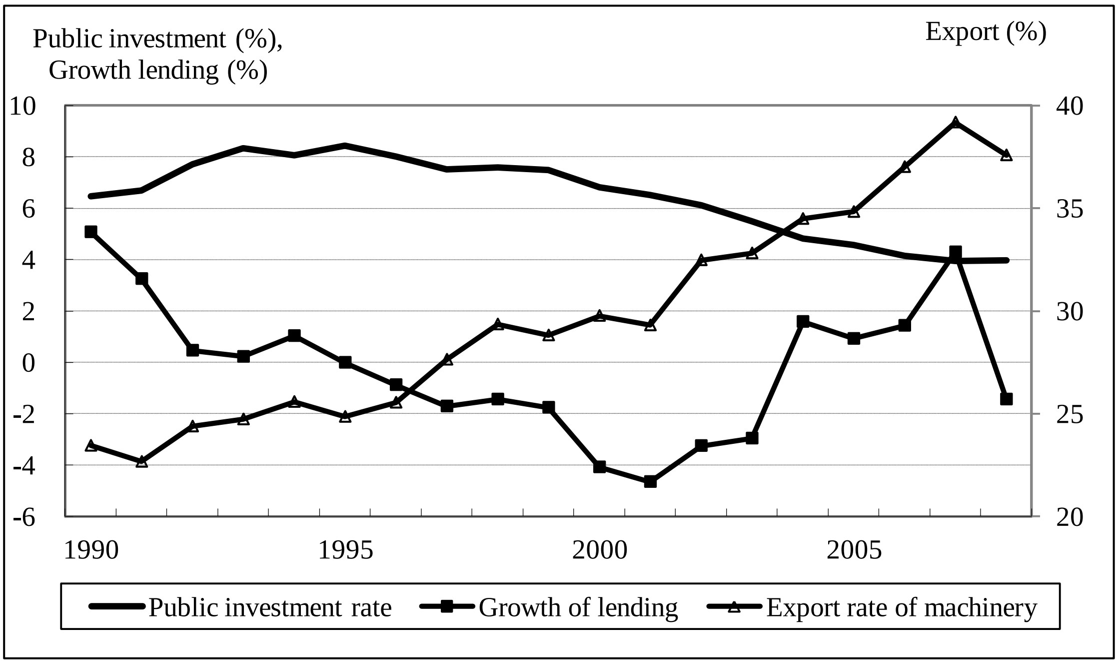
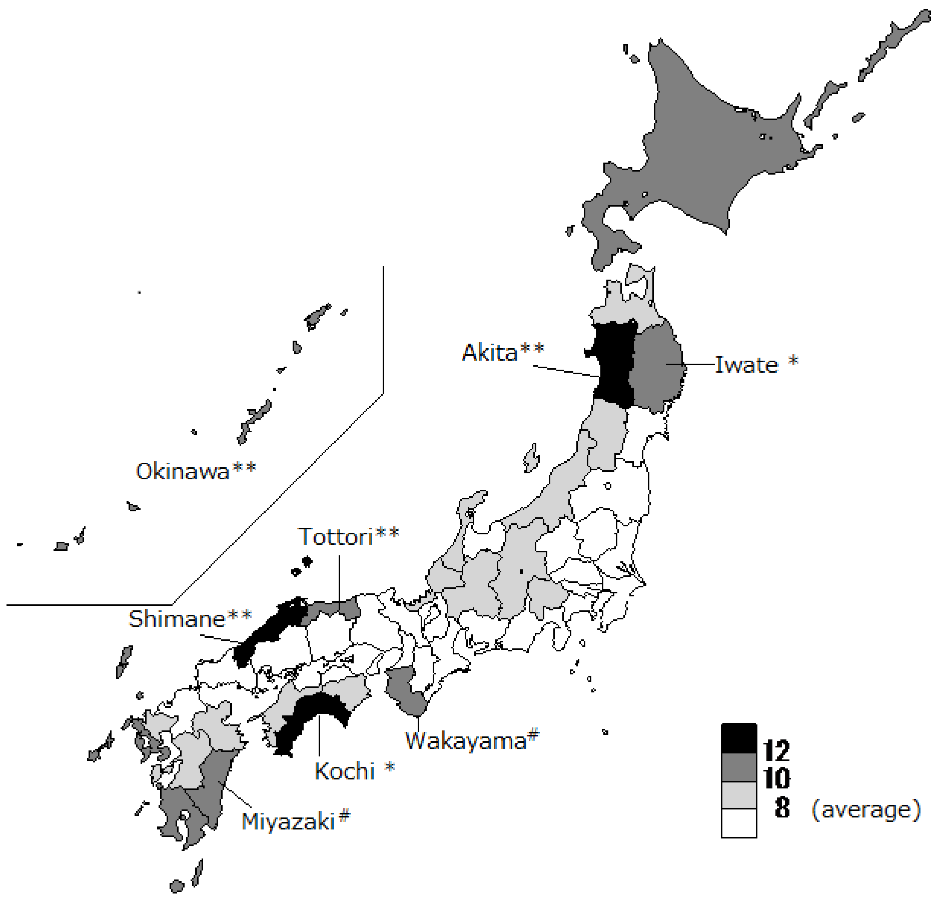


Table 3. Summary statistics of variables for panel analysis

	Mean	Standard deviation		
		overall	between	within
PCI(t)-JCI(t)	3.426	(7.324)	(5.049)	(5.353)
Public investment rate	8.186	(3.355)	(2.669)	(2.069)
Growth rate of lending	3.201	(10.076)	(1.414)	(9.978)
Machinery export	2.596	(1.565)	(1.428)	(0.673)

Figure 7. Prefectures with high public investment rate



Note: # indicates prefectures with large standard deviation of PCI(t)-JCI(t), * indicates those with low R^2 of the matching, and ** is used to indicate both cases.

Table 4. Estimation results of panel data analysis: 1990–2008

Depedent: PCI-JCI	Fixed-effects model		Dynamic model			
			Exogenous case		Predetermined case	
	(A)	(B)	(A)	(B)	(A)	(B)
Public investment rate	1.584 ***	1.427 ***	0.121 ***	0.107 ***	0.112 ***	0.110 ***
	(0.204)	(0.177)	(0.038)	(0.035)	(0.033)	(0.032)
Growth rate of lending	0.051 **	0.043 *	0.125 ***	0.125 ***	0.110 ***	0.110 ***
	(0.025)	(0.024)	(0.034)	(0.034)	(0.029)	(0.029)
Machinery export	0.779		0.057		0.008	
	(0.729)		(0.050)		(0.044)	
Lag of the dependent			0.875 ***	0.876 ***	0.875 ***	0.876 ***
			(0.017)	(0.017)	(0.017)	(0.017)
R-squared, within	0.327	0.322				

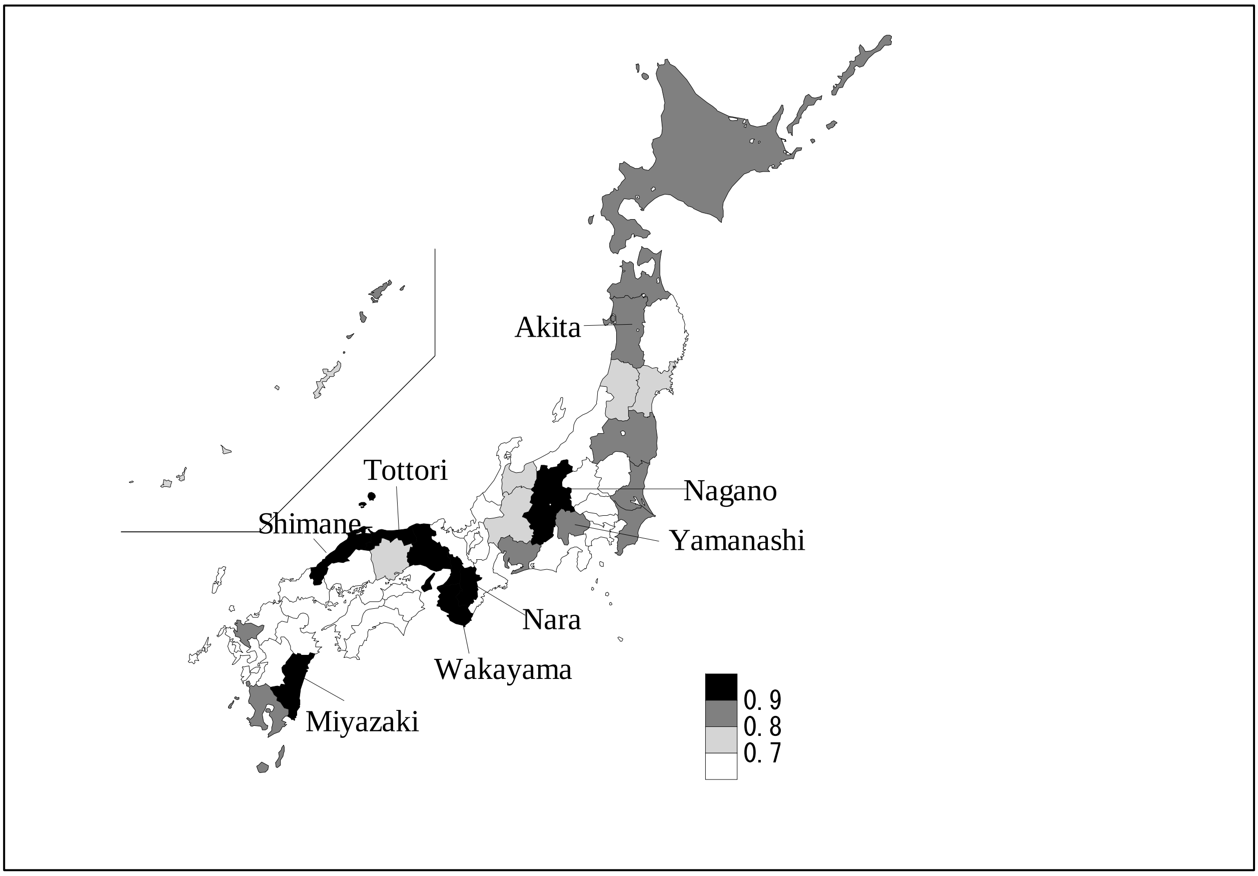
Notes: The sample includes 47 prefectures by fiscal year for 1990–2008. Constant terms are included in the estimation but not reported. Robust standard errors are reported in parentheses, and ***, **, and * indicate 1%, 5%, and 10% significant levels, respectively. The dynamic models are estimated by system GMM; the public investment rate and the growth rate of lending are treated as either "strictly exogenous" or "predetermined" explanatory variables.

Table 5. Estimation result of panel data analysis: 1990–2001 and 2002–2008

Depedent: PCI-JCI	Fixed-effects model		Dynamic model			
			Exogenous case		Predetermined case	
	1990-2001	2002-8	1990-2001	2002-8	1990-2001	2002-8
Public investment rate	0.765 ***	1.284 ***	0.034	0.098 **	0.063	0.078
	(0.238)	(0.237)	(0.062)	(0.045)	(0.055)	(0.060)
Growth rate of lending	0.017	0.084	0.126 ***	-0.0003	0.122 ***	-0.014
	(0.018)	(0.083)	(0.046)	(0.046)	(0.039)	(0.043)
Machinery export	-0.174	0.639	-0.064	0.076	-0.107	-0.020
	(1.036)	(0.430)	(0.072)	(0.073)	(0.075)	(0.076)
Lag of the dependent			0.937 ***	0.642 ***	0.905 ***	0.635 ***
			(0.033)	(0.027)	(0.021)	(0.027)
R-squared, within	0.047	0.247				

Notes: The sample includes 47 prefectures over the indicated fiscal years. Constant terms are included in the estimation but not reported. Robust standard errors are reported in parentheses, and ***, **, and * indicate 1%, 5%, and 10% significant levels, respectively. The dynamic models are estimated by system GMM; the public investment rate and the growth rate of lending are treated as either "strictly exogenous" or "predetermined" explanatory variables.

Figure 8. Regional deviation explained by panel analysis



Note: Prefectures designated are those with large CI disparity in Figure 2, and with calculated R^2 of at least 0.83.

Appendix A. Data sources

A1. Four components to construct CIs

(i) Production

Indexes of industrial production by prefecture are used. Data pertaining to approximately the last decade were collected from official prefectural websites, or by inquiring directly from the relevant statistics section in each prefecture. For earlier data, we applied seasonal adjustments to the series retrieved from Nikkei NEEDS and then connected the data using link coefficients.

(ii) Retail sales

Real sales values by large-scale retail stores by prefecture are used, after applying seasonal adjustment. The sales values are from the *Trade and Industry's Report on the Current Survey of Commerce*, Ministry of Economy, Trade and Industry. The values are converted real values using the Consumer Price Index (CPI) in each prefectural capital city. The CPIs are taken from *Consumer Price Index*, Ministry of Internal Affairs and Communication.

(iii) Income

The non-scheduled hours worked in industries by prefecture are used. Data are from the *Monthly Labor Survey (Prefectural Survey)*, Ministry of Health, Labour and Welfare, and from regional surveys published by each prefecture. The data are seasonally adjusted.

(iv) Employment

The seasonally adjusted values for numbers of active job openings by prefecture are used. Data are from the *Employment Referrals for General Workers*, Ministry of Health, Labour and Welfare.

A2. Three influential factors

(v) Public investment rate

The value of public investment in each prefecture is divided by gross prefectural production. Data are from *Prefectural Accounts Statistics* (*Kenmin Keizai Keisan* in Japanese), Cabinet Office, Government of Japan.

(vi) Growth rate of outstanding lending of financial institutions

The growth rate is calculated from outstanding lending of financial institutions. Data are from *Deposits, Vault Cash, and Loans and Bills Discounted by Prefecture (Domestically Licensed Banks) (Monthly data)*, Bank of Japan.

(vii) Export demand ratio of the machinery industry in a prefecture

Calculated by: (national export ratio) × (production ratio by prefecture). The national export ratio is calculated from export amounts divided by outputs. National export amounts are from *Trade Statistics*, Ministry of Finance, Japan. National outputs are from *National Accounts Statistics*, Cabinet Office, Government of Japan. The prefectural production ratio is calculated from prefectural production of the machinery industry divided by total prefectural production. Data are from *Prefectural Accounts Statistics* (*Kenmin Keizai Keisan* in Japanese), Cabinet Office, Government of Japan.

Appendix B. Algorithm of DPM

The algorithm of DPM follows Kamisaka and Ozeki (1990). Consider sets X and Y consisting of a sequence of elements $\{x(1), x(2), \ldots, x(\mathrm{n})\}$ and $\{y(1), y(2), \ldots, y(\mathrm{m})\}$, respectively. X and Y are matched under the following three conditions:

(1) Y is adjusted to obtain the highest similarity index, or to minimize the distance.

(2) The first and the last elements of X and Y, respectively, are matched respectively.

(3) The order of elements in the original Y are not reversed.

Let the distance be $d(i,j)$ for elements of $x(i)$ and $y(j)$, and the minimum distance be $g(i,j)$ between $\{x(1), x(2), \ldots, x(\mathrm{i})\}$ and $\{y(1), y(2), \ldots, y(\mathrm{j})\}$. Then, the minimum distance can be calculated by the following recurrence formula:

$$g(1, 1) = d(1, 1)$$
$$g(i, j) = d(i, j) + \min \{ g(i\text{-}1, k) | 0 \leqq k \leqq j \}$$

The choice of distance is the squared sum of residuals $\sum_{t=1}^{n} \varepsilon(t)^2$.

Also, the following two conditions are imposed.

(4) The maximum lead (lag) is limited to six months, in order to keep recession and expansion in the same business cycle.

(5) The maximum skip is limited to two months, in order to restrain sudden changes.

These conditions also help to reduce computational burden. Changes of these conditions do not alter the basic implications of the analysis. Note that leads and lags for first and last several periods might be varied when additional periods are observed, due to condition (2). Those periods are omitted in the analysis of Section 4.

Appendix C. Result by prefecture

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Prefecture	PCI-JCI	R-squared of matching				Time trend		Pub.	R-sq.
	St.dev.	None	DPM	St.Chg	Both	-2001	2002-	Inv.	Panel
Hokkaido	6.21	0.636	0.851	0.886	0.976	-0.027	0.163	11.3	0.826
Aomori	6.94	0.617	0.820	0.863	0.955	-0.014	0.025	9.7	0.885
Iwate	5.96	0.537	0.726	0.706	0.840	-0.040	0.023	10.8	0.666
Miyagi	5.71	0.598	0.817	0.926	0.974	-0.121	0.107	7.2	0.794
Akita	8.48	0.419	0.616	0.722	0.868	-0.040	0.107	12.6	0.835
Yamagata	4.23	0.849	0.948	0.936	0.980	0.002	0.017	9.7	0.743
Fukushima	4.98	0.873	0.952	0.925	0.980	0.010	0.025	7.2	0.880
Ibaragi	4.62	0.930	0.988	0.944	0.993	0.031	0.063	6.9	0.871
Tochigi	1.95	0.952	0.988	0.968	0.994	0.013	0.027	4.9	0.085

Gunma	2.95	0.874	0.962	0.878	0.964	-0.006	0.015	5.4	0.266
Saitama	2.01	0.940	0.990	0.948	0.994	-0.011	0.031	4.7	0.429
Chiba	4.37	0.850	0.950	0.930	0.987	-0.007	0.058	6.5	0.830
Tokyo	3.76	0.899	0.980	0.918	0.990	0.054	0.074	<u>3.0</u>	0.197
Kanagawa	4.22	0.927	0.985	0.952	0.994	0.039	0.107	4.4	0.467
Niigata	5.04	0.766	0.896	0.782	0.911	0.016	0.044	9.3	0.697
Toyama	4.38	0.928	0.985	0.931	0.986	0.040	0.037	7.7	0.737
Ishikawa	3.43	0.918	0.980	0.961	0.992	0.024	0.008	8.4	0.673
Fukui	4.71	0.923	0.983	0.944	0.988	0.021	0.061	10.0	0.374
Yamanashi	8.07	0.723	0.884	0.901	0.968	0.017	0.106	9.7	0.867
Nagano	10.40	0.682	0.854	0.936	0.979	0.023	0.111	9.3	0.911
Gifu	4.74	0.905	0.973	0.954	0.989	0.043	-0.020	8.2	0.757
Shizuoka	3.27	0.902	0.976	0.944	0.989	0.012	0.099	4.6	0.613
Aichi	5.13	0.895	0.972	0.943	0.994	0.028	-0.012	4.1	0.806
Mie	2.34	0.948	0.990	0.965	0.993	0.024	-0.009	7.0	0.441
Shiga	2.63	0.937	0.989	0.960	0.994	-0.010	0.012	6.2	0.339
Kyoto	3.92	0.874	0.964	0.919	0.985	-0.041	0.021	5.9	0.580
Osaka	6.29	0.950	<u>0.992</u>	0.964	0.994	<u>0.080</u>	0.056	4.0	0.928
Hyogo	5.09	0.949	0.990	<u>0.974</u>	<u>0.995</u>	0.028	0.024	7.0	0.910
Nara	7.01	0.757	0.893	0.864	0.955	0.017	0.116	7.0	0.915
Wakayama	7.44	0.661	0.859	0.771	0.925	0.021	<u>-0.046</u>	10.4	<u>0.930</u>
Tottori	<u>12.73</u>	<u>0.330</u>	<u>0.524</u>	0.807	0.911	-0.034	<u>0.194</u>	10.8	0.907
Shimane	10.45	0.479	0.693	0.744	0.865	0.005	0.087	<u>14.9</u>	0.903
Okayama	4.85	0.821	0.951	0.843	0.965	0.027	0.004	7.2	0.775
Hiroshima	2.87	0.928	0.990	0.937	0.991	0.008	0.037	6.7	0.343
Yamaguchi	3.76	0.795	0.948	0.888	0.983	-0.023	0.077	7.0	0.570
Tokushima	4.01	0.837	0.951	0.852	0.960	0.018	-0.017	9.8	0.433
Kagawa	3.77	0.763	0.935	0.916	0.986	-0.046	0.070	5.8	0.584
Ehime	5.32	0.533	0.732	0.782	0.912	-0.074	0.119	8.3	0.674
Kochi	4.83	0.685	0.836	0.775	0.888	-0.015	0.051	13.1	0.636
Fukuoka	2.06	0.937	0.987	0.962	0.994	-0.031	-0.009	5.9	-
Saga	6.40	0.828	0.929	0.877	0.962	0.018	0.089	9.6	0.876
Nagasaki	5.54	0.822	0.943	0.864	0.961	0.024	0.026	10.6	0.546
Kumamoto	3.64	0.936	0.985	0.962	0.992	0.013	0.041	9.0	0.577
Oita	4.26	0.716	0.870	0.832	0.944	-0.028	-0.006	8.8	0.654
Miyazaki	7.45	0.819	0.937	0.861	0.951	0.058	-0.002	10.6	0.916
Kagoshima	6.94	0.501	0.694	0.863	0.946	<u>-0.160</u>	-0.031	11.8	0.810
Okinawa	7.17	0.519	0.732	<u>0.627</u>	<u>0.827</u>	-0.004	0.188	11.8	0.753

Notes: Maximum and minimum are underlined.

(1) Standard deviation of {*PCI(t)-JCI(t)*}. Those marked are higher than 7%.

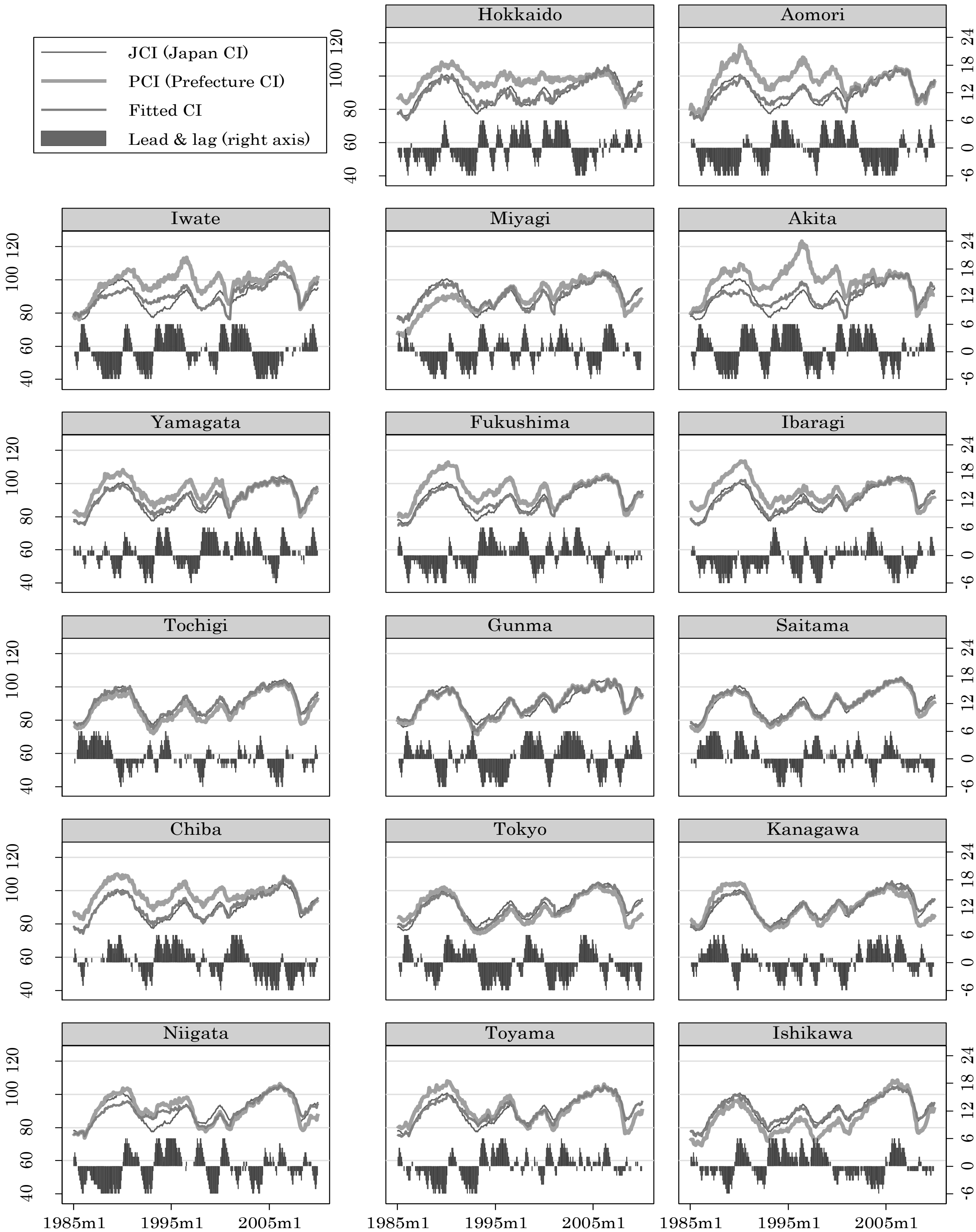
(2)–(5) R^2 of the matching analysis without DPM and structural change, with DPM only, with structural change only, and with both DPM and structural change, respectively. Those highlighted are lower than 0.92 in (5).

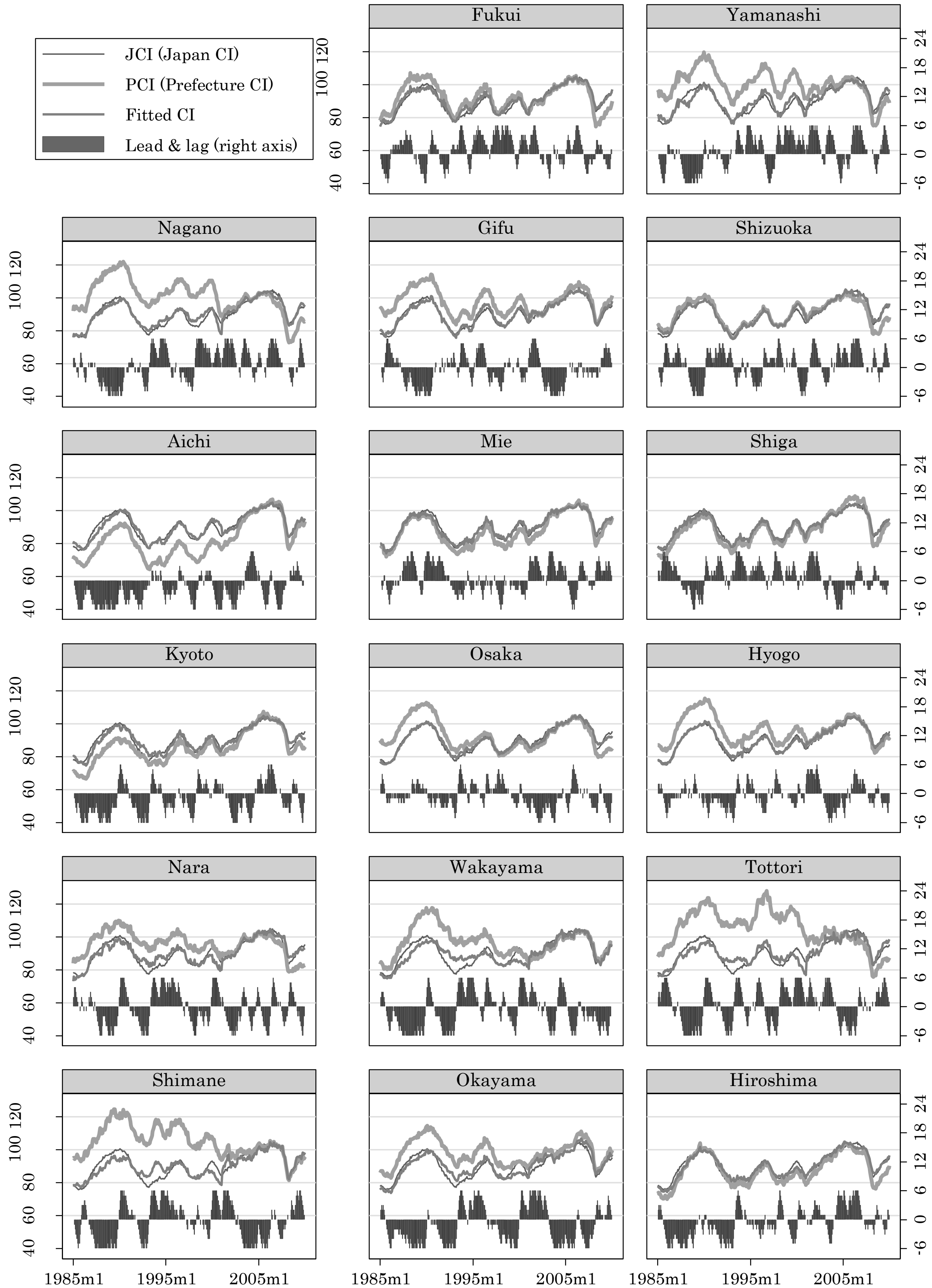
(6) (7) An estimate of time trend "before" (1985–2001) and "after" (2002–2010) the structural change from the matching analysis with applying both DPM and structural change. Those highlighted are negative after the structural change.

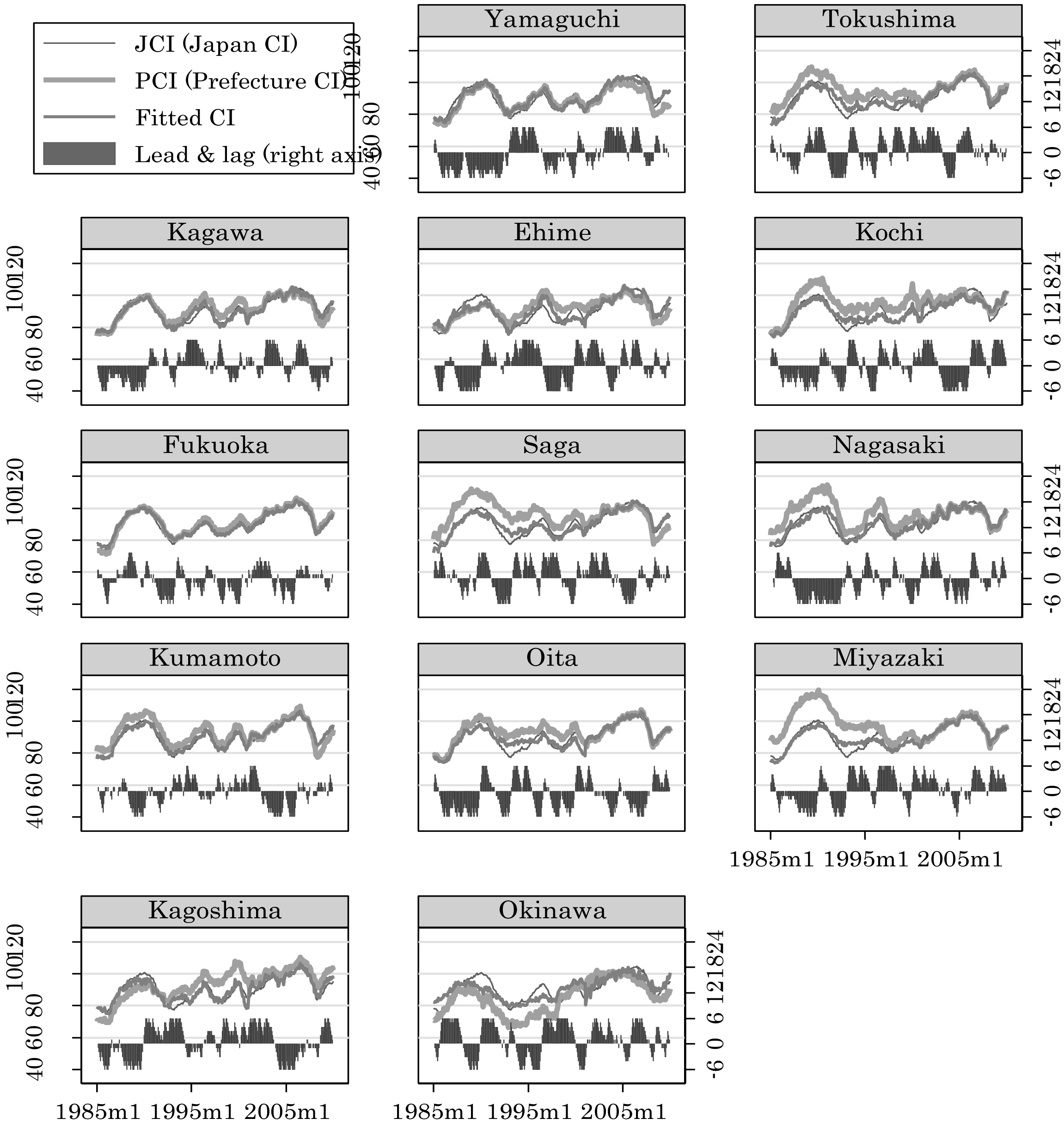
(8) Public investment rate averaged over the sample period 1990–2008. Those highlighted are higher than 10%.

(9) R^2 calculated for each prefecture, using estimates from a dynamic panel analysis in the predetermined case. Those highlighted are prefectures with large deviation in the dependent variable of {*PCI(I,t)-JCI(t)*}.

Appendix D. Figure A.1. Prefectural CI




JCI (Japan CI)
PCI (Prefecture CI)
Fitted CI
Lead & lag (right axis)
Fukui
Yamanashi
Nagano
Gifu
Shizuoka
Aichi
Mie
Shiga
Kyoto
Osaka
Hyogo
Nara
Wakayama
Tottori
Shimane
Okayama
Hiroshima
40 60 80 100 120
-6 0 6 12 18 24
1985m1
1995m1
2005m1


JCI (Japan CI)
PCI (Prefecture CI)
Fitted CI
Lead & lag (right axis)
Yamaguchi
Tokushima
Kagawa
Ehime
Kochi
Fukuoka
Saga
Nagasaki
Kumamoto
Oita
Miyazaki
Kagoshima
Okinawa
40 60 80 100 120
-6 0 6 12 18 24
1985m1 1995m1 2005m1

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