2J06 Regional Industrial Clusters, Output Productivity Growth Convergence and Technological Distance:

The Case of Japan's Manufacturing Sector

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ABSTRACT

This paper evaluates *output productivity growth convergence*, using modified Barro regressions, of Japanese prefectures grouped in various regional industrial clusters for the period 2000-2003, with respect to seven manufacturing sectors. A *specialization* indicator is designed in order to develop the concept of *cluster epicenters*, and establish an empirical basis for grouping prefectures according to their deeds in each manufacturing sector. Results show that in the electrical and transport machinery sectors alternative prefectural arrangements would have been more adequate industrial clusters than traditional ones, during the period in question, for reducing *output productivity growth* dispersion in these two manufacturing sectors across Japan, which in turn could have catalyzed Japanese industrial revitalization.

1. INTRODUCTION

Industrial clusters have traditionally been studied from the geographical viewpoint, in which economic activities are agglomerated based on proximity (Krugman, 1991). Geographic concentration of economic activity is a predominant feature of modern economies and a key aspect of industrialization. Regional approaches to industrial dynamics have also been regarded as meso-economic approaches; Caniels and Romijn (2003a) describe the industrial district literature as emphasizing the "competitive advantages arising from joint action by parties, which is driven by mutual trust and supportive institutions". In the Japanese context several studies have adopted the geographical and/or technological distance approach (Carvajal and Watanabe 2003, 2004).

However, regional and firm level approaches by themselves, can only give partial insights into industrial dynamics as rightly pointed out by Caniels and Romijn (2003). Nakamura's (2001) findings for the Japanese chemical and electric equipment industries, where licensed technology imports encourage innovation by enhancing foreign knowledge inflows; and recently.

Contrary to the conspicuous achievement up until the end of the 1980s, Japan's economy has been experiencing a long lasting economic stagnation over the last decade. This can be attributed to a vicious cycle between economic stagnation due to the bursting of the bubble economy in 1991, stagnation of industry's R&D (Watanabe, 1995), and consequent decrease in its innovativity (i.e. productivity of technology with respect to its contribution to innovation).

Recently, however, an increasing interest in Japan's industrial revitalization has urged government, firms, educational institutions, and especially Regional Bureaus, to constitute networks of cooperation, by means of agglomeration in potential industrial areas. In fact, the industrial policy currently being promoted by the Ministry of Economy, Trade and Industry (METI) for revitalizing regional economies emphasizes the formation of industrial cluster plans for developing world-class businesses to support local economies, based on the efforts Regional Bureaus are supposed to provide.

Thus, in this paper we use prefectural panel data for 12 manufacturing sectors and analyze value of shipments per worker and registered patents for the year 2000 in Japan, using Barro regressions, in order to check whether the convergence speed of output productivity growth increases (for each region during the period 2000-2003) when industrial clusters are constituted in and around prefectures that can work as *epicenters* of knowledge spillovers and in turn enhance output productivity. Kawagoe (1999) argues against the usage of Barro regressions for illustrating Japanese regional dynamics. Our study differs from Kawagoe's and Barro and Sala-i-Martin's (1997) in at least two fundamental ways: instead of using GNP per capita growth rate, we consider the growth rate of value of shipments per worker in different industrial sectors; additionally, we use convergence speed analysis in order to check how alternative clusters of prefectures – or alternative prefectural arrangements, grouped according to their productive capacities and new knowledge production capabilities, would help reduce the dispersion of output productivity growth throughout Japan in a specific manufacturing sector, and thereby contribute to industrial revitalization.

2. ANALYTICAL FRAMEWORK

Caniels (2001) makes extensive use of Verdoorn-Kaldor law in order to explain why output growth causes productivity growth. In particular it relates to productivity and output through static and dynamic economies of scale, which refer to large-scale production and knowledge spillovers, respectively, taking place inside a region and resulting more from *increasing returns to scale in processing activities*, than from any resource endowments that same region might have.

Now, Caniels (2000), uses the growth of technology stock as a measure of the technological gap between regions, which is in turn used as an indicator of technological distance. Also corroborating Jaffe (1986) measures technological proximity using patents data[1], with the following formula:

$$Tprox_{i,j} = \sum_{n=1} P_{n,i} P_{n,j} \quad \text{for} \quad \forall n \quad \text{and} \quad \forall i,j \qquad (1)$$

Where n is the patent class, for example, in accordance with the International Patent Classification (IPC) WIPO classification; i, j are the pair of prefectures. and $P_{n,i}$ and $P_{n,j}$ are the share of patent in class n in prefecture i and j, respectively. This variable measures orthogonality between the patents vectors of the different regions. The inclusion of patent class and share of patents per class in the formula tries to account for Griliches (1998) concerns in terms of patents differing greatly in quality, and the magnitude of the invented output associated with them.

Even though Caniels dismisses the neoclassical assumption that knowledge is completely mobile and spreads instantaneously to all geographical regions, and therefore focuses on regional *divergence* instead of *convergence* by assuming imperfect mobility and slow diffusion of technology, we regard the neoclassical convergence assumption *valid* when evaluating the performance of regions within a country (Barro and Sala-i-martin, 1997) insofar as differences in technology preferences, institutions, tastes and cultures tend to be small across regions in a particular country. Thus, regions are more likely to converge to similar steady states than countries, again, because legal, cultural, linguistic and institutional barriers to input factor movements are smaller across regions within a country than across countries.

Especially for the Japanese case where institutional incentives to information sharing and the flow of technological knowledge across firms boundaries are common. Branstetter's (2000) study on the competitive advantages of vertical *Keiretsu* linkages that still are particularly common in the manufacturing industry (Ohsono, 1995) demonstrating institution influencing industrial cluster policies. That is why we perform our analyses by *industrial sectors*, in order to provide additional support for the neoclassic *convergence* assumption, and account for Griliches (1998) concerns in terms of inventions that are not patented and/or not patentable.

[1] Acs *et al* (2002) provide empirical support for the use of patents as adequate measures of knowledge production.

After justifying the use of convergence theory to complement our analytical framework given this study's scenario, we will now explain what it entails. According to Barro and Sala-i-Martin (2004) *absolute convergence* applies when poor economies tend to grow faster than rich ones, while *conditional convergence* applies when the growth rate of an economy is positively related to the distance between this economy's level of income and its own steady state, in other words, when an *economy's growth rate reduces the dispersion of per capita income by effectively bringing an economy to its equilibrium*; however, when a group of economies (i.e. regional economies within a country) tend to converge to the same steady state (i.e. a country's economic equilibrium) the two concepts become identical, simply because absolute convergence leads to the conditional one.

In this paper the concept of reducing the dispersion of per capita income is associated to an industrial sector's output productivity (Value of the shipments per employee) convergence; therefore, our Barro regressions use nonlinear least squares estimates to calculate equations of the form:

$$(1/T)\cdot\log\left(y_{i,j,t}/y_{i,j,t-1}\right)=a-\left[\log\left(y_{i,j,t-T}\right)\right]\cdot\left[\left(1-e^{-\beta T}\right)/T\right] \qquad (2)$$

where $y_{i,j,t-T}$ is the value of shipments per employee in prefecture i in manufacturing sector j, from year 2000 to 2003, t is the period base for analysis of growth and T is the length of the interval (3 years).

Following this analysis, Regional dummies variables are included to analyze the effects of alternative prefectural settings as follows:

$$(1/T)\cdot\log\left(y_{i,j,t}/y_{i,j,t-1}\right)=a-\left[\log\left(y_{i,j,t-T}\right)\right]*\left[D_1\cdot\left[\left(1-e^{-\beta_1 T}\right)/T\right]-D_2\cdot\left[\left(1-e^{-\beta_2 T}\right)/T\right]\cdots-D_n\cdot\left[\left(1-e^{-\beta_n T}\right)/T\right]\right] \qquad (3)$$

where $D_1, D_2, \ldots, D_n$ are the Dummy variables to group prefectures, and β_1, β_2, …, β_n are the convergence coefficients that will describe the best grouping strategy if an increase in convergence speed results from a particular prefectural arrangement.

Herein the data sets are used by sectors, and aggregated by region. As mentioned before, a country's firms, institutions and universities tend to have access to similar technologies, and the case of Japan is more consequent with the convergence assumption since the regions share a common central government and therefore have similar institutional setups and legal systems, this homogeneity means that absolute and conditional convergence are more likely to apply across regions, prefectures and clusters; and to amount to a single definition of convergence, vis-à-vis, *reducing the dispersion of output productivity growth across Japanese prefectures, regions and industrial sectors* for the period 2000-2003, which should help trigger industrial revitalization.

3. VARIABLES AND MODEL

In this study we consider two types of variables: those referring to *value of shipments per employee*; and those referring to *registered patents*. The former indicates industrial sector's *output productivity* and the latter *innovativeness*. The yearly value of shipments and the number of employees by sector was obtained from the Research and Statistics Department, Economic and Industrial Bureau, *Ministry of Economy Trade and Industry*, meanwhile the number of patents registered by prefecture during the period 1998-2000 were gathered and organized with the help of the *Japan Institute for Invention and Innovation*. In many ways our analysis can be attributed to the patents information obtained, out of which we constructed a database covering each manufacturing industry sector in its respective Japanese prefecture. The data was first classified in four-digit IPC (International Patent Classification), and then re-classified in two-digits according to the Japanese version (JISIC) of the International Standard Industrial Classification (ISIC) for enhancing international comparability.

3.1. Growth as Related to Output Productivity

Output productivity growth is an adequate manufacturing proxy of an economy's overall growth, and specifically, of industrial growth. Most clustering or agglomeration studies focus on product location while ignoring shipments implications. (Hilberry et. al. 2002). Our use of shipment data related to an industrial sector's productivity provides insights into the role that outputs play in concentrating production. The data herein included corresponds to manufacturing sectors and not to wholesalers, so as to avoid double counting, meaning that the value of shipments per employee can be an adequate proxy of manufacturing sectors' growth by Japanese prefectures.

3.2. Epicenters

In this paper we evaluate the hypothesis that these variables can help detect *epicenters* as basis for cluster formation, which is one of the most important objectives of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of Economy, Trade and Industry (METI), namely: *identifying prefectures where high output productivity coincides with high innovative activity for the same manufacturing sector*, not just to help revitalize that particular industry throughout Japan, but to attract foreign direct investment as well.

3.3. Regional classification

The unit of analysis used is the prefecture, due to availability of comparable statistical data and the static or dynamic homogeneity of prefectural characteristics (i.e. value of shipments and patents). More specifically the spatial disaggregation to be used is as follows: 47 Prefectures grouped in eight regional blocks as shown in Table 1, which correspond to larger geographical areas, defined from north to south and including groups of neighboring prefectures, with the exception of Hokkaido and Okinawa which are separated from the main land, the former is defined as a whole region and the latter as a prefecture belonging to Kyushu region.

Table 1 Japanese Administrative Regions with their respective prefectures

Regions	Hokkaido (1)	Tohoku (2)	Kanto (3)	Tokai[2] (4)	Kinki (5)	Chugoku (6)	Shikoku (7)	Kyushu and Okinawa (8)
Dummies	D1	D2	D3	D4	D5	D6	D7	D8
Prefectures	Hokkaido	Aomori	Ibaraki	Nigata	Mie	Tottori	Tokashima	Fukuoka
		Iwate	Tochigi	Toyama	Shiga	Shimane	Kagawa	Soga
		Miyagi	Gunma	Ishikawa	Kyoto	Okayama	Shiime	Nagasaki
		Akita	Saitama	Fukui	Osaka	Hiroshima	Kouchi	Kumamoto
		Yamagata	Chiba	Yamanashi	Hyogo	Yamaguchi		Ooita
		Fukushima	Tokyo	Nagano	Nara			Miyazaki
			Kanagawa	Gifu	Wakayama			Kagoshima
				Shizouka				Okinawa
				Aichi				

Besides examining the convergence speed of the regional prefectural classification presented (in table 2), used by numerous publications: Asahi Shinbun, the National Land Agency of Japan, governmental agencies and institutions, the convergence speed of different prefectural arrangements will also be tested.

7 prefectures are defined as metropolitan areas: Tokyo, Saitama, Chiba, Kanagawa, Aichi, Osaka and Hyogo, surrounded by Ibaraki, Gunma, Gifu, Shizuoka, Mie, Kyoto, Nara, Wakayama and Fukuoka, while the remaining prefectures are regarded as rural areas. It is important to define Tokyo, Osaka, and Aichi as main metropolitan areas and poles of the Pacific Belt.

3.4. Methodology and model

Two methodologies were applied: one multivariate statistical techniques due to the exploratory nature of this study (Carvajal, Parra et al., 2004), and the other based on Patents as proxies determined by Technology stock and R&D intensity (Carvajal and Watanabe, 2004 and Watanabe and Carvajal 2004). Specifically, in order to check the validity of intuitively (politically or "artificially") established industrial clusters, and to compare their alternative performance, in terms of output productivity convergence speed, if prefectures were to be clustered empirically.

4. EPICENTERS AND CLUSTERS

In order to use the information provided by the indicator previously described as criteria for testing the convergence speed of alternative prefectural arrangements, we will only consider those *activities* contributing the most to the overall indicator (i.e. chemical output *productivity* and/or chemical *patents*) that is, the ones with the highest loadings times the transformed quantitative values; and constituting alternative cluster settings around *epicenter prefectures where high output productivity coincides with high innovative activity for the same sector*, and adhering adjacent prefectures to the epicenter based on their

[2] Tokai Region Consists of 3 sub-regions: Tokai, Koushinetsu and Hokariku.

respective productive capacity (value of shipments corrected by 1995 deflation) to effectively support the epicenter and leverage the cluster.

The following activities were identified as not contributing significantly to a prefecture's performance in terms of output productivity and/or innovation, and thereby to Japanese industrial performance: textile, publishing, ceramics and iron patents, that is, those activities grouped in the lowest quintile. This is no surprise due to the fact that quintiles of patents in the mentioned sectors exhibit negligible differences across Japanese prefectures, this in turn means that in terms of specialization: textile, publishing, ceramics and iron *patents* cancel out any contribution *productivity*, in these same sectors, may provide; therefore, these sectors (i.e. textile, publishing, ceramics and iron) are omitted from the convergence speed analysis that follows which leads to a non-counterintuitive preliminary result. Thus, in order to revitalize its industrial sectors, Japan should focus on manufacturing sectors that maximize prefectural productivity and innovativeness.

Out of this specialization data matrix (19 prefectures and 7 sectors) we now turn to identifying epicenter prefectures. Figure 2 shows a map of the prefectures in which a sectors' high output productivity coincides with high new knowledge production (high innovative activities), thus, it shows the epicenters for each sector in the following manner: **I**, stands for high output productivity coinciding with high innovative capabilities in the electric machinery sector; **II**, in the precision instruments sector; **III**, in general machinery; **IV**, in plastics; **V**, in transport; **VI**, chemicals; and **VII**, high output productivity concurring with high innovative capabilities in the fabricated metals sector. Additionally, the map points out the prefectures where an industrial sector's productive capacity contributes to 50% of the Japanese total output in that sector, as follows: **1**, refers to high productive capacity in the electric machinery sector; **2**, in the precision instruments sector; **3**, in general machinery; **4**, in plastics; **5**, in transport; **6**, chemicals; and **7**, indicates high productive capacity the fabricated metals sector. This is done in order to examine which prefectures, according to their productive capacity (again defined by a prefecture's value of shipments corrected by 1995 deflation), can complement the previously identified epicenters so as to effectively comprise an industrial cluster.

As Figure 1 evidences, many combinations in terms of epicenters and productive prefectures can be found: there are epicenter prefectures that are also highly productive in a specific sector(s), which is a non-counterintuitive result in the case of Aichi, Kanagawa and Shizuoka; and also purely productive prefectures like Saitama and Osaka. Additionally, there are prefectures, that by definition, can be regarded as epicenters of a certain industrial sector, but do not contribute to Japan's 50% total production of that sector, resulting in "pseudo-academic" prefectures, as shown in the case of Gifu general machinery sector.

In particular, Aichi prefecture specializes in four sectors: electrical machinery, precision instruments, plastics and transport machinery, meanwhile all the other epicenter prefectures specialize in only one or two sectors. Such that when in a one single sector there are various adjacent epicenter prefectures (i.e. neighboring prefectures that are epicenters for the same sector, as Tokyo and Kanagawa for both electrical machinery and precision instruments sectors) then those prefectures are more than likely representing an industrial cluster that can potentially improve all the regions' convergence speed and reduce the dispersion of output productivity growth for that one sector.

The key to our clustering methodology, however, is that those neighboring prefectures with high productive capacities in only a few sectors can be handled strategically so that epicenters can 'empower' them to increase regional convergence speed, in a particular sector's output productivity growth.

4.1. Analysis of β Convergence

We will now show how Japan's absolute and conditional convergence could have occurred faster for the period 2000-2003, more than likely triggering and maintaining industrial revitalization, had clusters been established and promoted according to prefectural productive capacities, and then gathered around one or more epicenter prefectures.

Several tests were conducted across sectors and prefectures, so that our model for measuring convergence speeds and selecting more efficient alternative clusters, could illustrate that traditional administrative regions do not necessarily constitute the best prefectural arrangements for promoting industrial clusters. Specifically, non-linear regressions are performed for seven different manufacturing sectors.

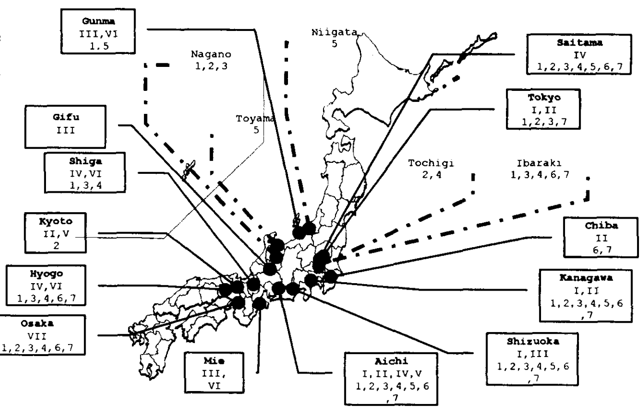

Figure 1. Map of Japan with epicenters and prefectures with high productive capacities for seven industrial sectors.

The alternative clustering process entails:

(i) Running the districts dummies model with clusters arranged following the regional administrative divisions in Japan (see Table 1.) The β 's obtained for each district dummy variable are compared with the β obtained in step two.

(ii) Running the model with alternative districts, or different prefectural arrangements, evidencing changes in convergence speed. At this point, "trans-regional interactions" are indispensable (i.e. using prefectures from different regions to constitute a new cluster and taking them out of their original administrative regions) by means of a geographical distance constraint (i.e. productive prefectures that are adjacent to epicenter prefectures.) Mostly, prefectures were retained in their administrative regions, but if one or more prefectures needed to be included in a different but promising cluster, they were rearranged following a new district definition. Convergence speed tests for 'sub-clusters' already defined by regional and local governments are also conducted (e.g. TAMA[3] region).

In general, if in a manufacturing sector there is an increase of β convergence speed due to an alternative prefectural rearrangement, then this signals the existence of a more suitable cluster that can be promoted in that industry.

Let us start by analyzing the results for one of Japan's most dynamic and promising fields: electrical machinery, to best illustrate the different convergence speeds that could have been obtained by promoting alternative clusters during the period 2000-2003, and then discuss the results for chemical industries, transport machinery, precision instruments, general machinery, plastics and fabricated metals.

4.1.1. Electrical machinery

In the first scenario for Electrical machinery, eight regions are defined according to the administrative regional division of Japanese prefectures shown in Table 2, yielding output productivity growth convergence speeds that appear in the second column of Table 5, since a specific industrial cluster was already defined for this industry in the regional government of Kanto (i.e. the TAMA Region encompassing Tokyo, Kanagawa and Saitama) which includes two epicenter prefectures identified in Figure 1 (differentiated in italic from now on), a ninth "region" or cluster was also added to the non-linear regressions analysis, leaving Ibaraki, Tochigi, Gunma and Chiba in their original Kanto region, as in column 3 of table 2. The fourth column shows the convergence speeds when including one highly productive cluster grouping all of Japan's epicenter

[3] TAMA Technology Advanced Manufacturing Area comprises the prefectures of Tokyo, Saitama and Kanagawa. This regional industry revitalization plan was proposed in 1997 (According to Kodama Toshihiro, senior fellow at the Research Institute of Economy, Trade and Industry - RIETI).

prefectures in the electrical machinery sector, which in Table 2 we refer to as clusters arrangement A. Further and detailed descriptions of these and other prefectural rearrangements (B and C) are:

TAMA: One Epicenter

Tokyo, Kanagawa, Saitama.

Clusters A: One Epicenter

(i) ***Tokyo, Kanagawa, Shizuoka, Aichi***

Clusters B: Two Epicenters

(i) ***Tokyo, Kanagawa*** with Saitama, Ibaraki, Gunma and Nagano.

(ii) ***Shizuoka, Aichi*** with Mie, Kyoto.

Clusters C: Two Epicenters

(i) ***Tokyo Kanagawa*** with Saitama, Ibaraki, Gunma.

(ii) ***Shizuoka, Aichi*** with Mie, Kyoto and Nagano

Table 2 Clusters comparison for Electrical machinery sector (2000)

	Regional	TAMA	Clusters A	Clusters B	Clusters C
adj. R^2	**0.6063**	**0.6059**	**0.6056**	**0.6196**	**0.6205**
b1	0.325	0.314	0.321	**0.352**	0.349
b2	0.358	0.347	0.354	**0.385**	0.382
b3	0.363	0.343	0.356	**0.430**	0.425
b4	0.352	0.347	0.348	**0.370**	0.366
b5	0.388	0.374	0.383	**0.417**	0.413
b6	0.371	0.358	0.366	**0.405**	0.401
b7	0.333	0.322	0.329	**0.363**	0.359
b8	0.319	0.309	0.315	**0.347**	0.343
b9		0.336	0.353	**0.394**	0.385
b10				**0.436**	0.427

There is a gradual increase in the R^2 as we increased the number of potential clusters. However, an increase in correlation does not assure a fast converging cluster (i.e. neither productive nor innovativeness) as it is clear from the fact that when we included the TAMA region (column 3), the convergence speeds for all of the regions decreased as compared to the traditional regional arrangement (column 2), as well as when we included the highly productive cluster grouping all of the epicenter prefectures in clusters arrangement A (column 4 Table 2), which is non-counterintuitive because we did not add any productive adjacent prefectures to support the epicenters and effectively leverage the cluster. More interesting results are obtained when testing clusters arrangement B, where Ibaraki, Gunma and Nagano (all very productive prefectures) are added to the TAMA region, while Mie and Kyoto support the epicenter formed by Aichi and Shizuoka; convergence speeds throughout all of the regions in Japan, towards a steady state output productivity growth of electrical machinery, are significantly enhanced. However, when adding Nagano to its original administrative region of Tokai, where Aichi and Shizouka are epicenters, with Mie and Kyoto from the Kinki region still supporting the cluster in clusters arrangement C (last column), convergence speeds are faster than with the traditional regional arrangement, but slower than previous one (clusters arrangement B.) This testifies to the fact that Japan's traditional administrative regions are not necessarily the most adequate prefectural arrangements for advancing an effective electric machinery industrial cluster policy.

Analogous procedures were applied for determining the fastest converging prefectural arrangements for chemical industries, transport machinery, precision instruments, general machinery, plastics and fabricated metals sectors. Tables showing the convergence speeds for each sector and alternative prefectural arrangements are presented in the appendix.

5. CONCLUSIONS

Even though our analytical approach is eminently evolutionary, insofar as we use the Verdoorn-Kaldor law, and Caniels' extrapolation of this law to relate *output growth* to *productivity growth*, we complement our framework by using convergence theory because in Japan imperfect mobility and slow diffusion of technology are very restrictive imputations in light of long-established cultural and business institutions like the *keiretsu*. We cannot overemphasize the importance of: using a specialization indicator that accounts for the quality and magnitude of patents, and establishes an empirical basis for identifying epicenters and grouping prefectures; as well as checking regional convergence speeds before defining industrial cluster policies given the fact that *alternative prefectural arrangements*, reducing regional dispersion of output productivity growth, can differ from *traditional administrative regions* and represent additional potential catalyzers of Japanese industrial revitalization, specifically in the case of electrical and transport machinery sectors.

In terms of chemical, precision instruments, general machinery, plastics and fabricated metals, the Japanese regional bureaus should continue in their roles as initiators of regional policies; creating conditions that enhance and evolve industrial clusters, promote industrial cluster products, sectors and networking, carrying out projects, benchmark among companies, technology transfer, providing additional public funding for existing *prefectural epicenters*, and laying the grounds for the development of new industrial poles. The formation of Japan's clusters is mainly due to: historical strategies, long-established large manufacturers, supporting industries, related industries in neighboring geographical areas, regional governments' policies and technology transfer. Our modified Barro regressions point to changes in policies such as regional allocation of public investment and fiscal transfer from central to local governments, taking into account that the traditional regional arrangements may not necessarily be the most adequate, and that not all industrial sectors justify the need for aggressive cluster policies. Future applications of this methodology could help developing countries establish a local definition of *epicenters* when promoting their own clustering policies.

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