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Testing localization of Thai Automobile Industries

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Abstract

The development of industrial clusters is crucially important for industries such as automobiles. However, it is still doubtful whether all parts suppliers should be localized, regardless of the parts categories. We tested the above hypotheses using data compiled from the Thailand Automotive Industry Directory 2014. First, the factors affecting the location of the Thai automobile industry were reviewed. Second, the kernel density of the bilateral distances between parts suppliers was estimated. Finally, hypothesis testing on the localization of parts suppliers was conducted. The study found that the automobile industry as a whole was significantly localized, and significant localization occurs only within 150 km, in terms of bilateral distance between firms.

Keywords: automobiles, localization, industrial clusters

JEL classification: C12, L62, R12

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1. Introduction

The development of a local supplier base and the formation of an industrial cluster are crucially important for strengthening the competitiveness of the industry and sustaining industrial growth. The formation of an industrial cluster increases the competitiveness of downstream industries by delivering parts and components at lower costs, in a shorter time, and with more flexibility. In particular, development of an industrial cluster is critical for industries such as automobiles, where parts and components are heavy and bulky, and the just-in-time manufacturing system is effective for reducing inventory.

However, it is still doubtful if all the parts suppliers should be localized, regardless of the category of the parts. Some parts—such as car seats and body panels—are heavy and bulky, so their close proximity to the customer could be more critical. Physical distance, on the other hand, may be less important if the parts are small, light with high value added in relation to the transport costs. As a result, the physical distance to the customers and the geographical spread of firms could be different, depending on the characteristics of the parts.

This study tests the above hypotheses using the data compiled from the Thailand Automotive Industry Directory 2014, which is a unique data set providing information regarding the location, year of establishment, and ownership structure of firms.

The method we employed is based on Duranton and Overman (2005). As shown below, this method departs radically from the traditional measures of spatial concentration, which include the Gini, Isard, Herfindhal, and Thile indices. These indices measure departure from the distribution benchmark of industrial activities: for instance, the Isard index is based on the absolute distance between the actual and benchmark employment distribution across regions. However, these indices were criticized by Ellison and Glaser

(1997) because they do not identify whether any unevenness comes from localization or industrial concentration.[1] Ellison and Glaser introduced a new measure of localization that controls for industrial concentration.[2] However, the above measures still face a range of aggregation problems, because they allocate establishments to geographical units at a given level of aggregation, such as countries, regions, or states.[3] The method developed by Duranton and Overman avoids these problems by discarding any geographical classification and basing the approach on the actual distance separating establishments.[4]

Many studies, including Duranton and Overman (2005), have tested the localization of different industries, but none of them have focused on parts and components within the same industry. This study tests the localization of auto parts suppliers in Thailand. First, this study considers the factors that affect the locations of

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[1] For example, in the US vacuum cleaner industry, about 75 percent of the employees work in one of the four largest plants. Obviously, it cannot be considered as geographically concentrated simply because 75 percent of the employees are concentrated in only four states. The concept of spatial concentration should be separated from that of industrial concentration (Ellison and Glaser, 1997).

[2] In addition, localization measures with the same properties as those by Ellison and Glaser (1997) have been developed by Maurel and Sédillot (1999) and Devereux, Griffith, and Simpson (2004).

[3] As a result, it is difficult to compare the result across different spatial scales because the existing indices are usually not easily additive across different levels of aggregation. Moreover, most existing geographical units are defined according to administrative needs, not economic relevance. Other problems facing the existing analytical methods include the fact that aggregating establishments at any spatial level leads to spurious correlations across aggregated variables and that downward bias is created when dealing with localized industries that cross an administrative boundary (Duranton and Overman 2005).

[4] Duranton and Overman (2005) assert that their measure satisfies the five requirements of the test for localization, that is, (1) it is comparable across industries, (2) it controls for the overall agglomeration of manufacturing, (3) it controls for industrial concentration, (4) it is unbiased with respect to scale and aggregation, and (5) it gives an indication of the significance of the result.

auto parts suppliers. It then investigates the bilateral distance between them. Moreover, it measures the distance between the parts suppliers and the nearest international port. Finally, we conduct hypothesis testing on the localization of parts suppliers, using the method based on Duranton and Overman (2005).

The study found that the automobile industry as a whole was significantly localized. Concurrently, all categories of automobile firms were localized. In contrast, only four categories of automobile firms—most notably services—were significantly localized after controlling for the overall localization of the automobile industry. Moreover, co-localization was identified between five pairs of different parts categories.

The paper consists of the following: First, the data set is introduced, followed by the analysis method. Second, the factors affecting the localization of firms are considered from the viewpoint of government policy and geographical factors. Third, the results of an empirical analysis on the spatial distribution of firms are presented. Finally, the paper concludes with the important findings.

2. Data

This study utilized data compiled from several sources. We began with data from the Thailand Automotive Industry Directory 2014, which contains information about automotive-related firms in Thailand[5]. The directory includes data on 1,954 firms. All the firms have address information, including postal codes in Thailand. However, several fields of information were lacking for our analysis. There were only 1,406 firms in the directory that specified their year of establishment. Some entries had no information

[5] The data set, Thailand Automotive Industry Directory 2014, was constructed using the budget provided by the Economic Research Institute for ASEAN and East Asia (ERIA). We would like to express our gratitude for their support.

about their ownership structure.

We searched for each missing item and updated the relevant fields for our analysis of the evolution of the firms in the industry over time, that is, the year of establishment, ownership structure, and parts category. For the ownership structure, we classified firms according to the nationality of ownership: 1) Thai firm (T) refers to a firm with a Thai share larger than 80 percent, 2) Joint venture (JV) refers to a firm with a Thai share between 20 and 80 percent, and 3) Foreign (F) refers to a firm with the Thai share less than 20 percent. We utilized information from the database published online on the Thailand Automotive Institute website.[6]

Regarding the parts category in the directory, the firms are classified according to the categories related to their business. As a result, firms in the directory can have as many as 225 categories of parts and/or activities. To make our analysis practical, we classified and regrouped the parts into smaller groups of parts, as indicated in our previous work (see Kuroiwa and Techakanont 2017).[7]

Although this data set includes the latest updates and is the most complete, some

[6] Based on our interview with the Thai Automotive Institute, the database has been compiled and updated, but the number of entries is less than those in the directory. In addition, the TAI database contained information about the ownership structure, i.e., the share of ownership by nationality. This information is the same as the business registration information at the Ministry of Commerce.

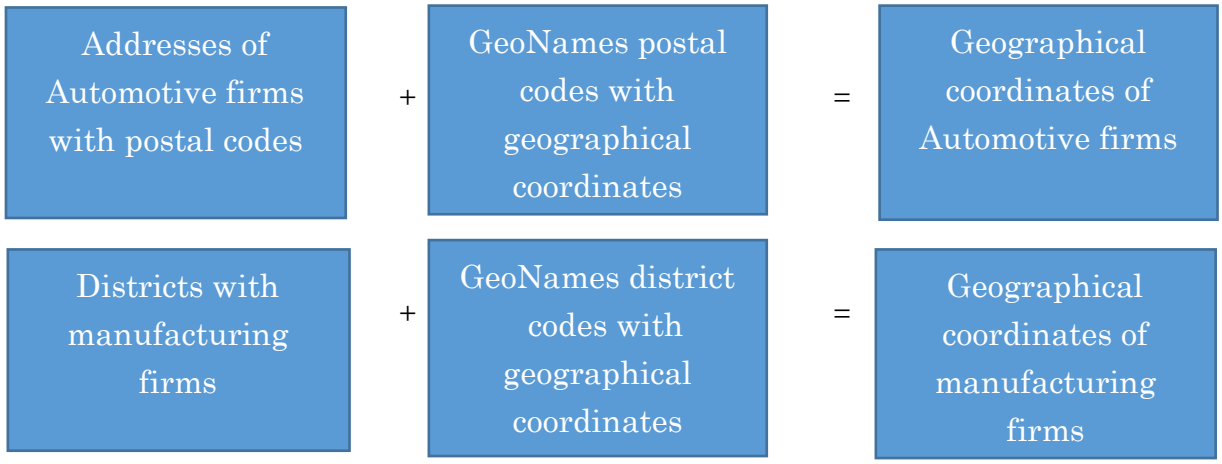
[7] In this study, we followed the auto parts classification at www.marklines.com, which classifies parts into 13 main, secondary, and tertiary categories. Each category consisted of several parts/components and sub-components. We then compared and matched the category of the main products from the Thailand Automotive Industry Directory 2014. However, we had to create some categories of parts that were not in the list of the auto parts classification, such as automobile assembly, agricultural machinery and other transport machinery; chemical, oil, lubricants, paint, etc.; accessories; services (trading, logistics, trade show, training, etc.); and machine tools, jigs and fixtures, molds, dies, etc.

limitations remain. It is a snapshot of the firms that existed at the time of writing this paper. It cannot reflect the actual evolution of firms from the past. Some firms that may have been operating in the past, but no longer exist at present, do not show up in this data set. In addition, information about the main business or main parts produced concerns about the firms' current production. Thus, when interpreting the evolutionary result of localization and agglomeration of firms in this study, this limitation should be noted.

Location data is necessary for the analysis of localization (dispersion) and co-localization (co-dispersion) of firms. Location in this paper is represented by geographical coordinates, that is, longitude and latitude. The process of assigning geographical coordinates to data is generally called "geocoding'." For automobile firms, postal codes obtained from the Thailand Automotive Industry Directory 2014 and other sources are matched with postal codes from GeoNames Postal Code files (http://www.geonames.org/postal-codes/) to generate the geographical coordinates of automobile firms. There are 770 unique postal codes, and geographical coordinates from the GeoNames Postal Code file for Thailand were downloaded for this study as they appeared in December 2016. Each automotive firm would be assigned one of these coordinates. On the other hand, the location of all manufacturing firms is based on Thailand's 2007 Industrial Census, which contains addresses of firms up to the district (or the second administrative) level. There are 929 unique second administrative level divisions, out of which 645 districts include one or more manufacturing firms. The second administrative level divisions mostly, though not always, coincide with the districts. The geographical coordinates of manufacturing firms are then generated by matching the second administrative level divisions in the Industrial Census with the district codes in

the GeoNames Postal Code files.[8] The geocoding process in this study is summarized in Figure 1 as follows:

Figure 1: The geocoding process



3. Method of analysis

The analysis framework of this study relies on the methodology proposed by Duranton and Overman (2005). This consists of (i) the estimation of the kernel density distribution of the bilateral distance between firms, (ii) the construction of counterfactuals and confidence intervals, and (iii) a comparison of the above two distributions.

According to this methodology, the algorithm to identify localization (or dispersion) of any *n* firms in any specific category is as follows: First, we estimated the kernel density distribution of the bilateral distance between all pairs of firms using the following formula:

[8] Geographical coordinates of postal codes are simultaneously used by those of districts. Therefore, the same geographical coordinates are used for both automobile firms and manufacturing firms.

$$\widehat{K}_A(d) = \frac{1}{n(n-1)h} \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} f\left(\frac{d - d_{ij}}{h}\right), \qquad (1)$$

where $\widehat{K}_A(d)$ is the estimator of the kernel density at distance *d*, *n* is the number of firms in a specific category, d_{ij} is the Euclidean distance between firms i and j, f is the Gaussian kernel function, and h is an optimal bandwidth based on Silverman (1986).

Second, we constructed the counterfactuals by randomly assigning the *n* firms to selected sites 1,000 times. A set of sites used as a benchmark, where firms could be assigned randomly, was chosen depending on the objective of the analysis. For instance, the benchmark can be the sites of postal codes where there are at least one or more manufacturing firms. Kernel density was estimated for each of 1,000 simulations. As a result, there would be 1,000 kernel density distributions of bilateral distances between manufacturing firms. Two confidence intervals, namely, local and global, were constructed based on these distributions. As in Duranton and Overman (2005), 5% global confidence intervals were constructed so that 5% of the randomly generated kernel densities lie above or below the boundaries across all distances between 0 and 180kms.[9] [10] The upper and lower global confidence intervals were denoted by $\overline{K}_A(d)$ and $\underline{K}_A(d)$, respectively.

Third, we identified localization (or dispersion) by comparing the kernel density distributions of bilateral distances (between firms in the specific category) to the confidence intervals. Then the index of global localization $\Gamma_A(d)$ and the index of global

[9] Meanwhile, the local confidence interval is defined as follows: For each industry, for each kilometer in the interval, we rank our simulations in ascending order and select the 5th and 95th percentile to obtain a lower 5% and an upper 5% confidence bound.

[10] Following Duranton and Overman (2005) and Nakajima, Saito, and Uesugi (2010), 180 km was used as the benchmark.

dispersion $\Psi_A(d)$ were computed using formulae (2) and (3), respectively.

$$\Gamma_A(d) = max\left(\widehat{K}_A(d) - \overline{K}_A(d), 0\right) \quad (2)$$

$$\Psi\_A\ (d) = \begin{cases} max\left(\underline{K}_A(d) - \widehat{K}_A(d), 0\right) & \text{if } \sum_{d=0}^{d=180} \Gamma_A(d) = 0 \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

Note that global localization is detected when the kernel density of an industry lies above its upper confidence bound. Global dispersion is detected when the kernel density lies below the lower confidence bound and never lies above the upper confidence bound in the distance between 0 and 180 km.

4. Factors affecting the location of firms

4.1 Influence of government policy

The car industry requires thousands of parts and components. Location choice is crucial in order to manage the supply chain and production efficiently. In this section, we discuss the influence of government policies that have affected the evolution of automotive firms' choice of location. In particular, we focus on the specific policies that shaped the agglomeration of automotive clusters in the central and eastern regions of Thailand. In addition to the local content requirement regulation, which was the most crucial policy in developing the industry, infrastructure development, such as seaports, industrial estates, road networks, and regional development within the eastern region, was equally important for the industry.

Historically, manufacturing activities have always been concentrated in Bangkok, because of its locational advantages, that is, proximity to the important Klong Toey Port and its capital city status. Most firms chose to locate near Bangkok, and this caused chronic congestion problems in the city. In 1972, the Industrial Estate Authority of Thailand (IEAT) was established, and the government began to develop infrastructure for

manufacturing activities around Bangkok, such as in Samut Prakarn, Bang Chan, and Lad Krabang. Assemblers chose these locations for their production plants, and localization of firms around these areas was observed during the 1970s. In the 1980s, IEAT established regional IEs in the northern region and eastern provinces, in line with the rural area development objectives.

The most important infrastructure development policy for the automotive industry was the Eastern Seaboard Project (ESB). Although this project was initiated in the mid-1980s, due to the chronic congestion problems in Bangkok and the port, it remained inactive until the early 1990s (Poapongsakorn and Techakanont 2008). Then industrial activities began to spread to the ESB area. The project received several sources of finance, including Japanese Official Development Assistance (ODA) and World Bank Loans. The Japanese government provided ODA and technical assistance for infrastructure construction from the 1980s onwards (Watanabe 2003, p. 142). The Board of Investment granted higher zoning incentives to firms in Zones Two and Three, and these were major drivers for industrial decentralization toward the eastern provinces.

Since the 1990s, industrialization in the ESB, which includes Chonburi, Chachoengsao, and Rayong, has accelerated. Lecler (2002) reported that the number of factories in these three ESB provinces increased rapidly during the 1990s, after completion of the ESB Development Plan I in 1990. The new seaport, Laem Chabang Port in Chonburi province, started operating in 1991. This is the largest seaport in Thailand and is the gateway for Thailand's exports at present.

Later, between 1996 and 2005, the number of IE and non-IE factories established in the ESB increased by about 19% (Poapongsakorn and Techakanont 2008). Chonburi attracted the largest number of factories, followed by Rayong. Accordingly, the ESB area

emerged naturally to the location of the major clusters of automotive factories, implying that there are strong agglomeration economies that attract manufacturing establishments to locate within the same cluster. Such economies include the flexibility of a large labor market and the availability of relevant inputs. Automotive-related firms chose to locate their new plants along the eastern highways to benefit from agglomeration economies and save transportation costs. In sum, the location of automotive-related firms has been shaped since the 1970s by a combination and streamlining of the government policies, including the establishment of IEAT, regional development schemes through the BOI's zoning investment incentives, and the infrastructure development for the ESB Project.

4.2 Evolution of spatial distribution of automobile firms

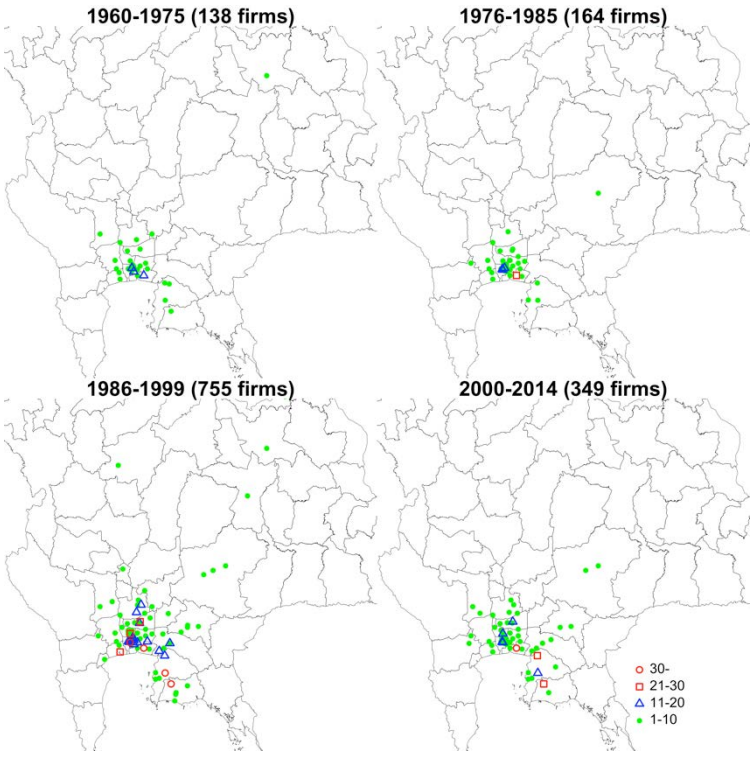
In the previous section, we laid out the evolution of the automotive cluster and the influence of government policies. It is clear how the latter, especially infrastructure development in the eastern seaboard, stimulated the agglomeration of firms. To capture these dynamics in greater detail, we examine and present the spatial distribution of firms during the past five decades. We follow Kuroiwa and Techakanont (2017) to divide the stages of industrialization of Thailand's automotive industry into four periods: 1) 1960-1975 (the initial stage of import substitution), 2) 1976-1985 (early stage of the rationalization policy), 3) 1986-1999 (the second stage of rationalization and export promotion), and 4) 2000-2014 (liberalization).

From our data, we analyzed 1,406 firms in the automotive industry with complete information about the firms' location, year of establishment, and type of business.

Figure 2 below shows that the number of establishments started to rise in Bangkok

and its vicinity, as well as in the central and eastern regions during 1960-75. Automobile assemblers started to invest in Thailand due to the import substitution policy initiated in the early 1960s. Firms chose the metropolitan area because it was the only area where infrastructure facilities and access to local markets could attract investors. For instance, Toyota, Isuzu, Hino, and Nissan set up assembly factories in Samut Prakan through the 1960s and up to the 1970s. Concurrently, parts manufacturing factories were established in nearby vicinities.

Figure 2: Maps of automotive firms established in each period (from 1960 to 2014)



Source: Calculated from the Thailand Automotive Industry Directory 2014.

From 1975 to 1985, the trend of the previous period was accelerated by the introduction of the local content policy in 1975 (which continued until 1999). This made it necessary for assemblers to increase in-house production, invite foreign parts suppliers

to Thailand, or provide technological assistance to the local suppliers. However, in-house production remained prevalent during this period.

The locations of firms spread geographically after 1985. In the 3rd period, 1986-1999, newly established firms concentrated in the Bangkok metropolitan area and along the Bangna-Trad road, which connects the area to the eastern region of Thailand. According to Kuroiwa and Techakanont (2017), the number of establishments, both foreign and local, surged in this period due to the appreciation of the Japanese yen after the Plaza Accord and the rapid economic growth of Thailand in the early 1990s.

The momentum continued in the 4th period, due to the rapid recovery of the automotive industry after the economic crisis in 1997. The process was spurred after Toyota decided to increase export-orientation and make Thailand its production and engineering hub for the Asia-Pacific region, and other key manufacturers, such as Honda and Nissan, followed this initiative.

As suggested by spatial economics, trade liberalization and economic integration are likely to decrease the locational advantage of the metropolitan area[11], while increasing the locational advantage of the frontier regions, such as port cities and border regions, which offer superior access to international markets. A notable example was the eastern region where the Laem Chabang Port opened in 1991, and Chonburi and Rayong became frontier regions for newly established export-oriented firms. Most notably, Mitsubishi set up an assembly factory in Chonburi in 1992, followed by Ford–Mazda and General

[11]During the period of import substitution, both inputs and markets were provided by the metropolitan area, where suppliers and consumers reside. Thus, the metropolitan area was the best location for import-substitution firms. However, once the market is opened to international trade, the metropolitan area loses such advantages, whereas the frontier region becomes more attractive, especially for export-oriented firms, owing to good access to imported inputs as well as to international markets (Fujita, Krugman, and Venables, 1999).

Motors, each of which established factories in Rayong in 1998 and 2000, respectively.[12]

Infrastructure development and tax incentives increased the locational advantages of the eastern region. Moreover, the Asian Financial Crisis was the tipping point that increased the export orientation of the Thai automotive industry and enhanced the locational advantages of the eastern region.

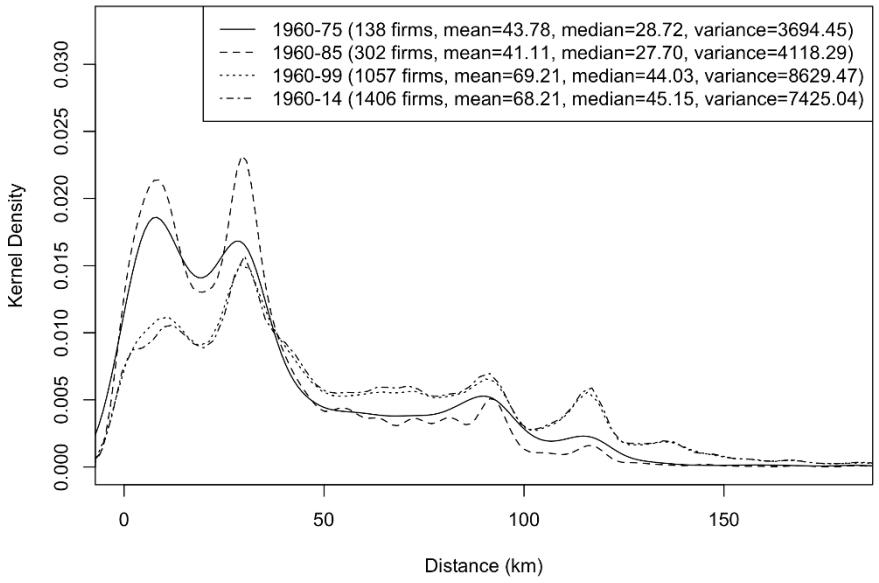
5. Results of the analysis

5.1 Kernel density distribution of the bilateral distance between firms

As discussed in Section 3, this study estimated the kernel density distribution of the bilateral distance between firms. As we used data from the Thailand Automotive Directory, we assumed to have included all the firms in the industry. Using Equation (1), the kernel density distributions of bilateral distances between automotive-related firms from 1960 to 2014 (divided into 4 periods with cumulative data) were calculated and are displayed in Figure 3. Consistent with the previous discussion, before 1986, firms tended to locate in the Bangkok metropolitan area. The spatial distribution of firms was characterized by a cluster of plants separated by an average of 41-43 kilometers, and a median of about 28 kilometers. As time passed, the bilateral distances between firms in the industry became more dispersed. The average distance increased to 69 kilometers and the median to 45 kilometers in the 3rd and 4th periods.

[12] Note that the assemblers that set up factories in Rayong and Laem Chabang were highly export-oriented, whereas Honda, which established a factory in Ayuthaya, had a lower dependency on exports (Kuroiwa, Bhandhubanyong, and Yamada, 2015).

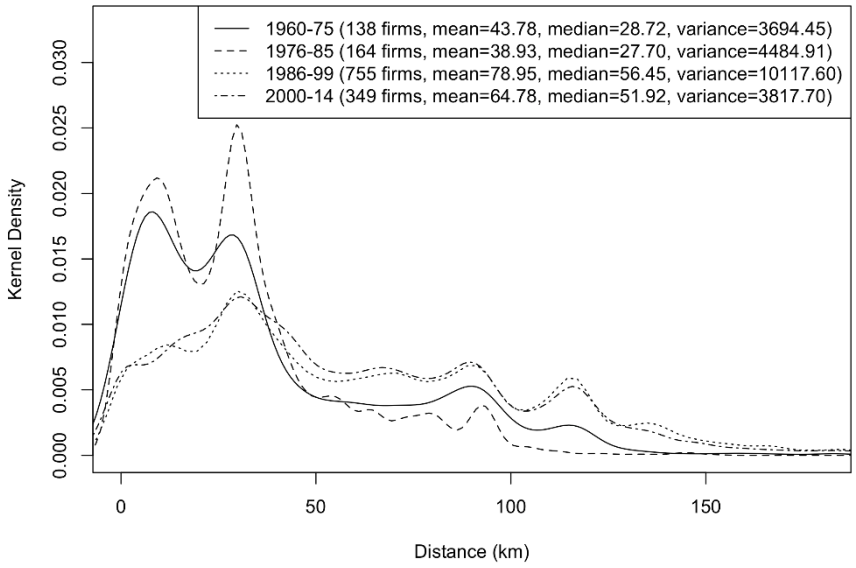
Figure 3: Kernel density distribution of bilateral distances between firms by period (Cumulative)



Source: Calculated from the Thailand Automotive Industry Directory 2014.

When analyzing the kernel density distribution of bilateral distances in each period in Figure 4, we found a clear dispersion tendency by the firms. Between the first and second period, there was a clear agglomeration of the firms, especially in the Bangkok area. Then, chronic traffic problems caused the government to promote regional industrial estates and infrastructure policy. The road network to the eastern seaboard played a crucial role in attracting firms to locate to that region. This was perhaps the key reason for the increase in the bilateral distance between firms during the second and third periods, as the average distance increased from 39 to 79 kilometers. The agglomeration of firms increased further as indicated by the shorter bilateral distance, in both the average and median distance, of firms in the fourth period.

Figure 4: Kernel density distribution of bilateral distances between firms by period

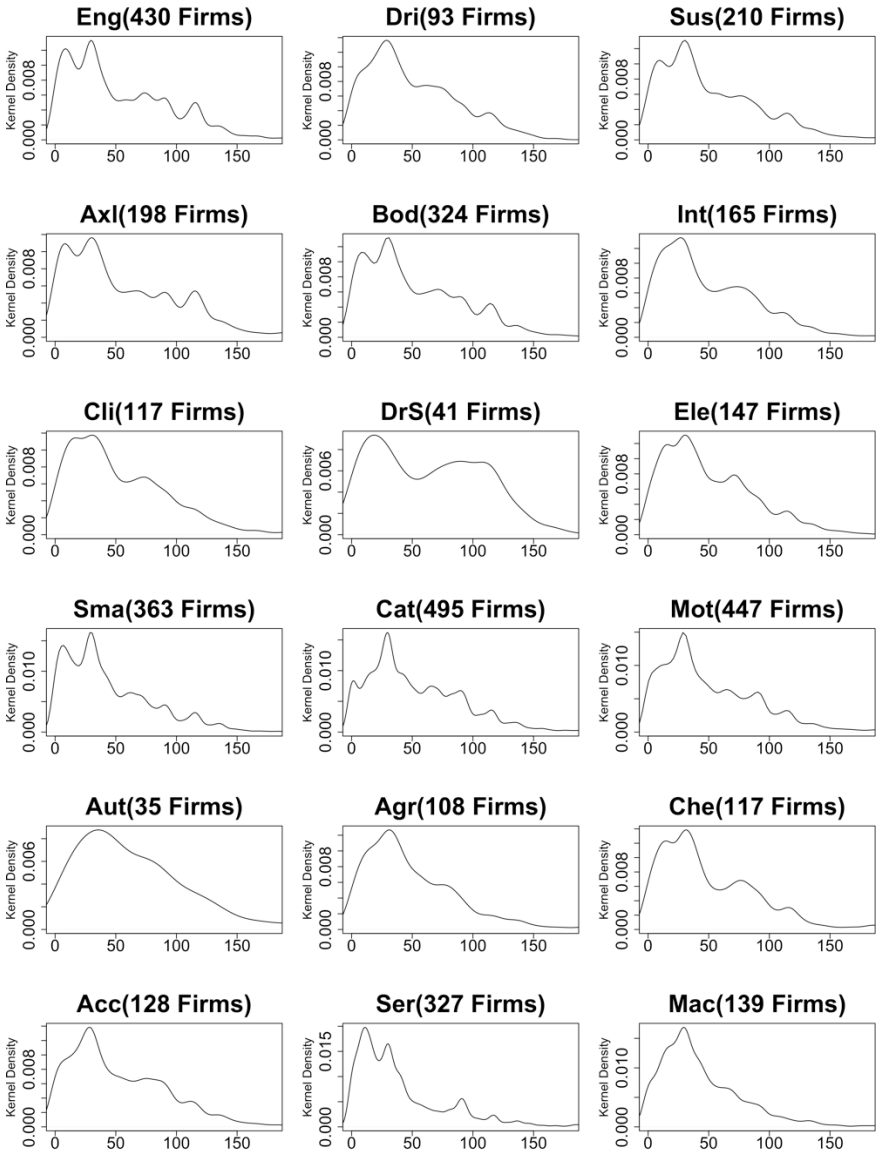


Source: Calculated from the Thailand Automotive Industry Directory 2014.

Is there a different location pattern based on the categories of parts and/or activities? To answer this question, we need to calculate the kernel density distribution of bilateral distances in all categories of parts. These are: 1) engine (Eng); 2) drive train (Dri); 3) suspension/steering/wheels and tires (Sus); 4) axle/brake/body control (Axl); 5) body and exterior (Bod); 6) interior (Int); 7) climate control (Cli); 8) driving support and security (DrS); 9) electronic/electrical parts (Ele); 10) small/general parts (Sma); 11) support activities and categories by production process (Cat); 12) clean energy system (we omit this since there was no firm in this category); 13) motorcycle parts (Mot); 14) automobile assembly (Aut); 15) agricultural machinery and other transport machinery (Agr); 16) chemicals, oils, lubricants, and paint (Che); 17) accessories (Acc); 18) services (trading, logistics, trade shows, training, etc.) (Ser); and 19) machine tools, jigs and fixtures, and molds and dies (Mac).

As can be seen in Figure 5 below, the automotive-related firms tended to locate close to each other—in most cases less than 150 kilometers apart. It is undeniable that the Bangkok metropolitan area is still the most attractive location for firms in this industry. Our data (geographical mapping in Figure 3) revealed the same pattern of location shift from Bangkok to the eastern region. However, some sectors deserve further discussion, for instance, the automobile assembly (Aut) parts firms located in the central and eastern region. Their factories are often in the same area or in the same industrial estate. For example, Toyota and Isuzu have factories in Samut Prakarn in close proximity, whereas several car manufacturers have factories in the Eastern Seaboard Industrial Estate. In contrast, the longest bilateral distance is about 500 kilometers (not shown in the Figure), thus showing weak dispersion beyond 150 kilometers, because there are some truck and bus manufacturers located in Nakon Ratchasima and Khon Kaen.

Figure 5: Kernel density distribution of the bilateral distance between firms by category of parts



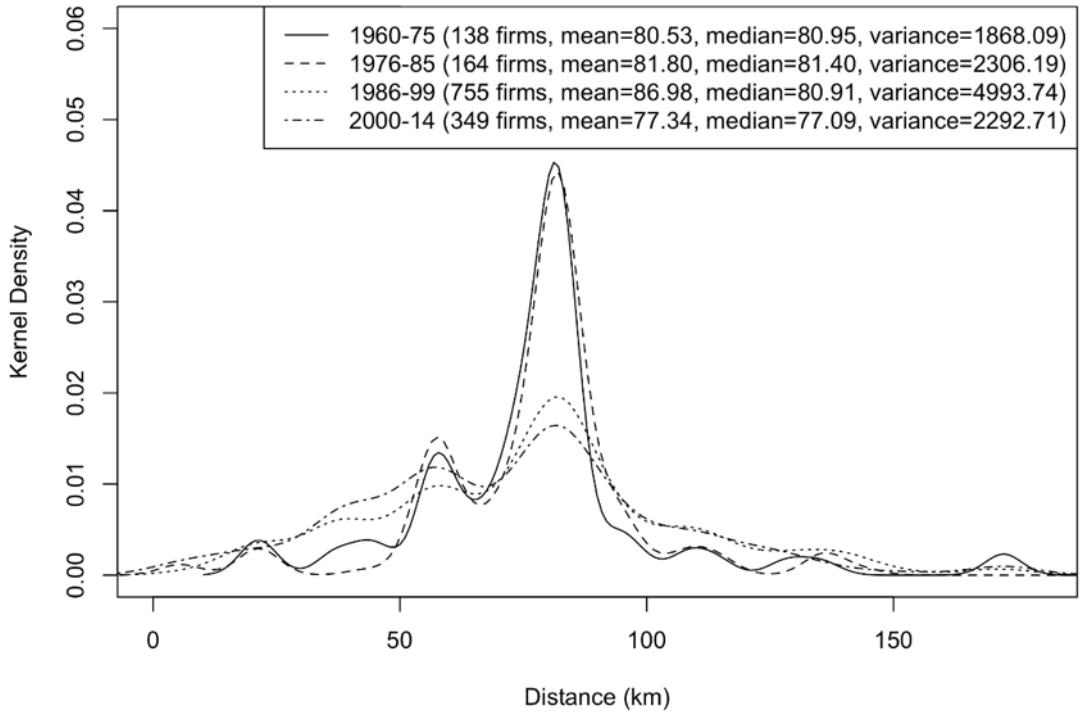
Source: Calculated from the Thailand Automotive Industry Directory 2014.

Some sectors show a clear localization. These are: drive train (Dri); interior (Int); climate control (Cli); driving support (DrS); support activities, categorized by production process (Cat), chemicals (Che), accessories (Acc) and services (Ser). Some automotive specifics, such as drive train, axles, brakes, and driving support, may need to stay close to their customers. This may explain why they locate around Bangkok and the eastern

region. In the next section, we test whether the categories of parts affect the localization pattern of firms.

As infrastructure is important, the ESB project is hypothesized to be a crucial factor in the agglomeration of firms. The Laem Chabang seaport and industrial estate was constructed in the 1980s and started operating in the early 1990s, in the third period of our classification. Instead of estimating the bilateral distance between firms, we calculated the kernel density distribution of distance between firms and Laem Chabang Port. Since we used Euclidean distance, one limitation should be noted. The distance between Laem Chabang Port and Bangkok Port is about 74 kilometers according to our calculation, but in fact the actual driving distance is about 116 kilometers. In Figure 6 below, the peak of the location of automotive firms in the first and second periods (1960 to 1985) was in Bangkok, about 80 kilometers from Laem Chabang Port. In the third and fourth periods (1986-2014), the average distance of firms to this port increased to 87 kilometers in the period 1986 to 1999, but later dropped to 77 kilometers after 2000. Nevertheless, the density of firms in Bangkok and its vicinity decreased significantly over the various periods, indicating that automobile firms have located away from the Bangkok metropolitan area and moved closer to Laem Chabang Port (which is indicated by the left-hand side of the distribution). Particularly, locations such as Rayong (Eastern Seaboard Industrial Estate) and Chachoengsao, which are about 36 and 70 kilometers from Laem Chabang, respectively, increased their density. The location choice in the ESB seems to be naturally suitable for automotive-related firms to agglomerate and reap the benefits of proximity, as pointed out by Poapongsakorn and Techakanont (2008).

Figure 6: Kernel density distribution of the distance (of firms) to Laem Chabang Port by period



Source: Calculated from the Thailand Automotive Industry Directory 2014.

5.2 Hypothesis testing on the localization of automobile firms

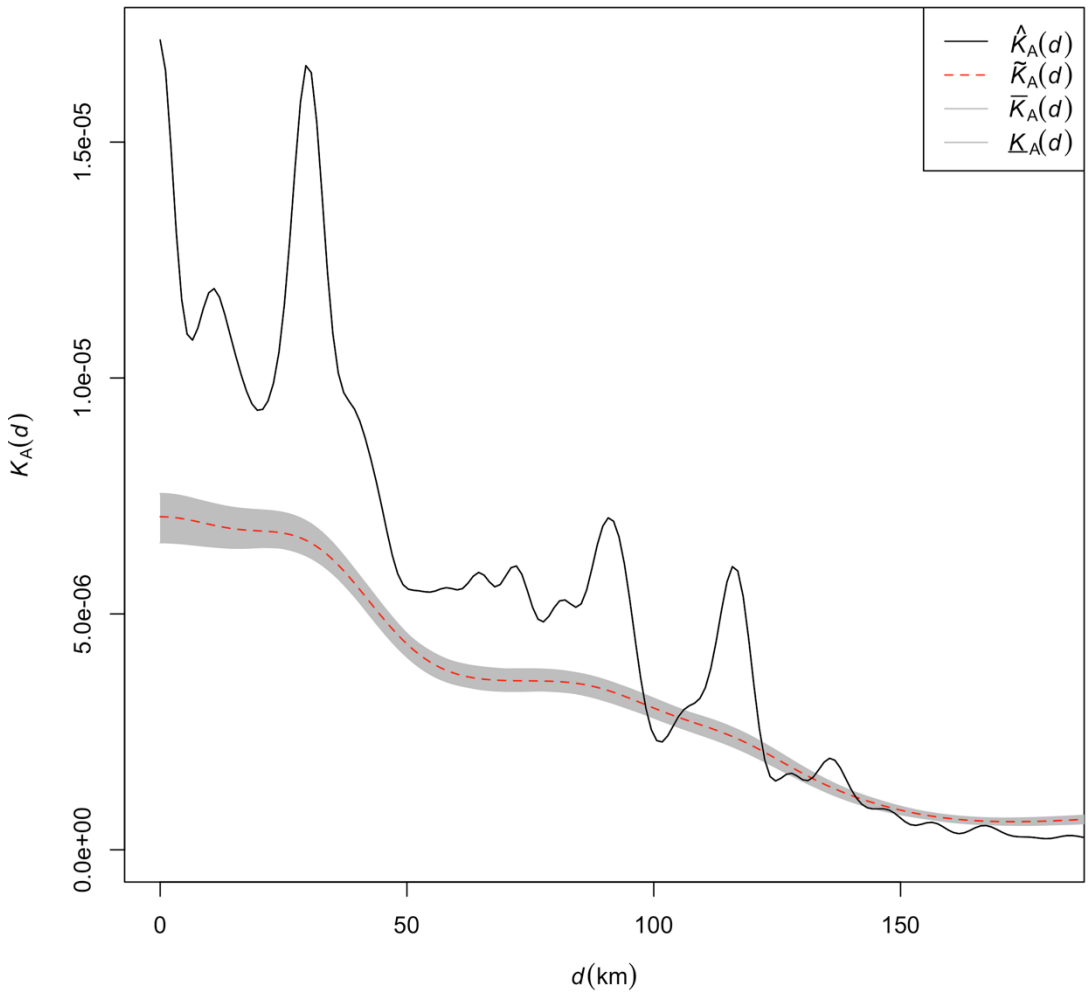
5.2.1 Testing the localization of automobile firms (1)

In this section, we conduct various tests on the localization of the automobile firms, using the method explained in Section 3.

Figure 7 shows the result of the hypothesis testing on the localization of automobile firms (for all categories of automobile parts combined) when a set of all the existing (postal code) sites occupied by the manufacturing establishments is used as a benchmark. The result shows that there are several peaks in the kernel density—which

indicates a multiplicity of clusters tens of kilometers apart from each other—and particularly the peak around 30 km is very high. The kernel density lies above the upper confidence boundary from 0 to around 100 km. Since the existing sites of the automotive-related firms are geographically concentrated in Bangkok and its vicinity, as well as in the eastern region, the kernel density of the bilateral distances deviates significantly from randomness.

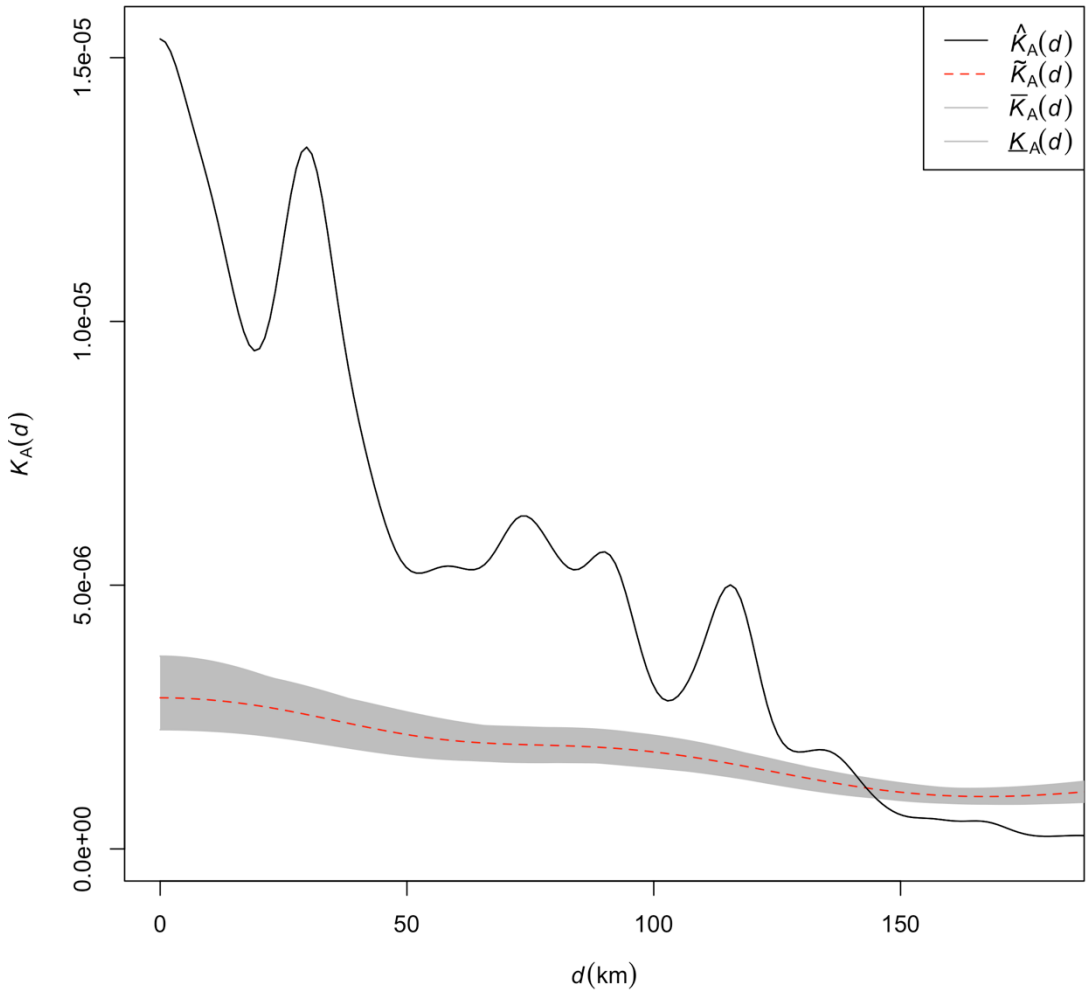
Figure 7: Hypothesis testing on the localization of automotive-related firms (Benchmark: manufacturing establishments)



Source: Calculated from the Thailand Automotive Industry Directory 2014.

Next, we conducted hypothesis testing on the localization of automobile firms by the categories of parts. The result shows that all categories (18 categories) of automobile firms are significantly localized, as shown by the example of the engine parts, which exhibit localization within 0 and 140 km in Figure 8.

Figure 8: Hypothesis testing on the localization of engine parts (Benchmark: manufacturing establishments)



Source: Calculated from the Thailand Automotive Industry Directory 2014.

5.2.2 Measures of localization

Two measures of localization are introduced in this section. First, for each industry A, we can define the following cross-distance indices: $\Gamma_A = \sum_{d=0}^{180} \Gamma_A(d)$, and $\Psi_A = \sum_{d=0}^{180} \Psi_A(d)$, where $\Gamma_A(d)$ and $\Psi_A(d)$ are derived from Equations (2) and (3). These

measures are respectively the sum of each industry's index of global localization and dispersion across all levels of distances (i.e., 0-180 km).

Table 1 shows that, as discussed in Section 5.2.1, all parts categories are significantly localized, and the highest localization is exhibited by drive trains ($\Gamma_A = 0.75$). Moreover, all other parts categories have very high index figures, exceeding 0.57. Therefore, it can be concluded that automobile firms are strongly localized, regardless of the parts category, when the spatial distribution of all manufacturing establishments is used as a benchmark.

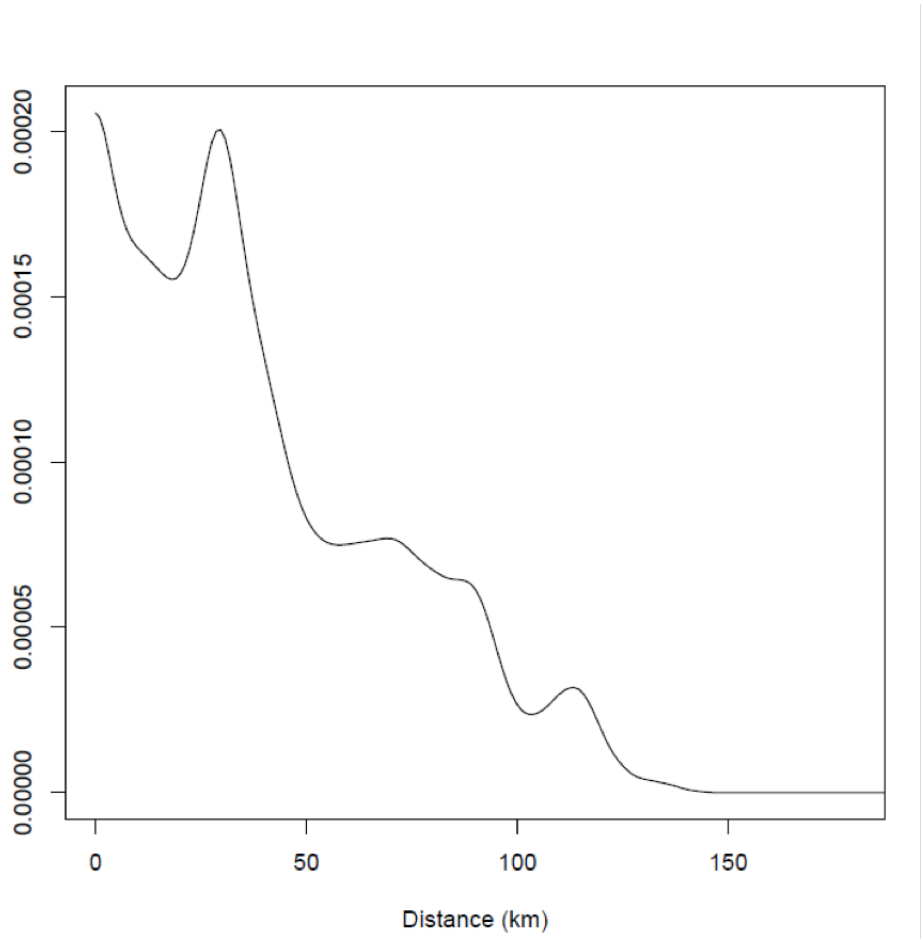
Table 1: Localization Index Γ_A

Parts	Index	Parts	Index
Drive train	0.75190	Agricultural machinery	0.65461
Chemicals	0.74265	Services	0.65341
Accessories	0.73225	Suspension	0.63463
Machine tools	0.73056	Small/general parts	0.62967
Driving support	0.72813	Body	0.62382
Electronic parts	0.72017	Automobile assembly	0.59989
Interior	0.71150	Engine	0.58086
Climate control	0.70784	Supprt activities	0.57743
Axle	0.66284	Motor cycle parts	0.57141

Source: Calculated from the Thailand Automotive Industry Directory 2014.

The second measure of localization is defined as follows: $\Gamma(d) = \sum_A \Gamma_A(d)$ and $\Psi(d) = \sum_A \Psi_A(d)$. These measures respectively indicate the extent of cross-industry localization and dispersion at any given distance d. Figure 9 shows that, as in Duranton and Overman (2005), the extent of localization is much greater over shorter than over longer distances. Moreover, in terms of bilateral distances between firms, statistically significant localization occurs only within 150 kilometers.

Figure 9: Index of localization by distance $\Gamma(d)$



Source: Calculated from the Thailand Automotive Industry Directory 2014.

5.2.3 Testing the localization of automobile firms (2)

In the previous section, hypothesis testing was conducted using the set of all the existing sites occupied by the manufacturing establishments as a benchmark. However, it would be more meaningful to sample the counterfactuals only from a set of the sites occupied by the automotive-related firms and test the localization of automobile firms by the category of parts. This test will show whether each category of automobile parts still exhibits localization even after controlling for the overall localization tendency of the automobile industry.

As expected, the result indicates less localization. Only four categories of parts—services, small/general parts, support activities, and machine tools—exhibit localization.[13] Table 2 shows the localization index Γ_A of all the localized parts. Services has by far the largest localization index, exceeding 0.06. For example, services exhibit significant localization between 0 and 30kms, as shown in Figure 10. Note that services tend to be concentrated in large cities like Bangkok, because service activities have a greater potential for external economies in a metropolitan area and use less land per employee (World Bank 2009).

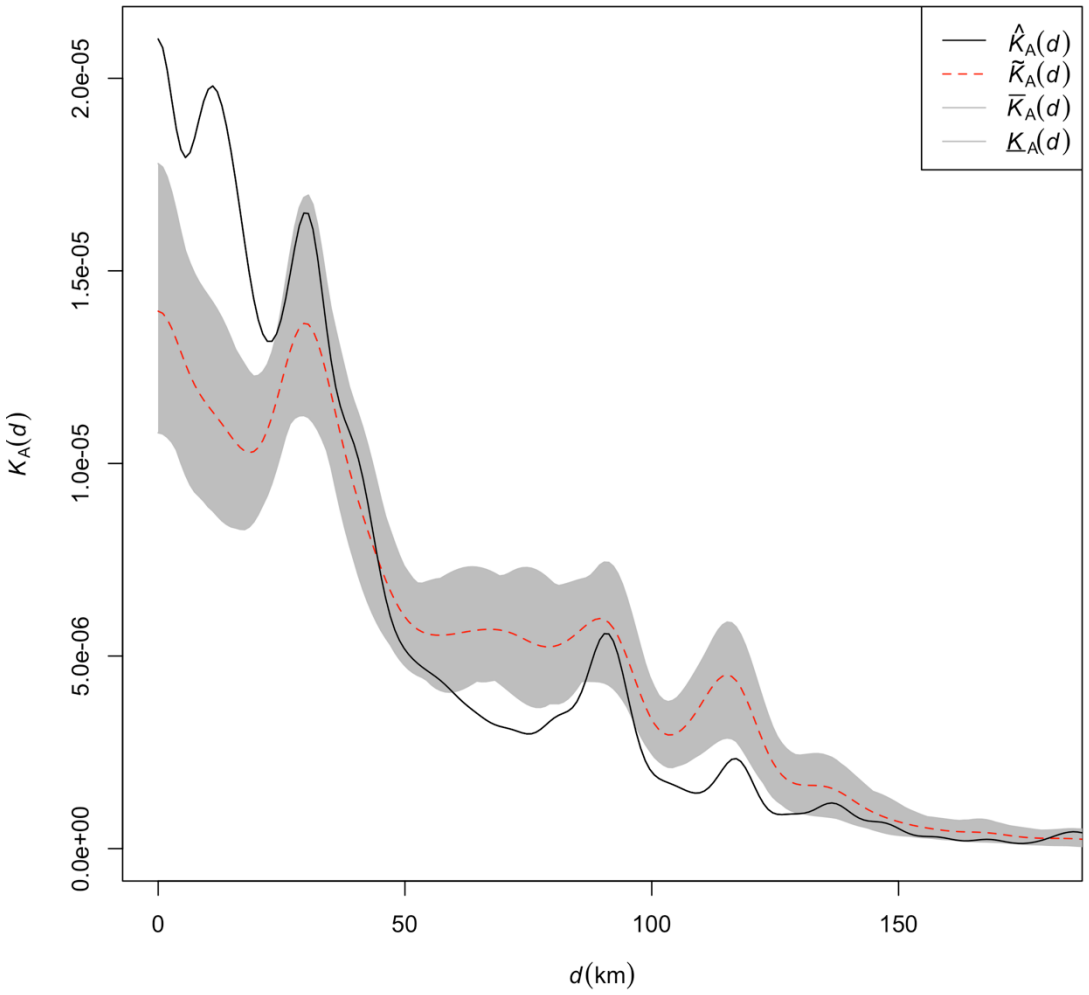
Table 2 Localization index Γ_A

Parts	Index
Services	0.06853
Small/general parts	0.00900
Support activities	0.00724
Machine tools	0.00281

Source: Calculated from the Thailand Automotive Industry Directory 2014.

[13] It is already shown that industries belonging to the same branch tend to have a similar localization pattern (Duranton and Overman 2005). It is thus understandable that automotive parts indicate similar localization patterns, and only a few categories of parts deviate from randomness in the above test.

Figure 10: Hypothesis test on the localization of services (Benchmark: automobile establishments)



Source: Calculated from the Thailand Automotive Industry Directory 2014.

On the other hand, only motorcycles indicate significant dispersion (see Table 3); the data show that the majority of motorcycle firms are located in Bangkok, Samut Prakarn, Chonburi, Chachoengsao, and Rayong, but some are located far away, such as in Lampoon, Nongkai, Songkhla, and Ubon Ratchatani.

Table 3 Dispersion index Ψ_A

Parts	Index
Motor cycle parts	0.00096

Source: Calculated from the Thailand Automotive Industry Directory 2014.

Moreover, the categories of parts and services that exhibit localization are all general activities related to all parts and components, whereas none of the specific parts and components—such as engine parts and drive trains—demonstrate significant localization (Table 2). It should also be noted that only motorcycles indicates significant dispersion, but its dispersion index is very small—less than 0.001 (Table 3).

5.2.4 Testing the co-localization of the parts suppliers

Some industries may locate closer to each other, and their clusters are located in the same or nearby areas. This co-location of clusters occurs as a result of the location choice by firms. For instance, co-location may occur because firms in different industries by chance happen to be close to each other, or because the factors driving localization in different industries share some similarity, which leads the firms to cluster together although there is no interrelation between them.

Alternatively, this can occur if firms in an industry decide to locate close to firms in an interrelated industry. For instance, such interrelated firms may have interactions, such as input-output linkages, labor market pooling, or knowledge spillover across the industry. Thus, these location patterns across industries are no longer independent.

Duranton and Overman (2005) respectively called the former two cases “joint-localization” and the latter case “co-localization.” Obviously, of particular interest is co-

localization, because it is a reflection of the agglomeration economies that accrue across different industries. Since our focus is placed on the co-localization of different parts categories, we apply the following formula to estimate the kernel density distribution of the bilateral distance between firms in two automotive parts categories:

$$\widehat{K}_{(A,B)}(d) = \frac{1}{n_A n_B h} \sum_{i=1}^{n_A} \sum_{j=1}^{n_B} f\left(\frac{d-d_{ij}}{h}\right),$$

where bandwidth (h) and kernel density function (f) are chosen as in Equation (1). A and B are the automotive parts categories tested for co-localization, and n_A and n_B are their respective numbers.

To conduct hypothesis testing on co-localization, Duranton and Overman (2005) suggest that the counterfactuals should be sampled from a set of the sites occupied by firms in either of the two automotive parts categories, that is, $A \cup B$, because this allows us to determine whether there are some interactions between parts categories A and B, such that the parts suppliers in category A, for example, have a tendency to be closer to the parts suppliers in category B than to the parts suppliers in the same category.

Table 4 shows that there are five pairs of parts categories that exhibit co-localization. Table 5 shows three pairs of co-dispersion. The pair of support activities and body parts indicates the strongest co-localization, followed by the pair of climate controls and engines parts, and a pair of small/general parts and suspension/steering/wheels and tires. In contrast, the pair of support activities and engines parts indicates the strongest co-dispersion, but its co-dispersion index is very low.

Table 4: Pairs of co-localization

Parts	Parts	Index
Support activities	Body	0.00994
Climate control	Engine	0.00781
Small/general parts	Suspension	0.00604
Suspension	Axle	0.00037
Electronic parts	Suspension	0.00026

Source: Calculated from the Thailand Automotive Industry Directory 2014.

Table 5: Pairs of co-dispersion

Parts	Parts	Index
Support activities	Engine	0.00061
Body	Drive train	0.00024
Engine	Suspension	0.00002

Source: Calculated from the Thailand Automotive Industry Directory 2014.

6. Conclusion

We analyzed the spatial distribution of the automotive-related firms in Thailand from 1960 to 2014. In the early stages, when the domestic market was small and the infrastructure was not developed, firms tended to locate in the Bangkok metropolitan area.

Apart from the rationalization policies, basic infrastructure development was vital to the success of industrialization. In the case of Thailand, the most important investment was the Eastern Seaboard Project (ESB). On account of the continuity and streamlining of the government policies and some international financial support through loans and ODA, the eastern region became vibrant with manufacturing activities, and automotive clusters emerged naturally in this region. Moreover, the Asian Financial Crisis was the tipping point that increased the export orientation of the Thai automotive industry and enhanced the location advantage of the eastern region.

The development of a local supplier base and the formation of industrial clusters are critically important for strengthening the competitiveness of industries such as automobiles, where parts and components are heavy and bulky, and the just-in-time system is introduced to reduce lead time for parts procurement. Based on our analysis, we found that automotive-related firms are significantly localized, especially in the Bangkok metropolitan area and the three eastern provinces—Chonburi, Chachoengsao, and Rayong.

Next, we conducted hypothesis testing on the localization of automotive-related firms. As expected, automobile firms as a whole are significantly localized, when the set of all the existing sites occupied by the manufacturing establishments is used as a benchmark. Similarly, all categories of automotive parts are localized, and statistically significant localization occurs only within 150 kilometers in terms of the bilateral distance between firms. In contrast, only four categories of automobile firms are significantly localized after controlling for the overall localization tendency of the automotive-related firms. Among them, services exhibits by far the strongest localization. On the other hand, only motorcycles exhibit significant dispersion.

Hypothesis testing on the co-localization between the pairs of different parts categories was conducted, and five pairs of parts categories are identified as being significantly co-localized, whereas three pairs of parts categories are co-dispersed.

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