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Abstract

The development of a local supplier base and the formation of industrial clusters are crucially important to strengthen the competitiveness of the industry and sustain industrial growth. In particular, the development of industrial clusters is critical for an industry such as automobiles, where parts and components are heavy and bulky and the just-in-time manufacturing system is required to improve competitiveness. However, it is still doubtful whether all the parts suppliers should be localised, regardless of the parts categories, because some parts are small and light with high value added in relation to their transport costs. We tested the above hypotheses using data compiled from the Thailand Automotive Industry Directory 2014. Firstly, the factors affecting the location of the Thai automobile firms were reviewed. Secondly, the kernel density of bilateral distances between the parts suppliers was estimated. Finally, hypothesis testing on the localisation of the parts suppliers was conducted. The study found that the automobile industry as a whole is significantly localised. Similarly, all categories of automobile parts are localised. In contrast, only four categories of automobile parts—particularly services—are significantly localised after controlling for the overall localisation of the automobile industry. Moreover, co-localisation was identified between five pairs of parts categories.

1. Introduction

The development of a local supplier base and the formation of an industrial cluster are crucially important to strengthen the competitiveness of the industry and sustain 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 an industry such as automobiles, where parts and components are heavy and bulky, and the just-in-time manufacturing system is necessary to reduce inventory.

However, it is still doubtful if all the parts suppliers should be localised, 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. However, the physical distance 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 could be different depending on the parts' characteristics.

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

The method we employed is based on Duraton and Overman (2004). Since this is important, let us discuss the background of the analytical method. Traditional measures of spatial concentration 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 criticised by Ellison and Glaser (1997) because they do not identify whether any unevenness comes from localisation or industrial concentration.[1] Ellison and Glaser introduced a new measure of localisation that controls for industrial concentration. Alternative localisation measures with the same properties have been developed by other researchers, such as Maurel and Sédillot (1999) and Devereux, Griffith, and Simpson (2004).

However, the above measures still faced a range of aggregation problems, because they allocate establishments to geographical units at a given level of aggregation, such as countries, regions, or states.[2] The method developed by Duraton and Overman avoids these problems by discarding any geographical classification and basing the approach on the actual distance separating establishments.[3]

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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. But it cannot be considered as concentrated simply because 75 percent of the employment are concentrated in only four states. Therefore, spatial concentration should be separated from industrial concentration (Ellison and Glaser, 1997).

[2] Hence it is difficult to compare the result across different spatial scales because 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. The other problems facing the existing analytical methods include; aggregating establishments at any spatial level leads to spurious correlations across aggregated variables; downward bias is created when dealing with localised industries that cross an administrative boundary (Duraton and Overman 2005).

[3] Duranton and Overman (2005) assert that their measure satisfies five requirements of the test for localisation. That is a measure (1) comparable across industries; (2) controls for the overall agglomeration of manufacturing; (3) controls for industrial

As discussed above, many studies have tested the localisation of respective industries, but none of them focus on the parts and components within the same industry. This study tests the localisation of automobile parts suppliers.

Firstly, this study investigated the factors that affect the various locations of the auto parts suppliers. Then, it investigated the bilateral distances between the auto parts suppliers. In addition, it measured the distance between these parts suppliers and the nearest international ports. Moreover, we conducted the hypothesis testing on the localisation of parts suppliers, using the method based on Duraton and Overman (2005).

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

The paper consists of the following: Firstly, the analysis method is introduced. Secondly, the factors affecting the localisation of firms are considered from the viewpoint of government policy as well as geographical factors. Thirdly, the results of this analysis are presented. Finally, the paper concludes with important findings.

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concentration; (4) is unbiased with respect to scale and aggregation, and (5) the test should give an indication of the significance of the result.

2. Data

This paper utilised data compiled from several sources. We began with data from the Thailand Automotive Industry Directory 2014, which contains information about automotive-related companies in Thailand. The directory includes data of 1,954 firms. All the firms have information about their address, and this was useful to analyse the firms' location. 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 about the ownership structure.

We researched each missing item and updated the relevant fields for our analysis of the evolution of the firms in the industry over time, i.e., the year of establishment, ownership structure, and category of parts. For the ownership structure, we classified firms according to the nationality of ownership: 1) Thai firm (T), refers to a firm with the Thai share larger than 80 percent, 2) Joint venture (JV), refers to a firm with the Thai share between 20 and 80 percent, and 3) Foreign (F), refers to a firm with the Thai share less than 20 percent. We utilised information from the database published online in the Thailand Automotive Institute website.[4]

Regarding the category of parts in the directory, the firms are classified according to their related business. As a result, firms in the directory can have as many as 225 categories of parts and/or activities.

[4] Based on our interview with the Thai Automotive Industry (TAI), the database has been compiled and updated, but the number of entries is less than 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.

Therefore, in order 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).[5]

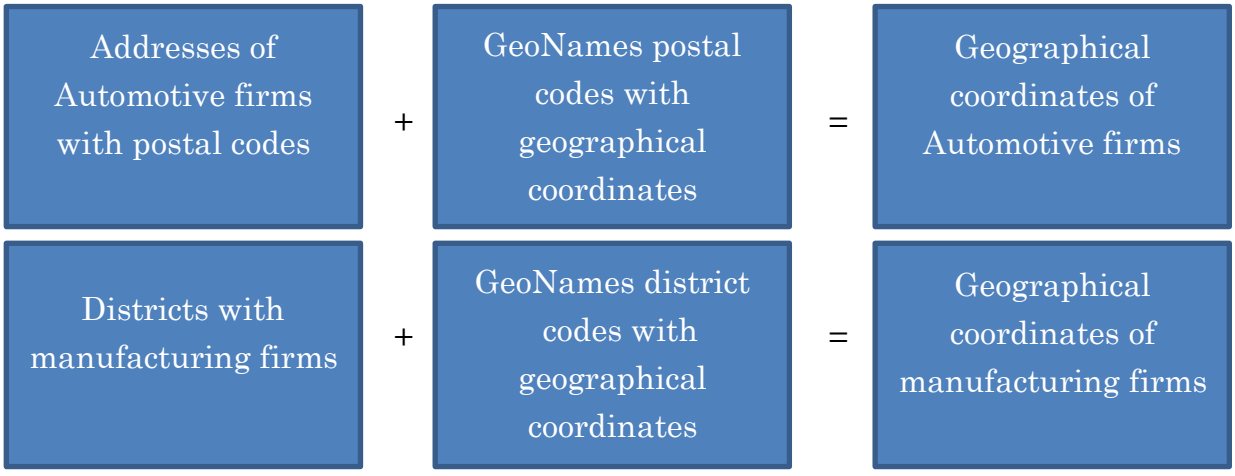
Although this data set includes the latest updates and is the most complete, some limitations remain. It is a snapshot of the firms that existed at the time of writing this paper. It cannot reflect the actual evolution of firms from the past. Some firms that may have been operating in the past but no 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 localisation and agglomeration of firms in this paper, this limitation should be noted.

Location data is necessary for the analysis of localization (dispersion) and co-localization (co-dispersion). Location in this paper is represented by geographical coordinates i.e. 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 in GeoNames Postal Code files (http://www.geonames.org/postal-codes/) to

[5] In this paper, 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, moulds, dies, etc.

generate geographical coordinates. There are 770 unique postal codes, and geographical coordinates in the GeoNames Postal Code file of Thailand was downloaded for this study as 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 have one or more manufacturing firms located. The second administrative level divisions mostly, though not always, coincide with the districts. Geographical coordinates of manufacturing firms are then generated by matching the second administrative level divisions in the Industrial Census and the district code in the GeoNames Postal Code files.[6] The geocoding process in this paper is summarized as follows.

Figure 1: The geocoding process



[6] 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.

3. Method of analysis

The analysis framework of this paper relies on the methodology proposed by Duraton and Overman (2005). This consists of (i) 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 localisation (dispersion) of any n firms is as follows: Firstly, we estimated the kernel density distribution of the bilateral distance between all the pairs using formula (1):.

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

where n is the number of firms; 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).

Secondly, we constructed the counterfactuals by randomly assigning the n firms to selected sites 1,000 times. A set of sites where firms could be assigned was chosen depending on the objective of the analysis. For instance, this can be the postal codes where there are at least one or more manufacturing firms, or where there are at least one or more automobile firms. Kernel density is estimated for each of 1,000 simulations. As a result, there will be 1,000 kernel density distributions of bilateral distances. Two confidence intervals, namely, local and global, were constructed based on these distributions. As in Duraton and Overman (2005), a 5% global

confidence interval was constructed such that 5% of the randomly generated kernel densities lie above or below the boundaries across all distances between 0 and 180kms[7][8] The upper and lower global confidence intervals were denoted by $\overline{K}_A(d)$and $\underline{K}_A(d)$ respectively.

Thirdly, we identified localisation (or dispersion) by comparing the kernel density distributions of bilateral distances with the confidence intervals. Then the index of global localisation $\Gamma_A(d)$ and the index of global dispersion $\Psi_A(d)$ were computed using the formulae (2) and (3).

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

$$\Psi_A(d) = \left\{ \begin{matrix} max\left(\underline{K}_A(d) - \widehat{K}_A(d), 0\right) \text{ if } \sum_{d=0}^{d=180} \Gamma_A(d) = 0 \\ 0 \qquad \text{otherwise} \end{matrix} \right\}. \qquad (3)$$

Note that global localization is detected when the kernel density of one particular industry lies above its upper confidence interval. Global dispersion is detected when the kernel density lies below the lower confidence interval and never lies above the upper confidence interval.

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

[8] Local confidence interval is defined as follows: For each industry, , for each kilometre 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 interval.

3. Factors affecting the location of firms

3.1 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 the eastern region of Thailand. In addition to the local content requirement regulation, which was the most crucial policy to develop the industry, infrastructure development, such as seaports, industrial estates, the road network, and regional development within the eastern region were equally important for the industry.

Historically, manufacturing activities have always been concentrated in Bangkok, because of its locational advantages, i.e., proximity with the important Klong Toey Port and its capital city status. Most firms chose to locate near Bangkok, and this caused chronic congestion problems in Bangkok. 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 localisation 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). Industrial activities began to spread to the ESB area. The project received several sources of finance, including Japanese Official Development Assistance 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 the highest zoning incentives to firms in Zone Three, and these were major drivers for industrial decentralisation towards the eastern provinces.

Since the 1990s, industrialisation 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 as having 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 labour market and the availability of relevant services. 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's policies, including the establishment of IEAT, regional development schemes through the BOI's zoning investment incentives, and the infrastructure development for the ESB Project.

3.2 Geographical factors and the location of firms: provincial-level trends

Some forces increase the localisation of industrial activities, while others achieve the opposite. The forces leading to localisation of industrial activities include physical conditions—such as a suitable climate, mineral resources, land, and water.[9] The localisation of industry also facilitates the exchange of knowledge in a profession; specialising in a specific production process, and matching the needs of the employers and employees. Moreover, saving transportation costs is an important factor in localisation, especially for the automobile industry for which parts and components are heavy and bulky, and the just-in-time manufacturing system is crucial to improve the industry's competitiveness.

On the other hand, centrifugal forces—such as higher factor prices,

[9] Various centripetal forces are described in Marshal (1890).

congestion, and competition in the local market—induce dispersion of industrial activities and spread industrial clusters to suburban areas or distant (well-connected) low-cost production sites[10]. It is important to consider both centripetal and centrifugal forces that affect the location of firms. In addition, as discussed in the previous section, the government's policy, such as infrastructure development and tax incentives, has significantly affected location of the firms.

Table 1 shows the number of establishments by period for all automobile firms. The table covers all the provinces where auto firms have been established until 2014 (Kuroiwa and Techakanont 2017). It shows that before 1960, only Bangkok and Samut Prakan had a small number of establishments, with the exception of one establishment in Nakhon Ratchasima.

Table 1 Establishment of automobile firms by province

[10] For the theory of spatial economics, see, for example, Krugman (1991) and Fujita, Krugman, and Venables (1999).

	-1960	1961-75	1976-1985	1986-99	2000-14	Total
Bangkok	18	75	102	293	133	621
Samut Prakan	4	41	47	159	82	333
Patum Thani		6	7	55	30	98
Samut Sakhon		12	10	49	10	81
Nakhon Pathom		5	7	22	5	39
Nonthaburi			1	12	2	15
Vicinity	4	64	72	297	129	566
Ayutthaya		3	1	41	14	59
Prachin Buri				11	4	15
Saraburi		1	1	9		11
Ratchaburi			2	3	3	8
Suphan Buri				2	1	3
Nakhon Nayok				1		1
Samut Songkram				1		1
Sing Buri				1		1
Kanchanaburi		1				1
Central	0	5	4	69	22	100
Chachoengsao		2	3	49	13	67
Chonburi		11	9	80	53	153
Rayong		3		73	33	109
East	0	16	12	202	99	329
Nakhon Ratchasima	1		1	14	5	21
Nong Khai			1	1		2
Udon Thani		1		1		2
Khon Kaen				1		1
Northeast	1	1	2	17	5	26
Lamphun				2	1	3
Phitsanulok				1		1
North				3	1	4
Songkhla				4		4
South				4		4
Total	23	161	192	885	389	1650

Source: Kuroiwa and Techakanont 2017

From 1961-1975, the number of establishments started to rise in Bangkok and its vicinity, as well as in the central and eastern regions. 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 in the 1960s through

to the 1970s. Simultaneously, parts manufacturing factories were established in nearby vicinities.

From 1975-1985, the trend of the previous period was accelerated by the introduction of the local content policy in 1975. This made it necessary for assemblers to either increase in-house production, invite foreign parts suppliers to invest in Thailand, or provide technological assistance to the local suppliers. However, in-house production remained prevalent during this period.

A rapid change occurred from 1986-1999. Firstly, investment from Japan surged due to the rapid appreciation of the yen, and automotive production started to accelerate. As a result, the number of firms established during this period—particularly foreign firms and joint ventures—increased very rapidly. Moreover, increased congestion and the scarcity of land raised operating costs in the metropolitan area. Such a change in the investment environment forced the firms to move to the provinces surrounding Bangkok and Samut Prakan, such as Patum Thani, Samut Sakhon, Nakhon Pathom, Chachoengsao, and Ayutthaya.

Moreover, infrastructure development promoted by the ESB Project, as well as investment incentives provided by the BOI's zoning policy, increased the locational advantages of the eastern region. As a result, the number of firms—especially foreign firms—established in the eastern region increased very sharply.

The number of firms also increased in the northeastern, northern, and southern provinces. Nakhon Rachasima achieved the greatest number

of firms in these regions. Other provinces that had more than one firm were the commercial or industrial centres in the respective regions, such as Lamphun in the north and Songkhla in the south, but the number of firms in these regions remained relatively small.

From 2000-2014, the number of new establishments declined, although maintaining a relatively high level. The trend in the various provinces was similar, with a notable exception in the eastern region, in particular Chonburi and Rayong, which continued to have a large influx of new firms. The key factor behind this change was the increased export orientation of the Thai automotive industry, particularly after the Asian Financial Crisis in 1997.

As suggested by spatial economics, trade liberalisation 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 is the eastern region when the Laem Chabang Port opened in 1991, and Chonburi and Rayong became frontier regions for international trade. As a result, 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 the suppliers and consumers resided. Thus, the metropolitan area was often the best location for import-substitution firms. However, once the market is open to international trade, the metropolitan area loses such advantages, while the frontier region becomes more attractive, especially for export-oriented firms, owing to good access to imported inputs as well as international markets (Fujita, Krugman, and Venables, 1999).

Motors, 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. Consequently, this attracted a large number of parts suppliers—especially foreign suppliers—so that competitive automotive clusters formed in this region.

4. Result of the analysis

4.1 Spatial distribution of automobile firms

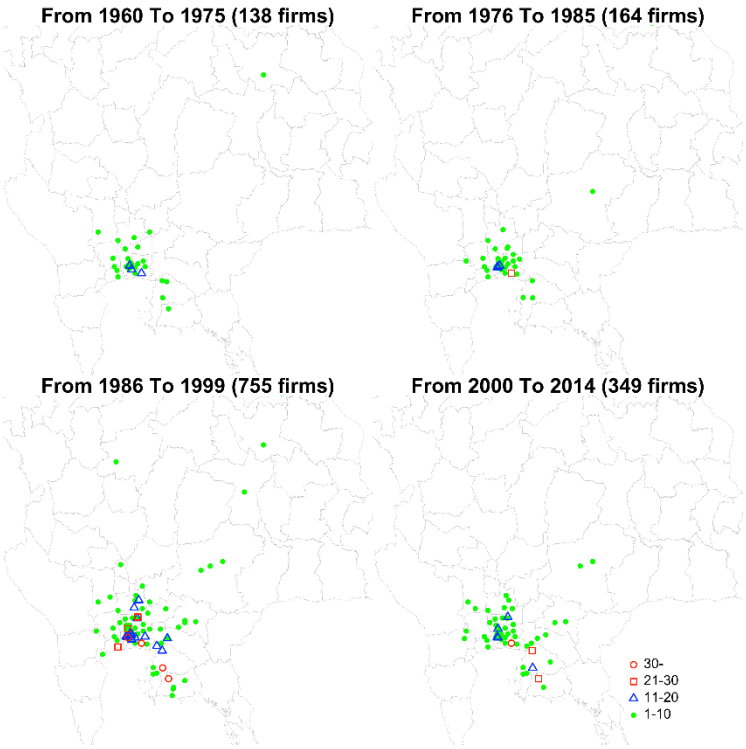
In the previous section, we laid out the evolution of the automotive clusters and the influence of the government's policies. It is clear how the government's policies, especially infrastructure development in the eastern seaboard, stimulated the agglomeration of firms in that area. In order to capture this dynamic 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 industrialisation of Thailand's automotive industry into four periods, 1) 1960-1975 (the initial stage of import substitution), 2) 1976-1985 (early stage of the rationalisation policy), 3) 1986-1999 (the second stage of rationalisation and export promotion), and

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

4) 2000-2014 (liberalisation).

From our data, we analysed 1,406 firms in the automotive industry with complete information about the firms' location, year of establishment, and type of business. In Figure 2 below, we observe that the location of the 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 that connects with the eastern region of Thailand. According to Kuroiwa and Techakanont (2017), the number of establishments in this period surged due to following reasons: On the one hand, the Japanese yen's appreciation after the Plaza Accord and Thailand's economic growth in the early 1990s. On the other hand, the government's intervention became more aggressive in terms of local content requirement (until 1999), the commitment to trade liberalisation in the early 1990s, and infrastructure development, in particular the ESB Project. All these factors combined to achieve a bourgeoning effect in regional development that paved the way for cluster formation in the eastern region of Thailand. 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 make Thailand its production and engineering hub for the Asia-Pacific region, and other key manufacturers such as Honda and Nissan followed this initiative.

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

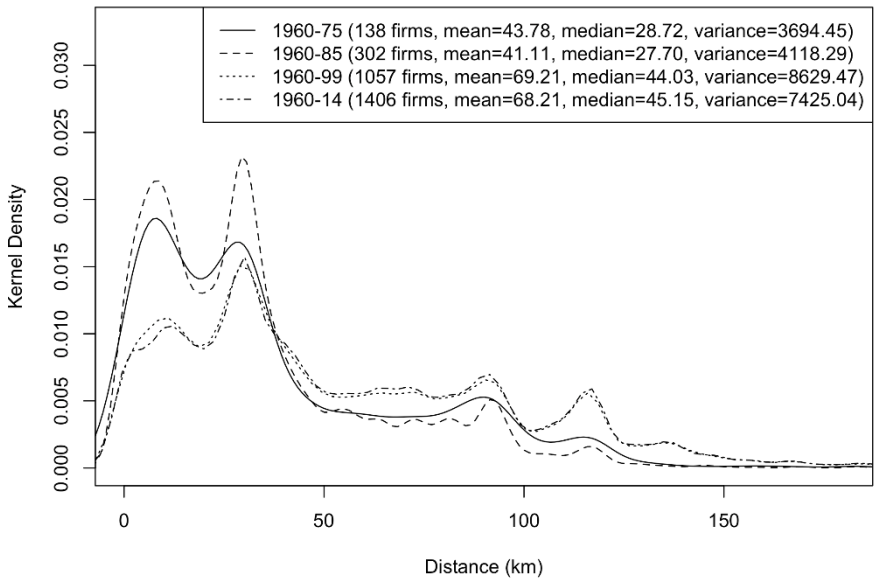


Source: The authors

This paper estimated the kernel density distribution, as discussed in Section 2, and the results of the bilateral distance between firms in the dataset is discussed below. As we used data from the Automotive Directory, we assumed to have included all the firms in the industry. The distribution of firms from 1960 to 2014 (divided into 4 periods) is 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 characterised by a cluster of plants separated by an average of 41-43 kilometers, the median about 28 kilometers. As time passed, the bilateral

distance between firms in the industry became more dispersed. The average distance increased to 69 kilometers and the median to 45 kilometers.

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

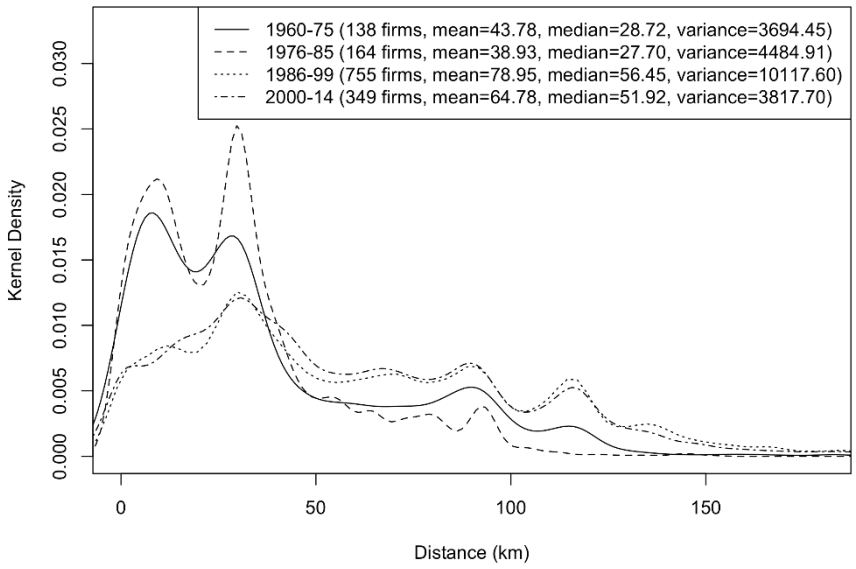


Source: The authors

When analysing the establishment information in each period in Figure 4, we found a clear dispersion pattern by the firms. Between the first and second period, there was clear agglomeration of the firms, especially in the Bangkok area. As discussed, chronic traffic problems caused the government to promote the 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 average and median distance, of firms in the fourth period.

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



Is there any different location pattern by categories of parts and/or activities? To answer this question we need to calculate the kernel density distribution of firms in all categories of parts. These include 1) engine (Eng); 2) drive train (Dri); 3) suspension/steering/wheel 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, categories by production process (Cat); 12) clean energy system

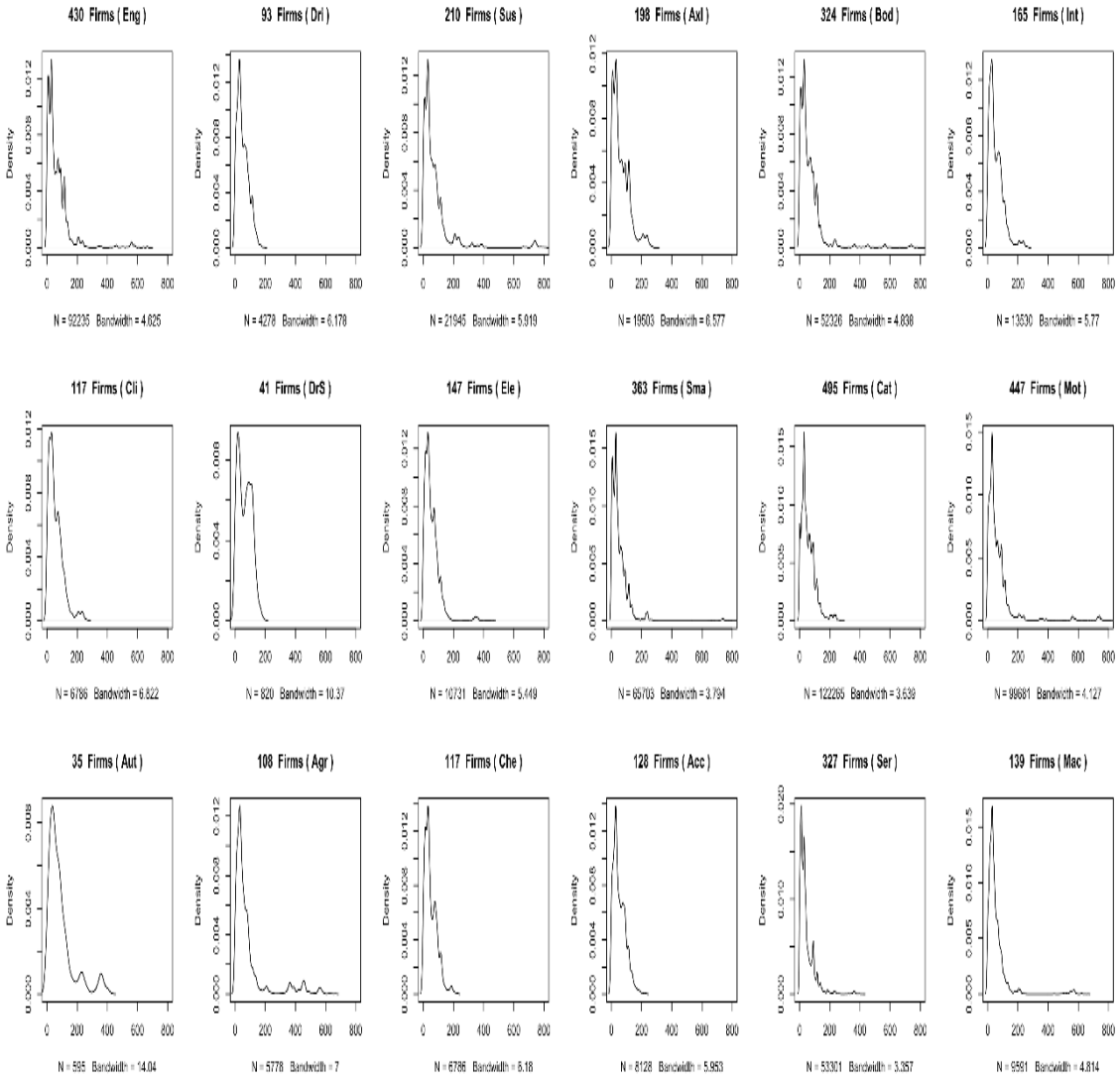
(we omit this since there was no firm in this category); 13) motorcycle parts (Mot); 14) automobile assembly (Aut); 15) agricultural machinery and other transport machinery (Agr); 16) chemicals, oils, lubricants, paint (Che); 17) accessories (Acc); 18) services (trading, logistics, trade shows, training, etc. (Ser); and 19) machine tools, jigs and fixtures, moulds and dies (Mac).

As can be seen in Figure 5 below, the automobile firms tended to locate close to each other, in most cases less than 100 kilometres apart. It is undeniable that the Bangkok metropolitan area is still the most attractive location for firms in this industry. Our data (geographical mapping) revealed the same pattern of location shift from Bangkok to the eastern region. However, some sectors deserve further discussion. For instance, the automobile manufacturers (Aut) located in the central and eastern region. Their factories may be in the same area or in the same industrial estate. For instance, Toyota and Isuzu have factories in Samut Prakarn, while several car manufacturers have factories in the Eastern Seaboard Industrial Estate. In the figure, the longest bilateral distance is about 500 kilometres, because there are some truck and bus manufacturers located in Nakon Ratchasima and Khon Kaen.

Some sectors show clear localisation. They include drive train (Dri), interior (Int), climate control (Cli), driving support (DrS), and support activities, categorised by production process (Cat), chemicals (Che), accessories (Acc) and services (Ser). Some automotive specifics, such as the drive train, axles, brakes, and driving support, may need to stay close to their customers. This may explain why they located around Bangkok and the

eastern region. In the next section, we test if the parts' category affected the localisation of firms.

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

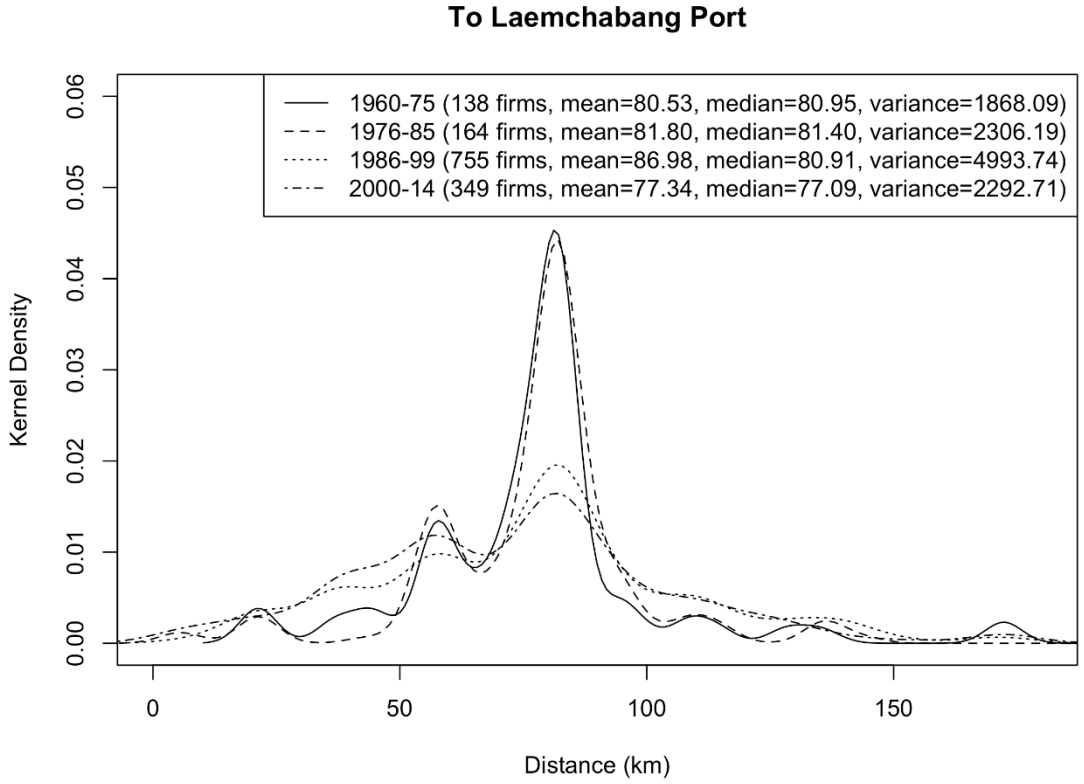


Source: The authors

As infrastructure is important, the ESB project is hypothesised to be a crucial factor for firms' agglomeration. 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 the euclidean distance, one limitation should be noted. The distance between Bangkok Port and Laem Chabang Port is about 74 kilometers according to our calculation, but in fact the actual distance by road is about 116 kilometers. In Figure 6 below, the peak of the location of automtive firms in the first and second periods (1960 to 1985) was in Bangkok, about 80 kilometers from Laem Chabang Port. From 1986 to 2014, the average distance of firms to this port increased to 87 kilometers from 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 automotive firms have located far from Bangkok's metropolitan area and moved closer to Laem Chabang Port. Particularly locations such as Rayong (Eastern Seaboard Industrial Estate) and Chachoengsao, which are respectively about 36 and 70 kilometers from Laem Chabang, increased their density (see the left hand side of the distribution in Figure 6). The location choice in the ESB seems to be naturally economical for automotive-related firms to agglomerate and reap the benefits of proximity, as pointed out by Poapongsakorn and Techakanont (2008).

Figure 6: Kernel density of the distance to Laem Chabang Port by period



4.2 Hypothesis testing on the localisation of automobile firms

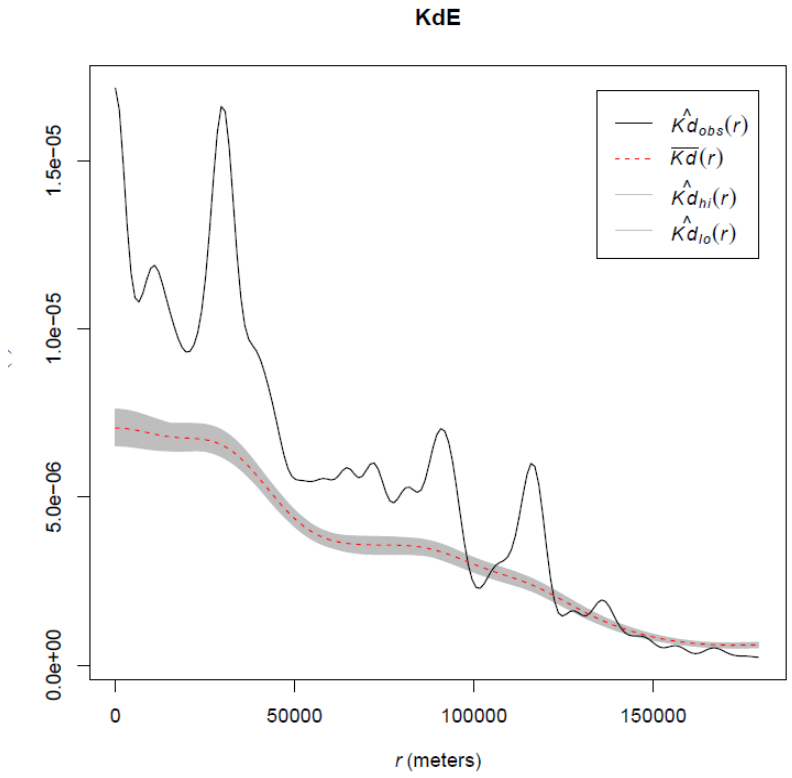
4.2.1 Testing on the localisation of automobile firms (1)

In this section, we conduct various tests on the localisation of the automobile firms. The method we employed is explained in Section 2.1.

Figure 7 shows the result of the hypothesis test on the localisation of automobile firms (including all categories of parts suppliers) when a set of all the existing sites occupied by the manufacturing establishments is used as the benchmark. The result shows that there are several peaks in the kernel density—which indicates a multiplicity of clusters close to 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. This suggests that automobile firms as a whole are significantly localised within this distance. As shown in Figure 7, the existing sites of the automobile firms are geographically concentrated in Bangkok and its vicinity, as well as in the eastern region, so that the kernel density of the bilateral distances deviates significantly from randomness when the set of the manufacturing establishment sites is used as the benchmark.[13]

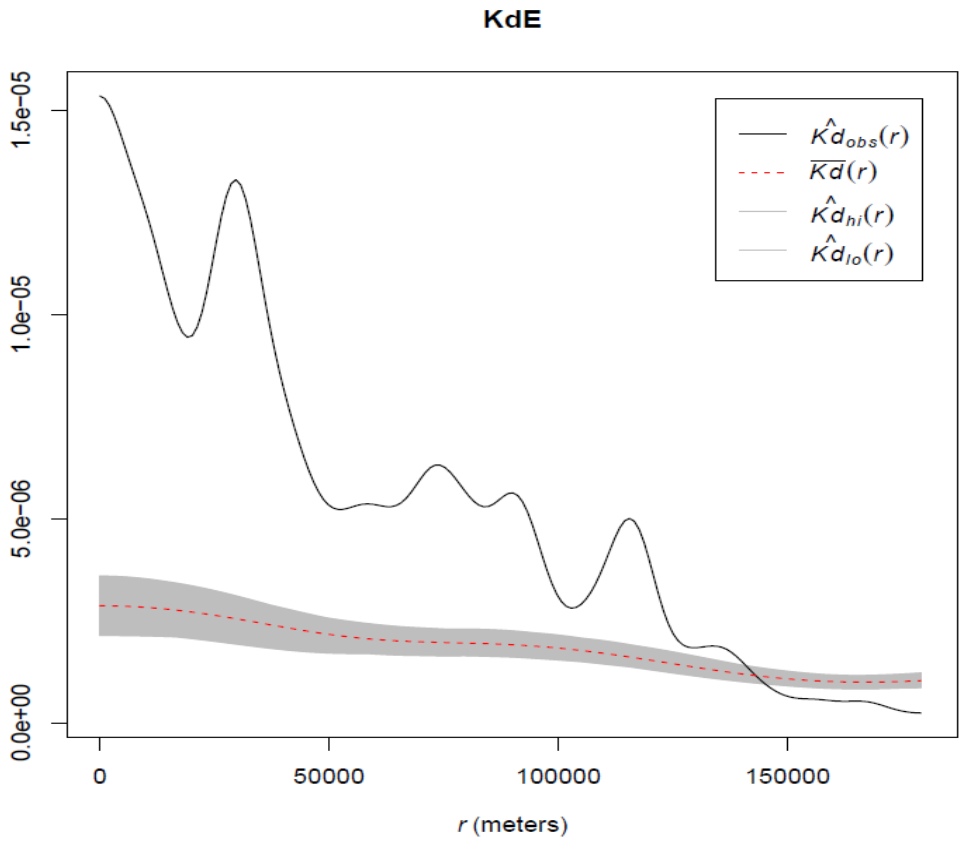
Figure 7: Hypothesis test on the localisation of automobile firms (Benchmark: manufacturing establishments)



[13] Note that manufacturing establishments include a large number of agricultural and resource-based establishments that are geographically spread all over the country. Thus, it is understandable that automobile firms are significantly localised compared to the spatial distribution of manufacturing establishments generally.

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

Figure 8: Hypothesis test on the localisation of engine parts (Benchmark: manufacturing establishments)



4.2.2 Measures of localisation

Using the index of localisation $\Gamma_A(d)$ in Equations 2 and 3, two measures of localisation are introduced in this section. Firstly, for each industry A, we

can define the following cross-distance index: $\Gamma_A = \sum_{d=0}^{180} \Gamma_A(d)$, and $\Psi_A = \sum_{d=0}^{180} \Psi_A(d)$. These measures are respectively the sum of each industry's index of global localisation and dispersion across all level of distances.

Table 2 shows that, as discussed in Section 4.2.1, all parts categories are significantly localized, and the highest localisation is exhibited by drive trains. All other parts categories have very high index figures, exceeding 0.57 (57 percent). Therefore, it can be concluded that automobile firms are strongly localised, regardless of the parts category, compared to the distribution of bilateral distances for all manufacturing establishments.

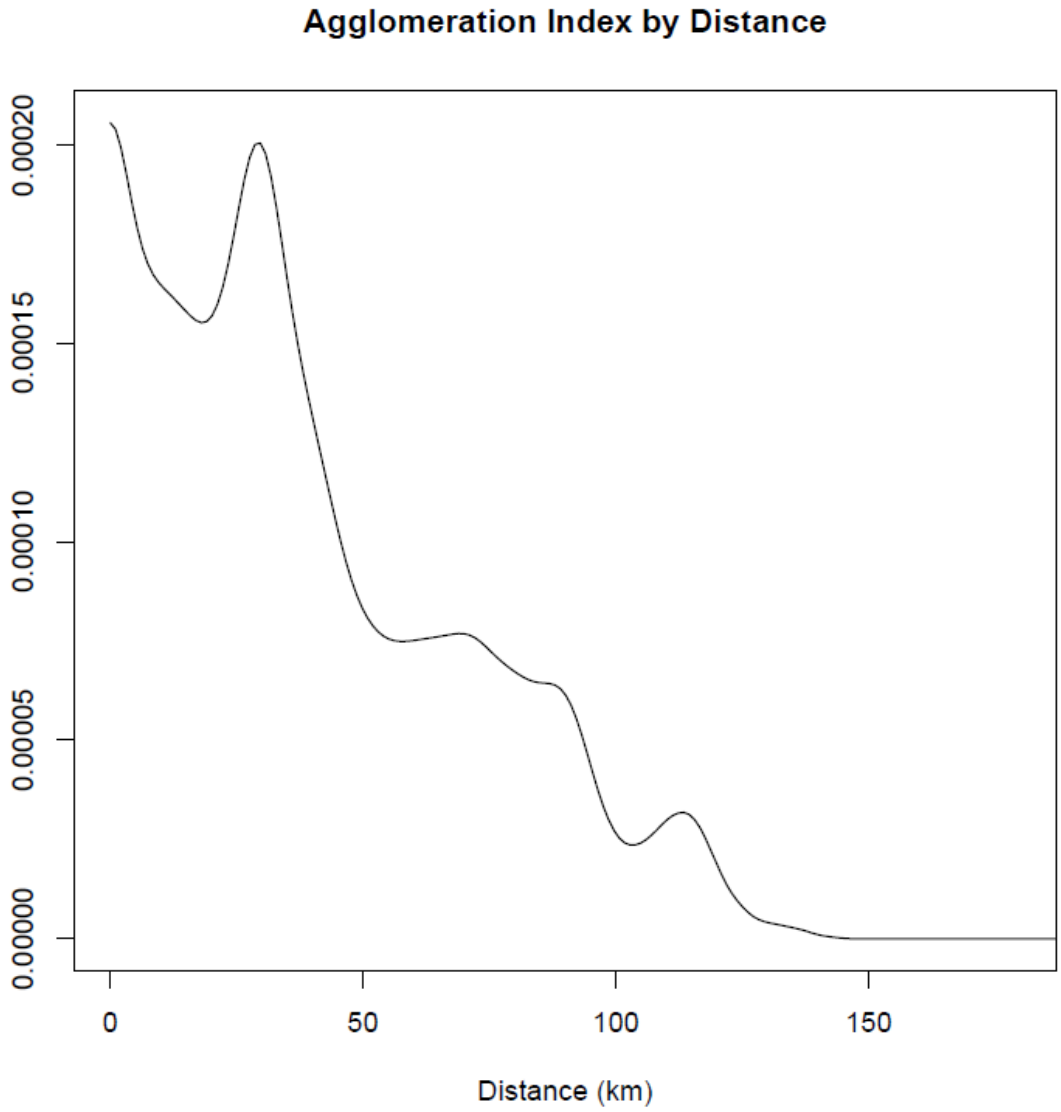
Table 2: Localization Index Γ_A

Part	Index	Part	Index
Dri	0.75190	Agr	0.65461
Che	0.74265	Ser	0.65341
Acc	0.73225	Sus	0.63463
Mac	0.73056	Sma	0.62967
DrS	0.72813	Bod	0.62382
Ele	0.72017	Aut	0.59989
Int	0.71150	Eng	0.58086
Cli	0.70784	Cat	0.57743
Axl	0.66284	Mot	0.57141

The second measure of localisation 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 localisation and dispersion at any given distance.

Figure 9 shows that, as in Duraton and Overman (2005), the extent of localisation is much greater over shorter distances than longer distances. Moreover, localisation occurs only within 150kms.

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



4.2.3 Testing the localisation of automobile firms (2)

In the above section, hypothesis testing was conducted using a set of all the existing sites occupied by the manufacturing establishments as the benchmark. However, it is more meaningful to sample the counterfactuals only from a set of the sites occupied by the automobile firms—instead of sampling from the existing sites of the manufacturing firms—to test the

localisation of automobile firms by the category of parts. This test shows whether each category of automobile parts still exhibits localisation after controlling for the overall localisation of the automobile industry.

As expected, the result indicates less localisation. Only four categories of parts—namely services, small/general parts, support activities, and machine tools—exhibited localisation after controlling for the overall localisation by the automobile industry.[14] For example, Figure 10 shows that services exhibit significant localisation between 0 and 30kms. This is because a large number of automobile firms providing services are concentrated in Bangkok and its vicinity.[15]

On the other hand, only motor cycles indicated significant dispersion: our data shows that the majority were located in Bangkok, Samut Prakarn, Chonburi, Chachoengsao and Rayong, but some were located far away, such as in Lampoon, Nongkai, Songkhla, and Ubon Ratchatani. Thus, this industry appears to be dispersed.

[14] It is already shown that industries that belong to the same branch tend to have a similar localisation pattern (Duraton and Overman 2005). It is quite understandable that automobile parts indicate similar localisation patterns, and only a few categories of parts deviate from randomness.

[15] Note that services tend to be concentrated in large cities because services' activities use less land per employee and have a greater potential for external economies (World Bank 2009).

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

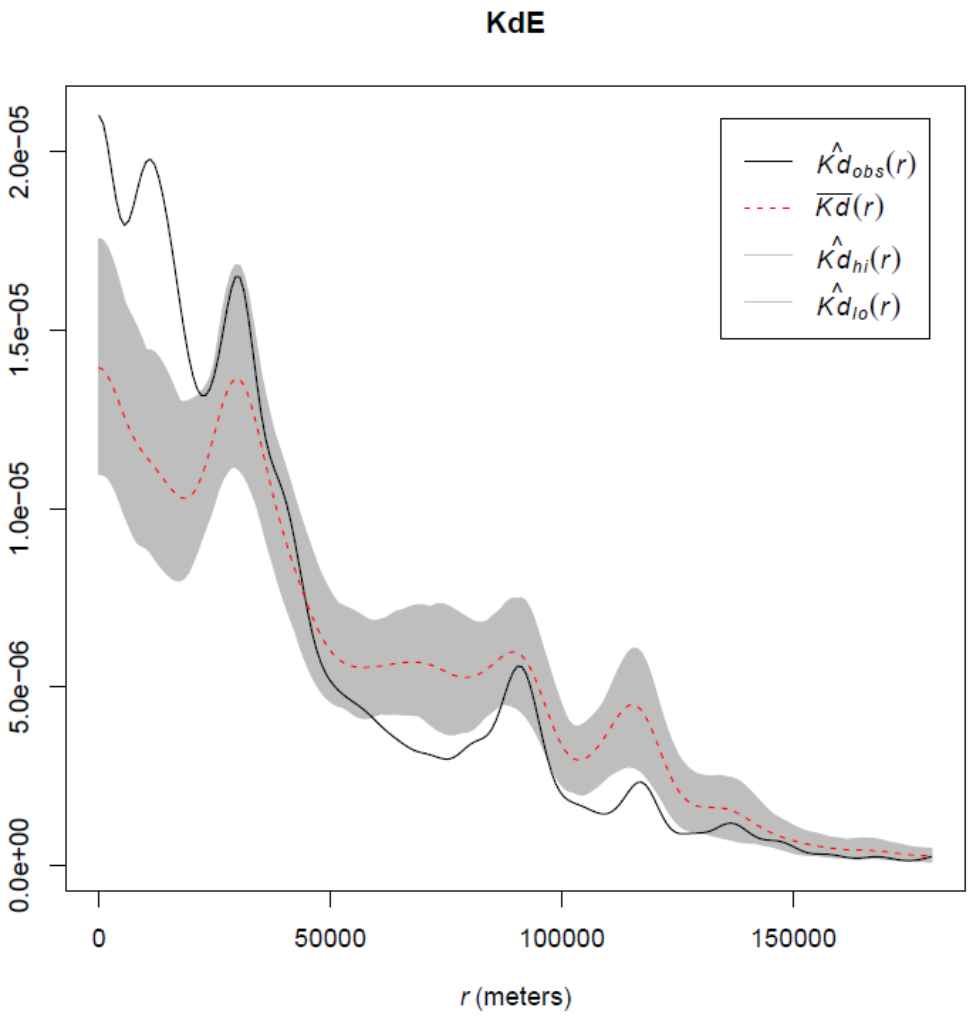


Table 3 shows the localisation index Γ_A of all the localized parts, which include services, small/general parts, support activities, and machine tools, while Table 4 shows the dispersion index Ψ_A for motor cycles. Services has by far the largest localisation index, exceeding 6 percent. In contrast, the dispersion index for motor cycles is very small—less than 0.1 percent.

Table 3 Localization index Γ_A

Parts	Index
Ser	0.06853
Sma	0.00900
Cat	0.00724
Mac	0.00281

Table 4 Dispersion index Ψ_A

Parts	Index
Mot	0.00096

4.2.3 Testing the co-localisation of the parts suppliers

Some industries may locate closer to other industries, and the clusters are located in the same or nearby area. This co-location of clusters occurs as a result of the location choice by firms. For instance, co-location may occur because of the random outcome that firms in different industries happen to be close to each other, or because the factors driving localisation in these industries share similarities that lead the firms to cluster together.

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

Duraton and Overman (2005) called the former two patterns 'joint-localisation' and the latter case 'co-localisation'. Obviously, of particular interest is co-localisation, because it is a reflection of the agglomeration economies. As our focus is placed on the co-localisation of parts supplies, we

apply the following formula to estimate the kernel density distribution of the bilateral distance between firms in two parts categories:

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

where bandwidth (h) and kernel function (f) are chosen as in Equation (1). A and B are two parts categories tested for co-localisation, and n_A and n_B are their respective numbers. $\widehat{K}_{(A,B)}(\cdot)$ allows us to calculate the bilateral distances between firms for the two parts categories A and B.

To conduct hypothesis testing on co-localisation, it is more appropriate to sample the counterfactuals from a set of the sites occupied by firms in either of two parts categories, i.e. A ∪ B, because this allows us to determine whether there is some interaction between parts categories A and B, and 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 A.

Table 5 shows that there are five pairs of parts categories that exhibit co-localization. Table 6 shows three pairs of co-dispersion. The pair indicating the strongest co-localisation is support activities and body parts, whereas the pair of support activities and engines parts indicates the strongest co-dispersion.

Table 5: Pairs of co-localisation

Parts	Parts	Index
Cat	Bod	0.00994
Cli	Eng	0.00781
Sma	Sus	0.00604
Sus	Axl	0.00037
Ele	Sus	0.00026

Table 6: Pairs of co-dispersion

Parts	Parts	Index
Cat	Eng	0.00061
Bod	Dri	0.00024
Eng	Sus	0.00002

5. Conclusion

Literature from the past indicated several factors influencing the development of the Thai automobile industry, but our paper focuses on a special aspect, the evolution of spatial distribution of the Thai automobile firms. We analysed the spatial distance of the automotive 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 to benefit from the better infrastructure and market access.

Apart from the rationalisation policies, basic infrastructure development was vital to the success of industrialisation. In Thailand's case, the most important investment was the development of the Eastern Seaboard Project (ESB). Thanks to the continuity and streamlining of the government's policies and some international financial support through

loans and ODA, the eastern region became vibrant with manufacturing activity, and automotive clusters emerged naturally in this region accordingly.

The location of the automobile firms may influence the suppliers' choice of location. This depends on the bulkiness of their products, the distance to their customers, and the need to interact with other firms. Based on our analysis, we found that automotive-related firms are localised within 100 kilometres, and the highest density locations are in the Bangkok metropolitan area and the three eastern provinces, Chonburi, Chachoengsao, and Rayong

Development of the local supplier base and formation of industrial linkages are crucially important to strengthen the competitiveness of the industry. In particular, the development of a local supplier base is critical for an industry such as automobiles, where parts and components are heavy and bulky and the just-in-time manufacturing system is important to improve the competitiveness of the industry. However, it is still doubtful that all parts suppliers, regardless of the parts categories are attracted to the vicinity of the customers.

Against such a backdrop, we conducted a hypothesis test concerning the localisation of the parts suppliers. As expected, automobile firms as a whole are significantly localised when the set of all the existing sites occupied by the manufacturing establishments is used as the benchmark. Similarly, all categories of automobile firms are localised, regardless of the parts category. In contrast, only four categories of automobile

firms—particularly services—are significantly localised after controlling for the overall localisation of the automobile industry. On the other hand, only motor cycles exhibited any significant dispersion.

Hypothesis testing of the co-localisation between a pair of different parts categories was conducted, and five pairs of parts categories were identified as being significantly co-localised, whereas three pairs of parts categories were co-dispersed.

Reference)

Devereux, Michael P., Rachel Griffith, and Helen Simpson (2004), "The Geographic Distribution of Production Activity in the UK", *Regional Science and Urban Economics*, 35 (5), 533-564.

Duraton, Gilles and Henry G. Overman (2005), "Testing for Localization Using Micro-Geographic Data" *The Review of Economic Studies*, vol.72, No. 4: 1077-106.

Ellsion Gllen and Edward L. Glasser (1997), "Geographic Concentration in in US Manufacturing Industries: A Dartboard Approach", *Journal of Political Economy*, 105 (5) 889-927.

Fujita, Masahisa, Paul Krugman, and Anthony J Venables (1999), *The Spatial Economy: Cities, Regions, and International Trade*. MIT Press: Cambridge. MA.

Krugman, Paul (1991), *Geography and Trade*. MIT Press: Cambridge. MA.

Kuroiwa, Ikuo and Kriengkrai Techakanont (2017), "Formation of Automotive Manufacturing Clusters in Thailand" ERIA Discussion Paper 2016-32.

Lecler, Y. (2002), "The Cluster Role in the Development of the Thai Car Industry," International Journal of Urban and Regional Research. 26(4): 799-814.

Marshall, Alfred, (1890), *Principle of Economics,* Macmillan: London.

Maurel, Francois and Beatrice Sedillot (1999), "A Measure of the Geographic Concentration of French Manufacturing Industries", *Regional Science and Unban Economics*, 29 (5): 575-604.

Nakajima, Kentaro, Yukiko Saito, and Ichiro Uesugi (2010), Measuring Economic Localization: Evidence from Japanese firm-level data, *RIETI Discussion Paper Series* 10-E-030: The Research Institute of Economy, Trade, and Industry (RIETI).

Poapongsakorn, Nipon and Kriengkrai Techakanont (2008), "The Development of Automotive Industry Clusters and Production Network in Thailand", pp. 196-256, in Production Networks and Industrial Clusters. Edited by Kuroiwa Ikuo and Toh Mun Heng, Singapore: ISEAS.

Watanabe, Matsuo. (2003). "Official Development Assistance as a Catalyst for Foreign Direct Investment and Industrial Agglomeration." In *External Factors for Asian Development.* Edited by Hirohisa Kohama. Singapore: ISEAS

World Bank (2009), *World Development Report: Reshaping Economic Geography*, the World Bank: Washington, DC.