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Logistics agglomeration in the US

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ABSTRACT

Governments around the world are investing significant resources in the development of logistics clusters. This paper develops a methodology for identifying them and applies it to answer several lingering questions in the context of the US. It contributes to a more general debate in the general industrial clusters literature: while many authors see industrial clusters growing, others see them dispersing. To answer this and related questions in the context of logistics clusters the paper first analyzes the prevalence of such clusters using a two-index methodology to identify clusters in the US. Evidence of increasing concentration of the logistics industry in clusters in the US over time is tested and documented. In addition, some evidence that logistics activities in counties inside clusters show higher growth than counties outside clusters is found.

1. Introduction

Governments around the world are investing significant resources in the development of new and the expansion of existing logistics clusters, all of whom are central nodes of the global freight transportation network. They are motivated, in large parts by a job creation agenda. For instance the Government of Aragón in Spain invested over €680 Million to develop Plataforma Logística – Zaragoza (PLAZA), the largest logistics park in Europe and the core of the Aragon logistics cluster. Panama is in the process of developing significant logistics clusters at both ends of the canal as part of the strategy to position the country as the center for trade and logistics for the Americas (Council of the Americas, 2011; Government of Panama, 2010). While new logistics hubs are being developed, existing clusters are expanding in scale and scope. These include major ones such as Singapore, Rotterdam, Duisburg (Germany), Dubai, Santos (Brazil), and multiple US locations such as New York, Miami, Chicago, Dallas/Ft Worth, Memphis, Louisville and Los Angeles.

Logistics can be broadly defined as the group of functions associated with production, design, and marketing, which include "...transportation, warehousing and facilities planning, and location" (Kasilingman, 1998). These activities add value to companies' supply chain and increase competitiveness.

The logistical need to move material, parts, and products into manufacturing, distribution and retail locations creates the (derived) demand for freight transportation. To this end, efficient transportation operations are crucial for efficient logistics since transportation costs are a relevant part of the retail price (Xu and Hancock, 2004). Also, the pressure to time-compress logistical operations and provide high level of service gives transportation a central role in logistics (Groothedde, 2005; Stank and Goldsby, 2000). Furthermore, as stated by Rodrigue and Hesse (2006) "...the role of transportation is considered more than a mere support to the mobility of freight within global commodity chains, but an integral part of the value generation process."

Dozens of interviews all around the world suggest that logistics clusters are growing. This finding is in line with the many authors who document and explain the advantage of industry agglomeration, or clustering. They cite tacit knowledge ex-

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change, the development of a local supply base, and the availability of a specialized labor pool (Marshall, 1890; Feser, 2008; Ellison et al., 2010). Other authors point out that the regions where these clusters reside enjoy high economic growth and a higher rate of innovation and capital formation than regions that do not include clusters (Porter 2000, 2003; Delgado et al., 2010; Benneworth and Henry, 2004). Other researchers, however, claim that negative externalities of clusters, the development of information technologies and the efficiency of global supply chains diminish the advantages of geographical proximity, leading to dispersion of like-businesses (Cairncross, 1997; Polenske 2001, 2003; Henderson and Shalizi, 2001). Also, Feitelson and Salomon (2000) point out to the increasing congestion in transportation networks that could lead to dispersion of logistics activities.

Although large investments in logistics clusters seem to suggest that policy makers believe in their positive effects, and though there are some studies that account for their benefits (see for instance Kasarda, 2008; De Langen, 2002, 2004a; Wu et al., 2006), the prevalence of logistics clusters has not been studied yet. This article defines logistics clusters, explains their advantages and tests this prevalence. It then uses a two-factor metric to identify logistics clusters in the US, validating the results through several approaches. Using data from 1998 and 2008 it provides evidence that logistics activities seem to be, in fact, agglomerating rather than dispersing over time.

Section 2 reviews the state of the art in clusters research, with an emphasis on logistics, and provides some context for the analysis. Section 3 presents findings from exploratory research used to develop the thesis of the paper. Section 4 reviews the methodologies used to identify clusters, while Section 5 depicts the model and the data used in analysis of the US. Sections 6 and 7 present the results, including a statistical analysis. Finally Section 8 concludes with final observations.

2. Industrial and logistics clusters

The literature concerning industrial clusters dates back to Marshall (1890), who discusses agglomeration economies and enumerates the externalities-based advantages for firms to co-locate. Economists distinguish among several types of agglomerations. Marshall (1890), and Weber and Friedrich (1929) discussed external economies of scale, resulting from multiple firms agglomerating geographically, as opposed to internal economics of scale, where a single firm expands its production (see, for example Isard and Schooler, 1959). Hoover (1937) defined two types of external economies of scale: urbanization and localization. Urbanization economies arise when many firms from different industries concentrate in the same region; localization economies arise when firms from a particular sector locate in the same region. This paper is focused on external economies of scale and localization economies of logistics firms and operations.

Porter (1998) summarized the main benefits of industrial clustering as follows: "A cluster allows each member to benefit as if it had greater scale or as if it had joined with others formally, without requiring it to sacrifice its flexibility." A related branch of literature argues that clustered firms enjoy not only the benefits of agglomeration economies (Feser, 2008; Ellison et al., 2010), but also higher collective learning and tacit knowledge exchange (Keeble and Wilkinson, 2000; Maskell, 2001; Cohen and Fields, 1999; Leamer and Storper, 2001). Intra-cluster competition drives firms to succeed by increasing their productivity, supercharging innovation, and by stimulating new business formation (Porter, 2000; Delgado et al., 2010). This also results is high economic growth (Baptista, 1998), reinforcing the importance of geographical concentration and supporting a continuing clustering trend.

However, several authors argued that the efficiency of supply chains, and advanced communications technologies represent the "end of geography" (O'Brien, 1992) and the "death of distance" (Cairncross, 1997). Others point to the negative externalities of clusters such as congestion and higher prices of land and labor, creating incentives for firms to leave clusters (Henderson and Shalizi, 2001; Glasmeier and Kibler, 1996; Teubal et al., 1991), as a result of "Dispersion Economies" (Polenske, 2003).

This paper explores the role of clusters in logistics and transportation. A logistics cluster is defined as the geographical concentration of firms providing logistics services, such as third-party-logistics (3PL-s), transportation carriers, warehousing providers and forwarders. Naturally, logistics clusters also include suppliers for such activities, such as packaging manufacturers and transportation maintenance depots.

The academic literature includes only a few articles about logistics clusters with little mention of their prevalence. Van den Heuvel et al. (2011)studied the logistics industry within three Provinces in the Netherlands, concluding that the concentration of relative and absolute employment in logistics firms there has increased in recent years.

The emergence of a logistics cluster depends on the quality of transportation service available in a region (Hong, 2007). Bok (2009) highlighted accessibility and general infrastructure quality as the main factors affecting the location preference of firms. Better accessibility typically drives logistics operations to locate relatively close to each other (Berechman, 1994), as it reduces costs for firms (Rietveld, 1994). Hong (2007) asserted that transportation accessibility is one of the important determinants of location decisions of foreign logistics firms.

Most of the literature related to logistics clusters is specific to ports or airports and not to the logistics sector in general. Haezendonck (2001), Klink and De Langen (2001) and De Langen (2002, 2004a, 2004b) investigated maritime clusters, arguing that, based on their findings, the concentration of maritime activities in clusters is likely to increase. This is not surprising as one considers the, more familiar, increased concentration of airlines in "hub fortresses." The economics of hubs for maritime and air freight are similar.

Martin and Román (2003) document the agglomeration of airfreight carriers in hub airports while Lindsay and Kasadra (2011) developed the concept of "Aerotropolis" – a full urban development around an airport. Interestingly, despite the attraction of airport and port clusters some observations suggest that their growth is sometimes constrained by lack of land and environmental regulations. The focus of this paper, in any case, is on logistics clusters in general, many of which are not focused on either a port or an airport.

Finally, Wu et al. (2006) argue that China's economic advantage goes beyond labor costs, and can be explained, in large measure, by the presence of "supply clusters." These clusters provide all the logistics services needed for the management of global supply chains. They add: "the large number of supply clusters formed in China in recent years has contributed significantly to the nation's manufacturing competitiveness."

3. Exploratory research

During 2010 and 2011 the authors conducted 135 interviews as part of an exploratory research with actors in and around logistics clusters, resulting in three main findings relevant to the work reported in this paper. First, these interviews suggest that logistics companies are clustering and those clusters are growing. Second, Governments play a key and necessary role in logistics clusters' development. And third, logistics clusters attract transportation carriers who build their networks around such clusters.

A description of the methodology of data collection through interviews and the analysis of this qualitative data is beyond the scope of this paper and is the subject of an upcoming paper. In summary, the first stage was exploratory and consequently open interviews were used to collect data. In the second stage more data was gathered through semi structured interviews to confirm the initial findings (Babbie, 2009). The interviews were conducted in existing logistics clusters in Singapore, the Netherlands (Amsterdam and Rotterdam), Germany (Duisburg and Frankfurt), Spain (Zaragoza), Panama (Panama City and Colon), Dubai, Brazil (Campinas and Santos – both in the State of Sao Paulo), Cartagena (Colombia), and the US (New York, Miami, Chicago, Dallas/Ft Worth, Memphis, Louisville and Los Angeles). The data was analyzed using grounded theory tools (Glaser and Strauss, 1967; Glaser, 1978), and following Charmaz (2006). The process included coding and clustering analysis to organize the data, as well as an evolving revision of the categories and results.

The interview data suggest a consensus on the advantages of logistics clusters for companies and regional economies. As many researchers point out, lower cost may not be the only reason why a firm selects a particular location (see, for example, Castells 1996; DiPasquale and Wheaton 1996; Porter 2001; Polenske 2003). Just as important, if not more, are high-level of transportation services.

Sheffi (2010) summarizes the transportation cost and service advantages of logistics clusters, including economies of scope, scale, and density; better service, and liquidity. Economies of scope arise due to the presence of many shippers, helping the balance of movements in and out of the cluster, minimizing equipment idle time and empty repositioning moves. Economies of scale result in from lower costs while the concentration of logistics operations in the cluster produce higher freight volumes, allowing carriers to use larger conveyances and enjoy higher utilization. Economies of density arise because the larger the number of companies in the cluster, the more efficient pickup and delivery operations get. Better level of service result from the higher freight volume leading to higher frequency of services as well as more direct services in and out of the logistics cluster. Finally, liquidity or price stability is the result of many shippers located in the same geography, served by many transportation carriers, thus minimizing situations of short-term mismatch between demand and equipment availability.

These advantages create a positive feedback loop rooted mainly in the economics of transportation: as more firms join the cluster, transportation costs go down and service improves, which in turn attracts more firms to the cluster, further reducing costs and improving transportation services.

In addition, the interviews suggest that companies in logistics clusters share equipment, lease space to each other for short-term surges and lulls in activity; and work effectively together when a logistics contract is moved from one provider to another. Cluster companies also have more weight in lobbying the local government, which in the case of logistics clusters the focus is typically on improved infrastructure and regulatory relief.

While many authors studying other industrial clusters (mainly high technology ones) argue that the role of government in their development and growth is minimal (OECD, 2001; Wadhwa, 2010), government is a major player in logistics clusters. This is due not only to the significant transportation infrastructure requirements of such clusters, but also due to the need for a favorable regulatory, tax, and trade policy environment. The interviews suggest that government interest in logistics clusters is, not surprisingly, primarily driven by the potential benefits for the local economy with an emphasis on jobs. Interestingly, they are also viewed – mainly in the US – as a vehicle for "economic justice" based on "professional mobility": providing starting jobs that pay better than the hotel or the agricultural industries to employees without high level education, and allowing them to be promoted from within as this industry values "on the floor experience" in its executives.

The interview data suggest that the major investments that are going into new and existing logistics clusters will go on, and that these clusters are growing (not dispersing); this is the basic hypothesis explored statistically in this paper.

4. Identifying logistics clusters

Before tackling the question whether US logistics operations are clustering or dispersing, one needs to identify the location of concentrations of logistics activities. Even by itself such identification can be of value; it can help firms identify sites to set up distribution activities. Governments using this information can identify competing regions which can then be used to benchmark effective policies (infrastructure, regulation, and administrative efficiency, among others) for success of logistics clusters.

Several of the most common indices employed to measure industry geographical concentration include the Location Quotient (LQ), Horizontal Clustering Location Quotient (HCLQ), Locational Gini Coefficient (LGC), Herfindahl–Hirschman Index (HHI), and the Ellison–Glaeser Index (EGGCI). Appendix A contains the formal definition of these indices.

Location Quotient (LQ) has widely been used in economic geography and regional economics since the 1940s (Miller et al., 1991). In fact, it was used by De Langen (2004a) in his analysis of maritime clusters. This technique has remained popular in large part because it requires relatively little data (Isserman, 1977). LQ is the ratio of employment share of the industry of interest in the area of interest and the employment share of that industry in a reference area (which is typically the country).

Some of the studies that have used this technique include Paige and Nenide (2008) in their analysis of the agglomeration trends in the Central San Joaquin Valley in California; Braunerhjelm and Carlsson (1999) who set to identify cluster activity and its evolution in Ohio and Sweden; Held (1996), who addressed the question about the State's participation in generating economic development through a cluster approach in the Hudson Valley of New York; and others (Zook, 2000; Malmberg and Maskell, 2002).

A value of the LQ greater than one suggests a higher than average share of employment in an industry of interest in a given area. Although this index provides information about the relative weight of a particular industry's employment in a geographical area (relative to a reference area), it does not provide information regarding the absolute size of the industry (Feser et al., 2002).

To correct this issue, Fingleton et al. (2004) proposed the Horizontal Cluster Location Quotient (HCLQ), which weighs LQ values with an indicator of magnitude, such as the local area share of nationwide jobs in a given industry. It thus takes into account both the relative and absolute local importance of the industry under study. HCLQ is the number of jobs in the local industry that exceeds the number that would produce LQ = 1 (Ratanawaraha and Polenske, 2007). An example is found in Echeverri-Carroll and Ayala (2010). They analyze wage differentials caused by the agglomeration of high-tech companies in certain cities of the United States. Using the HCLQ they suggest that clustering is the key factor behind innovation flows, knowledge spillovers and other cooperative linkages among firms.

Two additional measures of industry clusters include the Locational Gini Coefficient (LCG) and the Herfindahl–Hirschman Index (HHI). The former was proposed by Krugman (1991) to examine regional income disparities, based on the Gini coefficient used widely in studies of income inequality and poverty (see for example, Chakravarty, 1990; Lambert, 1990; Atkinson and Bourguignon, 2000). The LGC is a number that captures the distribution of employment in an industry across geographic areas, relative to the distribution of total employment. It signals the relative concentration pattern of employment in a certain economic *sector* in a given area in relation to other sectors in the same area.

The HHI is defined as the aggregation of the industrial shares of all areas in a region, usually the country (Kim et al., 2000). It measures the extent to which a given industry is distributed throughout a large number of sub-areas (say, counties or other geographical sub-units).

Neither the LCG nor the HHI are aimed at identifying logistics (or any other) clusters. They measure industry concentration in a country (or other reference area), but do not provide information on where the concentration is located within that reference area. As such these indices are not considered further in this paper (they are defined, though in Appendix A).

The main criticism of the LQ and HCLQ indices (and also of the LGC and HHI) is that, being based on employment, they do not account for the difference between a single large firm in a region and a set of multiple firms, that is, "they do not distinguish whether the concentration of an activity is due to internal or external economies of scale" (Ratanawaraha and Polenske, 2007).

One of the most sophisticated methods to measure the degree of spatial concentration of firms is the Ellison–Glaeser Index (EGGCI), which "eliminates the effect of the random distribution of establishments on firms' locations by comparing the estimated spatial HHI for a given industry to the expected value of HHI" (Li, 2006). However, the application of this measure is limited due to the extensive data requirements and its sensitivity to the geographic units used. Additional limitations are rooted in the difficulty of comparing the value of the index at the international level, because of the different sizes among regions and countries (Ratanawaraha and Polenske, 2007). Consequently this index is also omitted from further discussion.

5. Model

A desirable indicator for identifying and defining logistics clusters should: (i) identify the concentration of activities, (ii) indicate where that concentration is located (iii) give a sense of the size of the concentration in the geographic area, (iv) guarantee that the concentration is due to the presence of external economies of scale, (v) work with the available data, and (vi) be replicable.

To tackle this challenge, this approach described here combines two indicators: the Horizontal Clustering Location Quotient (HCLQ) and a newly defined Logistics Establishments Participation (LEP) index. HCLQ identifies both the location and magnitude of the concentration of logistics activities. The LEP guarantees that the concentration is due to the presence of external economies. Both indices require a minimum amount of available data (employment and establishment data), which in the US is available at the county level, from government statistics, thus allowing for replication. A cluster in this study is defined as a county with concentration of logistics activities or several adjacent counties with such concentration.

HCLQ is defined as:

$$HCLQ_j = E_j - \widehat{E}_J$$

where E_j = number of employees in the logistics industry in county j, and $\widehat{E}_J$ = expected number of logistics employees in county j, which is calculated as the number of logistics jobs in the county that would produce a Location Quotient equal to one. $HCLQ_j > 0$ implies that county j has a higher concentration of employment in the logistics industry than the country as a whole. The magnitude of the concentration is indicated by the absolute value (extra number of logistics employees in the county).

Since objective here is to identify logistics clusters, there is a need to have not only concentration of logistics employment, but also external economies of scale. This is particularly important since, as Henderson (2003) reports, activity at small and medium firms contributes significantly to external economies of scale. Thus, this paper introduces a Logistics Establishments' Participation (LEP) index, representing the share of the countrywide logistics establishments that a county has. It is defined as follows:

$$LEP_j = \frac{es_j}{ES}$$

where es_j = number of logistics establishments in county j, and, ES = number of logistics establishments in the country.

The larger the LEP of a given county, the larger is the number of logistics establishments located in the county. A cutoff value of 0.1% was chosen. It implies that to be considered a cluster, a region has to have at least 0.001 of the logistics establishments of the nation (in addition to HCLQ > 0). This cutoff value was chosen using the known group validity method (Babbie, 2009) shown below. The rationale for and the effects of the choice of the LEP cutoff value are shown in Section 1. The process leading to the particular value of 0.1% can be summarized as follows:

1. *Known clusters* – Data from reports and interviews with experts in the logistics industry from the MIT Center for Transportation and Logistics, the Harvard Institute for Strategy and Competitiveness and the Indiana Business Research Center were used to draw a list of seven known logistics clusters in the US today. This list included Los Angeles, Chicago, Memphis, Louisville, Miami, Houston and New York/New Jersey.
2. *Minimize Type I error* – Starting from a LEP cutoff value of 1, the cutoff was decreased until all seven known clusters showed up in the list of identified clusters. This happened at a cutoff value of 0.2%. At this point 31 additional clusters were identified, all of which were recognized by the experts as actual logistics clusters, thus minimizing type I error (H0: The identified cluster is a logistics clusters indeed).
3. The identification was further verified using information from City data. City data is a social and economic database for counties and cities in the US and Canada (http://www.city-data.com/). This database was used as a secondary source, rather than a primary source, because it is private and lack of bias could not be ascertained. Also, the city data base covers only the US and Canada and not available elsewhere else in the world. Lastly, the structure of this data base is such that to identify a cluster directly from city data one needs to examine whether each county has concentration of logistics activities, a manual task that prohibits detailed multiple analyses.
4. *Minimize false positives* – In order to capture additional logistics clusters, the LEP cutoff value was increased continuously until, at 0.1%, false positives started showing up. False positives were also checked as "clusters" that did not appear in the city database and were not recognized by our experts as actual logistics clusters. The number of false positives increased when the cutoff value was reduced further. Therefore 0.1% became the LEP value that minimizes type II error, resulting in 61 identified logistics clusters. The process is depicted graphically in Fig. 1.

5.1. Data

The data consisted of employment and establishments at the county level for 3095 US counties (excluding those of Hawaii, Alaska and Puerto Rico), based on the North American Industry Classification System (NAICS). Six-digit classification was used, based on the County Business Patterns (CBP) and Statistics of U.S. Businesses (SUSB) from the U.S. Census Bureau. The logistics sector definition includes the subsectors depicted in Table B1 in Appendix B. Even a casual inspection of the data source reveals the heavy weight of transportation activities in the database.

6. Results: cluster identification

With the data at hand, the sensitivity of the number of clusters identified to the LEP critical value was examined, since unlike LQ, LEP does not have a "natural" cutoff value and the process described in the last section was of our own making. Fig. 2 depicts the number of logistics clusters (defined as a group of one or more adjacent counties with HCLQ > 0) as a function of different levels of Logistics Establishments' Participation cutoff value (horizontal axis). When choosing a small critical value, the number of potential clusters explodes. When choosing a high critical value, the restriction on establishments

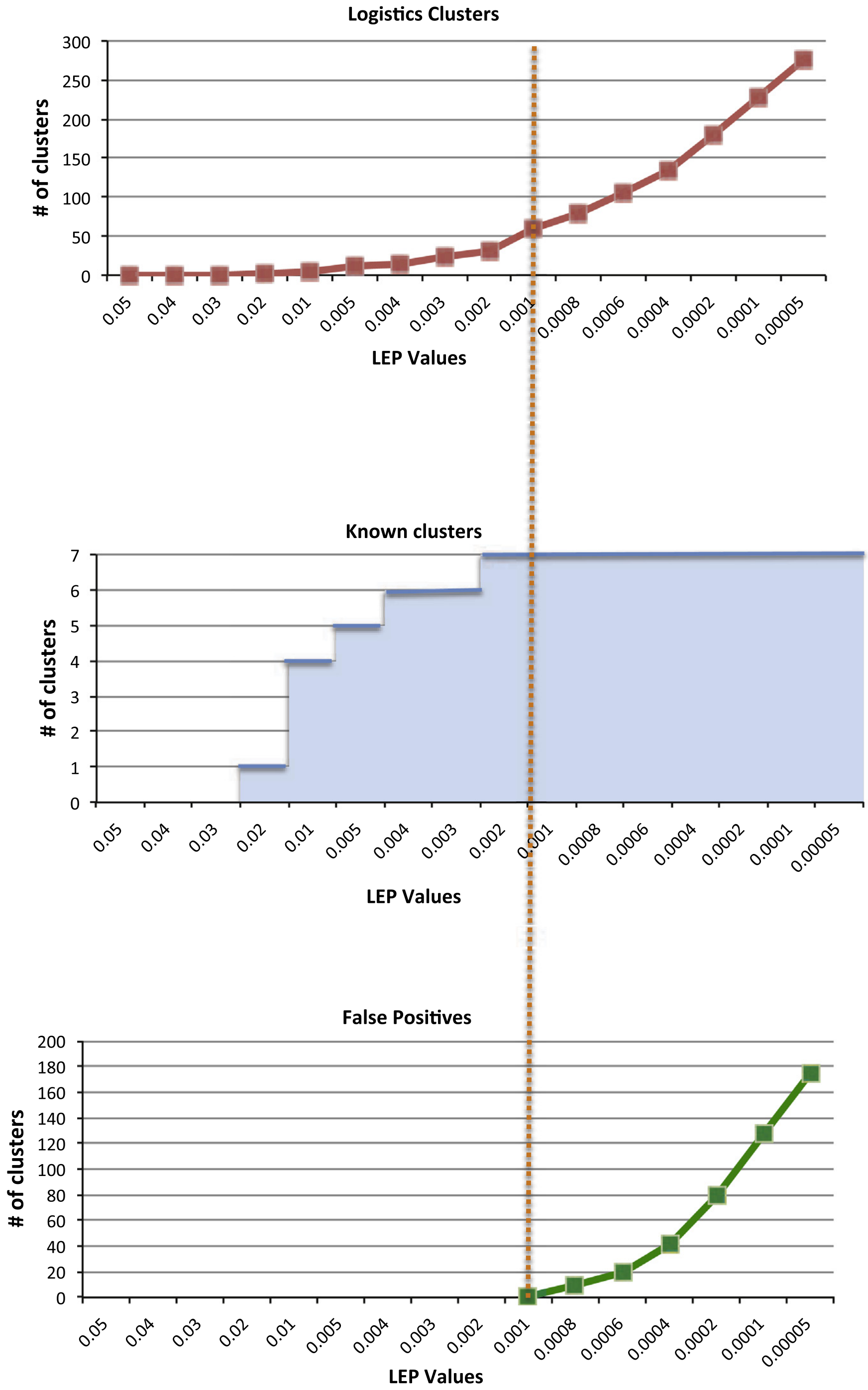

Fig. 1. Determination of LEP cutoff value.

(absolute concentration) increases and the number of logistics clusters identified goes to zero. A critical value of 0.1% leads to the inclusion of just over half (51%) of the logistics establishments in the US (and 76% of the employment), while identifying 61 clusters (comprising 97 counties).

Fig. 3 depicts the identified logistics clusters (HCLQ > 0 and LEP > 0.001) in the US. The pattern depicted in the legend of the figure represents the size of the cluster as measured by number of employees. Those with the highest index value include (in order of size): Los Angeles, Chicago, New York/New Jersey, Atlanta, San Francisco, Dallas, Miami, Denver, Columbus, Jacksonville, Indianapolis, Houston, Orlando, Chattanooga, Memphis, Detroit and Laredo. A brief description of the seven largest logistics clusters is presented in Appendix C.

Although the methodology has some data limitations, results were intuitive. All the 61 identified clusters are indeed agglomerations of logistics activities. This was verified empirically, first by using face validity by personal knowledge of researchers at the MIT Center for Transportation and Logistics; and second, by using convergent and construct validity. Convergent validity determines whether the scores of different indicators of a concept are empirically associated and thus convergent (Adcock and Collier, 2001). In this case it was carried it out by comparing the list of identified clusters to the Annual Logistics Quotient 2008 results, a ranking of the 72 most logistics friendly cities in the United States (Expansion Management and Logistics Today, 2007). Since warehouses, freight transportation terminals, distribution centers and logistics related activities usually locate in areas outside city limits an expanded area (30 miles) around the centroid of each city was used to compare with the identified logistics clusters. Comparing only the first 61 cities in the list to the group of logistics clusters (so to have equal number of entries), 56 out of the 61 clusters overlapped, a 92% success.

Construct validity considers a theoretical association between two concepts and then assesses whether two indicators (one for each concept) are empirically associated (Adcock and Collier, 2001). It was assessed by looking at the list of US Free Trade Zones (FTZs), compiled by the Import Administration of the US International Trade Administration (International Trade Organization, 2011). Free Trade Zones provide special customs and taxation reliefs to areas and facilities engaged in international trade. Bruns (2009) and Thuermer (2008) have pointed out the conceptual relationship between logistics clusters and FTZs. In this sense, most significant logistics clusters "should" have FTZs (since most of them should be engaged in international trade). Comparing the list of identified logistics clusters (using as a criterion 30 miles around the cluster's centroid) with the list of 358 FTZs, the overlap was 92%. Fig. 4 depicts these data.

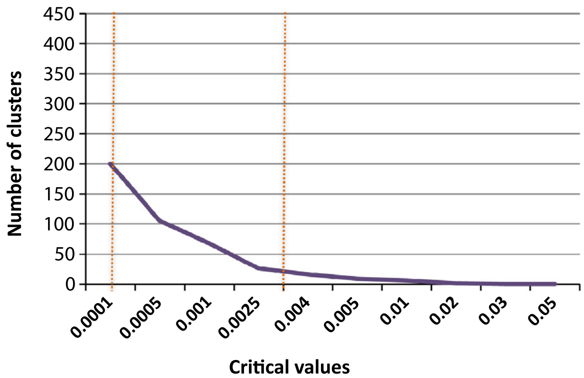

Fig. 2. Number of logistics clusters considering different critical values, 2008.

Fig. 3. US logistics clusters 2008.

6.1. Comparison of these results with other methods

The results of trying to identify logistics clusters using LQ and HCLQ are shown in Figs. 5 and 6. The results of both HQ and HCLQ are similar: LQ yields 502 counties (16% of total US counties) and HCLQ yields 511 counties (17% of total US counties), which is expected considering that HCLQ is based on LQ. However, they both face similar limitations. First, since they are based on fractions, the indicators may produce a high value because the denominator (county's share of total employment in the country) is relatively small. For example, Wibaux County in Montana shows concentration of logistics activities with both methods. However, the county has only 179 employees out of whom 18 work in logistics. In addition, it has only 2 logistics establishments. This is not a logistics cluster; in other words, it is a false positive. Similar false positives were identified by our experts in many other locations, including Aroostook and Penobscot counties in Maine, and multiple counties in Wyoming, Montana, South and North Dakota.

Second, results from LQ and HCLQ do not guarantee that the concentration of logistics activities is due to the presence of external economies of scale. Counties can show a concentration of logistics employment, but the concentration is the result of only a single company there. This is not a logistics cluster either. For example, counties in Wyoming show concentration of logistics activities, but this high activity is the result of a single Wal-Mart facility in the area. There are several similar examples that support the need of an additional indicator that guarantees that the concentration of activities is truly the result of the presence of a cluster, with many establishments that generate external economies of scale.

7. Results: trends and dynamics

To answer the question of whether logistics companies tend to cluster or disperse, one needs to look at trends over time. As the globalization and outsourcing trends continue, one would expect logistics clusters to grow – if, indeed, they provide value to companies located there. To test this hypothesis, the analysis presented in Fig. 1 (for 2008) was repeated using data for 1998. The result for 1998 is shown in Fig. 7, which the reader can compare to Fig. 3, depicting the data for 2008.

The number of logistics clusters seems to be stable, increasing only from 60 (encompassing 93 counties) in 1998 to 61 (97 counties) in 2008. Of the original 1998 counties 72% were identified as logistics clusters 10 years later. However, the 2008 data results in 10 new clusters (while nine diminished in importance and disappeared from the listing). The most prominent of the "new" clusters is Miami. The figures also show an increase in the relative concentration of the logistics industry. In general, Location Quotient values are higher in 2008 than in 1998 (darker in Fig. 3 than in 7), as seen, for example, in Dallas, Chicago, LA, Louisville, Laredo, Houston, Seattle and Orlando.

The comparison also indicates that counties inside logistic clusters seem to be increasing in size over time as compared to the rest of counties. Testing of the effect of clustering on logistics employment growth was based on the ratio between the change in logistics employment and the change in total employment (logistics employment growth rate/total employment growth rate), thus normalizing for the employment growth in the economy as a whole. This ratio was calculated in counties located inside and outside logistics clusters, and since data are not normally distributed the Mann–Whitney U test was used for comparison.

Fig. 4. Logistics clusters and free trade zones in the US.

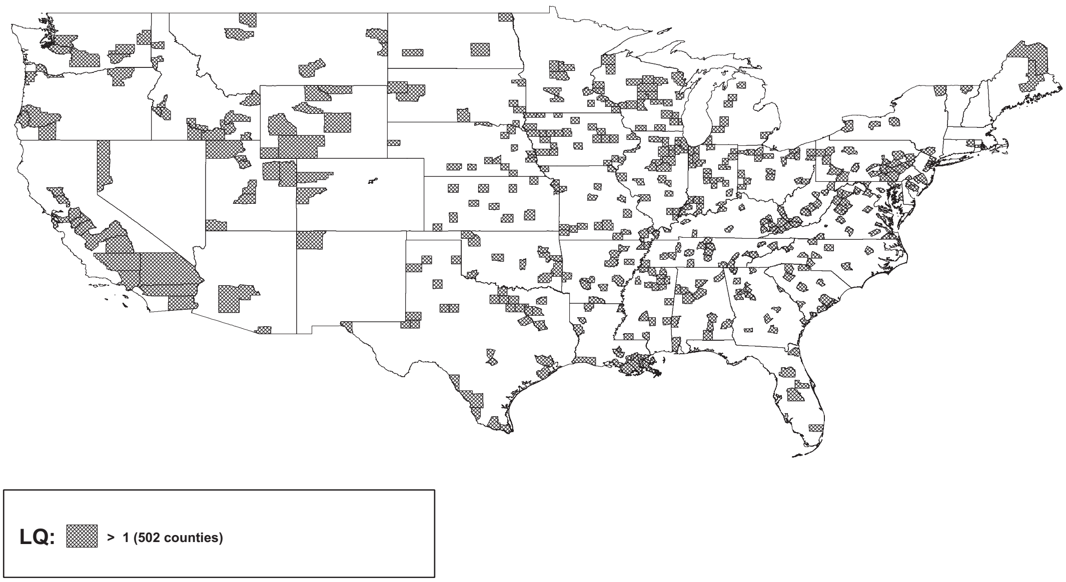

Fig. 5. Concentration of logistics activities using LQ, 2008.

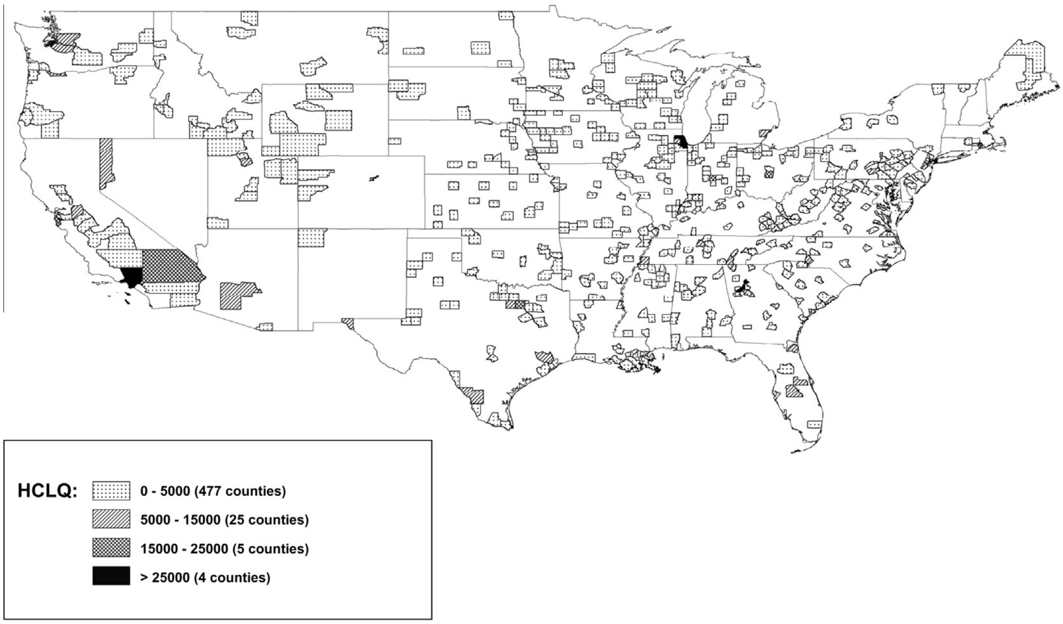

Fig. 6. Concentration of logistics activities using HCLQ, 2008.

The Mann–Whitney U test or Wilcoxon rank sum test is a non-parametric statistical hypothesis test used to assess whether one of two samples of independent observations tends to have larger values than the other (Corder and Foreman, 2009). The test is a non-parametric analog to the independent samples *t*-test (see e.g. Cooper and Schindler, 2003) and can be used when it cannot be assumed that the dependent variable is normally distributed (it is only assumed that the variable is ordinal).

Several studies have applied the Wilcoxon rank sum test (WRST) to compare the distribution of different responses or validate the effectiveness of a policy. In the field of transportation studies, Rosner et al. (2003) points that the WRST is frequently used when comparing measures of location because "…the underlying distributions are far from normal or not known in advance" (Rosner et al., 2003). Van Auken and Crum (1985) used it to study the effect of the motor carrier act of 1980, and Xenias and Whitmarsh (2013) used it to analyze the differences in opinion between two groups (experts and the British public) regarding the sustainability of the transportation network.

This approach is more convenient than other tests because "it is easier to enter ranks into a program for parametric analysis than it is to find or write a program for a nonparametric analysis" (Conover and Iman, 1981). When studying clustering

Fig. 7. US logistics clusters, 1998.

Table B1
Logistics sector definition. *Source*: U.S. Census Bureau

NAICS	Description
481112	Scheduled freight air transportation
481212	Nonscheduled chartered freight air transportation
481219	Other nonscheduled air transportation
483111	Deep sea freight transportation
483113	Coastal and great lakes freight transportation
483211	Inland water freight transportation
484110	General freight trucking, local
484121	General freight trucking, long-distance, truckload
484122	General freight trucking, long-distance, less than truckload
484220	Specialized freight (except used goods) trucking, local
484230	Specialized freight (except used goods) trucking, long-distance
488119	Other airport operations
488190	Other support activities for air transportation
488210	Support activities for rail transportation
488310	Port and harbor operations
488320	Marine cargo handling
488330	Navigational services to shipping
488390	Other support activities for water transportation
488410	Motor vehicle towing
488490	Other support activities for road transportation
488510	Freight transportation arrangement
488991	Packing and crating
488999	All other support activities for transportation
492110	Couriers and express delivery services
492210	Local messengers and local delivery
493110	General warehousing and storage
493190	Other warehousing and storage

effects, the use of parametric techniques tends to underestimate the *p*-values and reduce the range of the confidence interval, which is why nonparametric techniques are preferred over the *F*-tests and *t*-tests that are sensitive to the non-normality of the data. Sawilowsky (2005) claimed that it is a mistake to choose the *t*-test over the WRST when the interest is to test the shift in location parameters, because it can be non-robust. Even if normality assumptions are nearly met by the data, *t*-tests have a smaller power than the Wilcoxon rank sum test (De Winter and Dodou, 2010). When the data is non-normal its efficiency can exceed that of the *t* test by 100% (Meeter, 1968).

The null hypothesis was that there was no difference in the ratio of logistics employment growth to total employment growth between counties inside and outside logistics clusters, versus the alternative hypothesis that there was a difference:

$$H0: \left(\frac{\textit{logistics employment growth rate inside logistics clusters}}{\textit{total employment growth rate inside logistics clusters}}\right) = \left(\frac{\textit{logistics employment growth rate outside logistics clusters}}{\textit{total employment growth rate outside logistics clusters}}\right)$$

versus

$$H1: \left(\frac{\textit{logistics employment growth rate inside logistics clusters}}{\textit{total employment growth rate inside logistics clusters}}\right) \neq \left(\frac{\textit{logistics employment growth rate outside logistics clusters}}{\textit{total employment growth rate outside logistics clusters}}\right)$$

The results suggest that there is a statistically significant difference between the underlying distributions of employment growth inside and outside logistics clusters ($z = -5.962$, $p = 0.0000$). The employment growth inside logistics clusters was higher since the actual rank sums were higher than the expected rank sums under the null hypothesis. Appendix D presents the outputs of the statistical tests using STATA.

Due to the importance of external economics to the clustering phenomenon, an additional test examined the difference in the ratio between the change in logistics establishments and the change of total establishments (to account for changes in the whole economy) between counties located inside and outside logistics clusters (logistics establishments' growth rate/total establishments growth rate). The results show that the null hypothesis of a similar growth rate ($z = -2.896$, $p = 0.0038$) can be rejected, leading to a conclusion (with 99% confidence) that there has been a difference in growth. The number of establishments inside logistics clusters grew at a higher rate in counties located outside clusters because the actual rank sums were higher than the expected rank sums under the null hypothesis (see Appendix D).

These tests support the assertion that the growth of logistics operations, in terms of employment and establishments, was higher for counties located inside the identified clusters between 1998 and 2008, then for counties outside clusters. A comparison of Fig. 7 to Fig. 3 is in line with this finding. As mentioned above, the relative concentration of the logistics industry increased between 1998 and 2008 and in general – HCLQ values are higher in 2008. Some existing clusters seem to be expanding even to neighboring counties. That was the case, in particular, in Dallas, Atlanta and Allentown/Harrisburg (PA). For instance, in Atlanta, logistics operations were agglomerated in Chatham and Clay counties in 1998, and 10 years later they extended to three additional counties (Decatur, Franklin and Worth). In the Allentown/Harrisburg region the logistics industry was concentrated in York, Luzerne, Lehigh, Lancaster, Delaware and Berks counties in 2008, while this concentration was observed only in York in 1998. Naturally, the decline of logistics activities in some Mid-West areas may be a reflection of the decreasing manufacturing activities in the US heartland, while the increase in other areas is likely rooted in the increased cross country trade flows, and in particular, imports.

8. Conclusions and further research

Global supply chains are shaping the development and nature of the logistics industry. Globalization, naturally, results in flows over longer distances, underscoring the importance of efficient storage, transportation, consolidation, and transshipment activities. The agglomeration of logistics activities in clusters enhances the efficiency of global supply chains by reducing the cost and improving the service of the underlying transportation networks, making them more efficient and, in turn, enhancing globalization.

This paper reports evidence of increasing concentration of the US logistics industry in clusters, and these clusters seem to be growing over time. The statistical evidence of the growth trend of clustering is also supported by empirical evidence from interviews with private sector executives, government representatives, members of academia, and Chambers of Commerce conducted around the world. It seems that the presence of agglomeration economies is still an important factor for logistics firms' (and logistics functions') location decisions, since they allow firms to achieve lower transportation costs, better transportation service and higher flexibility.

Every method to measure concentration has limitations, and the combination approach presented in this paper is no exception, even though it overcomes many of the issues bedeviling existing methods. For example, while it seem to produce good results in the US context, it will be difficult to apply across the globe if the objective will be to make international comparisons. Furthermore, although one can imagine more sophisticated models, the lack of granular data and differences in regional sizes would limit their usefulness. Further research on more universal methodologies to measure clusters growth that allow comparative studies among logistics clusters with different sizes and locations will be useful.

Despite the growing literature on clusters, logistics clusters in particular have received scant attention. The work reported here raises a rich set of possibilities for future research, as logistics clusters in the US keep growing in size and number, and thus in economic relevance. These opportunities include understanding the connection between the formation of logistics clusters and regional economic development, studying how governments can enhance logistics clusters in their areas, and exploring particular benefits of employment in logistics clusters such as "upward mobility" which were mentioned in the interviews. These subjects may provide a significant contribution – especially to emerging markets – in terms of industrial policy.

Appendix A. Geographical Indexes for measuring spatial concentration/dispersion

Location Quotient (LQ)

$$LQ = \frac{E_{ig}/E_{in}}{E_{Tg}/E_{Tn}} \tag{A1}$$

where E_{ig} is employment in sector i in region g, E_{in} is employment in sector i in country n, E_{Tg} is total employment in region g, E_{Tn} is total employment in country n.

Horizontal Cluster Location Quotient (HCLQ)

$$HCLQ = E_{ig} - \widehat{E}_{ig} \tag{A2}$$

where E_{ig} is employment of sector i in region g, $\widehat{E}_{ig}$ is estimated employment of sector i in region g when LQ = 1.

Locational Gini Coefficient (LGC)

$$LGC = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}|x_i - x_j|}{2n(n-1)\mu} \tag{A3}$$

where x_i and x_j are LQs in each regions i and j respectively, μ is the mean of LQ of the reference area, usually the country, n is the number of regions.

Herfindahl–Hirschman Index (HHI)

$$HHI = \sum_{i=1}^{n}(s_i - x_i)^2 \tag{A4}$$

where s_i is the industrial employment share in region i, x_i is the total employment share in region i.

The Ellison–Glaeser Index (EGGCI)

$$EGGCI = \frac{\sum_{i=1}^{n}(s_i - x_i)^2 - (1 - \sum_{i=1}^{n}x_i^2)\sum_{j=1}^{n}z_j^2}{(1 - \sum_{i=1}^{n}x_i^2)(1 - \sum_{j=1}^{n}z_j^2)} \tag{A5}$$

where s_i is the industrial employment share in region i, x_i is the total employment share in region i, z_i is the market share of each individual firm in region j.

Appendix B. Data source

See Table B1.

Appendix C. Brief description of the seven largest logistics clusters in the US

- Southern California's logistics cluster is the largest in the country. The two largest U.S. ports, Los Angeles and Long Beach, are located right next to each other and in total account for approximately 35% of the maritime container traffic in and out of the US. Its location on the Pacific Ocean with access to rail and road infrastructure and large commercial and logistics facilities make this cluster the largest in the nation (Feemster et al., 2011).
- Chicago is a major industrial center and one of the world's leading shipping and distribution hubs. It is the focal point of all US railroads. In addition, Chicago's trading tradition, access to the Great Lake routes inland waterways, connectivity to major highways, four airports and large logistics parks (such as Elwood, Joliet, Logistics Park Chicago) make it an important logistics hub (Citydata.com).
- The operations of the Port Authority of New York and New Jersey include the world's busiest airport system and marine terminals and ports (Port Authority of New York and New Jersey, 2010). The area is well connected to the rest of the country by several interstate highways and railroad (CSX and Norfolk Southern).
- Hartsfield–Jackson Atlanta International Airport, the busiest airport in the world by passenger traffic, also has significant cargo activity (Rosenberg, 2011). The area is served by the CSX and Norfolk Southern Railroads, which allow for intermodal capabilities important for both container and bulk distribution.
- Because of its natural landlocked harbor, San Francisco has been a major trade and shipping center throughout its history. Today, with Oakland and several other smaller ports, as well as its airports, the Bay area handles a significant share of West Coast trade. The port of San Francisco offers storage and handling facilities for a wide variety of containers.
- The core of the Dallas cluster is the Dallas–Fort Worth International Airport, whose cargo shipments tripled in the last 10 years. Besides air operations, the presence of interstate highways and railroad connections make the cluster a leading distribution center for the Southwest.
- Miami International Airport is a major trade hub and serves as the principal commercial distribution center between North and South America (Miami-Dade Aviation Department, 2011). It has highway and rail connection. Two railway systems, Florida Eastern Railroad and Tri-Rail connect Miami by rail to the CSX and Norfolk Southern.

Appendix D. Two-sample Wilcoxon rank-sum (Mann–Whitney) test outputs

```
. *------------------------------------------------------------------------------------------
. * Wilcoxon-Mann-Whitney test for Logistics Clusters (our method)
. *------------------------------------------------------------------------------------------


- Two-sample Wilcoxon rank-sum (Mann-Whitney) test for employment (X)

       LC |      obs    rank sum    expected
-------------+---------------------------------
     0.00 |     2998   4592623.5     4642452
     1.00 |       97    198436.5      148608
-------------+---------------------------------
   combined |     3095     4791060     4791060

unadjusted variance    74279232
adjustment for ties  -4427564.7
                   ----------
adjusted variance      69851667

Ho: X(LC=0.00) = X(LC==1.00)
            z =  -5.962
   Prob > |z| =   0.0000


- Two-sample Wilcoxon rank-sum (Mann-Whitney) test for establishments (X')

       LC |      obs    rank sum    expected
-------------+---------------------------------
     0.00 |     2999   4617504.5     4642452
     1.00 |       96    173555.5      148608
-------------+---------------------------------
   combined |     3095     4791060     4791060

unadjusted variance    74279232
adjustment for ties  -88479.234
                   ----------
adjusted variance      74190753

Ho: X'(LC==0.00) = X'(LC==1.00)
            z =  -2.896
   Prob > |z| =   0.0038
```

```
. *------------------------------------------------------------------------------
. * Wilcoxon-Mann-Whitney test for Location Quotient
. *------------------------------------------------------------------------------


Two-sample Wilcoxon rank-sum (Mann-Whitney) test for employment (X)

       LQ |      obs    rank sum    expected
-------------+---------------------------------
     0.00 |     2593     3874656     4013964
     1.00 |      502      916404      777096
-------------+---------------------------------
   combined |     3095     4791060     4791060

unadjusted variance   3.358e+08
adjustment for ties   -20018128
                  ----------
adjusted variance     3.158e+08

Ho: X(LQ==0.00) = X(LQ==1.00)
           z =  -7.839
   Prob > |z| =   0.0000

.         ranksum y1, by(lq08)


Two-sample Wilcoxon rank-sum (Mann-Whitney) test for establishments (X')

       LQ |      obs    rank sum    expected
-------------+---------------------------------
     0.00 |     2593     4002621     4013964
     1.00 |      502      788439      777096
-------------+---------------------------------
   combined |     3095     4791060     4791060

unadjusted variance   3.358e+08
adjustment for ties  -400036.75
                  ----------
adjusted variance     3.354e+08

Ho: X'(LQ==0.00) = X'(LQ==1.00)
           z =  -0.619
   Prob > |z| =   0.5357
```

```
. *-----------------------------------------------------------------------------------------------------
. * Wilcoxon-Mann-Whitney test for Horizontal Clustering Location Quotient
. *-----------------------------------------------------------------------------------------------------


Two-sample Wilcoxon rank-sum (Mann-Whitney) test for employment (X)

     HCLQ |      obs    rank sum    expected
-------------+---------------------------------
       0.00 |     2584     3862405     4000032
       1.00 |      511      928655      791028
-------------+---------------------------------
   combined |     3095     4791060     4791060

unadjusted variance   3.407e+08
adjustment for ties   -20306292
                      ----------
adjusted variance     3.204e+08

Ho: X(HCLQ==0.00) = X(HCLQ==1.00)
             z =  -7.689
    Prob > |z| =   0.0000


Two-sample Wilcoxon rank-sum (Mann-Whitney) test for establishments (X')

     HCLQ |      obs    rank sum    expected
-------------+---------------------------------
       0.00 |     2584     3988631     4000032
       1.00 |      511      802429      791028
-------------+---------------------------------
   combined |     3095     4791060     4791060

unadjusted variance   3.407e+08
adjustment for ties  -405795.35
                      ----------
adjusted variance     3.403e+08

Ho: X'(HCLQ==-0.00) = X'(HCLQ==1.00)
             z =  -0.618
    Prob > |z| =   0.5365
```

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