The Geography of suppliers and retailers

Abstract

In the last decades, supply chains have increasingly transcended national boundaries developing into global supply chains. Along with the many opportunities arising from international sourcing and the extended commercial presence over the world, the management of a globally dispersed supply chain is highly complex. A key issue to consider when dealing with the global supply chain design is the location of facilities, not only with respect to firms' owned facilities but also the supply and distribution side as factors that affect supply chain complexity and operational performance. This paper sets out a methodological framework to characterize the geographical configuration of a firm's suppliers and retailer networks. Quantitative indexes of network spatial concentration and relative proximity measures based on a nonparametric kernel density estimator are developed to identify both intra- and inter-firm patterns between the supply and point of sales' distributions. The method is first described by means of a series of theoretical-illustrative examples and exemplified by analyzing the geographical dispersion of four practical cases from the fashion-textile industry (i.e., Adidas, Benetton, C&A, and Puma). Subsequently, managerial implications and potential use of the metrics are discussed, showing how the proposed approach can support researchers and practitioners to improve supply chain location decisions and logistic integration, and evaluate changes in either the purchasing or distribution strategy.

Keywords: supply chain geography, spatial concentration, geographical proximity

1. Introduction

In the last decades, industries have been characterized by a growing supply chain expansion, particularly toward international locations (Dornier *et al.*, 2008; Brennan *et al.*, 2015; Schotter *et al.*, 2017).

The design of a proper supply network is a fundamental part of the business of any company, and in particular for the so-called "extended global enterprises" (Romano, 2009)—that is, single multinational organizations with a globally dispersed supply chain (Danese and Romano, 2013). International manufacturing sources leading to the possibility of leveraging benefits like cost reduction, conforming to custom duties, and trade concessions are only some of the reasons why companies have extended their supply chain (Cagliano *et al.*, 2009; Ibrahim *et al.*, 2015; Ashby, 2016). At the same time, companies have expanded their commercial presence over the world to reach a global market. Globalization and advances in ICT have modified how companies operate, moving from independent business units focused on specific geographic regions to complex organizations with globally dispersed functional units and international distribution channels to gain access to overseas markets, capitalize on greater proximity to customers, and improve reliability (Frear *et al.*, 1992; Mudambi, 2008; Rugman *et al.*, 2011; Stanczyk *et al.*, 2017). The ongoing emphasis toward international and cross border operations has led to the development of global sourcing, global manufacturing, and global distribution strategies that are typically subsumed in the concept of global supply chains (Prasad *et al.*, 2000).

The literature has highlighted that companies can organize their global supply chain and structure operations in very different ways (Meixell and Gargeya, 2005; Alexander T.C. Onstein *et al.*, 2019, Cagliano *et al.*, 2009; Sabri *et al.*, 2016). Among the relevant factors, the fit between the supply chain structure and the business process configuration is found to affect performance significantly (Fisher, 1997; Ben Naylor *et al.*, 1999; Choi and Hong, 2002; Persson and Olhager, 2002; Martínez-Olvera, 2008; Romano, 2009; Alexander T. C Onstein *et al.*, 2019). In an effort to properly design the supply network, attention has been primarily devoted to the design of facilities (Meixell and Gargeya, 2005; Govindan *et al.*, 2017), their coordination in an uncertain environment (Vidal and Goetschalckx, 1997; Goetschalckx *et al.*, 2002; Cohen and Mallik, 2009), and the physical interconnection of the different elements (Vidal and Goetschalckx, 2001; Amaral and Kuettner, 2008).

A topic that several works have recognized as pivotal in supply network design is the geographical dimension of the supply chain (Stock *et al.*, 2000; Choi and Hong, 2002; Rodrigue, 2012; Kchaou Boujelben and Boulaksil, 2018). The physical location is a key decision managers have to consider at different levels, from the distribution side (Rodrigue, 2012; Gadde and Jonsson, 2018), to the manufacturing plants (Meijboom and Vos, 1997, 2004; Shi and Gregory, 1998; Meixell and Gargeya, 2005), and the suppliers (Cagliano *et al.*, 2009; Munson and Rosenblatt, 2009; Wu and Barnes, 2011; Sureeyatanapas *et al.*, 2018). In particular, the geographical dimension becomes even more relevant when key changes arise in the network, such as the relocation of production activities (Fratocchi *et al.*, 2014; Di Mauro *et al.*, 2018) and the restructuring of suppliers' portfolios (Masi *et al.*, 2013; Pihlajamaa *et al.*, 2017), as well as the implementation of new managerial paradigms such as lean management (Christopher and Towill, 2000; Cagliano *et al.*, 2004), postponement (Van Hoek *et al.*, 1999), and outsourcing (Fredriksson *et al.*, 2010).

Besides the extensive literature that addresses the importance of the facilities' location, limited information is found on how to properly represent the geographical distribution of a supply network. To date, the literature has not systematically addressed this problem, and the few contributions in this direction provide measures that are too simplistic to be relevant to companies' decision-making, and are, in some cases, misleading or even biased (e.g., Cagliano *et al*., 2009; Choi and Hong, 2002; Lintukangas *et al.*, 2009; Olhager *et al*., 2015; Stock *et al*., 2000).

This work contributes to both scientific and managerial knowledge by providing a methodology with which to investigate the geographical distribution of a supply network and evaluate the geographical characteristics of a supply chain. To explain the proposed approach, we focus on a prototypical two-tier supply chain consisting of an upstream and downstream level to represent anything coming into the company from raw materials to finished products, and the set of storage facilities and retailers used to deliver the finished product to customers, respectively.

The remainder of this paper is structured as follows: Section 2 discusses the relevant literature on network design. A discussion about current measures of geographical dispersion is presented, along with their main uses and limitations. In Section 3, the proposed measure is described and exemplified, first by means of a series of theoretical-illustrative examples (Section 4), and then by analyzing the geographical dispersion of four actual cases belonging to the fashion-textile industry (Section 5). A detailed discussion of the implications and applications of the provided measures is presented in Section 6. Finally, conclusions are drawn, and future developments are discussed in Section 7.

2. Theoretical Background

2.1 Network design

Network design literature dealing with global production and distribution channels has developed quite extensively among a wide range of topics (Olhager *et al.*, 2015). Since the first contributions, scholars have focused primarily on the coordinated planning of production and distribution systems throughout the supply chain (Thomas and Griffin, 1996; Vidal and Goetschalckx, 1997; Goetschalckx *et al.*, 2002; Cohen and Mallik, 2009). The main attention of the literature in this area has been to propose models for evaluating the optimal design of supply chains under different conditions, typically considering the perspective of the manufacturers of goods but also including additional supply chain actors (Rao and Young, 1994; Bhatnagar and Viswanathan, 2000; Meijboom and Voordijk, 2003; Woxenius, 2006). In detail, specific attention has been paid to integrating the manufacturing (Katayama, 1999; Sousa *et al.*, 2008; Bowling *et al.*, 2011), distribution (Manzini and Bindi, 2009; Georgiadis *et al.*, 2011; Guericke *et al.*, 2012), supply (Amaral and Kuettner, 2008; Bashiri *et al.*, 2012; Carle *et al.*, 2012), and transportation components (Amaral and Kuettner, 2008; Cintron *et al.*, 2010; Carle *et al.*, 2012; Sadjady and Davoudpour, 2012).

Global supply chains are characterized by a diffused geographical distribution of production, distribution, and consumption, which tend to make them more difficult to manage than domestic ones. Geographical distances increase transportation costs and complicate decisions in inventory management and production planning. On the other hand, globally dispersed demand characterized

by different socio-economic characteristics and market needs complicates the development of effective demand forecasting and distribution strategies. In general, it is not easy for companies with distributed units to establish a relationship between the center and the periphery; therefore, the control and ownership of supply, manufacturing, and distribution processes at an appropriate geographical level need to be addressed systematically (Hughes *et al.*, 1998). To cope with this issue, according to Trent and Monczka (2003), a potential strategy that companies may apply is to ''think global but act local'' in an effort to properly link the geographical distribution of the supply and manufacturing networks with the market geographical dispersion.

Risk and resilience perspectives in the design of the network also influence location decisions (Kumar and Gregory, 2013). Attention is paid to designing the structure of networks considering operational risks and including those that are geographically related, such as socio-political or extreme natural phenomena (Brennan *et al.*, 2015). For this reason, many authors have emphasized the need for designing global supply chains with high levels of flexibility (Frohlich and Westbrook, 2002; Heikkilä, 2002; Godsell *et al.*, 2006), distinguished by "dynamic flexibility" and "structural flexibility." Dynamic flexibility is achieved by increasing the agility of the company's existing factories, suppliers, and its extended supply chains (Christopher and Towill, 2000), while structural flexibility refers to the ease of re-configuring the global supply network in response to changes in the environment and specific disruptions (Christopher and Holweg, 2011).

2.2 Geographic considerations in network design

One major aspect to be considered in the supply chain design and location decisions is the geographical perspective and, in particular, the spatial distribution of suppliers and retailers, and their relative location compared to one another.

Concerning the geographical perspective on production and distribution networks, Kchaou Boujelben and Boulaksil (2018) provide a comprehensive literature review of international facility location models. This stream of the literature has been widely debated, mostly focusing on the design of a company's own network, rather than considering its suppliers' base. Using data collected from the International Manufacturing Strategy Survey (IMSS), Cagliano *et al.* (2009) analyze how manufacturing companies supply and distribute globally. In detail, they investigate network configurations according to the portion of purchases and sales done outside the continent where the plant is located, leading to the identification of four main configurations—local supply chain, global seller, global purchaser, and global supply chain. The longitudinal analysis conducted identifies a general trend toward a growing internationalization of supply chains. Other work has concentrated on how geographical factors affect the dynamics of global manufacturing networks (Hesse and Rodrigue, 2004; Rodrigue, 2012). Rodrigue (2012) analyses the concepts of the geography of production, distribution, and consumption, providing evidence that using multiple perspectives (suppliers, 3PLs, and customers) gives insights into how different types of companies structure their network.

In modeling the role of the geographical dimension in the design of supply networks, studies have proposed three main strongly related concepts: *geographical proximity*, *spatial complexity*, and *geographic dispersion*.

The literature has addressed the concept of *geographical proximity* (i.e., the relative distance between the different parts of a network) with respect to different elements: markets (Johansson *et al*., 2018), manufacturing activities (Kinkel and Maloca, 2009; Tate, 2014), suppliers (Wu and Barnes, 2011; Sureeyatanapas *et al*., 2018), and R&D activities (Bailey and De Propris, 2014).

Similarly, Choi and Hong (2002) elaborate on the concept of *spatial complexity*, which looks at the number of locations from which a company purchases and takes into account the average distance between two firms engaged in buying and supplying. The authors discuss the importance of this concept in conjunction with vertical complexity (i.e., the number of tiers in the supply chain) and the horizontal complexity (i.e., the number of suppliers in each tier).

The literature also introduces the concept of *geographic dispersion* as the extent to which the elements in a firm's supply chain are located across a wide range of geographic regions (Stock, 2000). Haleem *et al*. (2017) evaluate geographical dispersion (referred to as sourcing geography) as the percentage of sourcing done outside of the continent where the plant is located. Cagliano *et al*. (2009) advance the assessment of geographical dispersion by considering two dimensions: global sourcing—the percentage of sourcing done outside of the continent where the plant is located, and global distribution—the percentage of sales done outside of the continent where the plant is located. Stock *et al.* (2000) compute the degree of dispersion of production facilities, suppliers, distributors, and customers as the percentage of operations established in four macro-regions (i.e., North America, Europe, Asia, and others).

Geographic dispersion significantly impacts the performance of an extended network as well as the decision-making authority and coordination within the firm. In this regard, Stock (2000) provides evidence that the fit between logistic integration and geographic dispersion is strongly related to both operation and functional performance. Lorentz *et al.*, (2016) investigate the effects of the complexity of the supply base due to geographic dispersion and how this affects supply chain risks. Their results suggest that the geographic dispersion of sales and purchasing negatively affects supply chain performance. Thus, decisions regarding the localization of suppliers' localization must be taken with great care. An increase in spatial complexity is generally responsible for modifications of companies' performance. For example, the throughput time is increased when spatial complexity increases (Stock *et al.*, 2000; Danese *et al.*, 2006). Similarly, logistical complexity increases as companies move from centralized, vertically integrated, single-site manufacturing facilities to geographically dispersed networks of resources that collectively create value for the customer (Romano, 2009). This typically creates a trade-off between different operational performance: for example, companies increase the complexity of the supply chain to reduce labor costs but at the same time have to withstand longer processing times and higher logistic costs (Onstein *et al.*, 2019).

As different works in the current literature suggest (Stock *et al.*, 2000; Cagliano *et al.*, 2009; Lintukangas *et al.*, 2009), companies can decide to concentrate the localization of their supply network in a limited geographical span. This typically has some positive effects, such as a simpler supply network, inventory, logistics, transportation cost reductions, and the possibility of gaining higher localization advantages that characterize the area where suppliers are concentrated (e.g., low manufacturing costs). However, having a more distributed supply network can allow companies to better react to local market specificities and reduce lead times and inventory costs; companies can also become more reactive to customer needs and implement just-in-time approaches.

At the same time, companies face a similar decisional problem concerning the localization of their distribution network. On the one hand, companies can decide to have a very focused distribution into concentrated geographical areas to gain specific advantages, such as more efficient marketing and distribution investments, as distribution facilities are simpler to organize and flows are more controlled. On the other hand, companies can decide to distribute in different regions by trying to access customers globally; this has the advantages of increasing the span of their market presence and diversifying commercial risks.

Considering a simplified two-tier framework made of single supply and retail layers intended as upstream and downstream networks, the two decisions can lead to four exemplifying configurations (Figure 1).

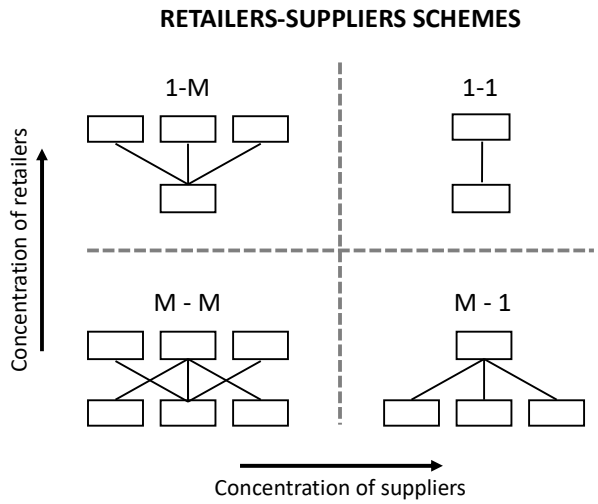

Figure 1. Retailers-suppliers schemes.

1. *1-to-Multi (1-M)*: A first group comprises companies that serve a dispersed set of retailers by suppliers concentrated on a few specific areas.
2. *1-to-1 (1-1)*: A second group comprises companies that serve concentrated markets by suppliers concentrated on a few specific areas.
3. *Multi-to-1 (M-1)*: A third group comprises companies that serve concentrated markets by suppliers concentrated on a specific area.
4. *Multi-to-Multi (M-M)*: A fourth group comprises companies that serve a dispersed set of retailers by means of a set of widely dispersed suppliers.

The literature has typically considered geographical dispersion by focusing either on the supply side of the network (Meixell and Gargeya, 2005; Wu and Barnes, 2011; Haleem *et al.*, 2017) or on the distribution side of the network (Johansson *et al.*, 2018), while only a few contributions have considered the two dimensions jointly (Stock *et al.*, 2000; Cagliano *et al.*, 2009; Lintukangas *et al.*, 2009). Moreover, most of the work focusing on such topics has relied on simplistic measures to assess the degree of network geographic dispersion. Several contributions (e.g., Stock *et al.*, 2000; Cagliano *et al.*, 2009; Lintukangas *et al.*, 2009; Lorentz *et al.*, 2016) have evaluated the network geographical dispersion by simply looking at the relative number of suppliers' or retailers' activities performed in a certain region (i.e., country or continent). This approach attempts to represent the

global large-scale network distribution without providing any information on the distribution within the same region, often making this measure too simplistic and unreliable. In fact, at a continental level (e.g., Cagliano *et al*. 2009; Lorentz *et al*., 2016) these evaluations can be biased as continents are extremely wide geographical entities and different nodes can be extremely far from each other, although belonging to the same continent.

Other works have evaluated the dispersion in the supply network by considering the average distance between the focal company and the different suppliers (e.g., Choi and Hong, 2002).[1] This approach works perfectly when the focus is the distribution of a network relative to a single node (i.e., the focal company); however, when the network comprises many different nodes this evaluation becomes too simplistic. Moreover, the average distance is not able to identify the spatial correlation between different nodes.

In light of these limitations, our study proposes a method to characterize the geographical configuration of both supply and retail networks that goes beyond the pitfalls of the most traditional measures used in the literature.

[1] See Meixell and Gargeya, 2005 and Olhager *et al*., 2015, for two comprehensive literature reviews of papers that adopted similar approaches.

3. Proposed Methodology

3.1 Spatial concentration measures

While understanding the geography of supply chains might have important implications at a managerial level, it has remained a relatively unexplored topic in the literature. Existing contributions have generally considered measures that cannot accurately capture the geographical/spatial patterns of suppliers' and retailers' distribution across areas.

When studying the location of entities (such as activities and events) and their interdependence, scholars have implemented spatial measures to detect phenomena of concentration and dispersion across territories. In this context, concentration metrics adopted to deal with the spatial arrangement of data have played a major role, gaining popularity in different sectors and applications, such as the study of the location of events (Flahaut *et al.*, 2003, Coppini *et al.*, 2011, Lublinski, 2003, Kanaroglou *et al.*, 2013) and economic activities (Ellison *et al.*, 1997, Mariotti *et al.*, 2010, Guimarães *et al.*, 2011), or the analysis of the structure of logistics agglomeration (Rivera *et al.*, 2014).

Regarding the aim of quantifying the degree of spatial concentration, two issues must be considered: the tendency of entities to locate close to each other (i.e., spatial correlation) and their concentration.

Traditional a-spatial concentration measures—such as the Herfindahl, Gini, and entropy indices—account for data intensity but overlook the entities' relative positioning, therefore being inappropriate to characterize spatial patterns. On the other hand, pure spatial correlation measure looks at the relationship between "close" spatial units, evaluating the extent to which observations of a certain phenomenon (e.g., the locations of suppliers is a network) are distributed over a certain area, independently or not. Given a set containing n geographical units, spatial correlation refers to the relationship between some variables observed in each of the n localities and a measure of proximity defined for all $n(n - 1)$ pairs chosen from the considered set (Hubert *et al.*, 1981). The most used global index of spatial correlation is the Moran's Index (Moran, 1950) based on the principle that spatial correlation is higher if entities that are closer to each other feature similar values. The global formulation of the index is widely appreciated for its general stability and flexibility, which yield a synthetic measure that summarizes the whole study area. However, this does not hold when the setting is not homogenous and fails to capture the presence of local clusters properly (Anselin, 1995). To overcome this limitation, a local formulation of the Moran's Index, also referred to as local indicators of spatial association (LISA), can be used. The local Moran's Index follows from the decomposition of the global Moran's Index at each spatial unit, highlighting the extent to which each spatial unit belongs to a local cluster or, is more likely an outlier.

Studies in the spatial literature (e.g., Arbia, 2005; Arbia and Piras, 2009; Guillain and Le Gallo, 2010; Guimarães *et al.*, 2011) argue that the most appropriate way to analyze the spatial concentration of entities over space is to couple a-spatial concentration with spatial correlation measures. On the one hand, a-spatial concentration measures do not explicitly account for the spatial distribution of events (e.g., where suppliers or customers are physically located). On the other hand, as suggested by Arpia (2001), spatial correlation metrics are not sufficient to properly identify the presence of agglomeration clusters (e.g., the presence of local concentrations of suppliers or customers).

The next section describes the methods we propose to characterize the configuration of supplier and retailer networks, with the idea of combining both spatial correlation and a-spatial concentration measures to grasp their configuration over space and the presence of potential agglomerates, or clusters. In particular, we rely on empirical distributions to derive quantitative measures of network spatial concentration and relative proximity to be used in the identification of both intra/inter-firm patterns (see Figure 1) between the supply and retailer distributions.

3.2 Kernel density estimation

To systematically represent the spatial distribution of retailers and suppliers, we adopt a nonparametric approach based on *kernel density estimation* that evaluates the local probability of plant location over space (e.g., Flahaut *et al*., 2003). In detail, the use of multivariate kernel density seeks to model the probability density function underlying the geographic distributions of recorded observations. Once estimated, this allows approximating the cumulative probabilities over a certain area and making an effective comparison of different sample distributions. The greatest advantage of this approach follows from the normalization of each firm's networks over the same continuous spatial grid. In this way, different networks can effectively be compared regarding their spatial correlation and concentration. We rely on a multivariate *Gaussian kernel estimator.* Since coordinates lie on a spherical surface, distance is computed according to the haversine distance metric, whereby the selection of the bandwidth (i.e., the smoothing parameter applied to the data) is based on the generalization of Scott's rule (Härdle *et al.*, 2004). In symbols:

$$f_H(\boldsymbol{x}) = \frac{1}{n}\sum_{i=1}^{n} 2\pi^{-\frac{d}{2}}|\boldsymbol{H}|^{-\frac{1}{2}}e^{-\frac{1}{2}(\boldsymbol{x}-\boldsymbol{x_i})^T\boldsymbol{H}^{-1}(\boldsymbol{x}-\boldsymbol{x_i})}, \tag{1}$$

where

- $\boldsymbol{x_i} = (lat_i,\ lng_i)\ i\ =\ 1, 2, \dots,\ n$ are vectors representing the GPS coordinates of points in the samples
- $d = hav(\boldsymbol{x} - \boldsymbol{x_i})$ is the great-circle distance between two points on a sphere.
- $\boldsymbol{H}$ = bandwidth (2X2 matrix).

The application of this measure considers the estimation of kernel density functions for each firm's retail and supply physical locations. This study considers each facility—both suppliers and retailers—to have equal weight. However, the framework can be easily adapted to account for the relevance of each supplier/retailer in their respective networks.[2]

With the aim of discretization, we set the grid resolution equal to 2.5 units of latitude and longitude, leading to about 3200 rectangles, indexed by i. Let P_{ik}^{sup} and P_{ik}^{ret} then be the estimated cumulative probability of suppliers and retailers for firm $k \in K$ over rectangle $i \in I$. These values sum up to 1 and represent the cumulative probability for firm k to locate one retailer/supplier in a

[2] The consideration of facilities' size, or any other weighting scheme, can be achieved by means of a weighted kernel density estimator (wKDE).

given area. When multiplied by the totals, the resulting quantity provides the expected number of firm k's retailers and suppliers, respectively. Figures 2a and 2b show the overall empirical distributions of retail and supply physical locations and their approximation by KDE considering the case of 17 multinationals in the fashion-textile industry. While both highlight the concentration of sales markets in Europe and North America, and supply in Southeast Asia, the Middle East, and South America, the kernel representation gives more rigorous information about the density of such populations, highlighting the rise of relevant agglomerates on a macro regional scale and leveling out differences on the micro scale.

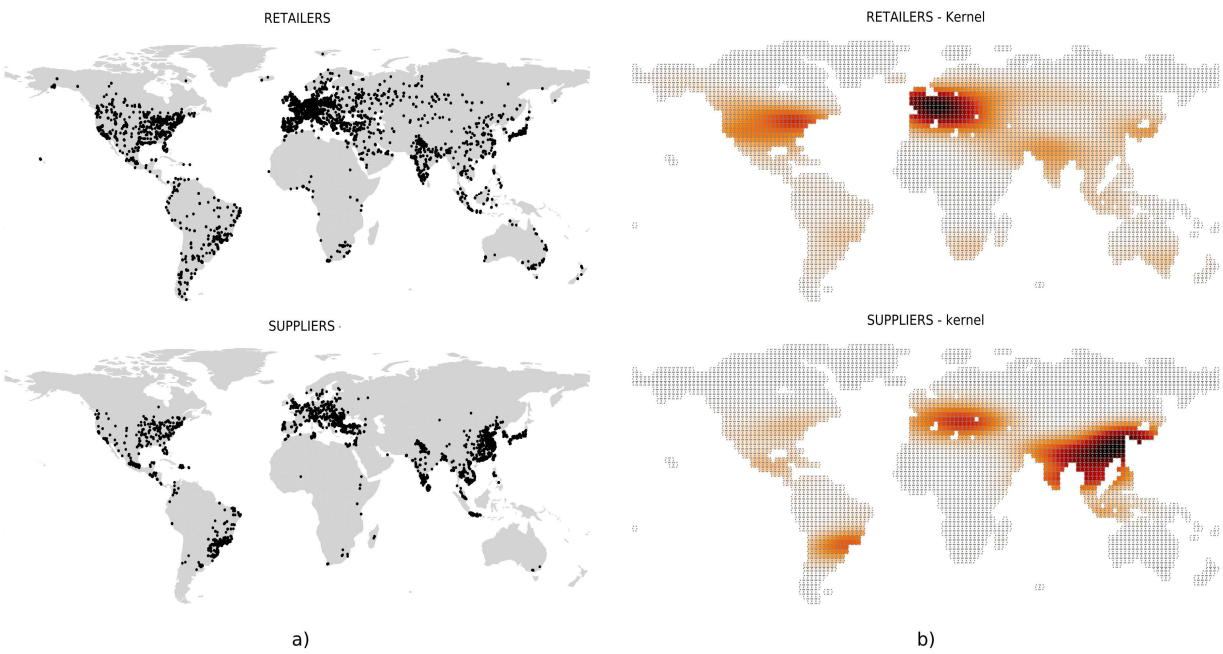

Figure 2. Empirical (a) and kernel (b) distribution of retailers and suppliers

3.3 Indicators

In the characterization of retailers and suppliers' networks regarding the proposed framework (Section 2), we develop two synthetic indicators: the *Kernel-Herfindahl Hirschman Index (K-HHI)* and the *Kernel-Relative Proximity Index (K-RPI)*. The K-HHI aims at capturing the degree of networks' spatial concentration, while the K-RPI quantifies the distance between the suppliers and retailers' networks as important features characterizing the configuration of supply/retailer networks.

K-HHI

K-HHI quantifies the degree of spatial concentration of network t for firm k by taking the HHI index over the related kernel distribution:

$$K - HHI_k^t = \sum_{i \in I} {P_{ik}^t}^2, \tag{2}$$

In general, the HHI is taken as a suitable measure for a-spatial concentration (e.g., see the "raw concentration index" in Ellison and Glaeser (1997) and Guimarães *et al.* (2007)). Using kernel estimates enriches the index by accounting for the spatial distribution and avoids major shortcomings of the a-spatial HHI when applied to data points or large predetermined areas (*See Section 4*). Therefore, the HHI computed on the tight grid of kernel estimates serves the purpose of representing the tendency of a network to be highly or poorly spatially concentrated around one or a few centroids. To make this clear, let us assume a simple kernel density estimator that propagates uniformly over neighboring cells and consider two different situations where two facilities are far from each other (a) or closer to each other (b), respectively (see Figure 3). The K-HHI would be equal to $0.2 = (2 * 0.3^2 + 8 * 0.05^2)$ and $0.205 = (2 * 0.3^2 + 6 * 0.05^2 + 0.1^2)$ for scenarios a) and b), respectively. Therefore, the higher value in scenario b) compared to scenario a) suggests that the described network is characterized by a higher spatial concentration. As kernel estimates are obtained by adding up the various contributions from the propagation of each data point (i.e., each facility), spatial units that lie in spatial clusters (or agglomerations) get higher values.[3] Taking the square of these values and adding them up provides a synthetic measure for the entire network that captures the presence of spatial agglomerates, or clusters.

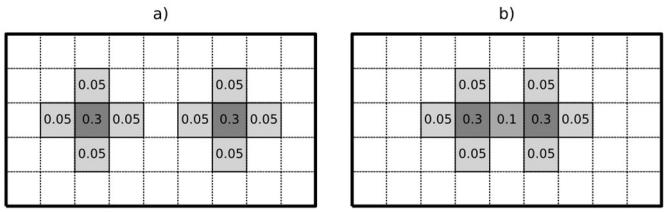

Figure 3. Illustration of the K-HHI measure

Relative proximity

Relative proximity refers to how close two different networks are. In our case, we are interested in evaluating the degree of physical proximity between suppliers and retailers, considering their spatial patterns. This is a relevant feature to consider as it is likely to affect the transportation cost and level of service. Given this aim, we introduce the following indicator:

$$K - RPI_k = \frac{\sum_{i \in I} \sum_{j \in I} z_{ij} P_i^{sup} P_j^{ret}}{\sum_{i \in I} \sum_{j \in I} z_{ij}}, \tag{3}$$

where z_{ij} is a decreasing monotonic distance-based weighting function. Therefore, the higher the indicator, the closer the two networks are. Different decay functions would, respectively, smooth ($e.g. w_{i,j} = 1/d^2$) or emphasize ($w_{i,j} = 1/\ln(d)$) farther connections. The use of kernel estimates has practical advantages for the specific goal of relating the suppliers' and retailers' networks. In particular, it allows explicit consideration of the level of spatial aggregation to reflect the logistic

[3] By doing so, the k-HHI index provides an alternative approach to the ones already used in the literature (e.g., based on spill-over effects, see Mariotti *et al.*, 2010) to account for spatial concentration among plants that belong to different grid units.

intuition according to which it is more efficient to serve concentrated supply networks (for instance, see cases B5 and B6 in Section 4).

In this study, the k-RPI is used to consistently represent the distance between networks considering their level of spatial concentration. In practice, it can be generally extended to represent the level of *direct connectivity* between supplier and retailer networks under various assumptions. To this aim, the proper choice of the smoothing function should be guided by practical considerations that account for the actual logistics costs or other factors relevant to the given situation. For instance, the z_{ij} can be replaced by a generalized cost of transport from i to j to reflect the actual cost of transportation or different distribution strategies more accurately (e.g., consider minimum paths only).

4. Illustrative Example

To understand the interpretation of the described indicators, this section presents simple illustrative examples highlighting some desirable properties of the k-HHI and k-RPI indexes, and their consistency in representing the degree of network' concentration and relative proximity.

Figure 4 contains eight simple cases (A1–A8) with different spatial configurations of a simple network of four (A1–A5), eight (A6) and 12 facilities (A7–A8), respectively. The gray-shadowed areas represent the areas where facilities are located. Table 1 provides the results of three different indexes: c-HHI, k-HHI, and Moran's Index. The c-HHI represents the HHI based on a delimited set of spatial units (marked lines) to illustrate the limits of simplistic approaches that rely on the count of facilities within predetermined areas (e.g., continents or macro areas) (Stock *et al.*, 2000). In other words, the c-HHI is calculated by taking the HHI on the percentage of facilities belonging to the different areas, similar to what is done by previous contributions in the literature (Hesse and Rodrigue, 2004; Cagliano *et al.*, 2009; Rodrigue, 2012; Kchaou Boujelben and Boulaksil, 2018). The c-HHI gives a higher score to case A8 (0.722) compared to A1 (0.375), highlighting the fact that in A8, ten locations out of 12 are in the same area, while in A1 they all belong to different areas. However, the same indicator gives the same value to A1 and A3. Unless the definition of areas is meaningful for the analysis, the use of c-HHI to characterize the degree of spatial agglomeration has a major limitation as it fails to consider closer facilities that belong to different macro areas (e.g., A1), as well as spatial dispersion within a macro area (e.g., A4, A3).

The k-HHI values are normalized regarding the most concentrated case (A1) to facilitate comparison. Throughout all the cases, the k-HHI consistently assigns higher values to more concentrated configurations, from the single-centroid case (e.g., A1, A5[4]) to the clustered ones (A6,

[4] Differences between A1 and A5 are due to their location as kernel propagation is limited by the surface boundaries. However, this effect is limited compared to the Moran's Index.

A7, A8), up to the most dispersed case (A2). It distinguishes between cases like A1 and A3 clearly thus accounting for their concentration.

The Moran's Index is calculated by considering two different decay functions ($1/d$ and $1/d^2$). The results of this index are very sensitive to the choice of the decay and to the size of the network (number of facilities). Moreover, negative values denoting negative spatial correlation complicate the interpretation of the values for our specific purpose. This index provides similar values for A1, A6, and A7, differing substantially both in terms of number of locations—4 vs. 8 vs. 12—concentration––1 cluster, 2 clusters, 3 clusters—and geographical distribution.

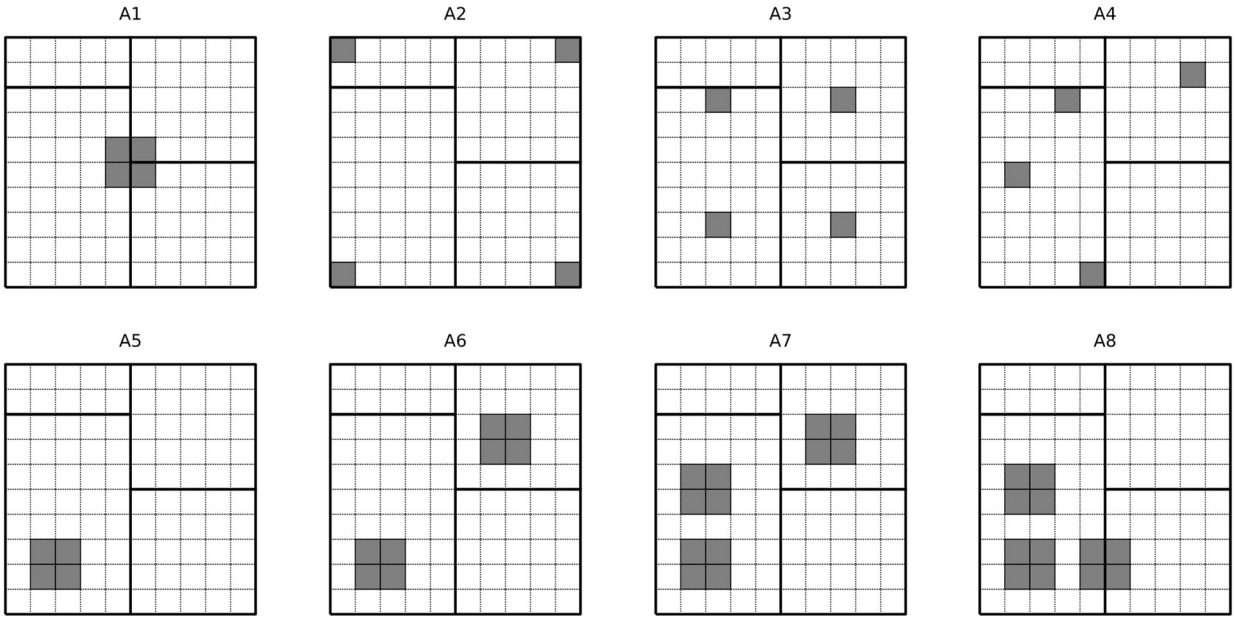

Figure 4. Illustrative examples: spatial concentration.

Index	A1	A2	A3	A4	A5	A6	A7	A8
C-HHI	0.375	0.25	0.375	0.625	1	0.5	0.5555	0.7222
K-HHI	1	0.0057	0.0401	0.0326	0.9999	0.1598	0.1061	0.1745
MORAN's I $(1/d)$	0.0499	-0.0058	-0.0256	-0.0206	0.0669	0.0406	0.0421	0.0734
MORAN's I $(1/d^2)$	0.1814	-0.0015	-0.0421	-0.0326	0.1990	0.1586	0.1505	0.1895

Table 1. Illustrative examples: spatial concentration

Figure 5 contains eight illustrative cases (B1–B8) that represent some potential configurations of two four-facility networks (e.g., four suppliers and four retailers in the same supply network)—characterized by gray and light-gray colors, respectively. To demonstrate the advantages of the k-RPI as a suitable measure of geographical proximity between supply and retail networks, Table 2 provides the results of three different indexes: the average distance, the a-RPI, and the k-RPI, normalized regarding the fully overlapped scenario, where the two networks are completely overlapped (B1). The average distance is measured as the average distance between each supply-retailer pair, while the a-RPI is calculated as the k-RPI but substituting the kernel estimates with a binary equal to 1 if a facility

is present, 0 otherwise. In doing so, the a-RPI applies the distance decay function but does not consider the agglomeration effect captured by the kernel estimates to demonstrate the benefit of using the kernel weights. The decay function is $1/d$ in both cases. The average distance has been widely used in the literature (e.g., Choi and Hong, 2002). However, it clearly fails to capture the presence of any spatial pattern and may produce very similar results for different situations. These are important aspects to consider, as from the managerial perspective, the ease to relate two networks is not solely dependent on the absolute distance between each facility and the others but it is also affected by each network's spatial configuration and their positioning relative to each other (Section 2). Consider, for instance, cases B5, B6, and B3. While both the average distance and the a-RPI assign very similar values to the cases, consistent with the logistic intuition, the k-RPI score for B6 is significantly higher than B5 and B3 owing to the second network being more spatially clustered. The k-RPI also provides reasonable and robust results regarding the M-M scenario (e.g., B7, B8).

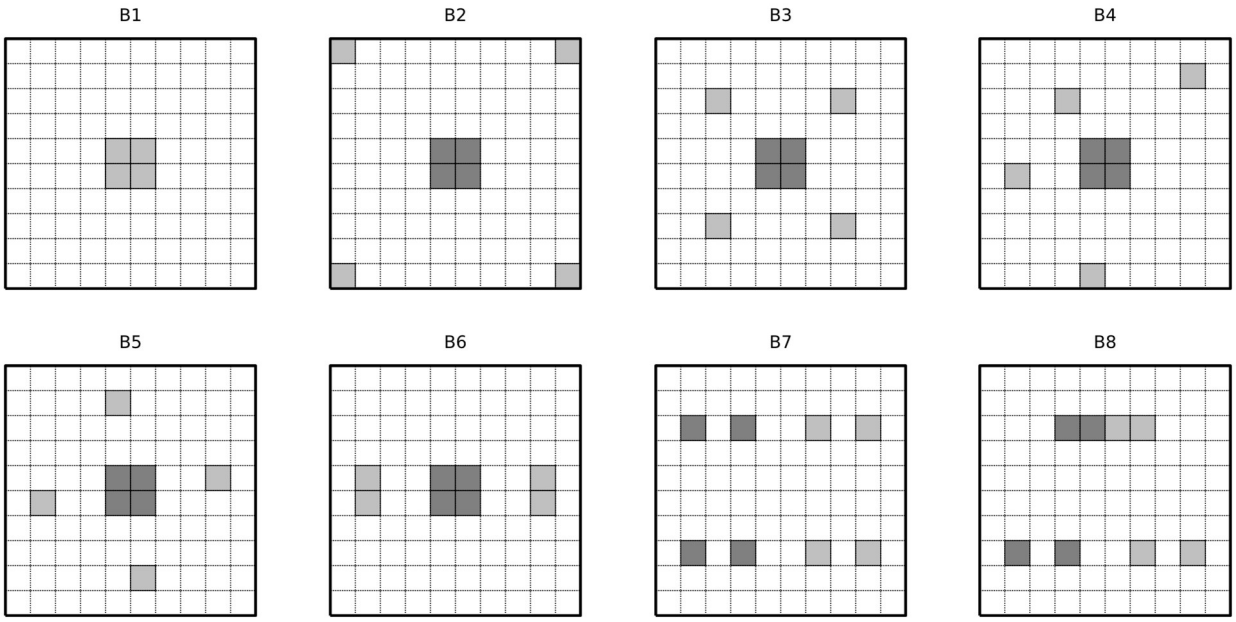

Figure 5. Illustrative examples: relative proximity

Index	B1	B2	B3	B4	B5	B6	B7	B8
avg distance	1	0.1337	0.2391	0.2126	0.2390	0.2393	0.1407	0.1765
a-RPI	1	0.2330	0.4226	0.3913	0.4219	0.4224	0.2675	0.4177
k-RPI	1	0.1380	0.3847	0.3296	0.3783	0.4549	0.2062	0.2816

Table 2. Illustrative examples: relative proximity

5. Empirical Example

This section demonstrates how the KDE-based indices, namely, K-HHI and K-RPI, perform in assessing retailers' and suppliers' spatial concentration, and their relative geographical proximity applied to real cases. To this purpose, we consider data gathered from four companies in the fashion-

textile industry, namely, Adidas, Benetton, C&A, and Puma. For each company, we collected information on each supplier (tier-1 and tier-2) about the name of the supplier and the address of production facilities.[5]

Each supplier was geo-localized using Google Maps Geo-localization services. Google was also used to identify the number of official retailers of each multinational company and their geo-localization. In this regard, we limited our sample to officially dedicated stores. Table 3 summarizes key descriptive statistics for the four companies considered.

Company	Revenues (bln €, 2017)*	N. suppliers	N. retailers
Adidas	25.74	1,010	2,258
Benetton	1.21	400	1,465
C&A	8.10	1,800	1,309
Puma	4.98	114	1,368

*Source: Orbis - Bureau van Dijk

Table 3. Descriptive statistics of the companies considered

These four companies are heterogeneous in size, ranging from Benetton with €1.21 bln to Adidas, with a total amount of €25.74 bln. In relative terms, C&A registers the highest number of suppliers per retailer (137%), while Puma is in the opposite situation, where suppliers account for just 8% of retailers.

Table 4 shows the values for the degree of networks' concentration and geographical proximity of the suppliers and retailers of the four companies, while Figure 6 provides a geographical representation of the data. For the sake of comparability, values are standardized. Benetton has a relatively concentrated supply chain at both the supplier and retailer level (K-HHI$_{supplier}$: 1.28; K-HHI$_{retailer}$: 0.03) with a large part of the two networks almost exclusively located in Europe (SC configuration: 1-1). Considering this geographical overlapping, the proximity between supply and retailer networks is high (K-RPI$_{supplier\text{-}retailer}$: 1.49). In contrast, Adidas registers the lowest levels of spatial concentration (K-HHI$_{supplier}$: -0.87; K-HHI$_{retailer}$: -0.72) as both suppliers and retailers are spread over the globe (SC configuration: M-M). In terms of geographical proximity, the two networks are relatively far away (K-RPI$_{supplier\text{-}retailer}$: -0.53), whereas a significant share of retailers are positioned in the United States; the most important fulcrum of suppliers is located in Asia. C&A and Puma represent two emblematic cases of the two other SC configurations, 1-M and M-1, respectively. C&A's retailers are highly concentrated in Europe (K-HHI$_{retailer}$: 1.40), while its suppliers are widely distributed across Asia, South America, and Europe (K-HHI$_{supplier}$: -0.72). In terms of networks' geographical distance, C&A registers a low value of proximity (K-RPI$_{supplier\text{-}retailer}$: -0.50). In contrast, Puma's networks highlight a pool of spatially concentrated suppliers in South-East Asia (K-HHI$_{supplier}$: 0.30), while it almost equally serves the Asian, the American, and the European markets (K-HHI$_{retailer}$: -0.72), similar to Adidas. The proximity between the two networks is relatively low (K-RPI$_{supplier\text{-}retailer}$: -0.46).

[5] Data were collected directly from the companies' websites and they all refer to suppliers declared active in 2018.

Company	K-HHI suppliers	K-HHI retailers	K-RPI
Adidas	-0.87	-0.72	-0.53
Benetton	1.28	0.03	1.49
C&A	-0.72	1.4	-0.50
Puma	0.3	-0.72	-0.46

Table 4. Standardized metrics

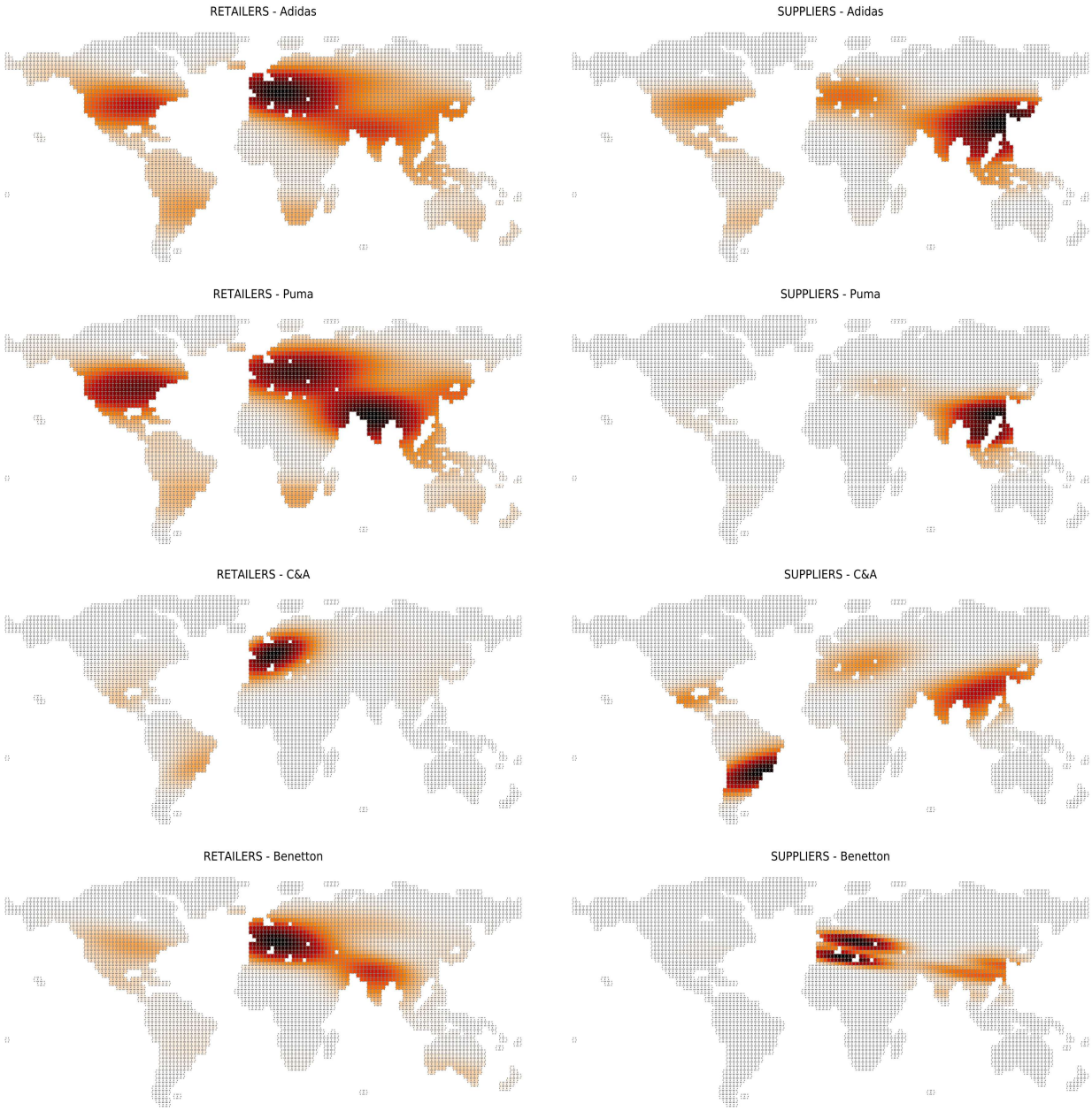

Figure 6. Kernel representation of each firm's suppliers and retailers

6. Discussion

The illustrative and empirical examples provided clearly show the intrinsic value of the proposed metrics as able to capture the complex characteristics of supply chains in a rather simple way. In particular, the k-HHI measure allows for qualifying the specific network in terms of spatial concentration and, by combining the metric for the retailers' and suppliers' networks, allows identification of different potential structures as summarized by Figure 7; it also provides the positioning of the empirical examples considered.

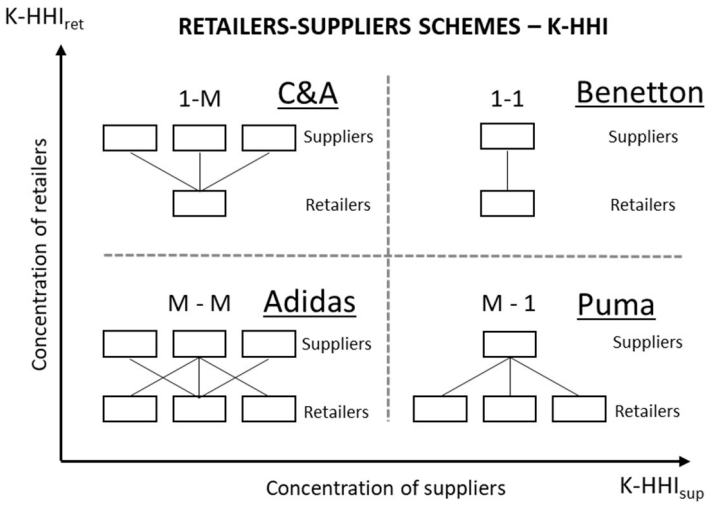

Figure 7. Retailers-suppliers schemes (1): firms' classification

The k-RPI metric allows evaluation of the overlap of the two networks considered. In particular, the higher its value, the higher the geographical proximity of the two networks.

The two metrics described provide two distinct types of information that can be combined to evaluate a proper qualification of the supply network. Figure 8 summarizes the possible conditions in which we can classify networks based on the set of indicators described.

A. When k-HHI$_{sup}$ and k-HHI$_{ret}$ are <u>high</u> and k-RPI is <u>low</u>, the two networks are extremely concentrated although not much overlapped geographically. In general, this case is common in companies that have a very focused strategy for both supply and distribution, such that the co-localization of the two networks is not a key priority and the benefits of higher networks concentration (e.g., higher control of supply sources, simpler supply networks) outweigh the diseconomies associated with high distances (e.g., high transportation costs, long lead times).
B. When k-HHI$_{sup}$ and k-HHI$_{ret}$ are high and k-RPI is also <u>high</u>, we have networks that are extremely concentrated, and tend to overlap geographically. This is the case of Benetton with a strong concentration of suppliers in Europe and Middle East, similar to the distribution strategy of its retailers. This is common for companies that decide to serve a local market with local networks, which enables them to serve customers from a closer location and limit the geographical span of their operations.

C. When k-HHI_{sup} is low, k-HHI_{ret} is high, and k-RPI is low, the network is characterized by a focused and concentrated market that must be served through a highly dispersed network of suppliers. This is common when companies require adoption of diversified supply strategies for serving the final customer, for example, because products and components are manufactured in very different areas or to the aim of mitigating the supply risk. In this case, the key attention is likely managing the supply-network complexity given certain market requirements. This is the case of C&A, where its main market is Europe; it is served by leveraging suppliers that are only partially located in Europe, as many others are located in South America and Asia.
D. When k-HHI_{sup} is low and k-HHI_{ret} is high, k-RPI cannot be very high due to the fact that the high dispersion of just one network makes the geographical overlap with the other limited. Still, companies can try to make the two networks overlap to some extent.
E. When k-HHI_{sup} is high, and k-HHI_{ret} and k-RPI are low, the network is characterized by a strong supply focus (i.e., all suppliers belong to a rather uniform region), but these are used to serve a paramount network of retailers. This is typically the case in networks that try to leverage the most on localization benefits (e.g., procurement from low cost countries) but that diversify their distribution strategies to reach a vast array of geographically dispersed retailers. Puma applies a similar strategy with a strong concentration of suppliers in South-East Asia, and retailers are almost equally distributed in the US, Europe, and India.
F. When k-HHI_{sup} is high and k-HHI_{ret} is low, k-RPI cannot be very high, for reasons similar to those highlighted in case D. However, companies can still try to overlap the two networks, for example, to serve local markets and limit high distribution and logistic costs to some extent.
G. When k-HHI_{sup}, k-HHI_{ret}, and k-RPI are low, essentially, we combine the characteristics of cases C and E. Companies purchase from many geographically dispersed areas and they provide products to a vastly dispersed network of retailers. This kind of network is extremely complex and, in some cases, can become very inefficient because of the difficulty in properly managing the flows of products and standardizing processes. Adidas appears to have a network characterized by a similar structure.
H. Last, when k-HHI_{sup} and k-HHI_{ret} are low, and k-RPI is high, companies decide to leverage dispersed networks both for supply and distribution, although they try to ensure geographical overlap. In this case, networks are likely to be designed to pursue *glocal* strategies, where processes are designed to consider both the global and the local perspectives.

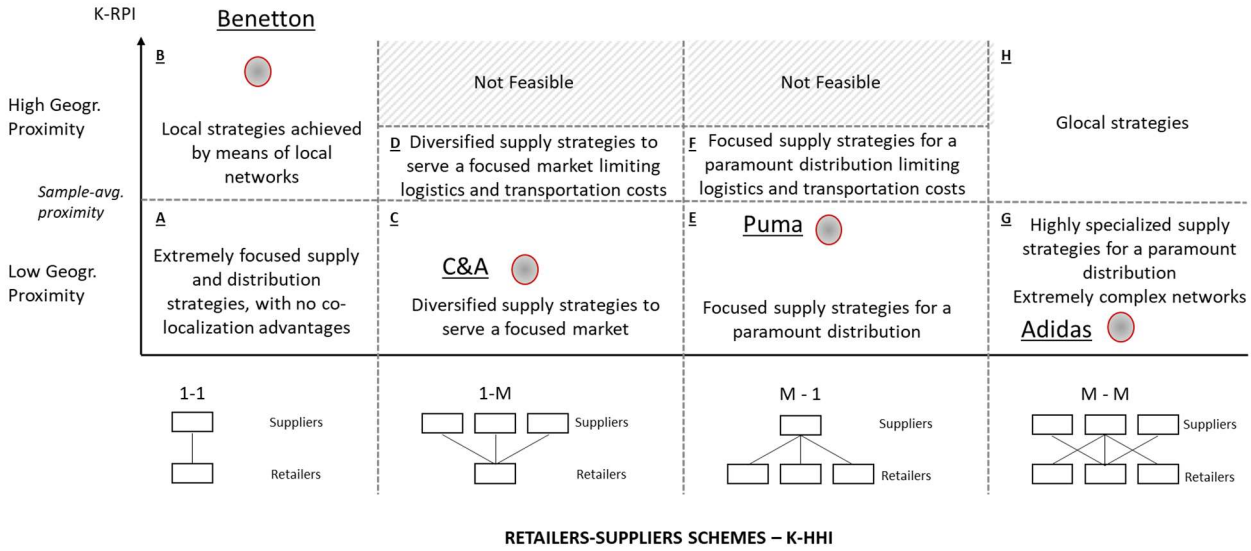

Figure 8. Retailers-suppliers schemes (2)

7. Final Considerations And Conclusions

This study makes an original and important contribution aimed at addressing a relevant gap in the supply-network design literature. While past contributions clearly show the relevance of geographical dimensions in the design of supply networks, limited attention has been given to supporting decision makers with proper measures of geographical dispersion and correlation between networks. Given this aim, the metrics developed in this paper improve the reliability of supply-network models that consider the geographical dimensions as a key factor, thus representing a valuable support for both researchers and managers engaged in the evaluation and design of the most promising network settings. In detail, they allow assessment of the geographical distribution of complex supplier and retailer networks and evaluation of the effect of operational changes, such as the need for a logistical facility in a specific location (i.e., where there is a high level geographical concentration of suppliers and retailers), or the effects of offshoring and reshoring processes (Di Mauro *et al.*, 2018).

The study finds itself at the intersection between different literature streams. Besides the main focus in the supply chain literature, its contribution may be of interest in the fields of spatial economic and economic geography, where alternative approaches based on location theory and the random utility model (RUM) have been widely used (e.g., Ellison *et al.*, 1997, Guimarães *et al.*, 2011) to quantify the degree of spatial concentration in economic activity.

Despite the contribution provided, the proposed metrics still require some additional considerations that could be potential areas of improvements in future research. First, in the evaluation of the spatial concentration indicator (k-HHI) the minimum requirement is to provide the indicator with the physical position of the network's elements (e.g., suppliers, retailers). We considered (but did not treat analytically here) the possibility of providing a weight for each network element such as size or relevance, to create a metric that evaluates the relative importance of each component. Still, the definition of which is the most suitable metric to evaluate the relevance of the

different parts of the network is debatable; in general, more depends on the specific need. In some situations, the relative size of a supplier or a retailer could be a relevant factor as it distinguishes suppliers according to the flows of goods they manage. However, several other dimensions could be considered, such as the impact on the quality of the products, the impact on the overall product cost, and the relative risk (Ho *et al.*, 2010; Hosseini and Barker, 2016). In this work, we have not discussed the implications of adopting different dimensions in evaluating the relative positioning of suppliers and retailers, but it would be an interesting development to create multidimensional versions of the proposed metrics to account for such cases.

Second, the proposed classification scheme has considered the presence of two networks—an upstream (suppliers) and downstream (retailers) network. Developments would involve further decomposition of multi-level network structures to better reflect the managerial complexity that characterizes the organization of global supply chains in practice. A primary case would involve the identification of a third layer—that is, the manufacturing network—between suppliers and retailers, and more complex situations may arise due to the presence of tier-2 and tier-3 suppliers.

An additional interesting development is related to cases where different sub-networks exist within a specific defined network. A sub-network is a physically defined entity, including plants, assets, manufacturing processes, and/or materials that are grouped according to the characteristics of manufactured products and the production processes used (Ferdows *et al.*, 2016). For example, in Section 5, we have considered all suppliers regardless of the kind of products they are producing (e.g., apparel vs. shoes vs. accessories). Therefore, within the same network, different sub-networks (i.e., groups of products) can coexist characterized by different structures related not simply to different manufacturing processes, but also to the different strategies pursued. In this perspective, the proposed methodology could be useful for comparing the characteristics of such sub-networks in an attempt to evaluate whether a company is adopting the proper supply network for each product.

A final point relates to the normative perspective that follows our contribution. As we have seen, several possible network combinations could exist. However, it would be useful to support managers with guidelines when deciding the most suitable characteristics of their specific case. In other words, the general framework depicted in Figure 8 is still descriptive rather than prescriptive. It would be of extreme interest to design a normative model that provides a reference for managers in designing the networks' concentration and geographical dispersion.

References

Amaral, J. and Kuettner, D. (2008) 'Analyzing supply chains at HP using spreadsheet models', *Interfaces*. doi: 10.1287/inte.1070.0336.

Anselin, L. (1995) 'Local Indicators of Spatial Association-LISA', *Geographical Analysis*. John Wiley & Sons, Ltd (10.1111), 27(2), pp. 93–115. doi: 10.1111/j.1538-4632.1995.tb00338.x.

Arbia, G. (2005) 'Modelling the geography of economic activities on a continuous space*', *Papers in Regional Science*. John Wiley & Sons, Ltd (10.1111), 80(4), pp. 411–424. doi: 10.1111/j.1435-5597.2001.tb01211.x.

Arbia, G. and Piras, G. (2009) 'A new class of spatial concentration measures', *Computational Statistics & Data Analysis*. North-Holland, 53(12), pp. 4471–4481. doi: 10.1016/J.CSDA.2009.07.003.

Ashby, A. (2016) 'From global to local: reshoring for sustainability', *Operations Management Research*. doi: 10.1007/s12063-016-0117-9.

Bailey, D. and De Propris, L. (2014) 'Manufacturing reshoring and its limits: The UK automotive case', *Cambridge Journal of Regions, Economy and Society*. doi: 10.1093/cjres/rsu019.

Bashiri, M., Badri, H. and Talebi, J. (2012) 'A new approach to tactical and strategic planning in production-distribution networks', *Applied Mathematical Modelling*. doi: 10.1016/j.apm.2011.09.018.

Bhatnagar, R. and Viswanathan, S. (2000) 'Re-engineering global supply chains: Alliances between manufacturing firms and global logistics services providers', *International Journal of Physical Distribution & Logistics Management*. doi: 10.1108/09600030010307966.

Bowling, I. M., Ponce-Ortega, J. M. and El-Halwagi, M. M. (2011) 'Facility location and supply chain optimization for a biorefinery', *Industrial and Engineering Chemistry Research*. doi: 10.1021/ie101921y.

Brennan, L. *et al.* (2015) 'Manufacturing in the world: where next?', *International Journal of Operations and Production Management*. doi: 10.1108/IJOPM-03-2015-0135.

Cagliano, R. *et al.* (2009) 'Supply chain configurations in a global environment: A longitudinal perspective', *Operations Management Research*, 1(2), pp. 86–94. doi: 10.1007/s12063-008-0012-0.

Cagliano, R., Caniato, F. and Spina, G. (2004) 'Lean, Agile and traditional supply: How do they impact manufacturing performance?', *Journal of Purchasing and Supply Management*. doi: 10.1016/j.pursup.2004.11.001.

Carle, M. A., Martel, A. and Zufferey, N. (2012) 'The CAT metaheuristic for the solution of multi-period activity-based supply chain network design problems', *International Journal of Production Economics*. doi: 10.1016/j.ijpe.2012.06.016.

Choi, T. Y. and Hong, Y. (2002) 'Unveiling the structure of supply networks: Case studies in Honda, Acura, and DaimlerChrysler', *Journal of Operations Management*, 20(5), pp. 469–493. doi: 10.1016/S0272-6963(02)00025-6.

Christopher, M. and Holweg, M. (2011) '"Supply Chain 2.0": Managing supply chains in the era of turbulence', *International Journal of Physical Distribution and Logistics Management*. doi: 10.1108/09600031111101439.

Christopher, M. and Towill, D. R. (2000) 'Supply chain migration from lean and functional to agile and customised', *Supply Chain Management*. doi: 10.1108/13598540010347334.

Cintron, A., Ravindran, A. R. and Ventura, J. A. (2010) 'Multi-criteria mathematical model for designing the distribution network of a consumer goods company', *Computers and Industrial Engineering*. doi: 10.1016/j.cie.2009.12.006.

Cohen, M. A. and Mallik, S. (2009) 'GLOBAL SUPPLY CHAINS: RESEARCH AND APPLICATIONS', *Production and Operations Management*. doi: 10.1111/j.1937-5956.1997.tb00426.x.

Coppini, G. *et al.* (2011) 'Hindcast of oil-spill pollution during the Lebanon crisis in the Eastern Mediterranean, July–August 2006', *Marine Pollution Bulletin*. Pergamon, 62(1), pp. 140–153. doi: 10.1016/J.MARPOLBUL.2010.08.021.

Danese, P. and Romano, P. (2013) 'The moderating role of supply network structure on the customer integration-efficiency relationship', *International Journal of Operations and Production Management*. doi: 10.1108/01443571311307226.

Danese, P., Romano, P. and Vinelli, A. (2006) 'Sequences of improvement in supply networks: Case studies from the pharmaceutical industry', *International Journal of Operations and Production Management*. doi: 10.1108/01443570610705827.

Dornier, P.-P. *et al.* (2008) *Global operations and logistics: Text and cases*. John Wiley & Sons.

Ellison, G. *et al.* (1997) *Geographic Concentration in U.S. Manufacturing Industries: A Dartboard Approach*, *Journal of Political Economy*.

Ellison, G. and Glaeser, E. L. (1997) 'Geographic concentration in U.S. manufacturing industries: A dartboard approach', *Journal of Political Economy*, 105(5), pp. 889–927. doi: 10.1086/262098.

Ferdows, K., Vereecke, A. and De Meyer, A. (2016) 'Delayering the global production network into congruent subnetworks', *Journal of Operations Management*. doi: 10.1016/j.jom.2015.11.006.

Fisher, M. L. (1997) 'What is the right supply chain for your product.pdf', *Harvard Business Review1*. doi: Article.

Fratocchi, L. *et al.* (2014) 'When manufacturing moves back: Concepts and questions', *Journal of Purchasing and Supply Management*. doi: 10.1016/j.pursup.2014.01.004.

Frear, C. R., Metcalf, L. E. and Alguire, M. S. (1992) 'Offshore Sourcing: Its Nature and Scope', *International Journal of Purchasing and Materials Management*. doi: 10.1111/j.1745-493x.1992.tb00565.x.

Fredriksson, A., Jonsson, P. and Medbo, P. (2010) 'Utilising the potential of combining local and global supply chains', *International Journal of Logistics Research and Applications*. doi: 10.1080/13675561003761978.

Frohlich, M. T. and Westbrook, R. (2002) 'Demand chain management in manufacturing and services: Web-based integration, drivers and performance', *Journal of Operations Management*. doi: 10.1016/S0272-6963(02)00037-2.

Gadde, L.-E. and Jonsson, P. (2018) 'Future changes in sourcing patterns: 2025 outlook for the Swedish textile industry', *Journal of Purchasing and Supply Management*. Elsevier Ltd, (April), p. 100526. doi: 10.1016/j.pursup.2018.12.004.

Georgiadis, M. C. *et al.* (2011) 'Optimal design of supply chain networks under uncertain transient

demand variations', *Omega*. doi: 10.1016/j.omega.2010.07.002.

Godsell, J. *et al.* (2006) 'Customer responsive supply chain strategy: An unnatural act?', *International Journal of Logistics Research and Applications*. doi: 10.1080/13675560500534664.

Goetschalckx, M., Vidal, C. J. and Dogan, K. (2002) 'Modeling and design of global logistics systems: A review of integrated strategic and tactical models and design algorithms', *European Journal of Operational Research*. doi: 10.1016/S0377-2217(02)00142-X.

Govindan, K., Fattahi, M. and Keyvanshokooh, E. (2017) 'Supply chain network design under uncertainty: A comprehensive review and future research directions', *European Journal of Operational Research*. Elsevier B.V., 263(1), pp. 108–141. doi: 10.1016/j.ejor.2017.04.009.

Guericke, S. *et al.* (2012) 'A stochastic model for the implementation of postponement strategies in global distribution networks', *Decision Support Systems*. doi: 10.1016/j.dss.2012.01.010.

Guillain, R. and Le Gallo, J. (2010) 'Agglomeration and dispersion of economic activities in and around Paris: an exploratory spatial data analysis', *Environment and Planning B: Planning and Design*. SAGE PublicationsSage UK: London, England, 37(6), pp. 961–981. doi: 10.1068/b35038.

Guimarães, P., Figueiredo, O. and Woodward, D. (2007) 'Measuring the localization of economic activity: a parametric Approach', *Journal of Regional Science*, 47(4), pp. 753–774. doi: 10.1111/j.1467-9787.2007.00527.x.

Guimarães, P., Figueiredo, O. and Woodward, D. (2011) 'Accounting for neighboring effects in measures of spatial concentration', *Journal of Regional Science*. John Wiley & Sons, Ltd (10.1111), 51(4), pp. 678–693. doi: 10.1111/j.1467-9787.2011.00723.x.

Haleem, F., Farooq, S. and Wæhrens, B. V. (2017) 'Supplier corporate social responsibility practices and sourcing geography', *Journal of Cleaner Production*. Elsevier Ltd, 153, pp. 92–103. doi: 10.1016/j.jclepro.2017.03.143.

Härdle, W. *et al.* (2004) 'Nonparametric Density Estimation', in, pp. 39–83. doi: 10.1007/978-3-642-17146-8_3.

Heikkilä, J. (2002) 'From supply to demand chain management: Efficiency and customer satisfaction', *Journal of Operations Management*. doi: 10.1016/S0272-6963(02)00038-4.

Hesse, M. and Rodrigue, J. P. (2004) 'The transport geography of logistics and freight distribution', *Journal of Transport Geography*. doi: 10.1016/j.jtrangeo.2003.12.004.

Ho, W., Xu, X. and Dey, P. K. (2010) 'Multi-criteria decision making approaches for supplier evaluation and selection: A literature review', *European Journal of Operational Research*. Elsevier B.V., 202(1), pp. 16–24. doi: 10.1016/j.ejor.2009.05.009.

Van Hoek, R. I., Vos, B. and Commandeur, H. R. (1999) 'Restructuring European Supply Chains by Implementing Postponement Strategies', *Long Range Planning*. doi: 10.1016/S0024-6301(99)00071-0.

Hosseini, S. and Barker, K. (2016) 'A Bayesian network model for resilience-based supplier selection', *International Journal of Production Economics*. Elsevier, 180, pp. 68–87. doi: 10.1016/j.ijpe.2016.07.007.

Hubert, L. J., Golledge, R. G. and Costanzo, C. M. (1981) 'Generalized Procedures for Evaluating Spatial Autocorrelation', *Geographical Analysis*. John Wiley & Sons, Ltd (10.1111), 13(3), pp.

224–233. doi: 10.1111/j.1538-4632.1981.tb00731.x.

Hughes, J., Ralf, M. and Michels, B. (1998) *Transform your supply chain: Releasing value in business*. Cengage Learning EMEA.

Ibrahim, H. W., Zailani, S. and Tan, K. C. (2015) 'A content analysis of global supply chain research', *Benchmarking*. doi: 10.1108/BIJ-04-2013-0038.

Johansson, M. *et al.* (2018) 'Offshoring versus backshoring: Empirically derived bundles of relocation drivers, and their relationship with benefits', *Journal of Purchasing and Supply Management*. doi: 10.1016/j.pursup.2018.07.003.

Katayama, H. (1999) 'Design of a global car production-logistics system for a future ASEAN-China region', *International Journal of Operations and Production Management*. doi: 10.1108/01443579910260892.

Kchaou Boujelben, M. and Boulaksil, Y. (2018) 'Modeling international facility location under uncertainty: A review, analysis, and insights', *IISE Transactions*. Taylor & Francis, 50(6), pp. 535–551. doi: 10.1080/24725854.2017.1408165.

Kinkel, S. and Maloca, S. (2009) 'Drivers and antecedents of manufacturing offshoring and backshoring-A German perspective', *Journal of Purchasing and Supply Management*. doi: 10.1016/j.pursup.2009.05.007.

Kumar, M. and Gregory, M. (2013) 'An exploration of risk management in global industrial investment', *Risk Management*. doi: 10.1057/rm.2013.8.

Lintukangas, K., Peltola, S. and Virolainen, V. M. (2009) 'Some issues of supply management integration', *Journal of Purchasing and Supply Management*. Elsevier, 15(4), pp. 240–248. doi: 10.1016/j.pursup.2009.03.001.

Lorentz, H. *et al.* (2016) 'The effect of a geographically dispersed supply base on downside risk: Developing and testing the N-shaped theory', *International Business Review*, 25(4), pp. 872–882. doi: 10.1016/j.ibusrev.2015.10.009.

Manzini, R. and Bindi, F. (2009) 'Strategic design and operational management optimization of a multi stage physical distribution system', *Transportation Research Part E: Logistics and Transportation Review*. doi: 10.1016/j.tre.2009.04.011.

Mariotti, S., Piscitello, L. and Elia, S. (2010) 'Spatial agglomeration of multinational enterprises: the role of information externalities and knowledge spillovers', *Journal of Economic Geography*, 10(4), pp. 519–538. doi: 10.1093/jeg/lbq011.

Martínez-Olvera, C. (2008) 'Methodology for realignment of supply-chain structural elements', *International Journal of Production Economics*. doi: 10.1016/j.ijpe.2008.03.008.

Masi, D., Micheli, G. J. L. and Cagno, E. (2013) 'A meta-model for choosing a supplier selection technique within an EPC company', *Journal of Purchasing and Supply Management*. doi: 10.1016/j.pursup.2012.07.002.

Di Mauro, C. *et al.* (2018) 'Offshoring and backshoring: A multiple case study analysis', *Journal of Purchasing and Supply Management*. doi: 10.1016/j.pursup.2017.07.003.

Meijboom, B. and Voordijk, H. (2003) 'International operations and location decisions: A firm level approach', *Tijdschrift voor Economische en Sociale Geografie*. doi: 10.1111/1467-9663.00274.

Meijboom, B. and Vos, B. (1997) 'International manufacturing and location decisions: Balancing

configuration and co-ordination aspects', *International Journal of Operations and Production Management*. doi: 10.1108/01443579710175565.

Meijboom, B. and Vos, B. (2004) 'Site competence dynamics in international manufacturing networks: Instrument development and a test in Eastern European factories', *Journal of Purchasing and Supply Management*. doi: 10.1016/j.pursup.2004.09.001.

Meixell, M. J. and Gargeya, V. B. (2005) 'Global supply chain design: A literature review and critique', *Transportation Research Part E: Logistics and Transportation Review*, 41(6 SPEC. ISS.), pp. 531–550. doi: 10.1016/j.tre.2005.06.003.

Moran, P. A. P. (1950) 'Notes on Continuous Stochastic Phenomena', *Biometrika*, 37(1/2), p. 17. doi: 10.2307/2332142.

Munson, C. L. and Rosenblatt, M. J. (2009) 'THE IMPACT OF LOCAL CONTENT RULES ON GLOBAL SOURCING DECISIONS', *Production and Operations Management*, 6(3), pp. 277–290. doi: 10.1111/j.1937-5956.1997.tb00431.x.

Ben Naylor, J., Naim, M. M. and Berry, D. (1999) 'Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain', *International Journal of Production Economics*. doi: 10.1016/S0925-5273(98)00223-0.

Olhager, J., Pashaei, S. and Sternberg, H. (2015) 'Design of global production and distribution networks', *International Journal of Physical Distribution & Logistics Management*. doi: 10.1108/IJPDLM-05-2013-0131.

Onstein, Alexander T. C *et al.* (2019) 'Importance of factors driving firms' decisions on spatial distribution structures', *International Journal of Logistics Research and Applications*. Taylor & Francis, 0(0), pp. 1–20. doi: 10.1080/13675567.2019.1574729.

Onstein, Alexander T.C., Tavasszy, L. A. and van Damme, D. A. (2019) 'Factors determining distribution structure decisions in logistics: a literature review and research agenda', *Transport Reviews*, pp. 243–260. doi: 10.1080/01441647.2018.1459929.

Persson, F. and Olhager, J. (2002) 'Performance simulation of supply chain designs', *International Journal of Production Economics*. doi: 10.1016/S0925-5273(00)00088-8.

Pihlajamaa, M. *et al.* (2017) 'Can supplier innovations substitute for internal R&D? A multiple case study from an absorptive capacity perspective', *Journal of Purchasing and Supply Management*. doi: 10.1016/j.pursup.2017.08.002.

Prasad, S., Babbar, S. and Calis, A. (2000) 'International operations management and operations management research: A comparative analysis', *Omega*. doi: 10.1016/S0305-0483(99)00031-6.

Rao, K. and Young, R. R. (1994) 'Global Supply Chains: Factors Influencing Outsourcing of Logistics Functions', *International Journal of Physical Distribution & Logistics Management*. doi: 10.1108/09600039410066141.

Rodrigue, J. P. (2012) 'The Geography of Global Supply Chains: Evidence from Third-Party Logistics', *Journal of Supply Chain Management*, 48(3), pp. 15–23. doi: 10.1111/j.1745-493X.2012.03268.x.

Romano, P. (2009) 'How can fluid dynamics help supply chain management?', *International Journal of Production Economics*, 118(2), pp. 463–472. doi: 10.1016/j.ijpe.2008.12.011.

Sadjady, H. and Davoudpour, H. (2012) 'Two-echelon, multi-commodity supply chain network design with mode selection, lead-times and inventory costs', *Computers and Operations*

Research. doi: 10.1016/j.cor.2011.08.003.

Schotter, A. P. J. *et al.* (2017) 'Boundary Spanning in Global Organizations', *Journal of Management Studies*. doi: 10.1111/joms.12256.

Shi, Y. and Gregory, M. (1998) 'International manufacturing networks-to develop global competitive capabilities', *Journal of Operations Management*. doi: 10.1016/S0272-6963(97)00038-7.

Sousa, R., Shah, N. and Papageorgiou, L. G. (2008) 'Supply chain design and multilevel planning-An industrial case', *Computers and Chemical Engineering*. doi: 10.1016/j.compchemeng.2007.09.005.

Stanczyk, A. *et al.* (2017) 'The dark side of global sourcing: a systematic literature review and research agenda', *International Journal of Physical Distribution and Logistics Management*. doi: 10.1108/IJPDLM-10-2015-0252.

Stock, G. (2000) 'Enterprise logistics and supply chain structure: the role of fit', *Journal of Operations Management*, 18(5), pp. 531–547. doi: 10.1016/S0272-6963(00)00035-8.

Stock, G. N., Greis, N. P. and Kasarda, J. D. (2000) 'Enterprise logistics and supply chain structure: The role of fit', *Journal of Operations Management*, 18(5), pp. 531–547. doi: 10.1016/S0272-6963(00)00035-8.

Sureeyatanapas, P. *et al.* (2018) 'Supplier selection towards uncertain and unavailable information: An extension of TOPSIS method', *Operations Research Perspectives*. Elsevier Ltd, 5, pp. 69–79. doi: 10.1016/j.orp.2018.01.005.

Tate, W. L. (2014) 'Offshoring and reshoring: U.S. insights and research challenges', *Journal of Purchasing and Supply Management*. doi: 10.1016/j.pursup.2014.01.007.

Thomas, D. J. and Griffin, P. M. (1996) 'Coordinated supply chain management', *European Journal of Operational Research*. doi: 10.1016/0377-2217(96)00098-7.

Vidal, C. J. and Goetschalckx, M. (1997) 'Strategic production-distribution models: A critical review with emphasis on global supply chain models', *European Journal of Operational Research*. doi: 10.1016/S0377-2217(97)80080-X.

Vidal, C. J. and Goetschalckx, M. (2001) 'Global supply chain model with transfer pricing and transportation cost allocation', *European Journal of Operational Research*. doi: 10.1016/S0377-2217(99)00431-2.

Woxenius, J. (2006) 'Temporal elements in the spatial extension of production networks', *Growth and Change*. doi: 10.1111/j.1468-2257.2006.00339.x.

Wu, C. and Barnes, D. (2011) 'A literature review of decision-making models and approaches for partner selection in agile supply chains', *Journal of Purchasing and Supply Management*. Elsevier, 17(4), pp. 256–274. doi: 10.1016/j.pursup.2011.09.002.