Inter-Cities’ Multinational Firm Networks and Gravitation Model

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Abstract

The capacity of cities to operate in global networks of firms is usually measured based on the degree of centrality of their position within networks of multinational firms across the globe. However, we assume that regional groups of cities that interact more intensively with each other are more relevant to define central positions. This paper aims to identify these regions and assess their relative influence on the globalization of cities through multinational firm networks. A global database has been generated for the network of 1 million direct and indirect ownership links between the 800,000 subsidiaries of the top 3,000 multinational firms of the world, which are located within 1,205 metropolitan areas. One finding that emerges from this research is that globalization occurs mostly through intra-continental linkages but is also facilitated by strong intra-national and even intra-urban sub-networks. Local intra-urban network complexity is shown to influence the process of global integration. Distance still influences globalization, but not with the same intensity within different parts of the world. The multi-scale centrality of cities is discussed based on the concepts of geographic and economic integration within multinational firm networks.

Key words: Multinational firm, cities, world regions, networks, gravitation model, graph theory

1 Introduction

Multinational corporations invest preferentially in cities, interacting with urban economic resources by integrating these plants into the strategic planning of the entire firm (Rozenblat & Pumain 1993; Castells 1996; Taylor 2001; Rozenblat 2010; Wall & van der Knaap 2011). Approximately 80% of multinational firms’ plants are located inside urban regions (Rozenblat, Pumain 1993; Scott 2001; Rozenblat, 2011). However, it is much more difficult to measure globalization in urban regions than on a national scale due to the lack of available data (Rozenblat, Pumain, 2007; Wall & van der Knaap, 2011). International studies of foreign direct investment between states still dominate the literature (Rugman, 1980; Rugman et al., 2012; Dunning, 1992, 1998; Wall et al., 2011; Dezzani, Johansen, 2012).

Interstate analyses of global integration processes are nevertheless relevant, even in urban studies, because the interdependencies between cities do not develop within territories that are homogenous and open as argued by Ohmae (1990) or Friedman (2005). Instead, multinational firms transversally weave a system of territories, producing their own properties, rules and regulations (Yeung, 1998; Dunning, 2002; Ghemawat, 2007; Rugman et al., 2012). Thus, the national level must be taken into account, but the continental level also seems to serve an important purpose due to the creation of free-trade zones, which tends to reinforce continental systems (Ohmae, 1996; Rugman, 2001; Dicken, 2003; Yeung, 2002; Rozenblat, 2004; Pomfret, 2007; Rugman et al., 2012). Nevertheless, continental regions as roughly defined are perhaps not the appropriate geographic level at which to detect cohesion, and other geographic associations may matter more to the organization of global economic links. From a national to a worldwide scale, firms are concentrated in sub-national regions (Scott, 2001) that are linked within national systems, sometimes with cross-border effects; with other national systems inside continental zones; and in an intercontinental framework.

In this multi-scale geographic system, intense economic specialization creates groups of cities that are more and more interrelated despite long distances (a tendency that is reinforced by national policies related to “poles of excellence” or “poles of competitiveness”). The most often quoted example of this phenomenon remains that of financial specialization, which has generated a “global city” linking New York, London and Tokyo (Sassen, 1991). The other cities of the world are supposedly
connected to this central system and are seen as being linked in a simple hierarchy that is erroneously based on unique rankings of “world cities” (Friedmann, 1986; Taylor, 2001; Brown et al., 2010).

Given the importance of the regionalization of the world, we instead assume that the “world cities” are not generating a system that is entirely independent of territorial boundaries or other geographical barriers and preferential relationships. Some regional systems have progressively created dense groups of interrelated cities. Our hypothesis is that firms take advantage of these “host regions” supported by very integrated urban systems, in which some world cities in each region serve as “bridges” to the global system. Moreover, we wish to determine to what extent national factors are still relevant and examine the influence of geographical scales ranging from the international to the local.

In this paper, we propose to identify the roles of these regions in the global integration of cities by empirically evaluating a large sample of networks of multinational firms. We focus on the network properties of these regions, comparing their capacity to integrate city networks. The international organization of networks of multinational firms will first be discussed in relation to the global integration of cities (section 1). We will test the combined effect of distance/city size using a gravitation model for the various continents (section 4). However, this gravitation model does not fit as expected, which suggests that other factors also matter in the process by which multinational firms develop intercity linkages. Thus, we will employ clustering analysis, defining the regions in which the cities are more intensively interlinked, and we will validate these regions using a new gravitation model (section 5). This process yields more satisfying results, with the organization of these regional classes of cities characterized in more detail. We will discuss these classes and the factors that have generated them.

2 Regionalization of Cities by Multinational Firms

The regionalization of cities by multinational firms is analyzed in three different fields:
- The world city networks are studied by geographers and sociologists;
- The regionalized world is studied by political sociologists and, using clustering techniques, by geographers and physicists;
- The determinants of firm internationalization are studied in business science and economics.

This multi-dimensional approach makes it possible to explain the mutual relationships between cities and firms. Cities and firms integrate mutually in a regionalized world due to specific integration factors.

Cities’ Systems and Multinational Firm Networks

Cities and business networks constitute a “duality” in which the latter now have a greater potential to structure the former (Neal, 2008). In return, businesses locate their headquarters and plants near the highly differentiated resources and markets offered by urban territories. The “space of flows” and the “space of places” (Castells, 1996) are closely connected in the structure and dynamics of cities, thus creating “systems within systems of cities” (Berry, 1964; Pred, 1977; Pumain, 1997, 2006). Global economic networks reinforce these city systems. In setting up their subsidiaries and production units and in generating internal and external exchange networks, multinational corporations position each territory and each city within a complex system of interdependencies. Synergies develop in particular locations through agglomeration economies (Marshall, 1920; Ohlin, 1933; Hoover, 1937, 1948; Jacobs, 1969; Henderson, 1988; Camagni, 1999; Gordon, Mc Cann, 2000; Duranton & Puga, 2004; Ellison & Glaeser, 2007) and between different locations through network economies (Castells, 1996; Bathelt et al., 2004; Johansson, 2005; Karlsson et al., 2005; Capello, 2009; Rozenblat, 2010). Bathelt et al. (2004) suggested that global interactions between cities are reinforced if the corresponding local networks are well developed, as empirically demonstrated by Rozenblat (2010). This dynamic within urban development may constitute part of the definition of the “world city”.

Patrick Geddes proposed the first definition of “world cities” in 1915, describing them as the places in which global
business is concentrated. The later definitions proposed by Hall (1966) and Hymer (1972), like the “world cities hypothesis” by John Friedmann (1986), were consistent with this tradition, exploring some functions of central and peripheral cities in the world economy (e.g., as the locations for headquarters and stock exchanges). The first measures of these hierarchies were based on population, the locations of headquarters, world events and air traffic passengers (Cohen 1981; Meijer, 1993; Lyons & Salmon, 1995). However, as argued by Alderson and Beckfield (2004), power is not related to location alone: “the power of world cities is inherently relational: cities do not have power in and of themselves; they have power to the extent that they function as command points and centers of planning and thus establish the framework in which other cities operate in the world economy”. (Alderson & Beckfield, 2004, p.812).

The definition of “global cities” presented by Saskia Sassen (1991) more specifically suggests that advanced production services (APS) spur on the process of globalization of cities by concentrating their power. This idea has been further developed by the Globalization and World Cities group (GaWC), led by Taylor (2001). However, the approaches developed by the GaWC group, which analyze the construction of networks of APS firms between cities, can be strongly criticized because complete graphs are built between all locations of every corporate group, which introduces some structural bias into the network analysis (Neal, 2012).

Wall and van der Knaap (2009) identify “global cities” based on rankings for networks of financial firms (APS firms) and identify “world cities” with reference to all economic sectors of multinational firms. The former were studied by considering the ownership networks formed by the series of stakeholder/subsidiary links (a maximum of five) for the most successful global corporations in all activity sectors (Rozenblat, Pumain, 1993; 2007; Wall, 2009). Alderson and Beckfield (2004, 2010) also adopted this approach but include only one level of subsidiary. The subsidiary links make it possible to specify “power” cities, which feature a concentration of ownership links, and “prestige” on another hand, meaning attracting subsidiaries.

National institutions, political coordination and economic and innovation resources support the development of enterprises and cities (Sassen, 2007). The economic and social strength of cities and nations interact, forming a national system that is able to integrate cities into the globalization system. This particularly benefits home headquarters that receive investments, workers from across the nation and knowledge spillover (Rosenthal & Strange, 2001). However, although there is evidence of this strong relationship between cities and national economies, the direction of the relationship is uncertain, and a feedback loop may exist between city and state development (Polese, 2005). Locally, cities foster specialization and skill in specific sectors (Henderson, 1988) as well as diversity (Glaeser, 1995; Quigley, 1998; Duranton et Puga, 2004). The local complexity created by the location of many enterprises very close to each other in the same urban areas that are financially linked is rarely considered because of the lack of data available on this scale. On a global scale, this phenomenon concerns European and Asian cities in particular but very few American cities (Rozenblat, 2010).

The network approach to a firm’s ownership structure permits a skewed perspective on cities. It also makes it possible to identify processes that develop inside and between cities (Rozenblat, 2010) and in interaction with territorial organizations on various geographical scales that integrate different economic and social systems and institutional rules. The network approach also permits us to use graph theory to determine the highest-density areas on the graph for the regions of cities in the world system.

Regionalization of the World Cities

The regionalization of the world is not simply an issue of cities. Since Myrdal (1957) and Wallerstein (1974), the regionalization of the world has been a topic of discussion (Chase-Dunn, Rubinson, 1977; Bornschier et al., 1978; Chase-Dunn, 1975; Sanderson, 2005; Dezzani, Johansen, 2012). Hymer suggested that the pattern of regionalization among the cities of the world is consistent with the hierarchy of countries (Hymer, 1972). Alderson and Beckfield (2004) confirmed this hypothesis, showing that the hierarchy of cities according to their multinational firm networks approximately matched their country’s status, whether central, semi-peripheral or peripheral, according to Bollen and Appold (1993). However, the researchers did not consider the geographical position of cities and countries, including the effects of geographic distance.
effects on these networks. Using a geographical approach, Grasland and Didelon (2008) regionalized the world according to barrier effects and regional preferences measured using the residuals of a gravitation model of international trade flows between 1996 and 2000 (Grasland, Didelon, 2008, p.73). The authors found 12 very well integrated regions within the world (with positive residuals), whereas the triad system appears less connected than expected (with negative residuals) (Fig. 1).

Many techniques have been developed in the last 15 years by physicists as a means of classifying networks according to their local densities (Blatt et al., 1996; Girvan & Newman, 2002; Clauset et al., 2004; Guimera et al., 2004, 2007; Guimera & Amaral, 2005; Reichardt, Bornholdt, 2006; Traag, Bruggemann, 2008; Sathik et al., 2011, Newman, 2012). These researchers applied their techniques within numerous fields, from biology to social networks. In particular, Guimera et al. (2005) used a clustering algorithm for airplane traffic flows that revealed regionalization patterns that were greatly consistent with those of continents. Vittali and Battiston (2011) studied the stakeholder/subsidiary networks for multinational firms in European regions. They did not directly employ a clustering method for these networks but demonstrated the Small World properties of networks inside countries. They indicated that a pair of nodes’ networks will decrease based on distance but that this change will vary according to the length of the path between the stakeholders and the subsidiaries. Thus, all of these studies demonstrate the relevance of the network approach and underline distance and country membership as factors that determine the organization of spatial networks for multinational firms.

Determinants of Multinational Firm Networks’ Location

The determinants of the locations of multinational firm networks have been continually studied in the business literature (for recent reviews, see Wall et al., 2011; Rugman et al., 2012). There are two primary general approaches: the micro-business and the regional economic approaches (Dunning, 2002).

At the micro-level of corporate strategy, business networks develop where local or regional clusters integrate the longest-range networks with different specific urban factors (Porter, 1996). According to Doz et al. (2001), our perception of systems becomes a global perspective on the world, including technology pockets, “intelligent markets” (i.e., specific markets) and identified capacities. However, firms that truly function in an entirely “global” manner and that perfectly consider the
complementarity that should exist between their various plants are extremely rare (Rugman, 2001; Ghoshal & Bartlett, 1990; Bartlett & Ghoshal, 2002). Ghoshal and Bartlett (1990) proposed a model that distinguishes between four different types of international organization for firms based on two criteria: their responsiveness to local markets and their corporate integration:

- “Multi-domestic” firms are oriented toward markets but have low corporate integration.
- In contrast, “global” firms are very well integrated but do not consider different markets.
- “Transnational” firms excel in both areas.
- “International” firms are balanced in these two respects, but their performance in these areas is much weaker than that of the transnational firms. Such firms will either become “real” “transnational” firms or maintain this incomplete pattern of production (as may sometimes occur based on the economic specialization of the firm; for instance, the British company Orange in the communication industry keeps its markets close to each other but encourages some homogenization without a strong global managerial orientation).

Transaction costs and benefits are crucial determinants of the character of such organizations (Coase, 1937; Williamson, 1975; Powell, 1990; Zayac and Olsen, 1993). Such costs and benefits can be influential whether they arise inside or outside the firm (Johanson and Vahlne, 2011). At the intra-firm level, a firm’s size, managerial structures, financial resources and R&D and marketing capabilities are the main factors that encourage internationalization (Rugman et al., 2012). Venables (1999) has indicated the role of distance cost in the fragmentation of the world production. In addition, the density of the linkages in a local or national context influences industry performance and company strategy (Westney & Sakakibara, 1985; Ghoshal & Bartlett, 1990). In fact, value is created at the level of individual partners or institutional networks that influence the economics or governance of the firm and based on the properties and institutions of particular territories (Gereffi, 1996; Gereffi et al., 2005; Mc Cann, Mudambi, 2005).

The regional economic approaches more deeply emphasize the interaction between firm advantage and contextual advantage (Dunning, 1992, 2009; Rugman, 1980, 2012). Recently, Wall et al. (2011) developed a database that aggregated companies’ ownership networks by country. Based on the “OLI paradigm” by Dunning (1992, 2009), Wall et al. (2011) empirically demonstrated that owner (O) advantages based on home-country-specific factors matter much more than location (L) advantages in determining the FDI flows between countries. These findings are consistent with the recent results of Rugman et al. (2012). In the home country, the degree of wealth (GDP), openness (relative international trade) and stock market capitalization greatly influence the strength of the FDI flows. In the host country, GDP also matters, but its influence is much smaller than that of distance. Wall et al. (2011) also demonstrate that physical distance has a negative effect, whereas cultural proximity (language and history) and difference in GDP have positive effects.

At the world city level, we consider how factors such as home city and host city advantages and distance are interconnected and how they influence the regionalization and hierarchies of cities. The dichotomy between cities and countries remains uncertain as we attempt to define the more relevant factors and the multi-scale organization of these networks connecting local places (cities), simultaneously including country and continent effects. The paper will present a regional analysis and graph analysis of the organization of these networks of multinational firms within the world city system. We will outline the evidence of this very complex system of cities, demonstrating how the continental approach can be outperformed by a clustering approach that is used to identify the more relevant regional sub-systems of the world.

3 Data and Methodology

To determine the positions of cities within such corporation networks, we first built a database of firm networks that includes all the direct and indirect subsidiaries of the top 3,000 worldwide company groups based on their turnover (Orbis, Bureau Van Dijk, 2010, Fig.2.a). According to their locations, we then aggregated these networks at the city level (with cities defined as large, functional urban areas) (Fig.2.b and Fig.2.c).
The 3,000 largest groups directly or indirectly own 800,000 subsidiaries located all over the world that are connected by 1 million direct or indirect financial links. We used all links that constituted more than 5% ownership without any restrictions, unlike Wall and van der Knaap (2009, 2011), who stopped at 5 levels. We also retained the observations with missing values, knowing that links below 5% represent approximately 10% of the available information. We found a maximum of 34 levels of subsidiarity in a single network (that of Shell); in other cases, loops render the concept of “levels” irrelevant. All of the headquarters and subsidiaries are described by their activity sector (NACE), their turnover and number of employees when it is available, and their owners and subsidiaries. The information regarding the weight of the financial link is only available in 60% of cases. Thus, there are two options: one can consider the weight of the links (and delete the 40% for which this information is not available) (as is not specified but was surely performed in Benetton, 2007 and Vittali et al., 2011); or one can use every ownership link without the weight for each link. We chose the latter option, knowing that this option does not weight the individual ownership links. However, the intercity relationships are weighted: aggregating the ownership links for pairs of metropolitan areas, we consider the “number of links” between and within these areas. After they have been aggregated, the inter-city links are weighted based on the number of links from the owner cities to the subsidiary cities (Fig. 2.b and 2.c).

Figure 2  Building data: from individual networks of firms to city networks
Source: Rozenblat (2012).
To aggregate the data within comparable cities, each of the 800,000 individual firms was precisely located in a metropolitan areas (a ‘functional urban area’ in Europe according to the ESPON definition 2010, a MSA for the USA and Canada and the equivalent for the main cities across the globe based on Google Maps) (IGUL, 2010). The links were aggregated by metropolitan area using their origin and their destination. This process yielded a matrix linking 1205 metropolitan areas from all over the world. These areas contain more than 85% of the overall number of links of the database. Although we have a larger sample of subsidiaries, we obtain less numerous urban units than Alderson and Beckfield (2004, 2010), with 3,692 cities for 2000 and 6,308 cities for the period 1981-2007, because we considered the definition of urban areas to be much broader (in Europe, large urban areas are defined according to commuting flows; for instance, Wolfsburg is associated with Braunschweig and Vevey with Lausanne).

In addition to metropolitan areas, we might also consider free trade zones given that we would like to evaluate the regionalization of the world. However, because the free trade zones are very numerous and overlap, it was difficult to select precise levels for these zones. Thus, we preferred to begin with the continental zones in 6 regions as defined by the UN. This basic grouping method will be compared to the use of empirical clustering, as discussed later.

4 Geographical Scales of Networks under Globalization

The matrix of firm linkages between cities was first aggregated by continent. Although the 3,000 top companies are based equally often in Europe, North America, and Asia, the position of European cities in this network is quite strong. More than the half of the total subsidiary links throughout the world, are located inside Europe, either inside one country or between two European countries. In addition, three quarters of the total ownership links are located in Europe alone or Europe and the rest of the world. These findings are easily explained by the high degree of fragmentation of Europe throughout history, which facilitated the industrial revolution, generating a high number of independent firms that had to develop agreements or merge, especially at the end of the 20th century under globalization. In addition, because of its national and industrial history, the European industrial system is much more complex than the Asiatic or the North American one (Dunning, 1992; Dicken, 2003). The urban system supports this complexity and, conversely, is very influenced by increases in economic network complexity (Mumford, 1961; Bairoch, 1985). This dynamic creates a very strong, diverse core that encourages network development and reinforces networks between the numerous European cities, from the smallest cities to the biggest metropolises.

Such complexity can also be found to some degree on the international scale, especially if we study FDI flows, considering monetary investment (Mucchielli, 1998; CNUCED annual reports). However, FDI studies do not reflect the distribution of flows within particular countries or the local influence of the agglomeration economies that support and interact with these ownership networks (Fig. 3).

![Image: Multinational Firms Networks](Spatial links between owners and subsidiaries based on regional scale)

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This study is the first to evaluate these essential local links, confirming the agglomeration economies play a role on a global scale (Bathelt et al., 2004; Rozenblat, 2010). Moreover, globalization is strongly rooted in national systems, with two thirds of linkages remaining domestic. National structures indeed still matter; as the strength of a national economy makes it possible for businesses to expand abroad. This idea is consistent with the work of Sassen (2007) and Polese (2005), which argues that the development of cities is linked to their national systems.

When we remove the local links inside urban areas (250,000 links) and retain only the “external” links between cities, we obtain a matrix that crosses all of the cities that host the plants associated with the top 3,000 business groups in the world. This matrix includes 600,000 subsidiaries spread out over 1,205 metropolitan areas of the world. Some 100,000 enterprises included in the survey are located outside metropolitan areas, but they represent less than 15% of the total number of subsidiaries.

Paris, London and New York dominate and are embedded in a dense network of cities of their continents. The global position of these large cities allows smaller cities with a more secondary position in the global network to access the entire world. Asia, in turn, is split into two parts; Japanese cities seem disconnected from Chinese, South East Asian and Australian cities. They do not play the same spatial role in globalization. A dramatically isolated group is formed around Moscow, which serves as a gateway between the other Russian cities and the rest of the world.

In terms of centrality in the network (“between centrality”), London is first, followed by Paris and New York. This result is consistent with those of Alderson & Beckfield (2010) and Wall & van der Knaap (2011) based on smaller samples. Paris only has one quarter of the number of foreign subsidiaries that London enjoys (5,000 versus 20,000). In particular, London hosts many American companies (35% vs. 23% for Paris) and Asian companies (6.6% vs. 3.6%), but interestingly, it also hosts many fewer European companies than the rest of the European cities. This finding confirms that London functions as a bridge for American companies in Europe but is much less integrated with the overall network of European firms than Paris (70% for Paris and 55% for London) (Rozenblat, Pumain, 1993, 2007). In addition, the capital cities of other European territories are also significant. This is particularly true in Central Europe, but it also holds for most of the world’s developing countries. Uncertainty regarding the administration in these countries and a lack of information regarding them leads companies to settle first in these capital cities. This strategy allows firms to remain near key institutions such as banks, to build a local professional network and to acquire information that will ultimately allow them to identify a more appropriate production location. The capital of a nation thus bridges foreign countries and national cities. Only robustly federal countries such as Germany exhibit more balanced openness to foreign companies among their various cities. They thus have better visibility from abroad and are more rapidly integrated into the diffusion process for new knowledge and practices. Nevertheless, cities situated in centralized countries also can have good access to these networks due to the bridging role of capital cities in their internationalization.

5 Test of Gravitation Model in Multinational Firms Networks

In addition to these multi-level geographic patterns, distance still influences the relationships generated by multinational firm networks (Vitali, & Battiston, 2011; Wall et al., 2011). In fact, geographical distance drastically decreases these connections for the multinational firms of the world (Fig. 4).

The curve decreases based on the well-known distance cost (Ravenstein, 1885; Reilly, 1931). Here, this cost reflects the cost of transporting goods, the difficulties of long range communication that persist even as new information technologies are developed, and the decreasing knowledge and increasing transaction costs associated with remote places. The world curve (Fig. 4.A) decreases rapidly until 2,000 km (the threshold below which most linkages are between cities in neighboring countries) and then slows at 4,000 km (the size of the continents). Oceans must be crossed at 5,000 km; then, between 6,000 km and 8,000 km, intercontinental links appear. The intra-continental decrease in the curve is much clearer for the European scale (Fig. 4.B). In essence, direct links appear to be limited by distance and barriers between continents.
Gravitation Model on Firms’ Ownership between Cities

The effect of distance and size can be formalized using a gravitation model that assumes that the flow from place $i$ to place $j$ is proportional to the mass of $i$ and $j$, and inversely proportional to the square of the distance between the two places (Ravenstein, 1885; Reilly, 1931; Isard, 1951; Ullman, 1954; Berry, 1964; Fotheringham & O’Kelly, 1989). The initial formula has been generalized with indexes for each independent variable, and the model is currently used in international economics to explain trade flows between countries (Bergstrand, 1985; Eichengreen & Irwin, 1998; Linder et al., 2008; Grasland & Didelon, 2008). The general formula that we wish to test is as follows:

$$F_{ij} = K \frac{M_i^{\alpha_1} M_j^{\alpha_2}}{D_{ij}^{\beta}}$$

where

- $F_{ij}$: is the number of companies of the city $j$ owned by companies of the city $i$
- $M_i, M_j$: are the mass of the cities $i$ and $j$
- $\alpha_1$: is the multiplier parameter of owner city $i$
- $\alpha_2$: is the multiplier parameter of subsidiary city $j$
- $D_{ij}$: is the distance from city $i$ to city $j$ (distance between cities $i$ and $j$; here, we built different distances)
- $\beta$: is the negative multiplier parameter of the distance, also called the friction of distance

Several independent variables were generated for these cities:

- Owner city: $i$
- Subsidiary city: $j$

Urban indicators for $i$ (Owner cities: $O_i$) and $j$ (subsidiary cities $S_j$):

- POPULATION_URB: City population based on the UN « Urban agglomerations » of the world (UN Demographic Yearbook 2008)
- INTRA_URB_LINKS: Based on our database, we summed the intra-urban links for each urban area;

National indicators attributed to $i$ cities (Owner cities: $O_i$) and $j$ cities (subsidiary cities $S_j$):

- NATIONAL_GDP: Each city was characterized based on its national GDP, a proxy for the national market that can be reached via each city (source: CNUCED 2011);
- NATIONAL_GDP/INHAB: Each city was characterized based on its national GDP per inhabitant, a proxy for the national wealth surrounding each city (source: CNUCED 2011);
- **INTRA_NAT_LINKS**: We summed the weighted intra-national links between cities (removing the intra-urban ones) and calculated the ratio of these intra-national links to the total links (also excluding the intra-urban ones);

**Bilateral Indicators**: \( D_{ij} \)
- **DIST**: the orthodromic distance between owner city \( i \) and subsidiary city \( j \);
- **R_GDP_INHAB**: The ratio of the GDP per inhabitant of the country to which the owner city belongs divided by that of the country to which the subsidiary city belongs; this indicator measures the difference between the levels of wealth of the two countries in question;
- **R_GDP**: Ratio of GDP of the country to which the owner city belongs divided by that of the country to which the subsidiary city belongs; this indicator measures the difference between the market sizes of the two countries.

The model can be easily tested if we apply logarithms on both sides of the equation:

\[
\log(F_{ij}) = \log(k) + \alpha_1 \times \log(P^1_i) + \alpha_2 \times \log(P^2_i) + \ldots + \beta_i \times \log(D^i_j) + \beta_j \times \log(D^j_j) + \ldots
\]

Using multiple linear regression, the model was applied to a global weighted matrix of ownership flows between the 1,265 cities excluding intra-urban linkages (which are used as the independent variable) and not taking into account the missing links (0 values). The model was tested on all of the global pairs of cities without missing values for the different parameters (24,769 pairs of cities) and for subsets of cities according to the continent to which they belong. Although this type of model has been criticized due to its logarithmic adjustment (Flowerdew & Aitkin, 1982; Linder et al., 2008), the model can be used to analyze the variance explained \( (R^2) \), whereas most other Logit models do not, indicating only the convergence of the model. Thus, we also used a binomial negative model to verify the latter while using a more appropriate model for these over-dispersed data (Long, 1997; Wall et al., 2011). Because the binomial negative model can include some qualitative variables, we used each pair of continents \( (O\_CONTINENT * S\_CONTINENT) \) as a bilateral variable.

**Application of the Gravitation Model on the Ownership Flows between cities by Continent**

Tables were used to summarize the different gravitation models tested for the total sample or the weighted ownership links between cities and by continent using multiple regression analysis based on the log-linear model (Appendices: Table 1).

The total model explains 32% of the variance in the ownership links between the 24,769 pairs of cities included in the data without missing values. The first variable emphasized by the model of stepwise multiple regression is \( O\_INTRA\_URB\_LINKS \), the number of intra-urban links among owner cities (with a partial \( R^2 \) 11.6%). These results, while based on another scale, are consistent with those found by Wall et al. (2011) at the national level: the findings indicate that home advantage is highly significant in the internationalization of firms.

But moreover, this result means the predominance of the complexity of linkages inside the owner cities to determine the weight of the links. It is unsurprising as this finding underlines the role of city resources in controlling external subsidiaries. Such resources might include specialized services, institutions, high productivity and highly skilled workers. The relationship between local and global links is emphasized here, especially given the power functions in cities, confirming studies regarding “global cities” and “clusters” that suggest that this relationship exists at the micro-level (Sassen, 1991; van den Berg et al., 2001; Bathelt et al., 2004; Grabher, Powell, 2004). Of course, the density of the intra-urban relationships within owner cities is stronger among large cities (Tab. II): the high simple linear correlation between the logarithms of both variables (densities of intra-urban links [\( O\_INTRA\_URB\_LINKS \]) and size of the cities [\( O\_POPULATION \)] is positive and quite significant \( (R=0.547) \).

This effect of intra-urban density is weaker for subsidiaries cities but continues to be important; this is the second-place variable in the stepwise multiple regression (partial \( R^2 = 10.2\% \)), together with the effect of population size for urban areas (\( (S\_POPULATION; \text{partial } R^2 = 2.1\% \)). Geographic distance matters for partial \( R^2 = 4\% \), whereas other types of distance have a significant but weaker effect.
National indicators for cities have only a very limited influence on the total model. However, national development is in part considered in the urban indicators, as shown by the high correlations between the intra-urban links and national GDP per inhabitant, which is greater for subsidiary cities than for owner cities (Tab. II). Nevertheless, for owner cities, intra-urban links are more related to national wealth (GDP/inhab.) than to their total markets (GDP). The same is true for subsidiary cities, but the relationships are much more intense. Urban/national relationships are quite complex: the density of inter-urban links between national cities seems to play a (low) negative role in these flows (Tab. I). In fact, the national density and intra-urban density of links are negatively correlated for owner cities but positively correlated with subsidiary cities (Tab. II). It reveals the greater concentration of ownership links in few cities for many countries, even for some of the more developed ones.

The various multiple regressions by continent indicate better adjustment of the gravity model inside continents than between them (Tab. I). The gain is not strong for each continent, especially if one considers that the number of pairs for each continent is much lower than the total, making the explained variance much more likely to be higher (except for the Middle East, whose results are not significant, with very few links). However, North America, Asia and Europe, which have many more observations than the other continents, have higher R² values than the total value. For Asia and Europe, distance appears with a stronger effect than it does for other continents. For both continents, inter-city links are much more sensible to distance than in North America, where this influence is especially weak. The inter-continental effect of distance is obviously weaker. It is also notable that for Africa, which has very few links, the only significant variable in its inter-cities linkages is the national density of inter-urban links. This finding reflects the status of the rare African countries that have several cities that are integrated via FDI flows, such as South Africa.

The negative binomial regression confirms these results with a convergence of the model (Tab. III), highlighting only the significant variables. The only significant continental effects concern pairs of cities inside Europe, inside Asia, and between Europe and Asia and Europe and Africa: These couples of continents have more intense positive effect on the links, when compared to all other couples of continents, on average. However, the continental pattern of organization has some limitations that we can attempt to overcome by generating regional analysis based on empirical clustering for the entire matrix.

6 Conclusion

This paper aims to measure the integration of cities in global firm networks using a multi-scale structure that includes intra-urban linkages and national, continental and inter-continental links. The share of inter-continental links is rather low; these networks largely develop at the national scale. The national scale remains essential to the economic integration of cities in global networks, as it contains two thirds of the total inter-urban linkages. However, the main factor that explains the flows of ownership between cities is the local density of links inside each city. This finding demonstrates the attractiveness of a well-connected local urban economy in foreign investment. Whereas some contend that only economic factors influence global investment, geographic distance does remain a significant factor.

However, one limitation of the urban approach is that it does not take into account the strategies of firms based on different geographic scales. To identify the possible regulations governing these networks, one also must consider the strategies of firms, which may be economic (e.g., concurrence, alliances, sub-contracting, division of labor, product cycles) or managerial (i.e., innovation in the global organization of firms), and which influence these different scales. Thus, integrating the “global value chain” of these networks via a multi-dimensional approach to the interaction between the reach of individual firms and that of particular territories may yield fresh, new research. Such research can effectively address the micro-networks of firms that exist inside and between countries, inside and between cities and inside and between continents.
References


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Westney, E. D. and Sakakibara K. (1985): “Comparative Study of the Training, Careers, and Organization of Engineers in the
Computer Industry in Japan and the United States," MIT Japan Science and Technology Program (September).


Table 1 Gravitation model of the MNF ownership flows between cities by continent (Multiple linear regression)

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Only estimated values with Pr > F below 5% are indicated

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Source: ORBIS, 2013
Table 2  Correlation matrix of all logarithms of variables

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Mentioned indexes:
- Correlation indexes: R
- Pr > F
- Number of observations without missing values
Table 3  Gravitation model of the MNF ownership flows between cities with 7 continents
(Negative binomial regression. Number of observations 24,769)

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<th>Estimated value</th>
<th>Standard Error</th>
<th>Wald confidence Interval at 95%</th>
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</table>

Only estimated values with Pr > F below 5% are indicated, and only significant CONTINENT and COUPLES OF CONTINENTS are listed.
The negative binomial dispersion parameter was estimated by maximum likelihood.
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source: ORBIS, 2013