Firm linkages, innovation and the evolution of urban systems

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Because a city cannot be conceived of as an isolated system but is always part of a *system of cities* (Berry, 1964), interaction between cities is an essential component of the dynamics of urban systems. Each town or city is a persistent and relatively autonomous entity whose evolution is influenced or limited by the towns and cities in the same interaction networks (Pred, 1977). It has been demonstrated that competition between towns and cities for resources and growth is the main driving force in the dynamics of systems of cities, which also explains the pervasiveness of their structure (Pumain, 2000). Most systems of cities link neighbouring towns and cities located on the same regional or national territory. But cities also have relationships with more distant competitors, especially in specialised networks, which is more and more the case in the current context of an increasingly global economy. Therefore, the hierarchical organisation of cities in systems of cities is no longer inclusive (if it ever was), since the multiple links connecting towns and cities can go anywhere. However, many of the relationships between urban actors are recurrent or use the same communication channels. Recurrent interaction patterns shape the structure of urban systems. This structure is universally characterised by strong hierarchical differentiation (Pumain, 2005). Several orders of magnitude separate the importance of towns and cities, in terms of population, gross product or influence. This importance can be defined by the relative position of a given city in interaction networks (centrality, betweenness), as well as by the urban attributes representing the cumulative effects of that position over time. Interaction flows in turn reflect (or are induced by) this structure of the urban system, since they are generated by the attributes of one city rather than another's.

We therefore share P.J. Taylor's view that there is a need for more studies about networks of cities, particularly studies that draw on databases of inter-urban flows. This paper presents the results of a survey illustrating the gradual emergence of an urban system on the scale of Europe, through the interactions created by firm linkages. A subsidiary owned by a multinational firm in a foreign country is interpreted as a directed interaction between the city where the headquarters are located and the city where the subsidiary is owned (after the foreign subsidiary is set up or acquired). We examine the position of cities in these ownership networks, which provides insights about the main factors in a city's capacity to participate in the formation of a system of cities on the European scale.

1 Cities and their networks in Europe

The integration of European society and territory is achieved mainly through the development of new linkages between cities, especially the largest. But, even if the familiar process of hierarchical diffusion of innovation in urban systems (Pred, 1977) is at work here, these linkages cannot be considered in principle as being limited to only a few cities or capitals. National urban systems as a whole are or will be involved in the expansion of interactions between territories at the international level. However, after a wave of comparative studies of large sets of European towns and cities in the 1980s and 1990s (Brunet, 1989; Conti and Spriano, 1990; Pumain and Saint-Julien, 1996; Cattan et al., 1999), there has been a shift in research towards monographs addressing a small number of global cities (Sassen, 1991; Hall, 1995).

Global cities raised new theoretical questions about the role of cities in the globalisation of the economy (Friedmann, 1986). Meanwhile, the changing status of cities and regions in a context of weakening nation-states was everywhere challenging the forms of their governance (Scott, 2001). Due to regional decentralisation and increasingly independent urban management, "city-regions" began negotiating directly with the actors involved in building global networks. For instance, the deregulation of the airline industry in 1993 gave a stronger role to airlines, airports and their strategic agreements in the organisation of the air transport networks connecting cities (Storper, 1997; Graham, 1998). Urban development can no longer be understood (and perhaps never was) without considering the networks and systems to which cities belong. In more and more situations, the economic competitiveness of places is now assessed from the perspective of networks. For example, the European Commission recommends a policy for developing polycentric urban systems to improve the capacity of the European space to be equitable and redistribute key activities (European Communities, 2001; ESPON, 2003). On another scale, urban managers frequently request assessments of the position and influence of their city in the European urban system, but there is a dearth of comparable urban data.

Relative positions in multinational networks can be defined according to two kinds of complementary information. To describe the power of nodal cities, their importance can be compared using a scale of urban attributes, or by measuring how they are connected by a subset of links or flows in one or several networks. These two methods of measurement are not opposite in significance, since both types of data can be represented either as attributes of the node, or by the intensity of some linkages (there is always a dual representation in networks). Even when the analysis is strictly limited to the relative position of the nodes in terms of their accessibility within a network, this structural analysis can give rise to different rankings of the nodes: a recent study of the worldwide air transport network (Guimera et al., 2005) demonstrated that the most connected cities (the nodes with the highest score or number of incident connections) are not necessarily the most central in the network (that is, cities through which most shortest paths go). Apart from physical networks, most studies of the global power of cities, in terms of the importance of their international activities or their actual or estimated linkages, give figures relating to economic activities or multinational firms (Cohen, 1981; Rozenblat and Pumain, 1993; Taylor and Walker, 2001). Another recent study conducted for the public management board of the City of Marseilles, Euroméditerranée, and DATAR (the territorial development and regional action division of France's ministry of regional development), compared 180 European cities (urban areas with a population of at least 200,000 in 2000) in the European Union, Norway and Switzerland using a set of 15 synthetic indicators of their global weight or influence (Table 1) (Rozenblat and Cicille, 2003).

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Table 1: Fifteen indicators of global influence

Indicators	Source
Population of urban agglomerations 2000	National censuses
Population change (1950-1990)	Geopolis, 1993
Harbour traffic 1999	*Journal de la marine marchande*, ESPO
Airline passengers 2001	Airports Council International
Airline and railway accessibility 2002	Amadeus Global Travel Distribution
Headquarters of large European firms	Forbes, 2002
Stock exchanges	The Bankers Almanac 2002 (Reed BI)
Tourist overnight stays 2001	National censuses and tourist sites
Fairs and exhibitions 2002-2003	Paris Chamber of Commerce
International conferences 1993-2000	Union des Associations Internationales
Museums 2002	International Council of Museums (ICOM)
Cultural sites and events	Michelin 2001
Students 2001	National or regional institutes
Scientific publications	Institute for Scientific Information (ISI) 2000
Research networks	CORDIS, 2002

Source: Rozenblat, Cicille (2003)

The classification of cities according to their global influence revealed four different principles of spatial ordering and distribution of international functions (Rozenblat and Pumain, 2004), satisfactorily validating the theoretical approach previously suggested by Cattan et al. (1999) and put forward in ESPON (2003):

1- principle of hierarchical networking;
2- principle of national integration;
3- principle of selective specialisation;
4- principle of regional cross-border integration.

Particularly in the case of network functions, the combination of these principles creates complex effects, exhibiting at the same time high concentrations in a few cities and a wide variety of urban configurations.

For example, the map representing the distribution of multinational firms' headquarters (Fig.1) reveals that, besides the dominance of London and Paris, many headquarters are still located in old industrial cities of the Ruhr, and they include new activities such as banking, insurance and new technologies. In the case of banking, concentration, which occurred earlier than in other sectors, increased the size of financial groups while reducing the number of banks. Banking networks are now multinational and use the upper part of the national urban systems for locating their branches (Fig.2). The major stock exchanges in Europe are located in only four cities: London, Paris, Frankfurt and Luxembourg. They concentrate 80% of European financial flows (Pagetti, 1998). German cities are organised into a polycentric system of eight cities with stock exchanges. Other locations of European stock exchanges linked to Euronext include Lisbon, Porto, Valencia and Bilbao.

Even if the networks of economic activities are largely coordinated through telecommunication systems, physical accessibility still contributes to the development of every international function. As an illustration, we provide an accessibility map, which measures for each of the 180 European cities the number of cities that can be reached by plane or train in a one-day return trip (Fig. 3). Despite the hierarchical ranking produced by the airline connections of large capitals, many places located in border regions are also highly

accessible, due to the high density of neighbouring cities. This is the case of the Rhine Valley in Germany (especially Düsseldorf), of northern Italy with Bologna, and of France with Lyons. Accessibility is theoretically related to the centrality of cities within all urban systems, because their potential for trade depends on their position. Hence good international accessibility is favourable to the development of international functions. We observed that our indicator is only partly related to a city's size. Other significant correlations are found with regional urban density and proximity to international borders. With an equal population size, the number of cities that are accessible from a European city is fairly highly correlated with the number of international banks located in that city (R=0.76), the number of conferences held there (R=0.7) and, to a lesser extent, the number of headquarters (R=0.49), tourists (0.43) and international fairs (0.41).

Figure 1
Headquarters in European Cities
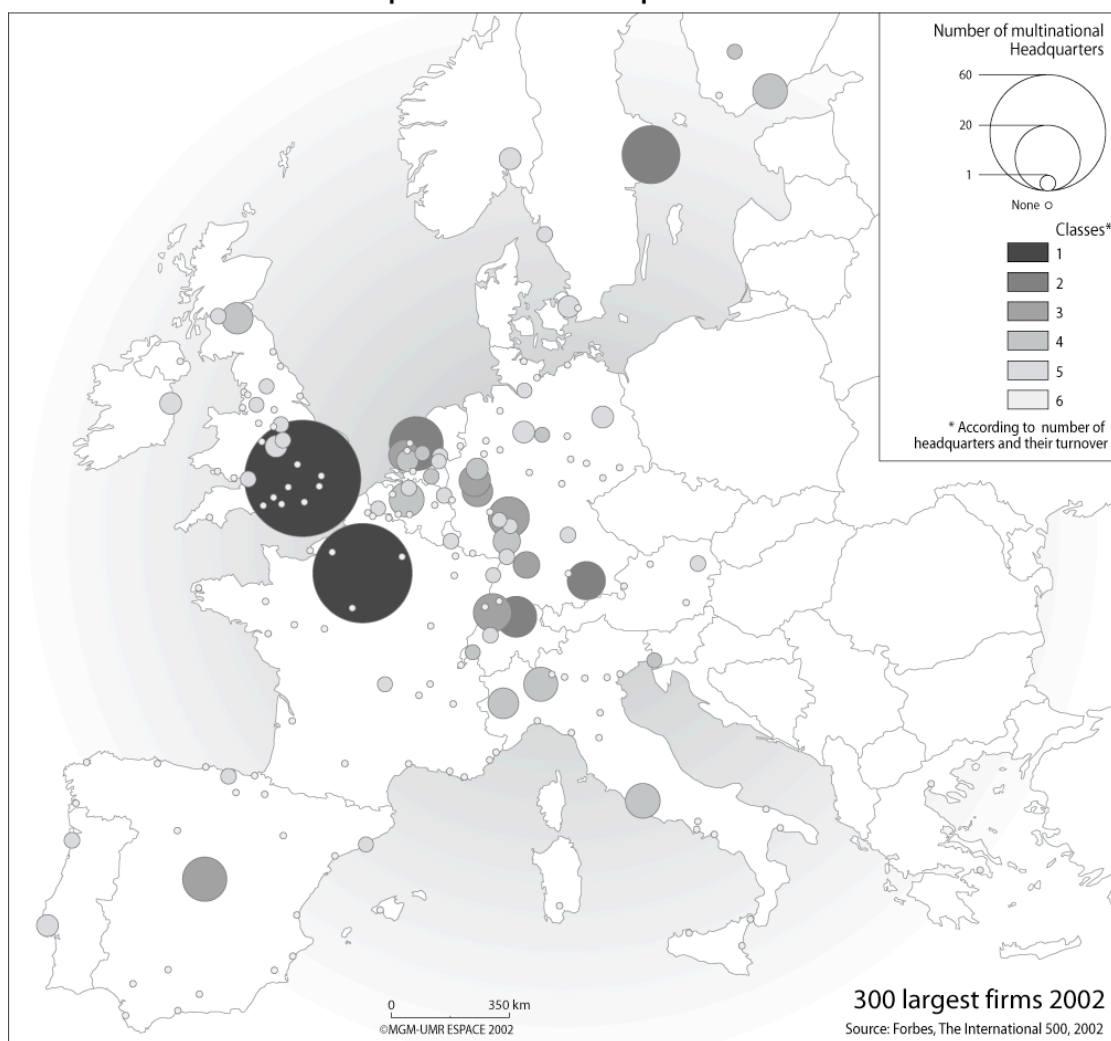
According to that study (Rozenblat and Pumain, 1993 and 2004), there is some evidence that regional and long-range accessibility, together with urban hierarchy, national divisions and economic specialisation, are the basic structures influencing the integration process of cities in Europe. Their effects are combined differently depending on the nature of each function and the city's location in the European urban system, since the international division of labour creates some specialisation in each city and corresponding specialised inter-urban connections.

Rozenblat C., Pumain D. (2007). Firm linkages, innovation and the evolution of urban systems .In Taylor et al. Eds. « Cities in Globalization : Practices, policies and theories ». Routdledge, pp.130-156
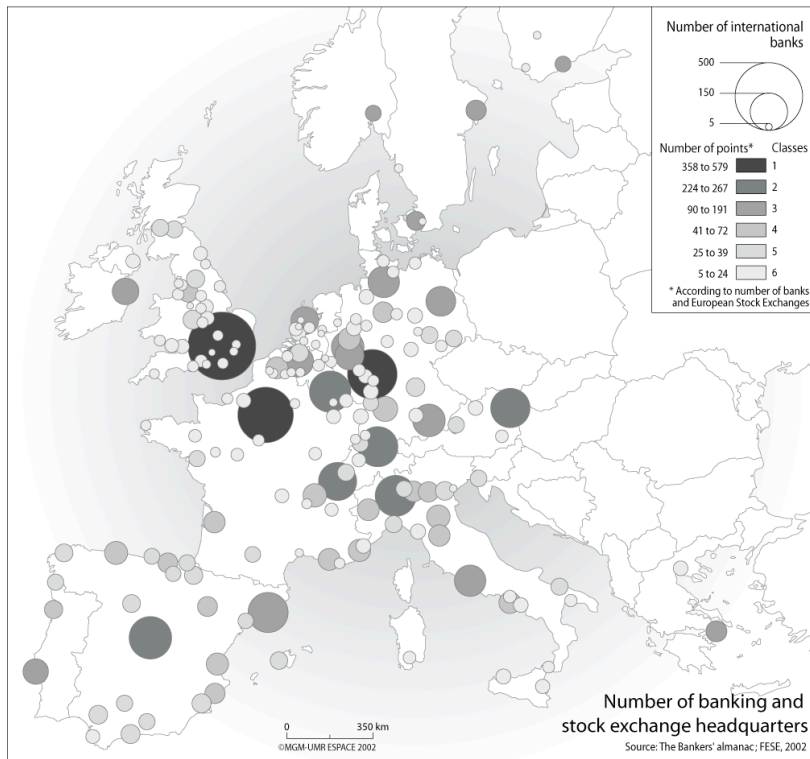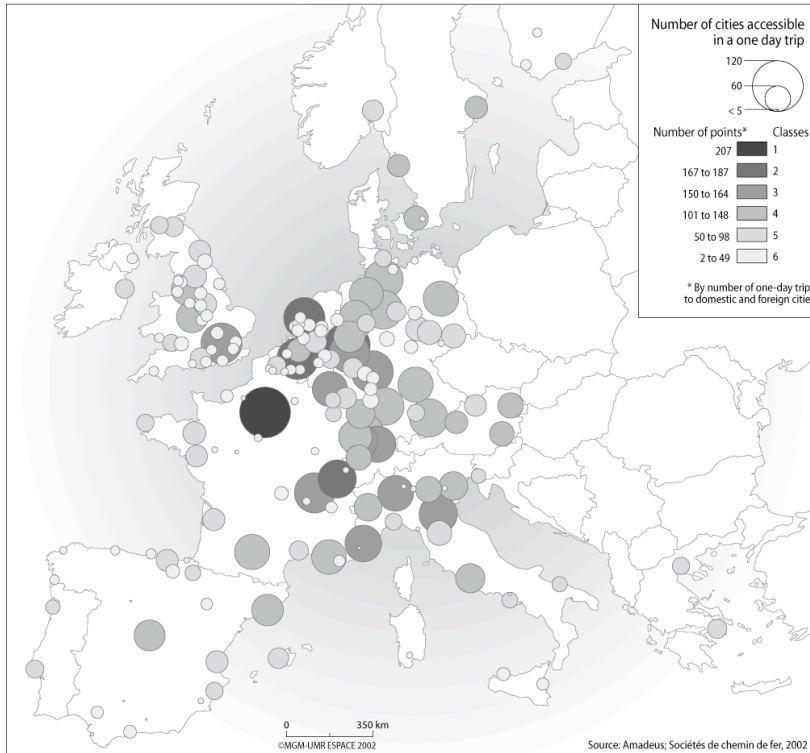
Figure 2
Stock exchanges in European cities

Figure 3
Accessibility of European cities

2 An example of the inter-urban connection process

We shall examine here how a specific kind of inter-urban connection is created through the location process of multinational firms in European cities. The spatial strategies of firms aim to select locations that supply many kinds of local resources (natural and human resources, knowledge, infrastructure and institutions) to serve their purposes. The multiple locations of a multinational firm reflect complementary choices and may create networks linking different cities. Each city where a firm is located contributes to the competitiveness of that firm's economic network. There is thus an interaction between private global strategies and local attractiveness. The wealth and resources of each territory, and global economic and political actors' behaviour combine to form a complex system (Dicken and Malmberg, 2001). The associated advantages probably constitute a new kind of external economies, which can be called "network economies" by analogy with "agglomeration economies". In order to understand the interdependencies created between urban developments (Storper, 1997) through this process, we have decided to observe directly some effective linkages created by multinational firms between European cities.

2.1 Source material: two surveys of foreign firms' networks in Europe
We conducted two surveys (1990 and 1996) of foreign subsidiaries of multinational firms in Europe (Rozenblat, 1992; Rozenblat and Pumain, 1993; Rozenblat, 1997). We collected information on the 300 largest European firms (i.e. headquartered in Europe), about the exact location of all the entities they owned in other European countries, their size (turnover and number of employees), their sector of activity, and their function in the firm. The questionnaire, which was sent by post, asked each subsidiary the date it was set up or acquired, its activity and functional role in the group, and various size-related criteria for the purposes of comparison. Although most companies simply sent back their annual reports, without answering our questions precisely, we extracted information from the annual reports and requested additional information by letter or telephone where required.

We thus obtained homogeneous and useable information about thousands of subsidiaries, including their addresses, functions, activities, and ownership links with sub-subsidiaries. From one-third of the companies at each date (approximately 100 of the largest 300 groups) we collected a sample of approximately 3,000 subsidiaries in 1990 (Western Europe) and another sample of more than 4,000 in 1996 (Western and Central Europe). Based on the links of secondary ownership describing up to five successive levels of branching, we established the architecture of the ownership linkages connecting them.
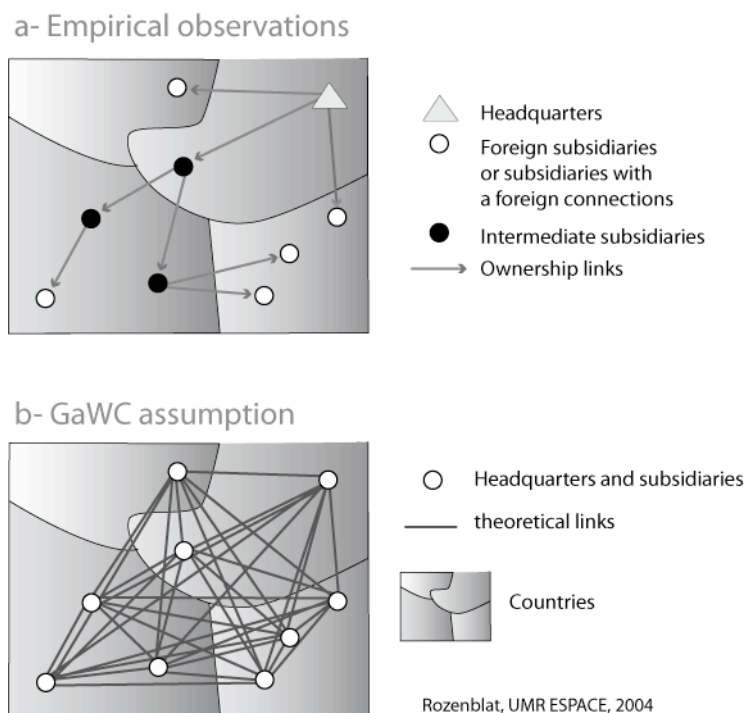
Firm ownership linkages have rarely been used to describe the structure of city networks, although they are highly significant. The architecture of ownership linkages is a marker of the decision-making and power channels between firms. Financial ownership controls the strategic orientation of the subsidiaries. However, not all firms are organised in the same way. There are differences in the structure of holdings depending on the degree of centralisation of the decision-making process. For example, in 64% of the 81 cases analysed by Francfort et al. (1995), the company organisation is highly centralised. In concrete terms, this involves a "system of control" operated either by means of "contracts" for subsequent control of results (60% of the cases) or by "standards, means or objectives" for prior planning of actions (40%) (Mintzberg, 1994; Francfort et al., 1995). The architecture of ownership linkages thus reflects the hierarchical decision-making process in a majority of groups of companies. According to many specialists, these features are even more important in the case of multinational

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corporations (Veltz, 1998; Zimmermann 1995; Michalet, 1997; Mucchielli, 1998; Bouinot, 2004).

The circulation of decision-making between the many entities of a multinational firm also varies depending on their functions. Headquarters perform fewer and fewer administrative functions to concentrate on strategic functions. These strategic functions, including strategic policy, common principles, oversight and benchmarking tools, are becoming more and more centralised. At the same time, purchasing is increasingly centralised to generate economies of scale. But "it is rare that production is formally organised on a world level" (Veltz, 1998). Production is generally organised into product or geographical divisions, of which the continent appears to be the most relevant scale. Between units on the same continent, coordination is closer and a decision to concentrate on some sites can put them in competition with each other. The marketing function seems to be the link between all the organisational scales, because it is present at all levels. In the case of research and development, the project structure fosters association between researchers, engineers and marketing specialists, without necessarily bringing them spatially closer (Zarifian, 1993).

This description of operations within multinational groups demonstrates the decisive role of the legal structure of firms in their concrete organisation. We therefore decided to use the legal structure to describe the economic linkages between cities in the globalisation process (Fig.4). Instead of using the GaWC method, which implies that cities are connected to all the other cities where a subsidiary of the same group is located (Fig.4b), we use the network of firm ownership in the strict sense to determine which cities are actually connected by ownership linkages (Fig.4a). Contrary to the GaWC's research, we do not create more information than what we have in our data. The networks linking cities through the location of multinational firms that we show thus represent the minimum but actual inter-firm networks, whereas the GaWC maps show the maximum possible networks (Fig.4b).

Figure 4
Firm linkages

a- Empirical observations

△ Headquarters
○ Foreign subsidiaries or subsidiaries with a foreign connections
● Intermediate subsidiaries
→ Ownership links

b- GaWC assumption

○ Headquarters and subsidiaries
── theoretical links

Countries

Rozenblat, UMR ESPACE, 2004

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2.2 Examples of firm networks through ownership linkages

In Figure 5, the location of the headquarters of three large firms is represented by a triangle. The links between cities are legal ownership relationships (subsidiaries at least 50 percent-owned) either between the headquarters and subsidiaries located in a foreign city (the size of the circle representing the city is proportional to the number of branches), or between a national subsidiary and its sub-subsidiary located in a foreign city. These three examples of firm networks demonstrate that firm ownership linkages between cities in different countries are sometimes very indirect, highlighting the role of intermediate subsidiary companies in the globalisation process. One headquarters can own several subsidiaries, which in turn own several sub-subsidiaries, and so on. A firm's foreign subsidiaries are not necessarily owned or directly controlled by its European headquarters, but by intermediate headquarters. This legal organisation may reflect a decentralised management organisation, based on a regional and/or sector division of labour or markets. Several decision-making levels (continental, national, by branch or product) can remain relatively independent from each other (as shown by Veltz, 1998 and Crozet et al., 2004).

Figure 5
Three examples of multinational firms'
ownership networks in 1996
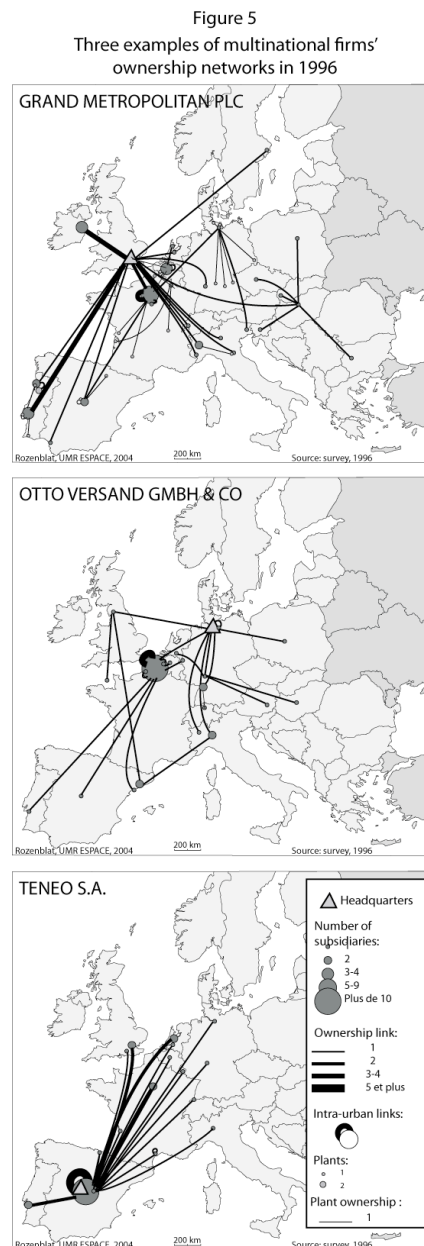
This representation of the effective linkages between firms considerably improves on the description that is generally made of the globalisation process using data on foreign direct investment (FDI) (Michalet, 1999; Mucchielli, 1998). FDI is calculated by national statistics offices from capital flows across international boundaries. These figures do not take into account possible multiple locations of investment within a foreign country. Also, because they do not identify the national origin of headquarters, they do not show the globalisation networks created by firm ownership linkages. FDI data thus produce a fragmented image of the globalisation of companies, failing to show their overall strategies. This image is not without interest, in particular for representing spatial interactions between countries, but is only a partial view of complex multinational economic networks.

2.3 Types of intermediate cities as a distinctive characteristic of city networks according to firm ownership linkages

Using 100 firm networks, we calculate the links connecting two cities i and j according to the number of times that a firm located in city i owns a subsidiary in city j (Fig.6).
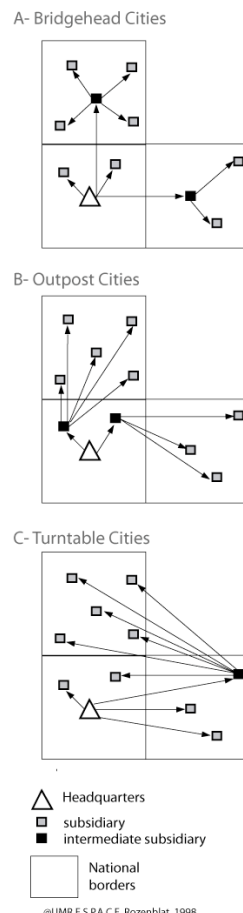
Figure 6
From firm linkages to urban networks
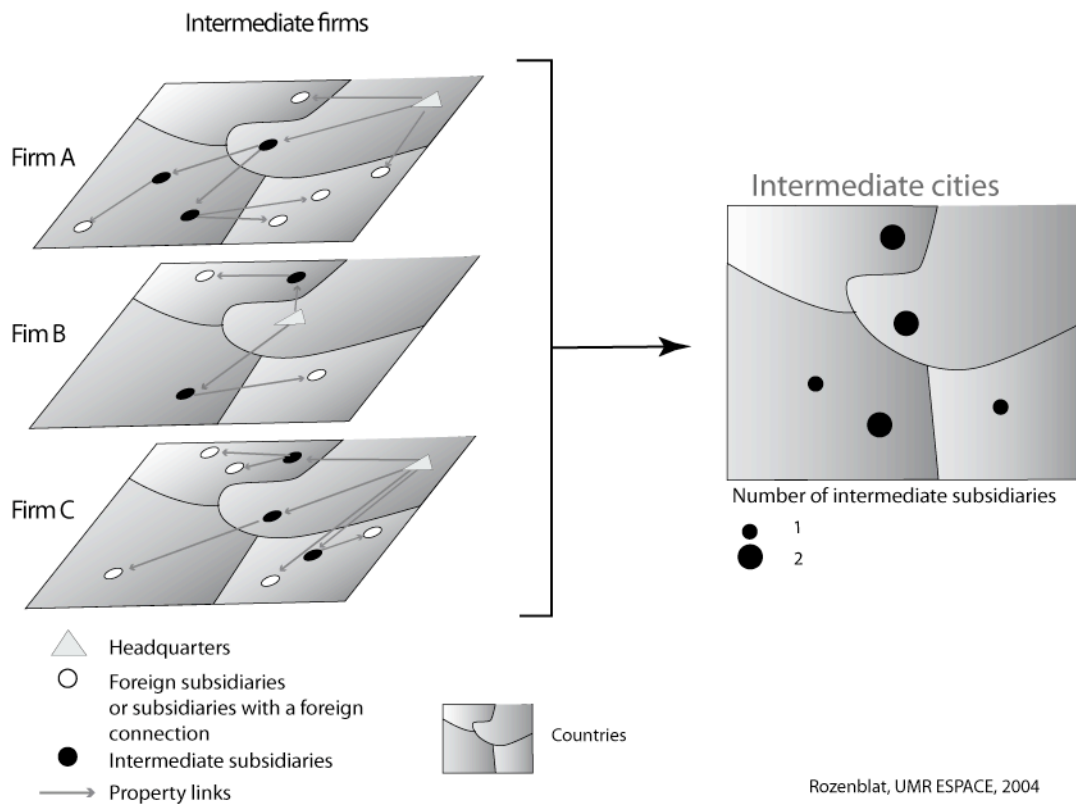
One link of legal ownership represents one link between city i where the headquarters of firm K (*A, B* or *C* on figure 6) is located and city j where the subsidiary of firm K is located. To construct the graph of connections between cities through firm ownership linkages, we look at the orientation of the links. In order to describe the basic networks connecting cities through multinational firm ownership linkages, a first qualitative distinction can be made according to the relative position of cities where subsidiaries are located. A comparison of the nationalities of the three cities – the city of the intermediate subsidiary, the city of its headquarters, the city of its sub-subsidiary companies – shows up three "types" of "intermediate" city (Fig.7):

A — "Bridgehead" cities. These cities host one or several subsidiaries from a city in a foreign country; they in turn have one or more subsidiaries in the same country. The bridgehead city is used as an entry point for foreign investment: upstream it is connected to foreign cities by links of subordination (e.g. firm control), and downstream it dominates other cities in its own territory through linkages of economic control. When companies are organised by region, these intermediate headquarters generally control the subsidiaries in the country of investment. Most of these intermediate cities that act as entry points for foreign investment are the largest cities in each country, especially those where the urban system is dominated by primate cities, such as London, Paris, Vienna, Milan, Madrid, Barcelona and Brussels. From these central cities, foreign companies thus radiate to other cities in the same country. However, this type of nodal function has different spatial configurations. For example, Madrid and Barcelona perform this role with the same intensity, but not with the same territorial extension: Madrid controls sub-subsidiary branches of foreign companies all over Spain, whereas Barcelona's range is limited to Catalonia. From this point of view, London is similar to Barcelona: more than half of the foreign sub-subsidiary companies that it controls are located in its own urban area. In general, the bridgehead function reinforces national or regional urban hierarchies by magnifying the central role of some cities, which are essential in the early stages of capital diffusion. These cities provide companies with the necessary information and knowledge about a whole national territory. These cities are also selected for their accessibility in terms of transport, institutional contacts, etc. This process reinforces the need for central administrative offices and infrastructure in these cities, which in turn enhances the attractiveness of the cities.

Figure 7
Intermediate cities
in international firm ownership linkages

A- Bridgehead Cities

B- Outpost Cities

C- Turntable Cities

△ Headquarters
▫ subsidiary
■ intermediate subsidiary
☐ National borders

@UMR E.S.P.A.C.E.,Rozenblat, 1998

B — "Outpost" cities. For each city we measured the number of domestic subsidiaries controlling sub-subsidiary companies abroad. The city is used here as a node for foreign direct investment: upstream it is connected to a city on its own territory where the headquarters of the group are located, and downstream it is directly connected to foreign cities in which it controls subsidiaries. These outpost cities act as springboards towards foreign countries, as is the case for Paris, London and Vienna. In other cases, this situation results from the vertical or horizontal integration of companies whose various headquarters have remained fairly independent. Veba, a company present in both our surveys, is typical of this form of organisation. The company is the result of an industrial merger between petrochemical firms (Huls A.G., Raab Karcher and Veba Oel headquartered in Essen, and Stinnes Interoil headquartered in Hamburg), energy companies (Preussenelektrika in Hanover), storage firms (in Essen and Lubeck) and wholesale firms (in Essen and Kaiserslautern). Veba's foreign subsidiaries are controlled from the total subset of these cities. It is well known that similar mergers or acquisitions of companies have occurred since the 1990s, with the same intensity in all countries. Conversely, not all urban systems offer companies the same opportunities for maintaining headquarters simultaneously in several places. While German cities (Essen, Stuttgart, Köln-Bonn, and to a lesser degree Frankfurt), some British cities (such as Birmingham) and Austrian cities (such as Linz) can perform the function of headquarters for foreign subsidiary companies, this is less common in French cities other than Paris. On the territory of France, a study of inter-urban command by the headquarters of multi-entity firms confirms, on another level of company organisation, the strong polarisation of companies' national capacity in Paris (Rozenblat, 1998). Other French cities may act as small, secondary centres, because they host the headquarters of large national companies. This is the case, for example, of Clermont-Ferrand (Michelin), Lyons (Renault Trucks), Saint-Etienne (Casino) and Strasbourg (Aventis, Kronenbourg). In recent years, headquarters located in French regional capitals have tended to lose strategic power. Indeed, in the past decade, most strategic functions have moved to the capital, whereas an increasing number of entities dedicated to other functions (mainly production) have moved out of Paris (Jourdan, 2004).

C — Multinational "turntable" cities. For each city we counted the number of foreign subsidiaries that own sub-subsidiary companies abroad. Amsterdam seems to play a specific role as an international node for almost half the groups in our sample (in both 1990 and 1996). Many European groups locate foreign subsidiaries in Amsterdam, and these subsidiaries develop sub-subsidiaries abroad. The function of these intermediate subsidiaries is primarily financial. They benefit from the advantageous tax treatment offered by the Netherlands (for both foreign subsidiary companies and companies that own other subsidiaries abroad (Mignolet, Pierre, 1998). They also take advantage of Amsterdam's international functions, which are more developed than one might assume from its population size (under 2 million, Rozenblat and Cicille, 2003). The international functions of Amsterdam are particularly developed in the sectors of finance and air transport, which are the activities most strongly related to attractiveness for the location of registered offices. The city of Luxembourg also plays a similar role, but with less intensity (12 groups from the sample in 1990 and 8 in 1996).

In the hierarchical legal organisation of the companies, the intermediate subsidiaries enable cities to maintain at once positions of control and dependence. Indeed, the cities accommodate the two positions simultaneously because the same subsidiary is at once under the domination of its head office and dominant over its sub-subsidiaries. Crozier and Friedberg (1977) have stressed the essential role of nodes in any organisation. These nodes have a dual function (Crozier and Friedberg, 1977, p.164). On the one hand, for the organisation, they constitute a "segment of environment", a source of information on the organisation's ability to adapt to the

environment (past history, institutions, resources, culture, etc.) and thus can be considered as "reducers of uncertainty". In addition, for the environment, they represent "the organisation and its interests". They form part of "a permanent process of exchange through which an organisation opens, so to speak selectively, into the broader system in which it takes part, and by which it integrates more or less permanent parts in its own system of action for thus being able to adapt it to its own requirements" (1977, p.179). For this reason, a group's intermediate subsidiaries are the interfaces between the group and the economic environment and territory. One aim of our approach is to understand the role played by these intermediate subsidiaries between territories, given that their nodal position depends on the "degree of monopoly available to each partner vis-a-vis the other in both space and time" (Crozier and Friedberg, p.172). The positions of the intermediate subsidiaries (and the nodal cities that host them) depend on the nationality of their headquarters and their sub-subsidiary companies.

2.4 Centrality and hierarchical innovation diffusion as characteristics of inter-city linkages and their evolution

The combination of all firms' networks according to their location in cities can give rise to a more general network representing the position of cities within linkages of firm ownership. Because the ownership linkages are oriented, the network is also an oriented graph where the arcs connect a subsidiary-sending city to a subsidiary-receiving city. According to the analysis above in 2.1., the arcs follow the decision-making path and thus reflect a city's position in the process of European economic integration. In our approach, foreign subsidiaries are considered as being under the direct control of the decisions taken by their headquarters, which can centralise the design of new products, the organisation of production, decisions about training, and industrial and financial strategies. Through a common policy, the headquarters control all the activities of the group's entities and subsidiaries (Dicken, 1992). By putting all the foreign subsidiaries under the direct control of the European headquarters, centralisation of decisions within the firm is taken to the extreme. Domestic companies taking part in the globalisation process are not taken into account. This representation is only a partial reflection of the actual operation of groups, since practices may vary from one group to another, and even within the same group, depending on the sector of activity. This step nevertheless makes it possible to map out a system of control-dependence between the cities hosting the headquarters and the cities where the groups' foreign subsidiaries are located. This approach has been used previously by Alan Pred for United States (1973, 1977), and by Paul Le Fillâtre (1964) for France (headquarters-entity links were identified from the first annual survey of firms by INSEE), in order to represent the spatial configuration of economic control between cities.

On the basis of the relationships of control between headquarters and their subsidiaries, one can define relative measures of centrality among cities. In geography, the centre always represents a place that dominates relationships based on unequal exchanges. The exchanges generated by the relationships of subsidiary ownership are indeed dissymmetrical, since they include interactions of dependence that arise from strategic decision-making, financial transfers, and sometimes human transfers or trade in goods. Centres and peripheries are thus distributed among the nodes of a network shown in the oriented graph representing the geographical positions of the headquarters of the groups relative to their foreign subsidiaries.

We plotted the graph of intercity linkages F_{ij} through foreign firms' property by using the following equation:

$$F_{ij} = \Sigma_k \, PL_{kij}$$

where PL_{kij} represents the ownership link between the headquarters located in city i to the subsidiary located in city j (in another country) for the firm k.

The position of each city on the graph of the relationships of control or dependence defines its degree of centrality. Interpreting the cumulated linkages in terms of "power over" and "power to" command other cities, means a capacity or a medium (Friedmann, 1978; Allen, 1997; Taylor et al., 2002). The transfer of companies' power to their space of reception is part of the process through which a centre reproduces the conditions of its centrality and reciprocally for the periphery. However, the dynamics of cities, considered on the scale of urban systems, are clearly a different process from the centralisation that describes the concentration of power at the level of the internal organisation of institutions, whether economic or associative (as opposed to decentralisation). Furthermore, the location of the centre depends on the geographical scale that is considered, a fact that is usually overlooked in traditional approaches (Myrdal, 1957; Hirschmann, 1958; Amin, 1973; Wallerstein, 1980; Reynaud, 1981). Depending on the geographical scale under consideration, the centres and peripheries may change role, since a central position in one network can become peripheral in a network on a higher scale.

Within a relatively short period of time, between 1990 and 1996, this system of enterprise control between cities has reinforced urban interdependency on an increasingly vast territory, while remaining highly selective (Fig.8). By a process of hierarchical innovation diffusion, the most central cities have strengthened their positions in the networks of control: this is the case for the London-Paris-Brussels triangle, as well as for German, Dutch and Swiss cities in the centre of Europe. On the geographical periphery, cities such as Lisbon, Stockholm and Budapest have joined the network. Thus, the system of European cities strongly integrated by multinational corporations is reinforced and made more compact. Interactions between these cities are increasing, with a growing number of ownership linkages. They can be considered to form a "European urban system" representing the major centres connected through European economic integration. The most central cities are above all those for which the ratio of the number of headquarters to the number of foreign subsidiaries is highest (Fig.8a). From this point of view, London is the main centre in the network of company control. However, Paris is connected to the highest number of cities and therefore has the highest betweenness centrality. In 1990, Brussels, Milan and Madrid formed a first peripheral crown, which was confirmed in 1996. New linkages of economic control have arisen since 1990 in the vicinity of Vienna and from Brussels to Milan. These "transversal" links, which are developed across the levels in the size hierarchy, are more common in 1996, in the vicinity of Düsseldorf, Essen, The Hague and Zurich. These cities form secondary centres of control by multinational corporations.

Figure 8
Centres in Economic Networks
Main linkages through subsidiary ownership
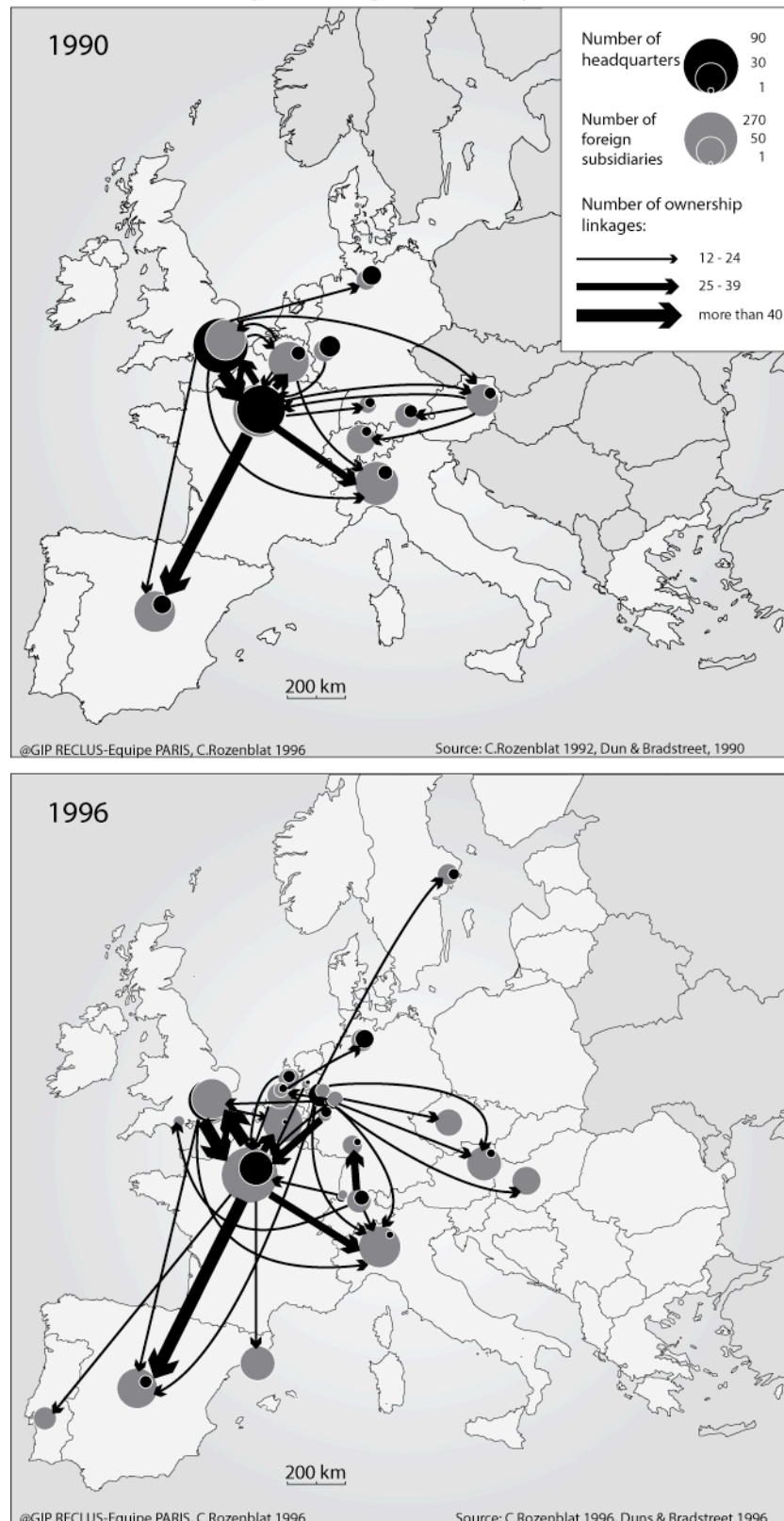
The most satisfying interpretation of these observations is that investment in foreign markets by European firms can be seen as a special case of the hierarchical diffusion of an innovation in a multinational urban system. The process of foreign investment, leading to the

international expansion of firms, is one of the organisational innovations of the last third of the 20th century (Dunning, 1977, 1992). The strategy of firms is first to enlarge their own market by taking positions on territories outside their country of origin (Dicken, 1992), second to diversify their production to adapt it to local demand (Krugman, 1988), and third to make use of some comparative advantage that the new locations can offer, within the framework of "flexible capitalism" (Porter, 1996, Storper, 1997). First they select locations that offer good connections in a whole country and that minimise the risks associated with their investment. Most European capitals and large economic metropolises now meet these conditions. From a city's perspective, that innovation requires a minimum level of international functions in order to provide a favourable business environment and suitable living conditions for foreign firms' employees. Since more than half of European companies' headquarters are concentrated in London and Paris, it is not surprising that these two leading cities, far ahead of any other in size, form the core of the diffusion process. The first tiers of cities reached at a second stage by the "innovation" process are of two kinds: cities that belong to the core of urban Europe and specialised in international activities, such as Brussels and Luxemburg, and major cities or capitals of the main countries, such as Milan and Madrid. Although the diffusion process follows a classical hierarchical pattern in what could be considered to be an emerging European system of cities, it remains hindered by national boundaries and cities' former functional specialisations.

Different sectors are at different stages of the diffusion process of globalisation. The most advanced sectors in this process have a higher number of foreign subsidiaries (Mucchielli, 1998). At both dates, chemicals, electrical and electronics sectors account for more than half of the sample of foreign subsidiaries. These activities are also among the most concentrated in the large cities. They tend to spray out of the large cities like all businesses involved in the manufacture of staple consumer goods. This trend is also observed for some chemicals subsidiaries that process farm goods (such as those of Ciba-Geigy), which are naturally located outside urban environments (Rozenblat, 1992). Subsidiaries in the construction sector and financial services were the most concentrated in large cities in 1990. The concentration in the largest cities of business services subsidiaries increased between 1990 and 1996, whereas most other types of activity seem to have diffused to smaller cities (Rozenblat, 1997). Some urban specialisations appear in the subsidiaries hosted, very often reinforcing existing local specialties: with equal activity and city size, Amsterdam and Zurich are specialised in financial activities and business services. But these specialisations are not very strong and the higher a city is in the urban hierarchy, the less strong its specialisations (Pumain and Saint-Julien, 1989; Rozenblat, 1992). Thus, the largest cities, which accommodate more subsidiaries, have a more diverse range of activities: their markets (consumer and labour), infrastructure and hosting capacity increase their attractiveness for all types of activity from abroad.

In addition to urban effects, there is a strong national effect that results in significantly different rates of penetration of foreign subsidiaries in different countries. The global impact of the size of cities takes different values depending on their nationality (Rozenblat, 1993). For instance, with equal population, a Dutch city will tend to attract more foreign subsidiaries than a French city. This can be checked statistically using variance analysis (taking into account the nationality of the cities) combined with regression (taking into account their population). One thus obtains a strong statistical explanation for the number of foreign subsidiaries in a city (R^2=94%). This demonstrates that national effects remain highly significant in the diffusion process (approximately 30% of the variance, with city size alone accounting for 64%). The level of functions not only reflects the size that cities have acquired

over a long period, mainly in line with the development of the national urban system to which they belong. A country's openness also determines its cities' average capacity to host foreign multinational corporations. According to Mucchielli and Puech (2003), the varying attractiveness of European countries for foreign companies can be attributed mainly to differences in payroll costs. Other authors stress the tax burden (Mignolet, Pierre, 1998).

The two geographical levels, urban and national, thus combine to determine location choices in a multilevel approach, also according to regional data analysed by Mucchielli and Puech (2003). Cities' population size and national structural characteristics are still essential for understanding the current development of territories. It is therefore important to keep in mind the spatial pattern of European cities. The hierarchy of cities and their spacing remain two major factors in their integration into global networks. Networks where large cities are regularly spaced, as is the case in Eastern Europe, could induce a broad diffusion of global networks in the urban system. However, foreign investment in those countries is riskier than elsewhere in Europe (Michalet, 1999). The evolution of the relative concentration of headquarters and subsidiaries, compared with the concentration of urban size, seems to depend on how long the process of multinational integration of cities has been operating in each country. The urban hierarchy can thus be interpreted as a kind of attractor, exerting a feedback effect from the macro geographical system to the behaviour of urban actors. Over the long term, the various hierarchies of the same territory fit together and mutually reinforce each other. The urban hierarchy itself can also undergo transformations due to the concentration of the other functions. These characteristics can be interpreted within the framework of a more comprehensive evolutionary theory of urban systems.

3 Innovation and evolutionary theory of urban systems

Many uncertainties still hamper our ability to forecast the future of urbanisation. With the advent of new technologies and the political reorganisation of territories, geographers observing globalisation processes are puzzled by the possible next trends in urban concentration, dispersion and relative growth. By applying ideas and models developed by a new field of investigation known as complexity theory, we could learn more about the universe of possible evolution stemming from observed urban dynamics, and perhaps discover some abstract hidden processes that may better explain the similarities appearing in urban structures and evolution, despite the overwhelming diversity of physical, economic, political, social and cultural forms that urban systems take around the world. The concept of urban system is actually a good example of a complex system (Pumain, 1998). Urban systems produce self-organised multi-level structures that are evolving via dynamic social processes where non-linearity, discontinuity, irreversibility, as well as permanent adaptation through co-operation and competition, are general rules.

What are the emergent properties of urban systems and how are they produced? We shall focus here on structural features that characterise the macro level of a system of cities, and that emerge from the interactions between towns and cities at the meso level. In this case, interactions occur through multiple exchanges of people, goods and information that circulate continuously from one city to another through a multitude of networks (Allen & al., 1999; Massey & al., 1999). Since it is hardly possible to represent all of them in a model, we have selected those that are considered responsible for the emergence and maintenance of structural features at the upper level, and to represent them in an abstract way.

The main structural features of urban systems are defined according to the principles that organise their internal diversity, regardless of the period or country in which the system is observed. Such general features are well known. First there is a principle of hierarchical organisation, including important scaling properties for attributes such as size, spacing and level of socio-economic activities of towns and cities. These features were previously formalised by central place theory. Geographers have criticised that theory because it is static and based upon a restricted set of urban activities (mainly services to residents), which does not consider specialisations in non-central functions (for instance industry and tourism). Therefore, a more general framework is needed.

However, this does not mean that all the observations explained statically by central place theory are no longer valid. Hierarchical structure and spacing regularities are still relevant, as shown for instance by the map in Figure 9, representing the location and size of towns and cities (urban agglomerations with populations of more than 10,000 defined in a comparable manner) in countries of Western and Eastern Europe. A simple analysis of this map by the cartographic filtering method illustrates the evidence of the hierarchical and spatial organisation of urban systems, according to research by Céline Rozenblat (1995). In Figure 10, the agglomerations in Figure 9 were initially connected by a straight line when the distance between them was less than 25 km. The resulting pattern clearly shows three main types of urban system in Europe: a central part with much higher densities, a more contrasting western part (mainly France and Spain) and an eastern part with highly regular spacing. Combined with size, these three types would fit into the typology established by Etienne Juillard ("Rhenish", "Parisian" and "peripheral" urban networks, Juillard and Nonn, 1976) But the point here is that the general pattern is maintained if the minimum distance is raised to 50 km, or the minimal population size to 100,000 (with a separating distance of 100 and 150 km). This result confirms the high consistency of the hierarchical and spatial organisation of urban systems.

The hierarchical organisation is an emergent property that characterises the level of observation of systems of towns and cities. It is produced by the multiple interactions occurring between individual towns and cities. The fact that a town or city keeps its size to a given proportion of other cities' sizes, that the spacing between cities is more or less regular and that over long periods of time there is a fairly consistent persistence of the hierarchical order cannot be inferred from the nature and function of a single city. One has to search for processes that can explain this emergent property at the level of the urban system according to the *rules of interactions* occurring at the level of individual cities.

This has been interpreted in many models by simulating the competitive growth process, which represents both the dynamics of each town and the resulting statistical aggregate in the form of the distribution of city sizes (Robson, 1973; Pumain, 1982; Guérin-Pace, 1993). However, the demonstration in these models is statistical and non-spatial. We have formalised the complex dynamics of spatial interactions in the growth process, including reversal of influence over time according to the definition of neighbouring places by a simple modular model (Page et al., 2001). The relationships between cities' mass and spacing, and their evolution over time, have been studied by Anne Bretagnolle (1999), who showed how urban interactions regulate the relative size of the elements in an urban system, depending on the speed and intensity of spatial interactions. The hierarchisation is generated from the bottom by the short-circuiting of smaller intermediate centres linked to the process of space-time convergence, and from the top by the various processes of hierarchical diffusion of innovations in the urban system (Bretagnolle et al., 2002).
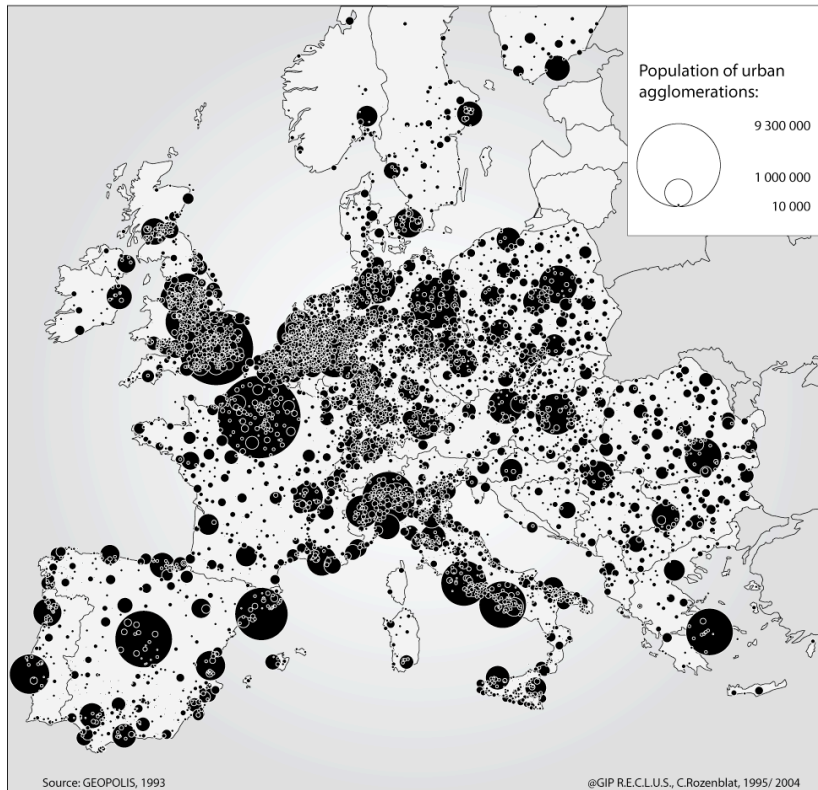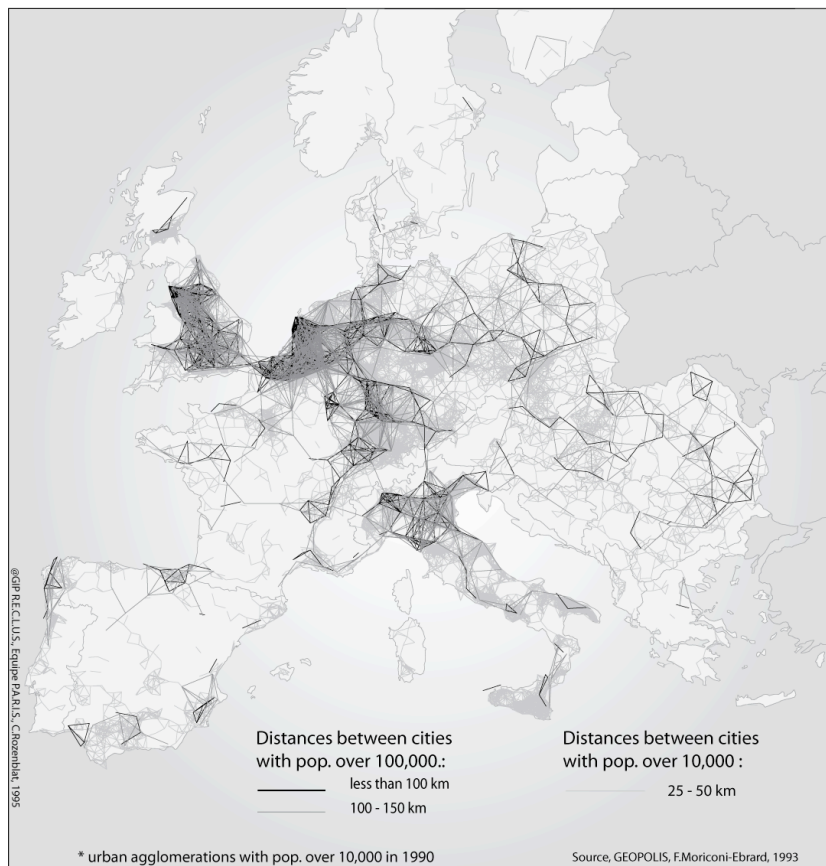
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Figure 9
Population of European Cities

Source: GEOPOLIS, 1993   @GIP R.E.C.L.U.S., C.Rozenblat, 1995/ 2004

Figure 11
Patterns of urban systems
in Europe

@GIP R.E.C.L.U.S., Equipe P.A.R.I.S., C.Rozenblat 1995

Distances between cities
with pop. over 100,000.:

——— less than 100 km

——— 100 - 150 km

Distances between cities
with pop. over 10,000 :

——— 25 - 50 km

* urban agglomerations with pop. over 10,000 in 1990   Source, GEOPOLIS, F.Moriconi-Ebrard, 1993

A link is then established with the second main structural property of urban systems, which is their qualitative socio-economic diversity, as expressed in typologies of the functional specialisation of towns and cities, which generally lasts without major changes for several decades. These slow dynamics of relative change in the interurban division of labour are produced through small deviations in a general process of diffusion of socio-economic changes, which is much more rapid (Paulus, 2004). According to that extremely incremental process of interactive adjustments, all cities change in more or less the same direction and intensity in the space of activities phase, as illustrated by a correspondence analysis for French cities for the period 1962-90 in Figure 11. This result introduces a way for generalising central place theory in the broader framework of an evolutionary theory of urban systems (Pumain, 2000). Urban hierarchy and functional diversity are emergent properties stemming from a co-evolution process of towns and cities, which are co-operating and competing for access to socio-economic innovations, by attempting to secure better relative positions in spatial and social networks.

Figure 5 : Trajectories of main cities in the space of economic activities, 1968 - 1990
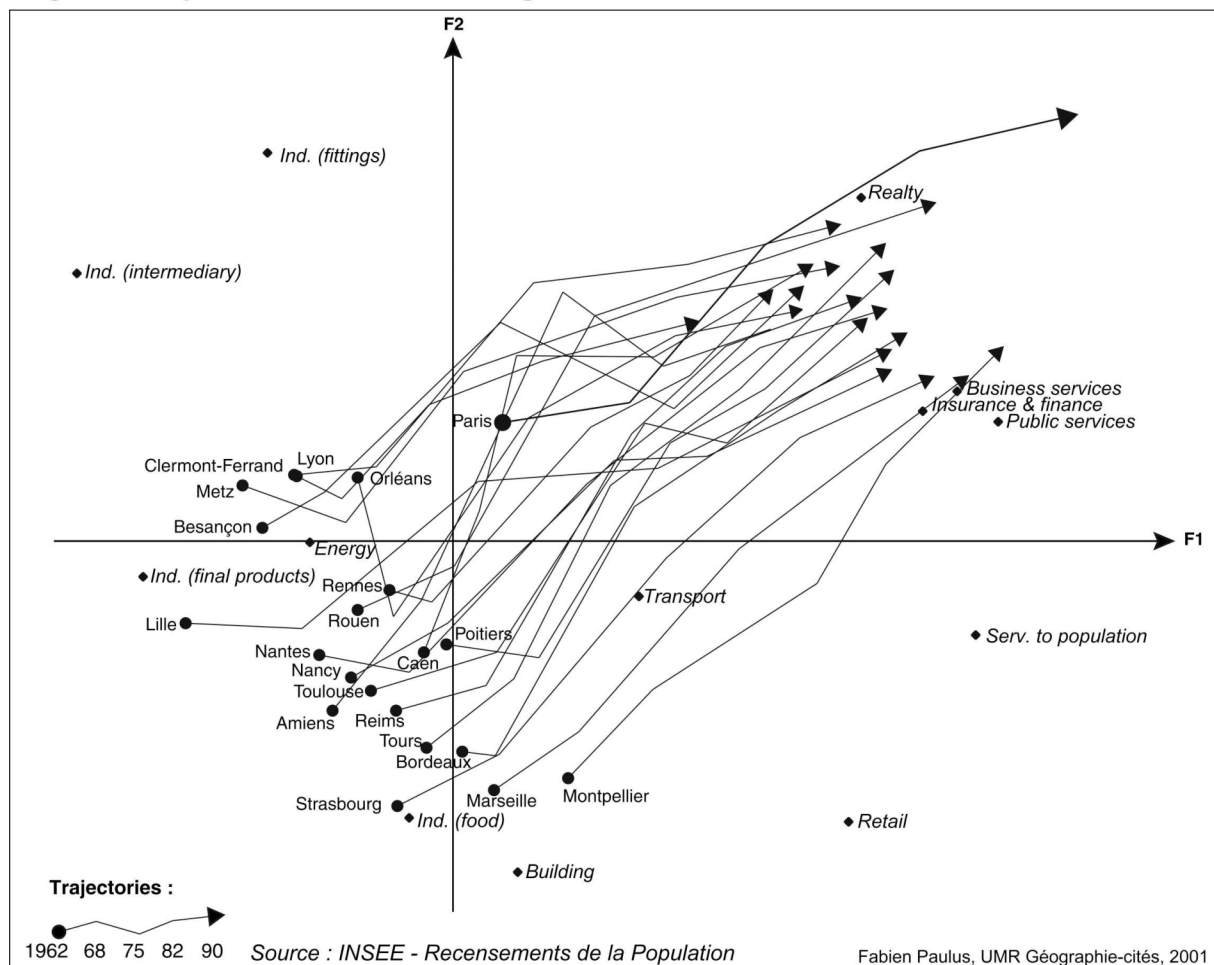
Conclusion

The observations we make about the location of multinational firms in Europe and their ownership linkages among cities, at two dates, 1990 and 1996, are a good example of urban co-evolution, even as these new connections contribute to the creation of a still emerging

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"European system of cities". The former hierarchical structure of the urban system has a strong regulation (or feedback) effect: the main capitals, London and Paris, are at the core of the process, whereas almost none of the smallest towns (population under 200,000) are involved in the diffusion process as yet. But two distinct processes are superimposed on the classical hierarchical diffusion process: one is a reinforcement of specialisation in multinational activities for cities already engaged in international business, especially financial business (as is the case for Brussels, Luxemburg and Zurich); the other, even more effective, process is linked to the existence of national borders, which guide the location of foreign firms towards national capitals, regardless of their relative size within the European urban system, and towards cities located close to international borders (which also gives an advantage to cities in the smallest countries, which are on the whole more "open" to external exchanges than the largest countries). These two processes have the potential to reshape the European urban system, but to what extent? Two points in time are not enough to identify the possible consequences of these trends. A third survey, currently in progress, could bring clearer answers.

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