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Knowledge externalities and networks of cities in creative metropolis: the case of the metropolitan region of Barcelona

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Abstract: Cities and metropolitan areas are our main engine of production and development. They have long concentrated and coordinated the use of urbanized land, labor and capital. Metropolitan areas produce, process, exchange and market the main amount of knowledge and creativity in the world. At the same time they generate agglomeration economies and obtain spatially mobile network economies from their links with other cities. Departing from the fact that metropolitan growth is the sum of the growth of the cities that form the metropolitan area, the present research explores why some metropolitan cities grow faster than others. The hypothesis is that the differential growth of the metropolitan cities is related to the existence of external economies within and between cities many of which arises from knowledge and creativity. The objective of the research is to understand and model how the external economies affect the intrametropolitan urban growth with special attention to the effects of knowledge and creativity and their transmission across the metropolitan urban system. The text is divided in five sections. After the introduction, section two explains the traditional paradigm of the agglomeration economies enhanced with a separate treatment of the knowledge and creativity externalities, and the introduction of a spatial (inter-cities) dimension of externalities and knowledge. Section three introduces an econometric model to evaluate the effects of dynamic externalities in time and space on the urban growth, as well as the sources of data and variable definitions. Section four explains the results of estimates which provide evidence on the existence of localization, urbanization, knowledge and creativity externalities and their diffusion across the urban system through complex network patterns. Knowledge transmission through hierarchical networks of cities produces the most important effect on urban growth and goes beyond the impact of agglomeration economies and diffusion in physical proximity or in horizontal networks. This result suggests that in metropolitan environments, where the network of cities is hard dense and all the socio-economic dimensions of proximity short, the impact of the knowledge metropolitan spillovers can be bigger than the local ones. Section five presents the conclusion and a discussion on policy implications.

JEL: R11, R12, O3
Keywords: agglomeration economies, knowledge externalities, networks of cities, metropolitan areas, creative cities

1. Introduction

Cities and metropolitan areas are our main engine of production and development. They have long concentrated and coordinated the use of urbanized land, labor and capital. Urban land has been transformed to become independent from the forces of nature and nerved of infrastructures and artificial resources. Urban labor has been divided and organized until acquire specialized skills and the superior skills of continuous learn and creativity. Capital is also concentrated in cities and, as was eminently described by Marshall (1890), mainly consists of knowledge and organization. Metropolitan areas produce, process, exchange and market the main amount of knowledge and creativity in the world. At the same time (and for this reason) they generate agglomeration economies and obtain spatially mobile network economies from their links with other cities. The merged ability to generate knowledge, creativity and external economies turns cities and metropolitan areas in the most powerful of the productive artifacts which become a keystone for development and competitiveness.

Metropolitan growth is the sum of the growth of the cities that form the metropolitan area. Why some metropolitan cities grow faster than others? The hypothesis is that the differential growth of the metropolitan cities is related to the existence of external economies within and between cities many of which arises from knowledge and creativity. The objective of the research is to understand and model how the external economies affect the intrametropolitan urban growth with special attention to the effects of knowledge and creativity and their transmission across the metropolitan urban system.

To explore these features we will center in the Metropolitan Region of Barcelona as one of the most interesting exponents of knowledge and creative metropolis. The Metropolitan Region of Barcelona starts in 1986 a process of economic and territorial expansion until become one of the ten biggest urban agglomerations in Europe, with a size similar to the 10th North American agglomeration (Washington) and ranked as one of the thirty largest metropolises in the OECD. The territorial expansion arises not from a process of hierarchical decentralization but rather as the effect of the increasing interaction between the urban continuum of Barcelona and a group of medium-sized cities that were old industrial centers. The unit used for metropolitan planning is currently composed by 164 cities which have 4.8 million inhabitants and 2.2 million jobs. The metropolitan region is structured as a polycentric network of cities looked like a constellation of stars where the most important city is Barcelona. The recent process of growth and metamorphosis from a set of industrial cities to a knowledge and creative metropolis is related to the existence of intense increasing returns of territorial nature. These increasing returns are associated with internal economies and new organizational models, external agglomeration and network economies, and the transformation of the productive model towards the knowledge economy (Boix 2006).

The text is divided in five sections. After the introduction, section two explains the traditional paradigm of the agglomeration economies enhanced with a separate treatment of the knowledge and creativity externalities, and the introduction of a spatial (between cities) dimension of externalities and knowledge. Section three introduces an econometric model to evaluate the effects of dynamic externalities in time and space on the urban growth, as well as the sources of data and variable definitions. Section four explains the results of estimates which provide evidence on the existence of localization, urbanization, knowledge and creativity externalities and their diffusion across the urban system through complex network patterns. Section five presents the conclusion and a brief discussion on policy implications.

2. Agglomeration economies, knowledge, creativity and space

2.1. Agglomeration economies

Marshall (1890) was the first in distinguish between internal and external economies. The former depends on the resources, organization and management of the individual firms and the latter on the general development of the industry. *Regional and urban economics* use the concept of "agglomeration economies" to describe the relation between internal/external economies and the cities. The term combines the "factors of agglomeration" (transport advantages) (Weber 1929) with the Ohlin-Hoover "concentration" advantages on production (Ohlin 1933; Hoover 1937). The original agglomeration economies include internal economies and two basic sources of external economies: localization and urbanization.

Localization economies arise from the concentration of many small firms of similar characteristics in particular localities (Marshall 1890) or more generically from the concentration or growth of a particular industry in a certain location (Ohlin 1933; Hoover 1937). The microfoundations of the localization economies are associated with a particular form of organization and the existence of a skilled labor pool, specialized suppliers and knowledge spillovers (Marshall 1890).

Urbanization economies regard on the size of the local markets of resources and consumption (market size), the scope of the economic structure and the generation of information and knowledge spillovers (diversity and density). Urbanization economies were originally related to the concentration of industry in general (Ohlin 1933); to an increase in the total economic size of the city in terms of population, income, output or wealth; and to a labor urban market efficient, flexible and skilled (Hoover 1937). Although the benefits of the existence of several local specializations were already exposed by Marshall (1890), scholars pointed out on the effects of diversity after Chinitz (1961) and Jacobs (1961 and 1969). Chinitz (1961) relates external economies to industry structure (industrial mix) and density. Diversified metropolitan areas exhibit more stability in their growth because they do not depend on some few industries. Jacobs (1969) claims that cities grows by an “epigenesis” process of gradual diversification and differentiation of their economy which arises from a process of imports substitution. Diversity is based on the mixture among uses, variety of activities and people, market dimension and density (Jacobs 1961) that generates a dense and varied network of agents that fosters mutual economic and social support, knowledge transfer, and promotes innovation. Ciccone and Hall (1996) emphasize the role of the spatial density of economic activity (intensity of labor, human, and physical capital relative to physical space) as a source of increasing returns. This hypothesis can be related to Hoover and Vernon (1962) since denser places use to coincide with the most central parts of the metropolis, rich in positive externalities. There, (small) establishments find advantages to place and higher levels of entrepreneurship boost greater employment growth. Leone and Struyk (1976) propose a most comprehensive approach to density and centrality dynamics in intra-urban location by introducing a dynamic process where in a second stage, mature firms or activities move to lower density areas where other advantages (as cheaper land) are available.

2.2. Knowledge and creative city

After knowledge became endogenous in the growth models (Romer 1986 and 1990; Lucas 1988) the territorial approach has placed a central role in explaining the processes of knowledge generation. Conceptually, Glaeser et al. (1992) bridge the theories of agglomeration economies to the knowledge paradigm. They separate the traditional localization and urbanization economies in static and dynamic. *Dynamic economies* are related to knowledge spillovers which have the ability to produce irreversible changes in the production function (MAR, Jacobs and Porter dynamic externalities) while static agglomeration externalities only produce transitory shocks.

From the 1990s researchers have directly stressed on the importance of cities and metropolitan areas as the biggest concentrations of knowledge as well as the importance of knowledge for urban growth and competitiveness (Knight 1995; Lever 2002; Trullén et al. 2002, Van den Berg et al. 2004). The *knowledge-based cities* have a significant share of their productive and social structure specialized in the production, consumption and exchange of knowledge as well as generate dynamic externalities in the form of knowledge spillovers (Knight 1995; Boix 2006). Landry (2000) and Florida (2002, 2005a and 2005b) propose a refinement based on the concept of “creativity” closely related to the Jacobs (1961 and 1969) theories. Information and knowledge are inputs for creativity and the output is innovation. The joint expansion of technological innovation and a class of creative workers become the motor of economic growth, and cities, like “cauldrons of creativity”, concentrate and channel the human creative energy (Florida 2005a).

2.3. Spatial economies (external economies between cities)

Regarding the spatial dimension of the urban economy, Capello (2006) distinguishes four families of theories. First, the “geographical-metric space” of the location theory which is continuous and operates as physical distance and transportation costs. Second, the “abstract-uniform space” of the old regional growth theories, reduced to abstract boundaries (regions) to apply macroeconomic models where agglomeration economies are not considered. Third, the “diversified-stylized space” of the New Economic Geography, again reduced to abstract unconnected points although agglomeration economies and processes of endogenous growth are allowed within. Finally, the “diversified-relational space” of the theories of regional development, where productive agents are linked in the space and space produces economic advantages in the form of external economies and knowledge spillovers within and between cities that leads urban growth. The free exchange of ideas between places alters the forces of industrial localization (Marshall 1890). Robinson (1931) distinguished between immobile and mobile external economies. The former depends on the size of an industry in a locality whereas the latter depends on the size of this industry in the world as a whole and can be shared by firms outside the districts or countries in which the economies arise.

Since agglomeration economies explain the shape of the within cities externalities, several theories and paradigms explain the form of externalities and knowledge spillovers across the space. Christaller (1933) and Lösch (1954) argue that between cities relationships are hierarchically organized in the space and information diffuses hierarchically across the urban system from the higher rank to the minor rank centers (Weber 1972). Hägerstrand (1967) explains that spatial knowledge diffusion of innovations depends on the social network of interpersonal relationships. In a first stage, innovations spread within the innovation poles. In a second stage, innovations spread hierarchically and then by proximity. Finally, when saturation takes place, spatial diffusion is casual. Pred (1973 and 1977) criticizes the validity of the hierarchical theory of diffusion of information across the city systems and gives the bases for the comprehensive paradigm of the network of cities. This paradigm was reinterpreted and enhanced by Dematteis (1989), Camagni and Salone (1993) and Capello (2000) and allows for knowledge diffusions in hierarchical and non-hierarchical interactions between cities of the same or different rank, and with more or less reliance of distance depending on the socioeconomic determinants of the flows. The main characteristics of the networks of cities are the possibility of hierarchical and non-hierarchical structures, competition-cooperation between the cities, and the generation of advantages related to the organization and exchanges between cities[1].

3. Model, data and variable definitions

3.1. Model

[1] Some researchers (Camagni and Salone 1993; Capello 2000) restrict the concept to horizontal links between cities. However, this approach takes the paradigm away from a global interpretation, since it does not allow for hierarchical links and restricts its application.

Rosenthal and Strange (2004) suggest five ways to capture the effects of agglomeration economies, based on econometric approaches. The first is the direct estimation of a production function (Sveikauskas 1975). The other four are indirect approaches based on the employment growth (Glaeser et al. 1992; Henderson et al. 1995), the births of new establishments and their employment (Rosenthal and Strange 2003), wages (Glaeser et al. 1992) and rents (Roback 1988). The estimated function takes the generic form $y = g(A)f(x)$, where y is the variable under study, *g(A)* is a function of technology or external economies and *f(x)*is a vector of inputs. The relation between the dependent and explanatory variables depends on the theoretical assumptions of the model although theoretical models frequently lead to a linear specification. When the dependent variable is expressed in growth rates or the explanatory variables are time lagged it is possible to test the existence of dynamic external economies.

Since the information on employment is available, it is proposed the estimation of a model based on the employment growth in the Metropolitan Region of Barcelona. Following Combes (2000b) three specifications on the relations between the dependent and the explanatory variables were considered: levels (Glaeser et al. 1992), mixed log-levels (Henderson et al. 1995) and log-linear (Combes 2000a; Trullén and Boix 2005). Although all specifications can be supported by theoretical models, the preliminary exploration of the data supports the log-linear function where the dependent variable is the logarithm of the employment growth rate and the explanatory variables are a proxy for agglomeration and spatial external economies. As in the vast majority of researches, external economies and diseconomies associated with a factor can not be separated so that it is impossible to differentiate their effects. Under the assumption that both effects can be aggregated, the results show the net effect on the differentials of urban growth. The equation to be estimated takes the generic form:

$$\log(L_{ij}^{t} / L_{ij}^{t-1}) = \log(Localization, Urbanization, Knowledge, Creativity, Space) \qquad [1]$$

3.2. Data

The *Metropolitan Region of Barcelona* is composed of 164 cities which have 4.8 millions inhabitants and 2.2 millions jobs. The *dependent variable* is the growth rate of the employment in the metropolitan cities between 1991 and 2005 grouped by knowledge intensity. The OECD (2003) differentiates four manufacturing groups and two services groups by knowledge intensity. Since high-technology manufactures are not present in many metropolitan municipalities we decided to group manufactures in only two groups: high and medium-high technology manufactures (HTM), and low and medium low technology manufactures (LTM). Activities not classified as manufactures or services are included in a residual group named Other (OT) (Table 1).

Table 1. OECD (2003) classification of technology and knowledge. Adaptation to 2 digits ISIC/NACE

High and medium-high technology manufactures (MHM): (30) Office, accounting and computing machinery; (32) Radio, TV and communications equipment; (33) Medical, precision and optical instruments; (24) Chemicals; (29) Machinery and equipment; (31) Electrical machinery and apparatus; (34) Motor vehicles, trailers and semi-trailers; (35) Transport equipment.

Low and medium-low technology manufactures (MLM): (23) Coke, refined petroleum products, nuclear fuel; (25) Rubber and plastics products; (26) Other non-metallic mineral products; (27) Basic metals; (28) Fabricated metal products; (15+16) Food products, beverages and tobacco; (17 to19) Textiles, textile products, leather, footwear; (20) Wood and products of wood and cork; (21) Pulp, paper, paper products; (22) Printing and publishing; (36) Manufacturing, n.e.c.; (37) Recycling.

Knowledge-intensive services (KIS): (64) Post and telecommunications; (65 to 67) Finance and insurance; (71 to 74) Business activities (not including real estate); (80)Education; (85) Health.

Non -knowledge intensive services (NKIS): (50 to 52) Retail and repair; (55) Hotels and restaurants; (61 to 63) Transport, storage and communications; (70) Real state; (75) Administration, defence and social security; (90 to 99) Other services.

Other activities non classified by the OECD (OT): (01 to 05) Agriculture, hunting and forestry. Fishing; (10 to 14) Mining and quarrying; (40+41) Electricity, gas and water supply; (45) Construction.

Source: Elaboration from OECD (2003)

Data on employment (jobs) come from the Social Security register of wage-earning. In 2005, HTM account for 7.9% of the metropolitan employment (148,000 wage-earning) although from 1991 they lose jobs at an average annual rate of -0.5%. LTM add up to 12% of the metropolitan employment (224,000 wage-earning) and lose jobs at an annual average of -2%. Knowledge-intensive services (KIS) account for 29.9% of the metropolitan employment (556,000 wage-earning) and were the most dynamic activities with an annual growth rate of 10.7% (they multiplied by 2.5 in 15 years). Non-knowledge intensive services (NKIS) add up to 41.4% of the metropolitan employment (770,000 wage-earning) and show an annual growth rate of 3%. OT account by 8.8% of the metropolitan employment (163,000 wage-earning) with an annual growth rate of 2.3% (Table 2).

Table 2. Wage-earning in the Metropolitan Region of Barcelona. 1991-2005

a) Employment (wage-earning)

	HTM	LTM	KIS	NKIS	OT	Total
1991	158,729	311,558	222,247	544,576	122,833	1,359,943
2005	147,878	223,634	555,715	770,760	162,860	1,860,847

b) Distribution of the employment

	HTM	LTM	KIS	NKIS	OT	Total
1991	11.7%	22.9%	16.3%	40.0%	9.0%	100.0%
2005	7.9%	12.0%	29.9%	41.4%	8.8%	100.0%

c) Growth rate 1991-2005

	HTM	LTM	KIS	NKIS	OT	Total
Annual average	-0.5%	-2.0%	10.7%	3.0%	2.3%	2.6%
Accumulated	-6.8%	-28.2%	150.0%	41.5%	32.6%	36.8%

d) Shift-share industrial mix

	HTM	LTM	KIS	NKIS	OT	Total
1991-2005	-42.8%	-53.7%	58.3%	3.0%	18.8%	

HTM = high and medium-high technology manufactures ; LTM = low and medium low technology manufactures; KIS = Knowledge-intensive services; NKIS = Non-knowledge-intensive services; OT = Other activities.

Source: Our elaboration from Department of Labor of Catalonia

Following the theoretical introduction (epigraph 2) and the suggested model (epigraph 3.1), five sets of *explanatory variables* (localization, urbanization, creativity, knowledge and space) were included to explain urban growth differentials. The data on employment and number of firms come from the Social Security. The data to differentiate between resident employees and local jobs, educational levels of employees and jobs, ISCO categories inside the sectors, and inter-city commuting come from the Census 1991. Data on urbanized land comes from the Catalonian Department of Territorial Policy. Patent database was elaborated with data from the Spanish Office of Patents and Trademarks. All data refers to 1991 to force causality and avoid simultaneity problems.

Localization economies include a location quotient on firms (also on employment) $LQF_{ij} = \left(F_{ij}/F_i\right) \Big/ \left(F_j/F\right)$ to capture the effects of specialization, where F is the number of firms, i is the knowledge group and j is the city. The quotient of firm size $S_{ij} = \left(L_{ij}/F_{ij}\right) \Big/ \left(L_i/F_i\right)$ captures the organizational form (large or small firms)[2], where L is the number of employees (jobs). The specialized labor pool quotient is the ratio between the local supply of resident workers (LR) by knowledge group and the local demand of workers (L) by knowledge group $LP_{ij} = LR_{ij} \big/ L_{ij}$. It is supposed that specialization, small firms and the skilled labor pool increases the labor growth rate.

Urbanization economies include a proxy to the Ohlin-Hoover's potential size of the local market $M_{ij} = L_j - L_{ij}$; the inverse of a normalized Herfindahl index to

[2] Although initially related to Marshall's localization economies (Marshall 1890), the impact of the small firms is also closely related to urbanization economies in Jacobs (1961) since urban dimension and diversity permit the survival of small economic units. Glaeser et al. (1992) use this coefficient as a proxy to the Porter's hypothesis that local competition fosters growth. In O´hUallacháin and Satterthwaite (1992) it is used as a proxy for scale economies.

approach Chinitz-Jacobs' diversity $DIV_{ij} = \left(1 \Big/ \sum_{i' \neq i}^{I} \left(L_{i'j} \Big/ L_j - L_{ij} \right) \right) \Bigg/ \left(1 \Big/ \sum_{i' \neq i}^{I} \left(L_{i'} \Big/ L - L_i \right) \right)$; and the potential density on urban land $D_{ij} = L_{ij} / U_j$ to approach the Ciccone-Hall density economies, where U is the urbanized land.

Florida's creativity tries to approach the 3T: technology, talent and tolerance. Technology includes the density of local patents $TP_{ij} = P_j / L_{ij}$, where P are patents. Talent includes the share of local tertiary graduates (ISCED university and equivalents groups 5 and 6) within each knowledge group $E_{ij} = ISCED56_{ij} / L_{ij}$ as a proxy for Lucas' human capital; and the rate of creative jobs in the knowledge group $CC_{ij} = C_{ij} / L_{ij}$, where C are creative occupations or creative class (ISCO-88 scientist, engineers, artist, cultural creatives, managers, professionals and technicians) to capture the effects of creativity. Tolerance can be approached by the share of foreign workers in the knowledge group $T3_{ij} = FB_{ij} / L_{ij}$, where FB are foreign born workers. The approach to *the knowledge-based city* combines variables from localization (skilled labor pool), urbanization (diversity and density) and creativity (patents, tertiary graduates and creative class).

Spatial network externalities are captured by a synthetic indicator which is the spatial lag of the dependent variable Wy. This indicator is usual in spatial econometrics and is constructed by multiplying the dependent variable y by a matrix of spatial contacts W which allows to include the shape of the urban structure. Upton and Fingleton (1985) argue that there is a problem of simultaneity in the interpretation of this variable. However, regarding other approaches which include several spatial exogenous variables (Trullén and Boix 2005) the spatial lag has the propriety of model and synthesizing in a single coefficient the spatial impact assuming, for example, that it is a function of the external economies proceeding from the other cities or is caused by synergetic effects. Another possibility is to specify an unmodeled shape for the spatial spillovers introducing the externalities in the error term of the regression and assuming a spatial random process $\varepsilon = \lambda W \varepsilon + u$, where λ is the spatial autoregressive parameter and u is a vector of i.i.d. errors with variance σ^2. As in the modeled lag, the shock in the error at any location is transmitted to other locations following a multiplier based on the "Leontief expansion" (Anselin 2003).

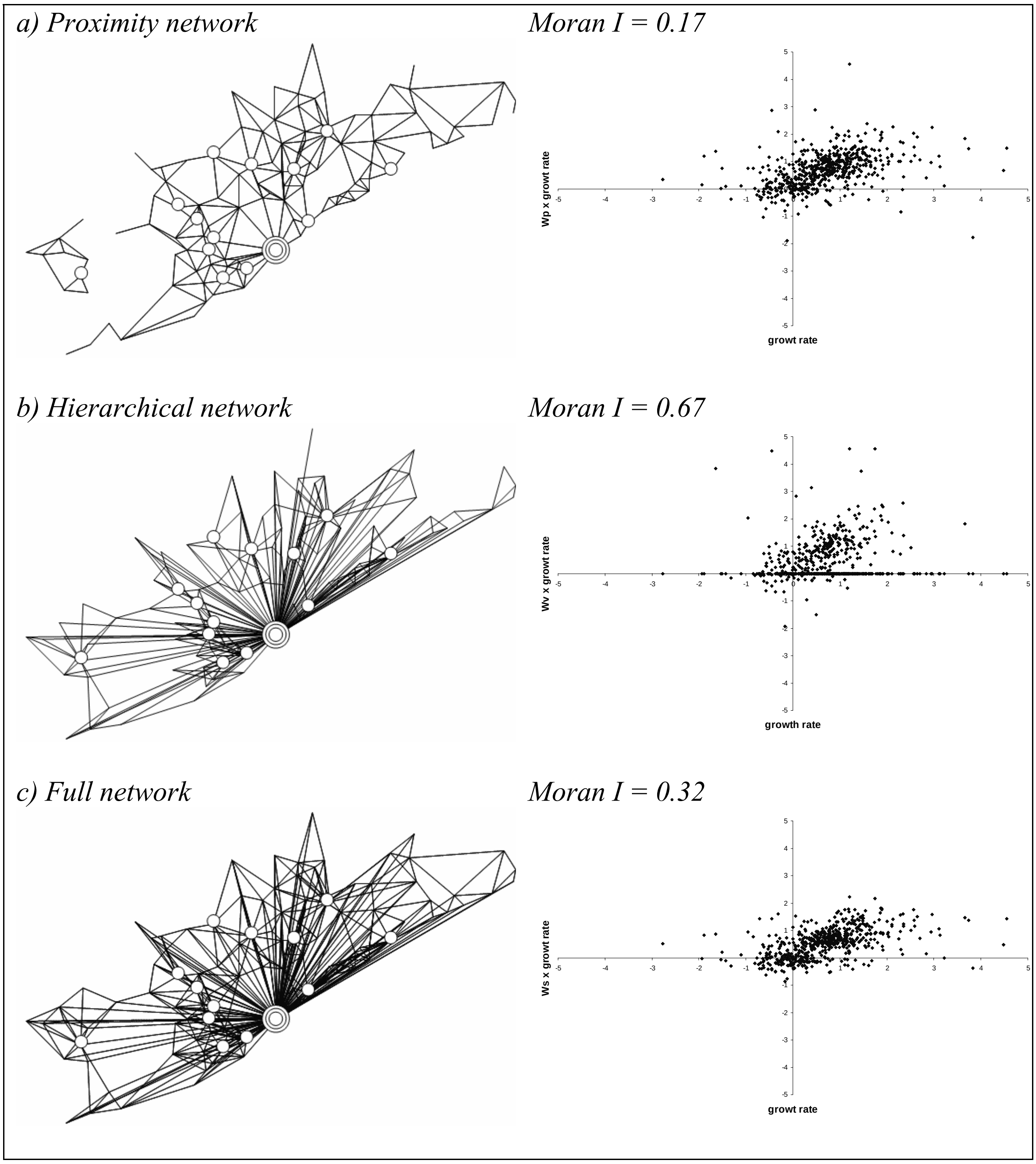
Contrary to the diffusion within cities, where no information uses to be available to test the shape of the spatial contacts, we have information enough to model mechanisms of diffusion between cities. Under the assumptions that spatial knowledge diffusion of innovations depends on the social network of interpersonal relationships (Hägerstrand 1967; Boschma 2005) and that diffusion occurs easier if the networked cities resemble in terms of their knowledge structure (synergetic approach), three *matrices* were elaborated to test how spatial externalities spill over across the urban structure: hierarchy (central place models), proximity, and network synergy (networks of cities paradigm) (figure 1).

The matrix of "geographical proximity" includes physical adjacency between municipalities in all directions ("queen" criterion) which is binary and symmetric. This produces a shape of irregular tessellation similar to a fisher's net, where no subcentre emerges (Figure 1a).

The matrices of "hierarchy" and "full network" were elaborated extracting the four nearest neighborhoods (destinations) of each city sorted by intensity of commuting in 1991. The matrix of hierarchy is binary and asymmetric and includes only the links of each city with other cities of upper rank. Different from the former, it shows the shape of an unfinished spider's web where the most important subcentres of the network emerge by structuring the space and revealing the internal organization of the metropolitan region of Barcelona as a polycentric network of cities (Figure 1b). Finally, the full network matrix is binary and symmetric and includes the four nearest neighborhoods (and the adjacent cities if any is not included as neighborhood). It includes hierarchical, heterarchical and bottom-up linkages and its shape reminds one of a complete web where important linkages exist no only with the city of Barcelona and the metropolitan subcentres but also between other small and medium cities (Figure 1c). The latter two networks allow to see how economic linkages in the space are much more complex than the geographical proximity and incorporate cognitive, social, organizational and institutional proximities (Boschma 2005). All matrices where row-standardized so that the indicator is a weighted average of the networked neighborhoods.

To balance the *sample* we use 115 cities where data on jobs are no zero for all the knowledge groups at the initial and final years and additionally we control for a possible selection bias. These cities account for more than 98% of the metropolitan employment in each knowledge group.

Figure 1. Graph representation and Moran scatterplots of the spatial interaction



4. Estimation results

The five knowledge groups are pooled and a strategy in three steps is followed: first, we start by estimating separated regressions for localization, urbanization, creativity, knowledge and spatial effects to separately test the contribution of the different externalities to the employment growth rate. Pooled estimates force the slopes of the coefficients to be the same for all knowledge groups. Second, a full model including all the non spatial variables is estimated and next we relax the hypothesis that the slopes between knowledge groups are similar by testing within groups fixed and random effects, and random coefficients. Third, spatial knowledge externalities were introduced in the panel structure. Since any pattern for heterogeneity was found, White's correction for heteroskedasticity (cross sectional or diagonal) was implemented where necessary (Greene 2003). Sample selection was tested using the Heckman's (1979) two-stage procedure although there was not any evidence of bias.

4.1. Pooled estimates of partial models

Localization economies explain between 35 and 43% of variation in growth rates (R^2, regressions 1.1 and 1.2 in Table 3). The negative relationship between employment growth and average firm size (-0.23 and -0.41) suggests that spatial organizational forms based in small firms tend to be more dynamic regarding jobs generation. The existence of a local specialized labor pool affects positively the differential growth of employment in partial regressions (0.19). Both variables support the existence of localization economies and the Marshall-Becattini hypothesis on the local atmosphere.

On the contrary, negative growth differentials are related to the specialization coefficient[3]. This coefficient measures relative concentration of a knowledge group in a city regarding the metropolitan one. Although it is a usual coefficient used as a synthetic proxy for localization economies (Glaeser et al. 1995; Henderson et al. 1995), it also tends to capture saturation (in resources, market or technology), life-cycle effects and delocalization processes (Combes 2000a; Trullén and Boix 2005). The coefficients of the estimated parameters (-0.29 and -0.37) indicate that, in general, a knowledge group grows less when the city is strongly specialized in this group.

Urbanization economies explain 29% of variation in growth rates (R^2, regression 1.3). Positive impacts are related to the Hoover's hypothesis on the size of the urban market (0.06) and the Chinitz-Jacobs hypothesis on the diversity of the urban environment (0.18). The Ciccone-Hall hypothesis on knowledge effects from density is rejected because coefficients are negative (-0.12 to -0.31) and according to Leon and Struyk's dynamic incubator hypothesis, employment growth seems to respond to land availability in less denser cities[4].

C*reativity* explains 16% of variation in growth rates (R^2, regression 1.4). Consistent with the Florida's hypothesis, technological intensity measured by patents (0.11) and the intensity of creative people (0.26) are positive and statistically

[3] Since the specialization coefficient on employment data is highly correlated with other variables in the models, it is only included in the equation 1.1 and substituted in the other regressions by a specialization coefficient calculated using firms. The latter is most consistent with Marshall's (1890) description.

[4] To check this hypothesis, we compared the density indicator with another indicator elaborated as the growth of built-up land between 1991 and 2005 (land registry source) divided by the employment at the initial year. The indicator reveal the high correlation (-0.60 to -0.85) between a low initial density and land growth.

significant. Tertiary graduates show a negative correlation with employment growth (-0.09) although the coefficient is statistically non significant. Tolerance indicator (foreign born workers) was removed from estimates because it was statistically non significant and caused strong collinerarity.

Wider *knowledge* externalities can be verified adding to the Florida's creative resources the Glaeser's dynamic externalities from the localization and urbanization economies. They explain 34% of variation in growth rates (R^2, regression 1.5). Knowledge regression estimates does not introduce significant changes in the positive coefficients of labor pool (0.28), diversity (0.13) and patents (0.06) although the creative class coefficient reduces to 0.09 and becomes statistically non significant. The negative coefficient related to density (-0.18) suggest again that there is not evidence on density economies or that firms prefers land availability to higher intra-urban knowledge externalities.

Finally, spatial knowledge externalities across cities explain between 0.09 and 26% variation in growth rates (R^2, regressions 1.6 to 1.8). The most important impact is produced in hierarchical transmission of knowledge (0.67) while the combination of vertical plus horizontal flows (0.32) and first order geographical proximity (0.17) produce smaller effects.

4.2. Pooled estimates of the full model and treatment of within-groups heterogeneity

All the local variables were included in a full model (regression 2.1, Table 4). Regarding *localization economies*, organization in small firms continue to be associated with employment growth because firm size coefficient is still negative (-0.34) and statistically significant. Specialized labor pool reduces to 0.10 and it becomes statistically non significant. Specialization coefficient, which mainly captures saturation, metropolitan life-cycle effects and delocalization, continue to be negative (-0.15) and statistically significant. *Urbanization economies* also show small differences regarding partial estimates. Market size (0.05) and diversity (0.03) are positive but their impacts continue to be small, and diversity becomes statistically non significant. Density is negative suggesting that land availability is more important than local knowledge spillovers. Regarding *creativity*, technological intensity measured by patents (0.05) and creative class (0.14) show positive impacts on urban growth and are statistically significant. Tertiary graduates is still negative (-0.10) but statistically non significant.

Next, we test if the slopes between knowledge groups or between cities are similar or different. The poolability test suggests that slopes are different and knowledge-group effect dominates city-group effect, the combination of city+knowledge fixed effects or other specifications[5]. This specification performs like an industry-mix effect in shift-share analysis and the estimates improve since the R^2 rises to 0.49 and BIC decreases to 2.01 (regression 2.2, Table 4). As was expected, estimated fixed effects for Knowledge-intensive services show a positive and large

[5] We also tested between-groups effects, random effects (Hausman test) and random coefficients although knowledge-fixed effects continue to prevail over the other specifications. Knowledge fixed effects allow modeling the different slopes by introducing a specific component by knowledge group. An additional possibility is to model each knowledge group in separate regressions like Trullén and Boix (2005) which is very similar to consider a fixed coefficients specification. The later separates the impacts of the variables of interest over each knowledge group by city although has the disadvantage of not allowing an integrated view of the effects.

effect (0.62) followed by Non-knowledge intensive services (0.38). The other knowledge groups show negative effects ranging from -0.19 for High and medium-high technology manufactures to -0.40 for Medium-low and Low technology manufactures and Other activities.

Regarding localization economies, firm size is still negative (-0.23) and statistically significant whereas the specialized labor pool and the specialization coefficient decreases to 0.05 and become statistically non significant. Regarding *urbanization economies*, market size slightly rises to 0.07, density decrease to -0.23 and diversity continue to be statistically non significant. Finally, in *creativity* variables, patent coefficient slightly rises to 0.07, tertiary graduates continues to be negative by decreasing to -0.22, and creative class decreases to 0.02 becoming statistically non significant. When within-group effects are controlled, the changes in the coefficients suggest that external economies and creativity have a different performance depending on the knowledge group. Thus, specialized labor pool, technology, human capital and creative class effects could be centered only in certain groups. Since the results conflicts with the theory of the human capital (Lucas 1988), an explanation may be that the metropolitan productive system is not still using with intensity the advantages that the most educated people offers[6].

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[6] In their research on Catalonia, Trullén and Boix (2005) found that when separate regressions on employment growth are estimated for each knowledge group, education is positive and statistically significant for Knowledge-intensive services (β=0.36) while for manufacturing groups (-3.31 to -0.37) and the Other activities it is negative (-0.23). Other indicators as the average of years of education and the share of secondary and tertiary employment provide similar results. It could be consistent with the productive reality of the Spanish economy which since 1996 is based in a production function labor intensive although with poor contributions of technological and human capital.

4.3. Externalities between cities: fixed-effects estimates of the spatial lag model

The synthetic spatial coefficient was introduced to test the existence of spatial knowledge externalities between cities and the form through it performs across the urban structure (Table 4, regressions 2.3 to 2.5). Two mechanisms of transmission of spatial externalities are tested introducing a direct spatial lag on the dependent variable (spatial diffusion between units) and a spatial autoregressive process in the error term (spatially correlated shocks) although our main interests relies on the modeled effects. Since the spatial variables Wy and $W\varepsilon$ are endogenous, the parameters are estimated by ML (Anselin 1988 and 2006; Elhorst 2003 and 2005). We offers the estimates for the spatial lag model which offers better results (R^2 and BIC) and is also preferred because allows to model spatial knowledge externalities. Non-spatial coefficients suffer little variations except the specialization coefficient (which becomes again negative and statistically significant) and market size which becomes statistically non-significant (maybe because the important is the size of the metropolitan market).

Knowledge transmission in hierarchical networks (regression 2.4) produces the most important effect on urban growth (0.44) whereas the full network (hierarchical and non hierarchical links) produces a smaller coefficient (0.25) and geographical proximity effects (0.08) are statistically non significant. This result suggests that in metropolitan environments, where the network of cities is hard dense and all dimensions of proximity short, the impact of the knowledge metropolitan spillovers can be bigger than the local ones. Moreover, the urban structure plays an important role since knowledge flows are specially intense (or effective) from the upper rank to the lower rank centers.

Table 3. Pooled estimates. Partial models. Dependent Variable = log ($Employment_{2005}/Employment_{1991}$)

Explanatory variables in logs	**(1.1) Localization**	**(1.2) Localization**	**(1.3) Urbanization**	**(1.4) Creativity**	**(1.5) Knowledge**	**(1.6) Proximity**	**(1.7) Hierarchy**	**(1.8) Network**
Constant	0.3930	0.4260	0.3913	0.7270	0.4868	0.5653	1.5502	0.5123
	(10.96)	(9.70)	(1.71)	(5.55)	(3.31)	(11.16)	(16.62)	(8.41)
Specialization (jobs)	-0.3791							
	(-8.52)							
Specialization (firms)		-0.2905						
		(-4.20)						
Firm size	-0.2337	-0.4164						
	(-5.91)	(-8.45)						
Specialized labor pool	0.1905	0.1897			0.2842			
	(3.26)	(2.64)			(4.69)			
Market size			0.0673					
			(2.41)					
Diversity			0.1833		0.1333			
			(4.61)		(3.55)			
Density			- 0.3112		-0.1816			
			(-10.40)		(-5.55)			
Patents				0.1157	0.0621			
				(5.19)	(2.91)			
Tertiary graduates				-0.0916	-0.0987			
				(-0.93)	(-1.22)			
Creative class				0.2618	0.0969			
				(2.71)	(1.39)			
Spatial lag (ρ)						0.1789	0.6775	0.3229
						(3.32)	(21.24)	(4.79)
BIC	2.4606	2.2278	2.0925	1.8597	2.1857	2.5802	2.2781	2.5098
R2-adj	0.4368	0.3579	0.2994	0.1633	0.3453	0.0925	0.2627	0.1589

t-student in brackets

Regressions (1.1) to (1.5) White heteroscedastic consistent estimates

Regressions (1.6) to (1.8) Maximum Likelihood estimates of the SAR or SEM models

Table 4. Pooled estimates. Full model. Dependent Variable = log ($Employment_{2005}/Employment_{1991}$)

Explanatory variables in logs	**(2.1) Full model**	**(2.2) Knowledge fixed effects**	**(2.3) Proximity Knowledge-fixed effects**	**(2.4) Hierarchy Knowledge -fixed effects**	**(2.5) Network Knowledge -fixed effects**
Constant	0.0938				
	(0.34)				
Specialization (firms)	-0.1515	0.0549	-0.2053	-0.1676	-0.2137
	(-2.26)	(0.60)	(-3.09)	(-2.47)	(-3.25)
Firm size	-0.3457	-0.2354	-0.2810	-0.3105	-0.2700
	(-6.78)	(-3.25)	(-3.43)	(-3.78)	(-3.35)
Specialized labor pool	0.1083	0.0559	-0.0530	-0.0304	-0.0445
	(1.46)	(0.73)	(-0.74)	(-0.41)	(-0.62)
Market size	0.0522	0.0700	-0.0078	0.0246	-0.0191
	(1.86)	(1.99)	(-0.21)	(0.62)	(-0.53)
Diversity	0.0337	-0.0192	-0.0165	-0.0047	-0.0129
	(0.87)	(-0.48)	(-0.43)	(-0.12)	(-0.33)
Density	-0.1189	-0.2321	-0.1269	-0.1246	-0.1166
	(-3.46)	(-5.62)	(-3.00)	(-3.00)	(-2.75)
Patents	0.0530	0.0729	0.0606	0.0643	0.0598
	(2.63)	(3.63)	(3.08)	(3.22)	(3.03)
Tertiary graduates	-0.1069	-0.2298	-0.3312	-0.3566	-0.3143
	(-1.37)	(-2.00)	(-3.20)	(-3.45)	(-2.98)
Creative class	0.1421	0.0249	0.0825	0.0898	0.0803
	(2.09)	(0.30)	(0.86)	(0.94)	(0.82)
Spatial lag (ρ)			0.0830	0.4483	0.2527
			(1.00)	(3.36)	(1.93)
F-test Fixed Effects		20.27*	9.14*	3.51*	3.59*
BIC	2.1097	2.0192	2.0973	2.0897	2.0944
R2-adj	0.4206	0.4899	0.5064	0.5172	0.5104

t statistics in brackets
Regression (2.1) using OLS White heteroscedastic consistent estimates
Regression (2.2) using the within-groups estimation procedure with White heteroscedastic consistent estimates
Regression (2.3) to (2.5) within-groups estimation procedure. ML estimates of spatial SAR with White heteroscedastic consistent estimates.

5. Conclusions

1. The merged ability to generate knowledge, creativity and external economies turns cities and metropolitan areas in the most powerful of the productive artifacts which become key for development and competitiveness. External economies and knowledge can be approached as separate elements although knowledge and creativity can be also conceived as the dynamic component of external economies. Metropolitan growth can be focused as the sum of the growth of the different cities that form the metropolitan area and their different composition and evolution in terms of knowledge types. The research tries to understand how external economies, knowledge and creativity affect the growth of the cities inside a metropolitan area.

2. To explore these features we will center in the Metropolitan Region of Barcelona as one of the most interesting exponents of knowledge and creative metropolis. It can be said that the metropolitan region of Barcelona has been transiting towards a knowledge-intensive and creative economy because the percentage of employees in knowledge intensive activities increased from 28% in 1991 to 37.8% in 2005, and creative class professionals have increased in 0.7 points annual average their share on total employment. Knowledge intensive services has been the most dynamic activities in the metropolitan region of Barcelona (10.7% annual average growth rate) and leaded the process of knowledge substitution. Manufacturing activities shows a negative growth rate which is especially intense for Low-technology manufactures (-2% annual average).

3. The net effects for growth of the different categories of external economies were tested for the cities of the Metropolitan Region of Barcelona using a time and

space-dynamic model of labor growth where activities are grouped by knowledge intensity. Estimates results conclude that external economies have an important role by explaining differential employment growth of metropolitan cities. Regarding the traditional approach to the urban externalities, the effects of localization economies are related to the organization in small firms and the existence of a skilled labor pool. Urbanization economies are related to the size of the local market and the diversity of the productive structure of the city. Localization effects seems to be larger than urbanization effects although this could be explained by the high degree of productive diversity in all the metropolitan cities and because the dimension of the metropolitan market is more important that the dimension of the local one. This should not be focused as a trade-off between localization and urbanization economies since both seem to be complementary and can combine in several ways. Indeed, the discussion is raised to a metropolitan scale because in the network of cities synergy and complementarity mechanisms work together so that the productive structure of each city is diversified as a whole but at the same time cities specialize in one or more activities

4. Creativity and knowledge can be focused as a time and space-dynamic component of the external economies since they have the ability to spill over and produce irreversible changes in the production function. This allows to establish a link between the traditional paradigms of regional economics and the new paradigms of the knowledge and creative city. The latter includes the dynamic part of localization and urbanization variables and specific variables for creativity. The performance in the econometric estimates of the skilled labor pool, diversity, density, innovative capacity and creative people indicates the link between knowledge-creativity and urban growth rates. On the other hand, the human capital variable is negative suggesting that in spite

of a constant transition towards a knowledge and creative economy, educated people are not being intensively used. Since the percentage of tertiary graduates of the metropolitan region of Barcelona continue to be significantly lower than other OCDE metropolitan areas (Boix 2006) and multifactor human capital productivity is still very slow, this point out a possible and dangerous weakness of the model which should be addressed as soon as possible.

5. Knowledge externalities are not limited to the boundaries of the cities rather than they diffuse through the metropolitan network of cities. Considering the dimension of the metropolitan region of Barcelona for each individual city and the density of interactions between cities, it is not strange although not for this less impressive that larger effects correspond to spatial knowledge externalities. Moreover, although spatial knowledge externalities follow a complex pattern where geographical distance, vertical and horizontal relationships are involved, the most important knowledge diffusion seems to take place through the hierarchical links of the urban structure.

6. Fixed effects estimates isolates the impact of each knowledge group and highlight the strong impact of Knowledge-intensive services on employment growth. As was expected, changes in the estimated coefficients when fixed effects are included suggest that knowledge and creativity does not affect in the same way all the knowledge groups.

7. A strong process of delocalization of the activity inside the metropolitan region of Barcelona is detected. This process is reflected in the negative impacts of local specialization and density of employment on urban growth. Although both coefficients can be interpreted as net diseconomies, it seems most feasible than for some firms,

advantages offered by some small and medium metropolitan cities are superior to advantages offered by the main subcentres.

8. The results have implications to the scope of local and metropolitan policies and can be extended to other places taking into account that each metropolitan area has its own specificity and mechanic translations are not advisable. Policy recommendations can be focused regarding the local and metropolitan scale although the later is limited because no comparison with other metropolitan areas is provided in this research. In both scales, the provision of conditions for the development of Knowledge-intensive services and creative class provides a possibility of expansion. Regarding the local scale, the comparison between the pooled and the fixed effects model suggest that effects of skilled labor pool and creative class seems to be strongly related to concrete activities, and initial conditions in the place should be taken into account before policy design. Small firm dimension is not a drawback but rather small firm environments seem to be most dynamics regarding jobs creation. Fostering innovative capacity can be also utilized as a growth factor since it seems to affect most of the knowledge groups.

On the other hand, local and metropolitan planners should take into account that the development of a place is strongly related to conditions in the other cities of the network. This restrict the scope of local policies because they results can be canceled by the conditions in the network of cities if this factor is not take into account. However, it can be focused as a potentiality since synergies and complementarities can be exploited. Even more important, knowledge and creativity not only depend on endogenous local factors, but also on a complex process, exogenous to the cities and endogenous to the metropolitan area, which transmits using the network of cities. Policies addressed to strength the metropolitan system of production and consumption of knowledge and creativity never should be designed as an isolated collection of local proceedings but taking into account the strength of the network effect. Centering knowledge and creativity policies in the main subcentres of the network can be a good point of departure since hierarchical knowledge transmission seems to be the most effective at this moment although most research is needed at this point to improve our knowledge on these processes.

Bibliograpy

Anselin, L. (2003), 'Spatial externalities, spatial multipliers, and spatial econometrics', *International Regional Science Review*, **26** (2), 153–166.

Anselin, L., Le Gallo, J. and Jayet, H. (2006), 'Spatial Panel Econometrics' In L. Matyas and P. Sevestre (eds), *The Econometrics of Panel Data, Fundamentals and Recent Developments in Theory and Practice* (3rd Edition), Dordrecht: Kluwer (forthcoming).

Boix, R. (2006), 'Barcelona ciudad del conocimiento', Barcelona: Ajuntament de Barcelona.

Boschma, R.A. (2005): 'Proximity and innovation: A critical assessment', Regional Studies **39** (1), 61-74.

Camagni, R. and Salone, C. (1993), 'Network Urban Structures in Northern Italy: Elements for a Theoretical Framework', *Urban Studies* **30** (6), 1053-1064.

Capello, R. (2000), 'The new city network paradigm: measuring urban network externalities', *Urban Studies* **37** (11), 1925-1945.

Capello (2006), *Regional Economics*, London: Routledge.

Chinitz, B. (1961), ‘Contrast in agglomeration: New York and Pittsburgh’, *The American Economic Review*, 51 (2), 279-289.

Christaller, W. (1933) *Die zentralen orte in Süddeutschland*, Jena: Gustav Fischer (translated by Baskin, C.W. as *Central Places in Southern Germany*, Prentice Hall 1966).

Ciccone, A. and R.E. Hall (1996), ‘Productivity and the density of economic activity’, *The American Economic Review*, 86 (1), 54-70.

Combes, P.P. (2000a), ‘Economic structure and local growth: France 1984-1993’, *Journal of Urban Economics*, **47**,329-355.

Combes, P.P. (2000b), ‘Marshall-Arrow-Romer Externalities and City Growth’, *CERAS working paper*, 99-06.

Cooke, P. (2002) ‘Knowledge Economies: Clusters, Learning, and Cooperative Advantage’, New York: Routledge.

Dematteis, G. (1989), ‘Nuove forme di organizzazione territoriale’, in Petsimeris, P. (ed) *Le reti urbane tra decentramento e centralita*, Milano: Franco Angeli.

Drucker, P.F. (1992), *The Age of Discontinuity*, U.S.:Transaction Publishers.

Elhorst, J. P. (2003), ‘Specification and estimation of spatial panel data models’, *International Regional Science Review*, **26** (3), 244–268.

Elhorst, J. P. (2005), ‘Unconditional Maximum Likelihood Estimation of Linear and Log-Linear Dynamic Models for Spatial Panels’, *Geographical Analysis*, **37**, 85–106.

Fagg, J.J. (1980): ‘A Re-examination of the Incubator Hypothesis: A case study of Greater Leicester’, *Urban Studies*, **17**, 35-44.

Florida, R. (2002), *The rise of the creative class*, New York: Basic Books.

Florida, R. (2005), *Cities and the creative class*, New York: Routledge.

Florida, R. (2005), *The fligh of the creative class*, New York: HarperCollins.

Glaeser, E., Kallal, H., Scheikman, J. and Shleifer, A. (1992), 'Growth in Cities' *Journal of Political Economy*, **100**, 1126-1152.

Hägerstrand (1967), *Innovation diffusion as a spatial process*, Chicago and London: The University of Chicago Press.

Heckman, J.J. (1979), 'Sample selection bias as a specification error', *Econometrica* **47**, 153-161.

Henderson, V., Kunkoro, A. and Turner, M. (1995), 'Industrial development in cities', *The Journal of Political Economy*, **103** (5),1067-1090.

Hoover, E.M. (1937), '*Location theory and the shoe and leather industries'*, Cambridge MA: Harvard University Press.

Hoover, E.M. and Vernon, R. (1959), 'Anatomy of a metropolis', Cambridge MA.: Harvard University Press.

Jacobs, J. (1961), '*The death and life of great American cities*', New York: Random House.

Jacobs, J. (1969), *The economy of cities*, London: Johnatan Cape.

Knight, R.V. (1995), 'Knowledge-Based Development: Policy and Planning Implications for Cities', *Urban Studies* **32** (2), 225-260.

Landry, C. (2002), *The creative city: A toolkit for urban innovators*, London: Earthscan.

Lazzeretti L., Capone F., Cinti T. (2004), *Economic enhancement of cultural and artistic heritage: focus on Community Programmes*, in Lazzeretti L. (ed), *Art cities, Cultural Districts and Museums*, Firenze: Firenze University Press, 77-109.

Leone, R.A. and Struyk, R. (1976), 'The incubator hypothesis: evidence from five S.M.S.A.s', *Urban Studies*, **13**, 325-331.

Lever, W.F. (2002): 'Correlating the Knowledge-base of Cities with Economic Growth', *Urban Studies,* **39** (5-6), 859–870.

Lösch, August (1954), *The economics of location*, New Haven: Yale University Press.

Lucas, R.E. (1988), 'On the mechanic of economic development', *Journal of Monetary Economics*, **22** (1), 3-42.

Marshall, A. (1920), *Principles of economics,* London: Macmillan. First edition 1890.

OECD (2003), *OECD Science, Technology and Industry Scoreboard 2003*, Paris: OCDE.

O´hUallacháin, B. and Satterthwaite, M. (1992), 'Sectoral growth patterns at the metropolitan level: an evaluation of economic development incentives', *Journal of Urban Economics*, **31**, 25-58.

Ohlin, B. (1933), *Interregional and International Trade,* Cambridge MA: Harvard University Press.

Pred, A. (1973), *Urban Growth and the Circulation of Information: The United States System of Cities 1790-1840*, Cambridge MA:Harvard University Press.

Pred, A. (1977), *City-sistems in advanced economies*, London: Hutchinson.

Roback, J. (1988), 'Wages, Rents, and Amenities: Differences Among Workers and Regions', *Economic Inquiry*, **26**, 2341.

Robinson, E.A.G. (1932), *The structure of competitive industry*, Cambridge: Cambridge University Press.

Romer, P.M. (1986), 'Increasing returns and long-run growth', *The Journal of Political Economy,* **94** (5), 1002-1037.

Romer, P.M. (1990), ‘Endogenous technological change’, *Journal of Political Economy* 98, 71-101

Rosenthal, S.S. and Strange, W.C. (2004): ‘Evidence on the Nature and Sources of Agglomeration Economies’, in Henderson, H. and Thisse, J.F. *Handbook of Regional and Urban Economics*, Volume *4: Cities and Geography*, London: Elsevier.

Sveikauskas, L. (1975), ‘The productivity of cities’, *The Quarterly Journal of Economics*, **89** (3), 393-413.

Trullén, J., Lladós, J. and Boix, R. (2002), ‘Economía del conocimiento, ciudad y competitividad’, *Investigaciones Regionales*, **1**, 139-161.

Trullén, J. and Boix, R. (2005), ‘Knowledge, networks of cities and growth in regional urban systems’, *Working Paper 05.04* Departament d'Economia Aplicada, Universitat Autònoma de Barcelona.

Van den Berg, L., Pol, P., Van Winden, W. and Woets, P. (2004), ‘European cities in the knowledge economy’, *Euricur Report R2004-1*, Rotterdam.

Weber, Alfred (1929), *Theory of the Location of Industries*, Chicago: The University of Chicago Press.

Webber, M.J. (1972), '*Impact of uncertainly on location*, Cambridge MA: MIT Press.