Do Software and Videogames firms share location patterns across cities? Evidence from Barcelona, Lyon and Hamburg

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Abstract:

The aim of this paper is to analyse common location patterns of Software and Videogames (SVE) industry in Barcelona, Lyon and Hamburg. This is a key industry in developed countries that are mainly located at the core of bigger metropolitan areas, looking for agglomeration economies, skilled labour and a wide range of spillover effects existent there. Cities used in our empirical application share some common features in terms of size, manufacturing tradition and, specially, economic strategies, as they have managed to promote high-tech neighbourhoods through ambitious urban renewal policies. When analysing location patterns of firms from the SVE industry, although our results highlight the predominant role of urban cores of three cities, also indicate important specificities in terms of core-periphery distribution of SVE's firms.

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1. Introduction

Nowadays, location patterns of firms belonging to high-tech industries are receiving increasing attention by both academics and policy makers. This interest can be easily explained because in developed and emerging countries these activities are growing faster than national average and, consequently, new firms and jobs are created. Nevertheless, these industries do not represent only an important source of economic growth through firms and jobs, but also a key challenge for the competitiveness of the areas generating and attracting high-tech firms. In this sense, these high-tech industries contribute in a stronger way to more growth (markets tend to expand), demand skilled labour, they do not imply intensive consumption of land, and do not generate negative environmental effects. To sum up, stronger specialisation in these industries is a desirable outcome for most of economies that can satisfy locational requirements of these firms, but it is also important to note that not all potential sites may be appropriate venues for a high-tech firm. In this regard, worldwide empirical evidence shows that, in general terms, these firms prefer areas with accessibility to skilled workforce and a dense network of high tech-firms (Baptista and Mendonça 2010) that typically correspond to urban environments and, more specifically, cores of big metropolitan areas (Van Geenhuizen 2007). This location behaviour does not respond only to some kind of path dependence, but to the necessity to benefit from knowledge spillovers (a key input for these firms) that tend to cluster at urban cores.

Despite of the relevance of high-tech industries as a whole, this paper intends to focus on a specific group of these industries that have experienced a very dynamic trend in recent years and that are hypothesized to continue this growth in a similar way in next years. We refer to Software and Videogames (hereafter SVE) industries, which currently benefit from massive growth rates, contribute to myriads of new firms, hire huge numbers of skilled engineers, and tend to locate at urban cores (although there are some specificities at city level). In addition to their high-tech profile, SVE's are considered as part of Creative Industries, which are defined as those economic activities that use creativity as one of the main inputs and that provide tangible (or intangible) goods or services that may generate revenues from trade and/or intellectual property (UNCTAD 2010). In terms of location patterns of Creative Industries, there is plenty of empirical evidence highlighting their strong preference for

central areas of bigger cities (Coll-Martínez et al. 2017).

We have selected three European capitals and their metropolitan areas as case study (Barcelona, Lyon and Hamburg). These cities are of a similar size, share a common manufacturing heritage, are not country capitals and have settled down relevant city strategies trying to orientate economic activities around technology, mostly through ambitious urban renewal policies[1] that have transformed previously peripheral low-income neighbourhoods into magnets of knowledge and economic activity generation, based on the attraction of high-technology firms and the endogenous development of local firms around them. As a consequence, SVE's firms have clustered in and around urban cores of these cities, in a process that has pulled many other related activities, as some technical events (e.g., professional exhibitions, gaming conventions) and education programs at local universities. Interestingly, in spite of these similarities, these cities have some differences in terms of location patterns of SVE's firms. In this sense, although in three cities SVE's firms locate at central areas, the intensity of centralization varies across them, as firms in Hamburg are strongly agglomerated at central areas, a phenomenon which is weaker for Barcelona and, specially, for Lyon. Nevertheless, there is a common pattern for all three areas, as SVE's firms co-locate close to firms belonging to other creative industries as Radio and TV, and Video and film industries. Although reasons behind that co-location are out of the scope of this paper and are left for future research, it is reasonable to assume that there are not only shared location patterns among SVE's firms and firms from these industries, but also some inter-industry linkages that favour spatial proximity[2].

Main aim of this paper is to explain how video games and software firms locate in urban areas focusing on *i)* their materialised preferences in terms of central vs. peripheral locations, and *ii)* the agglomeration strategies of these firms (i.e., whether SVE's firms tend to be located close to firms of the same industry or to other Creative Industries). Our assumption is that in addition to industry-specific characteristics that determine some external

[1] A detailed approach to these cities transformations can be found at Viladecans-Marsal and Arauzo-Carod (2012) (Barcelona), Moriset (2003) (Lyon) and Sepe (2014) (Hamburg).
[2] See Pablo and Arauzo-Carod (2012) for an analysis about inter-industry linkages and spatial proximity among firms.

requirements by these firms (*e.g.*, accessibility to skilled labour or specialised IT suppliers), there are some city-specific characteristics (e.g., urban policies, spatial distribution of economic activity) that also matter and shape location decisions taken by these firms, although their analysis is out of the scope of this paper due to space constraints.

We are interested in both software and videogames firms, but as videogames industry is quite recent, the availability of empirical evidence is still scarce. That's why for some analyses we will consider both industries together, even if they locational patterns are not strictly the same. Then, considering SVE's as a whole, it is a leading and influential industry that has important annual growth rates. Concretely, in 2010 SVE's contributed with 5.4% to world GDP (Dutta and Mia 2010). Firms from SVE's industries tend to locate at urban cores, as in these areas it is easier to obtain the skilled workforce employed at SVE's firms and the creative environment in which knowledge flows are stronger. In this sense, there is wide evidence about the importance of these skilled young professionals (i.e., computer programmers or software engineers) for SVE's firms (Autor et al. 2003).

The rest of the paper is organised as follows. Section 2 reviews *i)* the theoretical and empirical literature about firms' location determinants focusing on the importance of this industry for this cities, and *ii)* the case of Barcelona, Lyon and Hamburg from an historical and urban renewal strategic point of view. Section 3 describes data and methodology. Section 4 introduces some descriptive statistics and discusses results and, finally, section 5 presents main conclusions.

2. Location patterns of the software industry and common trends of Barcelona, Lyon and Hamburg

The aim of this paper is to compare location processes of videogames and software firms located in Barcelona, Lyon and Hamburg and in their metropolitan areas. These cities have been selected according to *i)* their importance in terms of attractiveness of firms from these industries, *ii)* their similar size, and *iii)* their similar institutional characteristics. Concretely, *i)* these cities have attracted a large number of video games and software firms at the same

time that local endogenous firms have emerged[3]; *ii)* according to recent data Hamburg is the biggest one with 1.7 million inhabitants (2015), followed by Barcelona with 1.6 million (2016) and, at a greater distance, by Lyon with 0.5 million (2014)[4]; *iii)* these cities play an important institutional role in their respective countries[5] but they are not country capitals, which implies that although they benefit from being regional capitals they do not support the advantages and disadvantages associated to country capitals.

Industry-specific characteristics that influence location decisions have been analysed from a spatial approach, as those of Méndez-Ortega and Arauzo-Carod (2017) and Coll-Martínez et al. (2017) for Barcelona and Murphy et al. (2015) for Dublin. Scarcity of empirical contributions is easily explained as video games and software are young industries that have exploded in terms of number of firms and employees especially after gaming expanded through mobile phones after the first iPhone was released (2007) and the appearance of the six-generation era of video consoles[6] between 2006 and 2007.

When discussing city-specific characteristics that may influence location decisions, numerous papers analyse that there is a potential growth in the number of high tech firms located in central areas of big cities, a phenomenon that occurs mainly in western cities fuelled by agglomeration economies, social relations, high skill workers, institutions, talent and human synergies (for example, Florida and Mellander 2016; Indegaard 2013; Hutton 2006; Van Oort and Atzema 2004). Concretely, these central areas act as "territorial innovation systems" (Morgan 2004) that favour innovation activities carried out by firms.

There are also several papers that analyse the positive effect of "techno neighbourhoods" (Duvivier and Polèse 2017) in terms of attraction of economic activity, economic growth and employment generation (Foord 2013; Viladecans-Marsal and Arauzo-Carod 2012; Rantisi

[3] See Méndez-Ortega and Arauzo-Carod (2017) for Barcelona, Moriset (2003) for Lyon, and Plum and Hassink (2014) for Hamburg.
[4] Similar size of Barcelona, Hamburg and Lyon make them easily comparable.
[5] Barcelona is the second largest city in Spain and the capital of the region of Catalonia, Lyon is the third largest city in France and the capital of the region of Auvergne-Rhône-Alps, and Hamburg is the second largest city in Germany and one of the 16 German states.
[6] Xbox360 (Microsoft), PlayStation3 (Sony) and Nintendo Wii (Nintendo).

and Leslei 2010; Pratt 2009; Bagwel 2008). Some of these techno neighbourhoods are related to urban policies aiming to generate clusters of these type of firms (*i.e.*, top-down strategies) and also those coming from local clusters being generated by firms' decisions (*i.e.*, bottom-up strategies) (Fromhold-Eisebith and Eisebith 2005)[7]. Obviously, both processes are interrelated and causality may act in both directions, as some urban policies are driven by ex-ante decisions taken by firms and some firms' strategies are triggered by urban policies favouring creation of video games and software firms' clusters. Aforementioned urban policies should depart from existing advantages of urban areas that, potentially, may take them to cluster formation, although uncertainty remains important and there is plentiful evidence of unsuccessful experiences (Braunerhjelm and Feldman 2006) that may be explained in terms of lack of connection of public projects with existent economic activity (Globerman et al. 2005). This point is extremely important for these industries in which turnover rates are quite high due to *i)* markets' dynamism and *ii)* low entry barriers (*i.e.*, amount of capital needed to start a new firm is very low), being that entries and exits modify regularly market's composition.

Given previous considerations, the experiences of Barcelona, Lyon and Hamburg are of interest, specially because their urban models differ in terms of core-periphery patterns and previous growth trends but, at the same time, they share some important urban renewal policies carried out in recent years. In general terms, experiences of these cities depart from ambitious urban transformation projects (22@ in Barcelona, *Confluence* in Lyon and *HafenCity* in Hamburg) that aim to renew lagged areas into hubs of high-tech activities, knowledge generation and economic transformation.

Barcelona has been affected by important economic structural changes in recent years, especially after the Olympic Games of 1992 that collaborated to generate an inflexion point in terms of internationalisation and economic transformation of the city. In this sense, the Poblenou district, that traditionally hosted mature manufacture activities, started a huge shift aiming to move from a 19th century manufacturing activities to a 21th century service activities. This strategy driven by local city council was called 22@ and helped to radically

[7] See Feldman et al. (2005) for a theoretical approach.

transform a huge area of the city quite close to urban core (Poblenou district). This has been a very successful policy that "managed to attract new firms from knowledge economy and transform an industrial structure based on mature manufacturing activities to one based on high-tech services provided by both private and public institutions" (Viladecans-Marsal and Arauzo-Carod 2012, p. 398).

Lyon shows some similarities with Barcelona as this city has an important manufacturing tradition coming from previous centuries[8], and has also some dissimilarities, as there are a couple of high-tech industries in which Lyon has an international reputation (pharmaceutical and bio-engineering). Although Lyon was not specialised in computer-related activities, this industry was boosted by the creation and location of worldwide leader firms in computer games (*Infogrames* and *Electronic Arts*, respectively) and *Confluence* quartier urban project, which is pretty similar to 22@ in Barcelona, but with additional emphasis into urban renewal designed to improve quality of life and, specially, to implement urban sustainable criteria.

Finally, Hamburg plays also a key role in this industry, as it is the most important German city for software and videogames firms. *HafenCity* project started in 2001 and has transformed a large part of the city (around 157 ha).[9] Concretely, this project is about urban renewal of the former Hamburg port, on the Elbe river. It is important to stress that *HafenCity* does not focus only on software and video games industries, but also on retail firms, restaurants, residential buildings, hotels, entertainment activities, offices and a cruise ship terminal. Although expectations are to receive important positive effects over these activities, it is also true that some period is needed in order to fully develop *HafenCity* projects and check their success.

[INSERT FIGURE 1]

Figure 1 shows SVE's yearly entries for each metropolitan area and the announcement data for each urban renewal project (2000 for Barcelona, 1999 for Lyon and 1997 for Hamburg).

[8] Though some of most important firms had moved their headquarters to Paris (Moriset 2003).
[9] *HafenCity* project is co-financed by private (€8.5 billion) and public investment (€2.4 billion).

A closer look to this figure shows how announcements foster entries in Lyon and Hamburg in following years, whilst for the case of Barcelona peak of entries were the year that the project was announced.[10]

Apart from previous specificities, all three cities share basic locational requirements from high-tech firms (Baptista and Mendonça 2010, Woodward et al. 2006) as accessibility (high-speed trains, airports and highways), availability of skilled labour (existence of reputed universities and post-graduated programs), high standards of quality of life (high-quality housing, cultural and recreational amenities), integration in a large and diversified market (European Union), and a previous network of firms of the same industry. These industry-specific assets increased attractiveness of these locations as they lower operational costs (Malmberg and Maskell 2002) and start-ups clusters' viability (Malmberg and Maskell 2006).

3. Data and Methodology

3.1. Data

Data used in this paper comes from different sources. About firms from Barcelona metropolitan area, data comes from the *Institut Català de les Empreses Culturals* and SABI (*Sistema de Análisis de Balances Ibéricos,* INFORMA). The former one is a department of Government of Catalonia that is responsible for digital media activities (including Videogames), and the latter compiles data on firms using the Register of Companies. The data at firm level for SVE's firms and the rest of creative firms are from the SABI Database. The data from the metropolitan areas of Lyon and Hamburg comes from Orbis Database, a worldwide database that contains detailed data of more than 200 million firms around the world[11]. From these datasets (SABI and Orbis) we obtain the constitution year, the address

[10] We hypothesise that as 22@ Project in Barcelona took a lot of years until it was formally launched potential investors may have had most of relevant information of this Project in advance and, therefore, had anticipated their entry decisions some years before official announcement.

[11] SABI and Orbis datasets include several firms' characteristics including year of constitution, balance sheets, income, expenditure accounts, number of employees, industry, sales, assets, and georeferenced location (i.e., X-Y coordinates). SABI and Orbis collect data from Mercantile Register, where all limited liability companies and corporations are obliged by law to deposit their balance sheets. Both are the most widely used datasets for

and the activity code of each firm in the interest to identify and classify each of them inside one of the creative sectors, as explained below.

In order to identify industries to be used in this analysis, we used the classification by UNCTAD (2010). This classification includes both manufacturing and service creative industries and is broadly accepted by researchers (e.g., Boix and Lazzeretti 2012). According to this classification, we obtain 17 categories, being a total of 18 if we divided SVE in Software firms (hereafter SOFT) and Videogames and Editing electronics firms (hereafter VGE) in two separate categories (see Table 1).

[INSERT TABLE 1]

As mentioned in the previous sections of the paper, we focus on the Metropolitan Areas (hereafter MA) of Barcelona, Lyon and Hamburg. Concretely, the MA of Barcelona, located in Catalonia, north-eastern Spain, covers an area of 636 km^2, has around 3.2 million inhabitants and includes 36 municipalities, the MA of Lyon (also called *Grand Lyon*) located in Rhône-Alpes, south-eastern France, covers an area of 515 km^2, has around 1.3 million inhabitants and include 59 *communes* (municipalities), and finally the MA of Hamburg, is the biggest metropolitan area subject to this study, covers an area of 2,087 km^2, has around 2.55 million inhabitant and include 37 municipalities.

The main reason to focus on these metropolitan areas is the large number of SVE's firms located in and around these cities and their metropolitan areas. Concretely the MA of Barcelona contains the 65.02% of the SVE's firms of all Catalonia, for the case of *Grand Lyon*, this contains the 85.26% of the SVE's firms of Rhône-Alpes and finally the MA of Hamburg contains the 85.09% of the SVE's firms in the State of Scheleswig-Holstein, State of Hamburg and Lueneburg District.

Although these cities are clearly the economic and institutional hub of their MA, there are

any country in the world when firm georeferenciation is required.

also some spatial heterogeneities at intra-city level that should be controlled. In order to do that, we will analyse location patterns at Barcelona, Lyon and Hamburg using intra-city administrative units (*i.e.*, districts).

[INSERT TABLE 2]

Table 2 shows the number of creative firms for each industry sorted by city and MA. It's important to highlight the high number of SVE's firms in all the cities, being the biggest creative sector in terms of number of firms for all the MA (except for Lyon, where Architecture and Engineering has 62 firms more than that of SVE). This fact highlights the importance of this industry inside the Creative industry for these metropolitan areas. Finally, regarding the firm distribution between City-MA, we observe that Barcelona and Hamburg have the most part of their creative firms inside their capital city

3.2. Spatial Methodology

In order to analyse the location patterns of SVE in the MA, we used the following techniques: Nearest Neighbour Index (NNI), Kernel densities, K-density Functions and Entropy Index.

The NNI (Clark and Evans 1954) analyses the spatial concentration of points (*e.g.*, firms) in a territory, and does not take into account whether firms are in different administrative units. The NNI is formulated as follows:

$$\boldsymbol{NNI = \frac{Observed\ Average\ distance}{Expected\ Average\ distance}}$$

Where Observed Average Distance and Expected Average Distance are defined as:

$$Observed\ Average\ distance = \frac{\sum_{i=1}^{n} d}{n}$$

$$Expected\ Average\ distance = 0.5\sqrt{\frac{A}{n}}$$

, where *d* is the distance, *n* is the number of neighbour links and *A* is the total area considered.

Values of NNI can be interpreted as follows: values around 0 indicate a clustered pattern, values around 1 indicate a random distribution, and values higher than 2 indicate an uniform pattern (the maximum possible value is 2.15 for a hexagonal grid). NNI has been used previously (Rehák and Chovanec 2012) to analyse the location patterns of creative industries in Slovakia.

Kernel density estimation is a non-parametric technique where the position of each firm is smoothed out from that firm into the surrounding area around it, defining a radius distance (in our case 250 and 100 meters for the MA and city level respectively) give an image of the firm distribution in a territory. The aggregation of the individually smoothed contribution of each point gives an overall picture of points' density, highlighting which locations have a high density of firms.

K-density functions (Duranton and Overman 2005) gives the density of firms using a distance-based approach in order to determine the distribution of bilateral distances between firms from the same activity and/or different activity. Let us define an industry *S* with *n* firms, then we compute a circle distance (*i.e.*, radius) between each pair of firms in that industry, obtaining $\boldsymbol{n(n-1)/2}$ bilateral distances for industry *S*. We denote $\boldsymbol{d_{ij}}$ as the distance in meters between firms *i* and *j*. Finally, the K-density function at any distance *d* is defined as follows:

$$\widehat{K}(d) = \frac{1}{n(n-1)h}\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} f(\frac{d-d_{ij}}{h})$$

, where *h* is the optimal bandwidth, and *f* is a Gaussian kernel function, where all densities are calculated. It's relevant to mention that an employment-weighted version of the *K*-density exists, but in this paper we are not using it[12]. This function will be used at intra industry and inter industry approaches, analysing in the first the density of firms (bilateral firm distances) of an industry and comparing it with the density of the whole creative activity, while in the second analyses the bilateral distance between a pair of industries also comparing it with the

[12] The employment-weighted version of the *K*-density function is not used because our research question, which focuses on the location and colocation of the Software and Videogames industry inside metropolitan areas, only considers the firm's location, not its employment size.

density of the whole creative activity. K-density Function has been used in numerous papers in order to analyse the density of firms for each distance and how firms agglomerate (*i.e.* Behrens et al. 2016).

Finally, the Entropy Index (Theil 1972) analyse whether a geographical unit is homogenous or diverse. Concretely, values close to 0 indicate that there is a predominant creative industry at the considered spatial unit (*e.g.*, a city district in this paper), whilst values close to 1 indicate that there is no a predominant creative industry (i.e., industrial diversity is high).

When used together, these techniques provide us an overall spatial approach for different industries at several levels, and allow to explain locational linkages of SVE's with firms from other industries.

4. The metropolitan location of the Software industry: some results

4.1 Kernel density and Nearest Neighbour Index

Kernel density

Kernel density results indicate a general spatial concentration of the creative firms at metropolitan and city levels and at city levels. Regarding SVE industry, by contrast, tend to be cluster inside some parts of the city centre, to be discussed below.

[INSERT FIGURE 2]

Figure 2 shows the spatial pattern of the aforementioned industries for the MA of Barcelona (hereafter MAB). It is important to note the existence of natural spatial discontinuities inside the MAB[13]. As shown on the map, there is a big concentration of creative industries inside Barcelona and the municipalities belonging to the MA but if only SVE's firms are considered,

[13] The city of Barcelona is bounded by the Mediterranean Sea in the east and by a wooded mountain area (Collserola) in the north-northwest between Barcelona and the North-Western municipalities.

then almost all of them locate in three areas of the city of Barcelona: Diagonal avenue, and Eixample and 22@ (Poblenou) district. Concretely, this is a polycentric pattern in which there is a huge number of firms at some central areas of the city at the same time that a similar number is located in high-tech neighbourhoods, a situation that is increasingly frequent in western big metropolitan areas, as showed for Barcelona (Méndez-Ortega and Arauzo-Carod 2017) and Toronto, Montreal and Vancouver (Duvivier and Polèse 2017; Duvivier et al. 2018).

[INSERT FIGURE 3]

Figure 3 shows the spatial pattern for the MA of Lyon (also called *Grand Lyon*). In a similar way as in Barcelona, all creative activities locate around all the MA but they are concentrated in the city of Lyon, specially for SVE's firms. It is worth mentioning that SVE's firms do not agglomerate in the *Confluence* zone, inasmuch as these firms are located in the most central areas of the city (CBD). We assume that these firms may tend to be close to central areas in order to get sufficient accessibility to skilled workers, institutions, creativity and social relationships, creating places with a high variety of industries (Hutton 2004). In this sense, there is the example of New York, where after the recent financial crisis, creative industries replaced finance as an economic driver inside the city (Indegaard 2013) and also the case of London, Vancouver and Singapore, where the collapse of Fordist production inside city centres produced a realignment of the metropolis core (Hutton 2006).

[INSERT FIGURE 4]

Finally, Figure 4 shows the spatial concentration for the MA of Hamburg. In a similar way as in Barcelona and Lyon, whilst creative industries locate across the whole MA, SVE's firms tend to concentrate inside the city of Hamburg and, concretely, in *HafenCity* quarter.

To sum up previous results, kernel densities suggest that there are three slightly different industry location patterns, one for each metropolitan area considered: *i)* in Barcelona there is a polycentric structure of SVE's firms as there are some subcentres in core areas and at the

urban renewal area (22@); *ii)* in Lyon SVE's firms concentrate around city centre, but not in the urban renewal area (*Confluence*); and *iii)* in Hamburg, there is a clear concentration at the urban renewal area (*HafenCity*).

Nearest Neighbour Index

NNI values shown in Table 3 provide an overview of clustering of *i)* all Creative Industries, *ii)* SVE's industries (i.e., Software, Videogames and Editing Electronics), *iii)* SOFT industries (i.e., Software) and *iv)* VGE industries (i.e., Videogames and Editing Electronics). For the sake of simplicity we will focus our analysis on SOFT and VGE industries for both metropolitan areas and capitals of these areas.

[INSERT TABLE 3]

Location patterns of aforementioned spatial areas and industries have important specificities according to these two dimensions but, specially, in terms of industries. In this sense, NNI values are much higher for VGE industries than for SOFT ones (i.e., concentration is stronger for SOFT industries), but for three metropolitan areas and cities they are pretty similar. Concretely, SOFT industries range from 0.332 to 0.365 at metropolitan level and from 0.300 and 0.391 at city level, whilst higher values for VGE range between 0.517 and 1.971 (metropolitan areas), and between 0.595 and 0.698 (cities).

In general terms SOFT industries have a similar concentration level across all metropolitan areas and cities (i.e., Barcelona, Lyon and Hamburg), but a further analysis allows to identify two slightly different patterns. The first one corresponds to Barcelona and Lyon, where concentration is higher for their metropolitan areas than for the city capitals, whilst the second one corresponds to Hamburg, where the situation is exactly the opposite. Obviously spatial scope of respective metropolitan areas matters as, for instance, quotients (e.g., in terms of population or jobs) between city capital and their metropolitan areas differ but, nevertheless, it is also obvious that this result illustrates some location specificities across these areas.

Results for VGE industries are not easy to analyse as number of firms is quite low compared

to that of SOFT firms (127 vs. 3019 in Barcelona, 254 vs. 1656 in Lyon, and 50 vs. 4506 in Hamburg) and also because spatial distribution of firms adjusts clearly to a CBD pattern as most of them locate at city capital instead of at the metropolitan area: Hamburg (90% of VGE firms locate at the capital), Barcelona (82%), and Lyon (56%). This is why results for VGE at metropolitan area level are less reliable in view of the small number of firms (e.g., 22 firms in Barcelona and 5 firms in Hamburg). If we focus on city level, then results indicate a lower concentration level (0.698 for Barcelona, 0.595 for Lyon and 0.675 for Hamburg) that even small but positive, suggests the existence of other location factors apart from physical proximity among firms of the same industry.

4.2 *K*-density Function

In next following graphs we show the *K*-density function of the SVE for the Metropolitan Areas and the relationship between SVE's firms and ADV, RTV, GA and VFI's firms[14].

Intra-Industry Analysis

Figure 5 shows firm density for SVE at city and metropolitan level. At first glance it is observed that density of these industries differs across cities, presenting a similar pattern for Barcelona and Hamburg, and a completely different distribution for Lyon in the first tram of the radios (up to 5,000 meters). SVE's firms have a similar concentration pattern almost identical to all creative sectors (dashed line), except for Hamburg, where SVE industry is more concentrated than all the creative in the first tram of the radius (0-10,000 meters).

[INSERT FIGURE 5]

Inter-Industry Analysis

In the following figures the relationship between SVE's firms with other high-tech creative firms will be compared.

[INSERT FIGURE 6, 7, 8]

[14]All calculations use a 0.05 significance level, using 1000 simulations. The dashed line corresponds to the benchmark scenario, that is the density of all the economic activity (All Creative firms in our case) and the shaded area is the confidence interval.

When the *K*-density between SVE vs VFI firms is compared, we observe that this pair of industries tend to be more concentrated than the whole creative sectors in a first tram of the radius for all the cities, indicating that these industries tend to locate close each other; the same happens with SVE vs ADV and SVE vs RTV as well, giving a *K*-density value higher than the whole creative sectors in the first tram of the radius for all the cities. In contrast, for the SVE vs GA case, we observe the opposite effect, since these sectors are less agglomerated than the whole creative sectors in a first tram of the radius for all the cities (i.e., agglomeration between SVE and GA firms is fewer than statistically expected at shorter distances).

Summarizing, these results support the role of intra-urban agglomeration of the SVE industry in economic activity, especially with other high-tech firms. These results show that Software firms tend to locate close to core locations, at least in these cities. These results are in line with Duvivier and Polèse (2017), where it is shown that high tech firms tend to be located near other creative industries such as Arts-related occupations and Financial Institutions.

4.3 Entropy analysis.

Finally, Entropy Index (*E*) provides a different approach about spatial / industrial heterogeneity as it allows to identify whether a spatial unit (*e.g.*, city district or municipality) is homogeneous or diverse. Concretely, *E* ranges between 0 and 1, being that values close to 0 indicate that in this area there is a predominant industry, and values close to 1 indicate that relative weights of each activity are similar. In this sense, figures A1, A2 and A3 show that, in general terms, core areas of three capitals are those with higher entropy levels, i.e. those with a more diverse composition of activities, being that peripheral areas tend to rely on lower number of industries.

[INSERT FIGURE A1, A2, A3]

Additionally, in order to try to identify drivers of entropy we have included number of firms at district / municipality level and, as expected, entropy is higher when there are a large number of firms. Concretely, high tech firms tend to locate close to places where values as tolerance, diversity and skilled human capital act as drivers of high technology entrepreneurship (Qian 2013). Finally, these are places where creativity and multicultural

environment provide an important stimulus to these firms in terms of innovation and growth (Florida and Gates 2003).

5. Conclusions

In this paper we have analysed whether location patterns and colocation strategies of SVE's firms share similar strategies across a sample of three European cities and metropolitan areas (Barcelona, Lyon and Hamburg) where these activities are of high importance. We have focused on this industry according to its growing importance, its specificities as a high-tech creative industry, its strategic role in terms of city marketing and knowledge generation and the potential higher European competitiveness in view of technological and human capital requirements of firms from SVE's.

Our results strongly show the existence of intra-urban agglomeration in economic activity, especially when dealing with creative industries. More specifically, these results indicate that although in Europe software firms typically tend to locate close to core locations, there are (at least) three models that may be easily identified when comparing location patterns of Software and Videogames (SVE) industry and Videogames (VGE) industry with those of all creative industries at city/metropolitan level: the first one consists on a strong concentrated pattern (Hamburg), the second one consists on an intermediate (polycentric) agglomeration pattern (Barcelona) and the third one consists on a moderate agglomeration (*intramuros*) pattern (Lyon). Obviously, these differences are triggered by specific local policies, urban structures, path dependence on previous spatial configuration of economic activity, and general city and metropolitan characteristics, but in general terms they confirm that there is no a single agglomeration strategy to be followed by creative industries, which also implies that different policies may be provided according to specificities of each metropolitan area. In this regard, one of main goals of policy makers should be the ex-ante identification of agglomeration preferences of these industries for a given metropolitan area, in order to decide whether to increase or not existent agglomerations.

Overall, our results should be interpreted with care due to some potential limitations that we aim to solve in future research. Firstly, they correspond to a specific period of time and,

therefore, may be biased due to different business cycle at city level[15]. Secondly, they refer to only three cities and metropolitan areas, and may include some city-specific effects not operating in other areas. Thirdly, they may be biased due to criteria used in order to identify metropolitan areas to be considered around each one of three main cities. Fourthly, they come from an overall analysis of firms from SVE's industry without taking into account whether differences in firms' size across the three metropolitan areas may imply as well some differences in location and agglomeration patterns. Further research should explore all these issues in order to provide more robust results by exploring alternative time spams, including other cities and metropolitan areas where these industries are relevant, testing alternative definitions of metropolitan areas, and differentiating firms by size.

[15]As a matter of example, in recent crisis contraction of economic activity started early in Barcelona and its duration has been longer than in Lyon and Hamburg.

References:

Apparicio P, Martori JC, Pearson AL, Fournier E, Apparicio D (2014) An open-source software for calculating indices of urban residential segregation. Social Science and Computer Review 32 (1): 117-128.

Bagwell, S. (2008) Creative clusters and city growth. Creative Industries Journal, 1: 31-46.

Baptista R, Mendonça J (2010) Proximity to knowledge sources and the location of knowledge-based start-ups. The Annals of Regional Science 45: 5-29.

Behrens K, Boualam B, Martin J (2016) The resilience of the Canadian textile industries and clusters to shocks, 2001-2013. CIRANO.

Boix R, Lazzeretti L (2012) Las industrias creativas en España: Una panorámica. Investigaciones Regionales 22: 181–205.

Coll-Martínez E, Moreno-Monroy AI, Arauzo-Carod JM (2018) Agglomeration of Creative Industries: An Intra-metropolitan Analysis for Barcelona. Papers in Regional Science, forthcoming.

Clark PJ, Evans FC (1954) Distance to nearest neighbor as a measure of spatial relationships in populations. Ecology 35(4): 445-453.

Duranton G, Overman HG (2005) Testing for Localization Using Micro-Geographic Data. The Review of Economic Studies 72(4): 1077–1106.

Dutta S, Mia I (2010) The global information technology report 2009 – 2010 ICT for Sustainability. World Economic Forum.

Duvivier C, Polèse M (2017) The great urban techno shift: Are central neighbourhoods the

next silicon valleys? Evidence from three Canadian metropolitan areas. Papers in Regional Science, forthcoming.

Duvivier C, Polèse M, Apparicio P (2018) The location of information technology-led new economy jobs in cities: office parks or cool neighbourhoods? Regional Studies 52 (6): 756-767.

Feldman M, Francis J, Bercovitz J (2005) Creating a cluster while building a firm: Entrepreneurs and the formation of industrial clusters. Regional Studies 39: 129-141.

Florida R, Gates G (2003) Technology and tolerance: The importance of diversity to high-technology growth. In: The city as an entertainment machine, Emerald Group Publishing Limited, pp. 199-219

Florida R, Mellander C (2016) Rise of the startup city: the changing geography of the venture capital financed innovation. California Management Review 59 (1): 14-38.

Foord J (2013). The new boomtown? Creative city to Tech City in east London. Cities 33: 51-60.

Fromhold-Eisebith M, Eisebith G (2005) How to institutionalize clusters? Comparing explicit top-down and implicit bottom-up approaches. Research Policy 34: 1250-1268.

Globerman S, Shapiro D, Vining A (2005) Clusters and intercluster spillovers: Their influence on the growth and survival of Canadian information technology firms. Industrial and Corporate Change 14: 27–60.

Hutton TA (2004) The new economy of the inner city. Cities 21(2): 89-108.

Hutton TA (2006) Spatiality, built form, and creative industry development in the inner city. Environment and Planning A 38(10): 1819-1841.

Indergaard M (2013) Beyond the bubbles: Creative New York in boom, bust and the long run. Cities 33: 43-50.

Malmberg A, Maskell P (2002) The elusive concept of localization economies: Towards a knowledge-based theory of spatial clustering. Environment and Planning A 34: 429–449.

Malmberg A, Maskell, P. (2006) Localized learning revisited. Growth and Change 37: 1–18.

Méndez-Ortega C, Arauzo-Carod JM (2017) Location of the Software & Videogames Industry: an insight into the case of Barcelona using microgeographic data. Working Paper CREIP 3-2017.

Morgan K (2004) The exaggerated death of geography: learning, proximity and territorial innovation systems. Journal of Economic Geography 4 (1): 3-21.

Moriset B (2003) The New Economy in the City: Emergence and Location Factors of Internet-based Companies in the Metropolitan Area of Lyon, France. Urban Studies 40 (11): 2165-2186.

Murphy E, Fox-Rogers L, Redmond D (2015) Location Decision Making of "Creative" Industries: The Media and Computer Game Sectors in Dublin, Ireland. Growth and Change 46 (1): 97–113.

Pablo F, Arauzo-Carod JM (2012) "Spatial distribution of economic activities: an empirical approach using self-organizing maps". In E Fernández-Vazquez and F Rubiera-Morollón (eds.), Defining the Spatial Scale in Modern Regional Analysis. Springer: Berlin.

Plum O, Hassink R (2014) Knowledge bases, innovativeness and competitiveness in creative industries: the case of Hamburg's video game developers. Regional Studies, Regional Science 1 (1): 248-268.

Pratt AC (2009) Urban Regeneration: From the Arts "Feel Good" Factor to the Cultural Economy: A Case Study of Hoxton, London. Urban studies 46 (5-6): 1041-1061.

Qian H (2013) Diversity versus tolerance: The social drivers of innovation and entrepreneurship in US cities. Urban Studies 50 (13): 2718-2735.

Rantisi NM, Leslie D (2010) Materiality and creative production: the case of the Mile End neighborhood in Montréal. Environment and Planning A 42 (12): 2824-2841.

Rehák Š, Chovanec M (2012) Exploring Spatial Patterns of Creative Industries with Firm Level Micro Geographic Data. Region Direct 2: 10–35.

Sepe M (2014) Urban transformation, socio-economic regeneration and participation: two cases of creative urban regeneration. International Journal of Urban Sustainable Development 6 (1): 20-41.

Suire R, Vicente J (2009) Why do some places succeed when others decline? A social interaction model of cluster viability. Journal of Economic Geography 9: 381–404.

Theil H (1972) Statistical Decomposition Analysis. North-Holland: Amsterdam.

UNCTAD (2010) Creative economy. Report 2010. UNCTAD, Geneva.

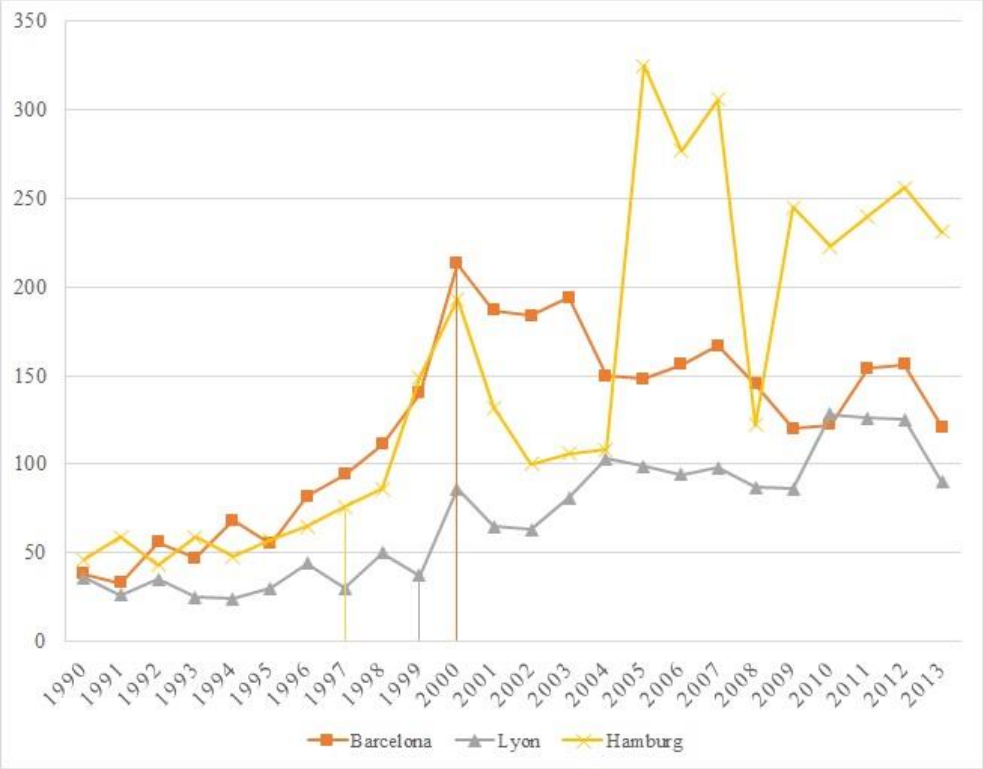
Van Geenhuizen, M. (2007). Modelling dynamics of knowledge networks and local connectedness: a case study of urban high-tech companies in The Netherlands. The Annals of Regional Science 41(4), 813-833.

Van Oort FG, Atzema, OA (2004). On the conceptualization of agglomeration economies: The case of new firm formation in the Dutch ICT sector. The Annals of Regional Science, 38(2), 263-290.

Viladecans-Marsal E, Arauzo-Carod JM (2012) Can a knowledge-based cluster be created? The case of the Barcelona 22@ district. Papers in Regional Science 91 (2): 377–400.

Woodward D, Figueiredo O, Guimarães P (2006) Beyond the Silicon Valley: University R&D and high-technology location. Journal of Urban Economics 60: 15-32.

Figure 1: SVE's firm's entries by year at Barcelona, Lyon and Hamburg at Metropolitan level.

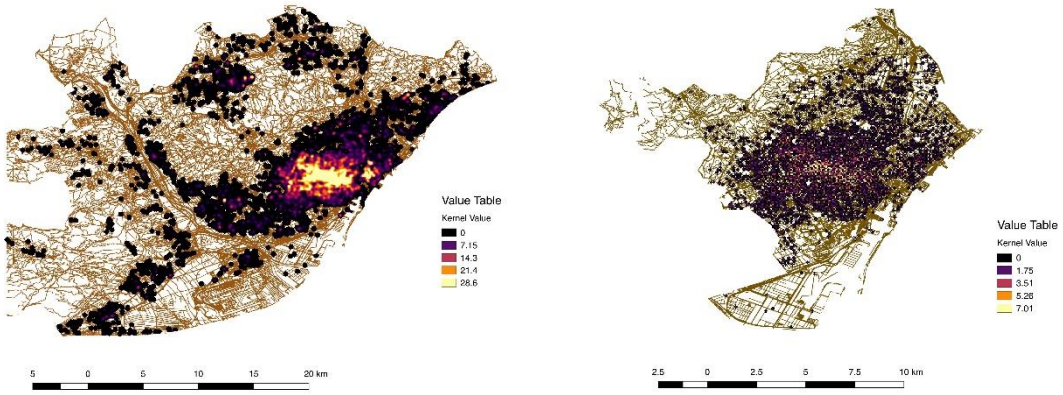


Note: The vertical lines represent the announcement year of each urban renewal project (2000 for Barcelona, 1999 for Lyon and 1997 for Hamburg).

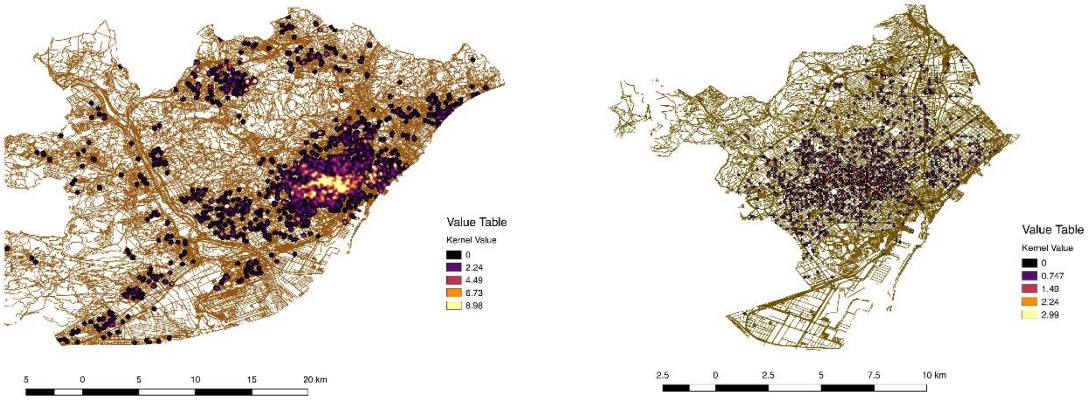
Figure 2: Kernel density for Barcelona at Metropolitan and City Scale.

Metropolitan Area City

All Creative firms



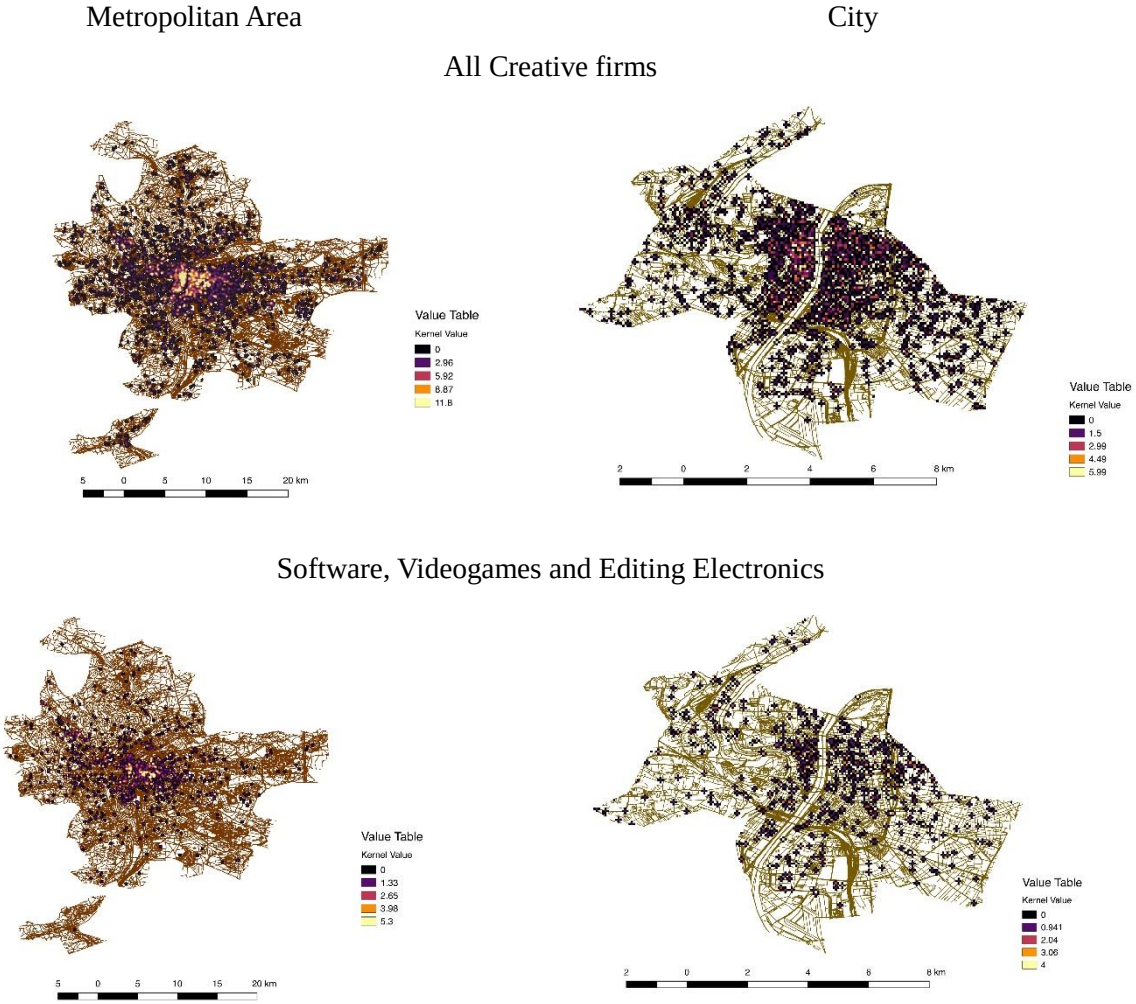
Software, Videogames and Editing Electronics



Note: The chosen bandwidth at Metropolitan level is 250 meters and 100 at city level. Source: Compiled by the authors.

Figure 3

Figure 3: Kernel density for Lyon at Metropolitan and City Scale

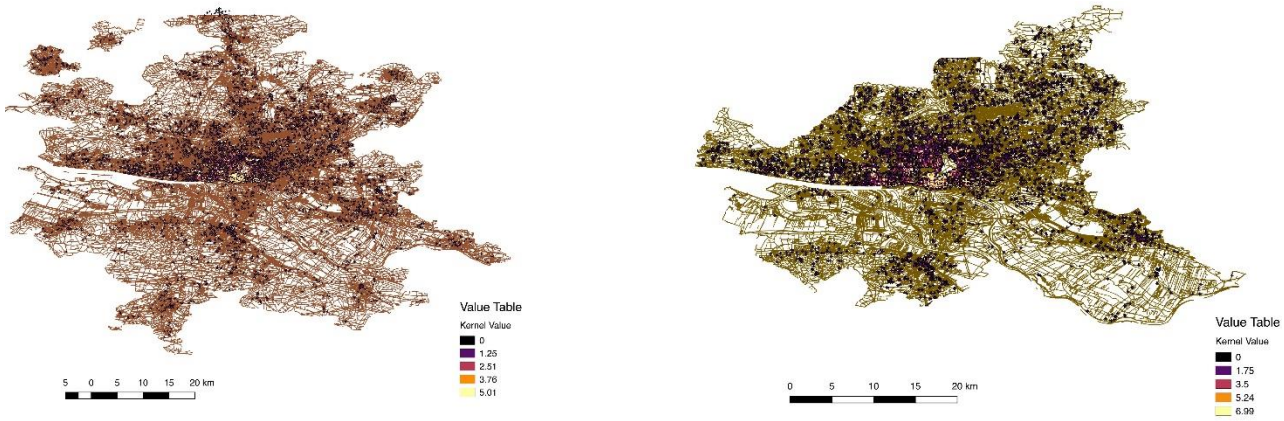


Note: The chosen bandwidth at Metropolitan level is 250 meters and 100 at city level. Source: Compiled by the authors.

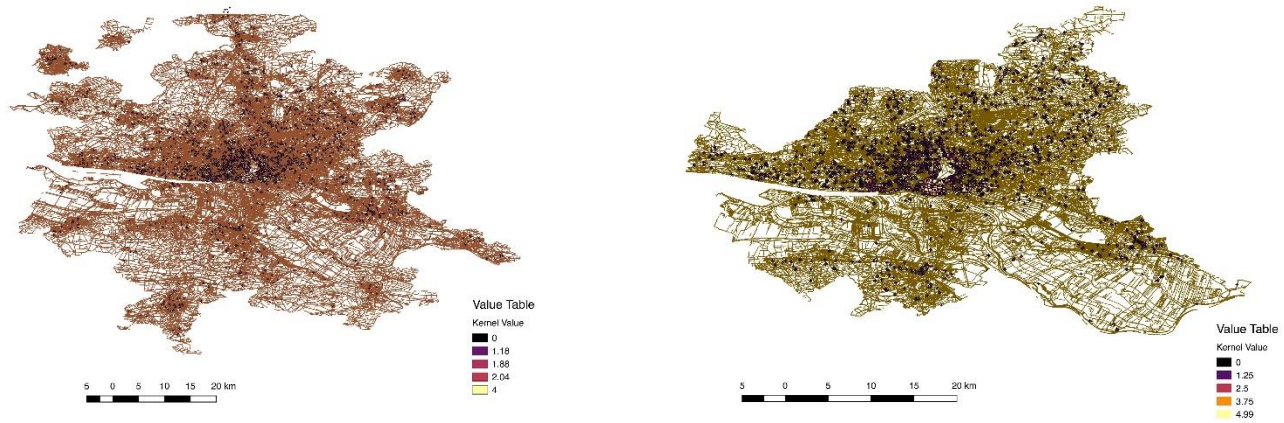
Figure 4: Kernel density for Hamburg at Metropolitan and City Scale

Metropolitan Area City

All Creative firms



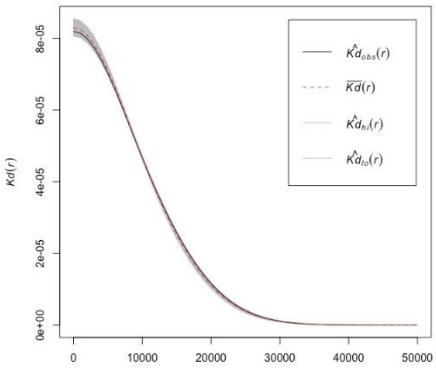
Software, Videogames and Editing Electronics



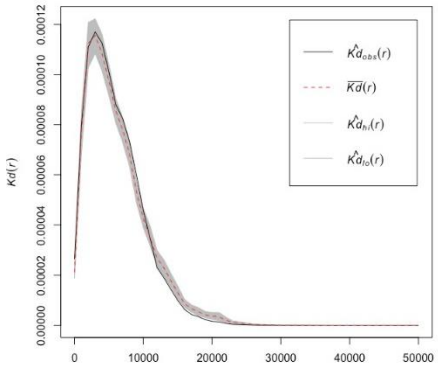
Note: The chosen bandwidth at Metropolitan level is 250 meters and 100 at city level. Source: Compiled by the authors.

Figure 5: Kd Function of SVE for the Metropolitan Areas of Barcelona, Lyon and Hamburg.

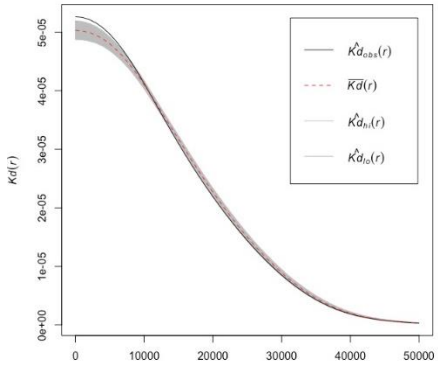
Metropolitan Area of Barcelona



Metropolitan Area of Lyon

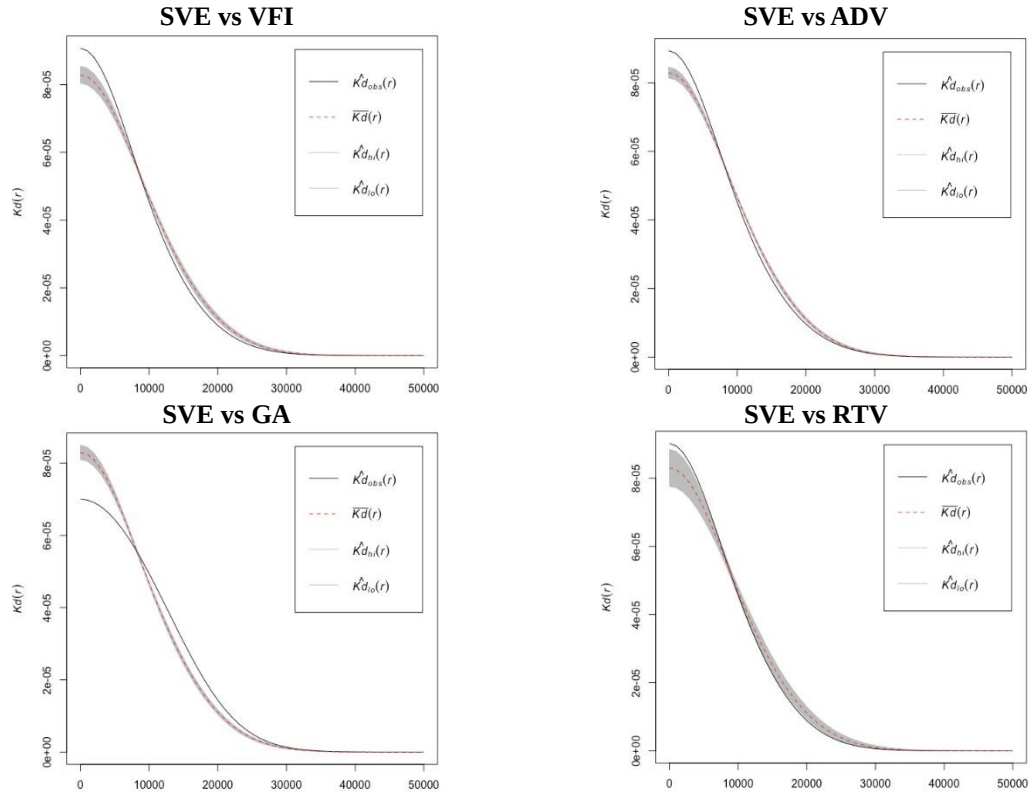


Metropolitan Area of Hamburg



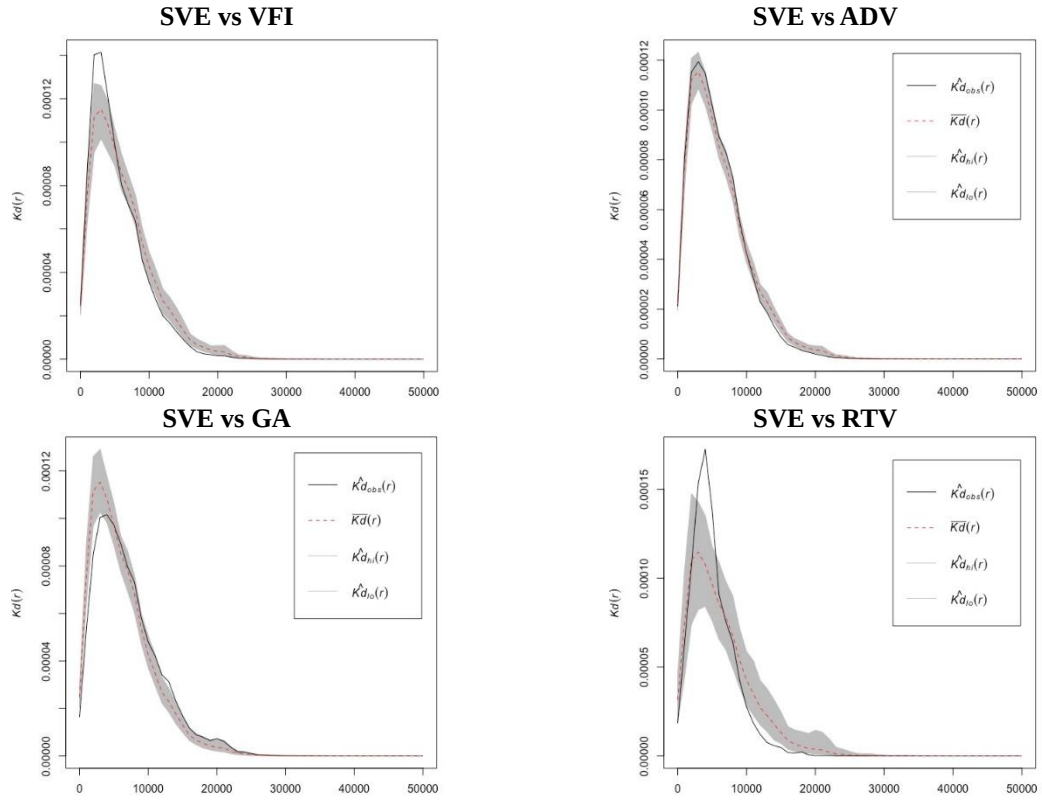
Horizontal axis units (r): meters. Source: Compiled by the authors.

Figure 6: Kd Function of SVE vs. some Creative sectors for the Metropolitan Area of Barcelona.



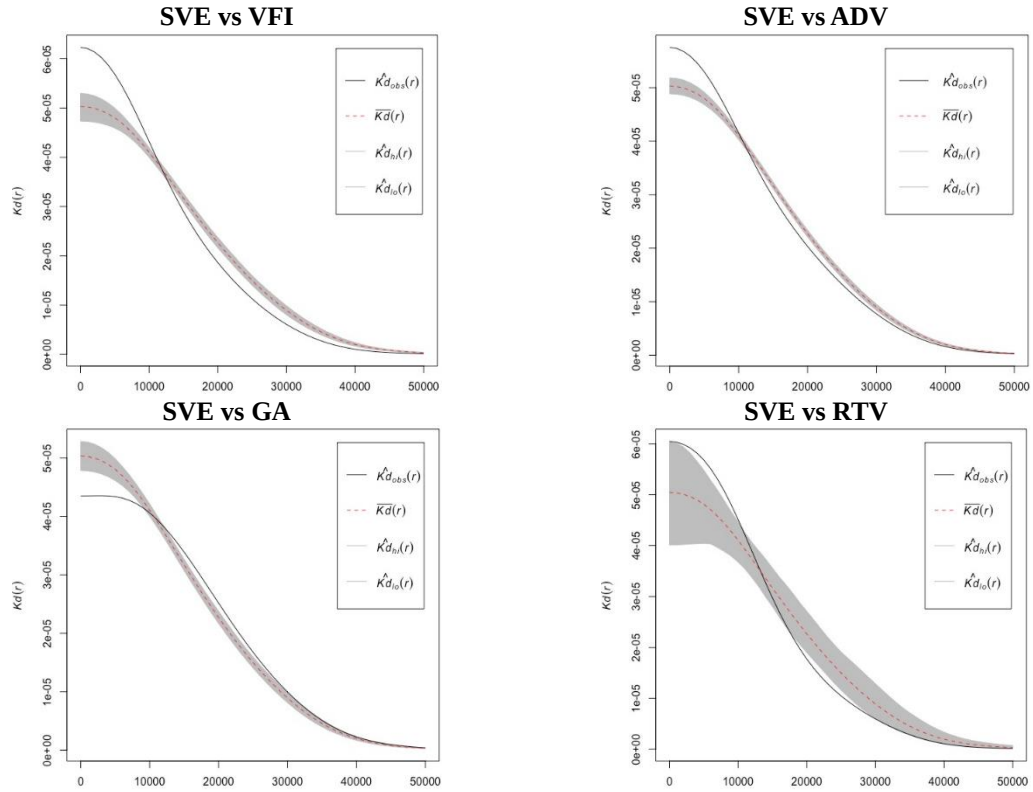
Horizontal axis units (r): meters. Source: Compiled by the authors.

Figure 7: Kd Function of SVE vs. some Creative sectors for the Metropolitan Area of Lyon.



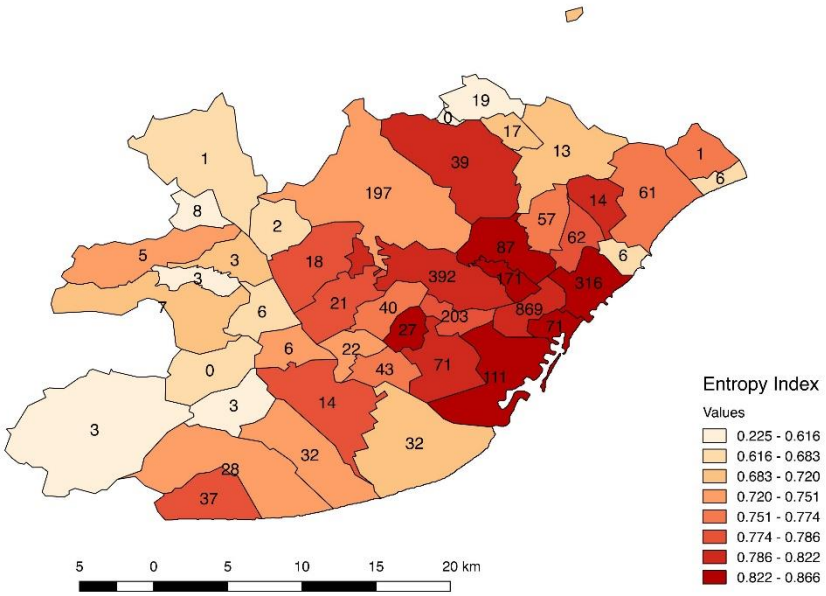
Horizontal axis units (r): meters. Source: Compiled by the authors.

Figure 8: Kd Function of SVE vs. some Creative sectors for the Metropolitan Area of Hamburg.



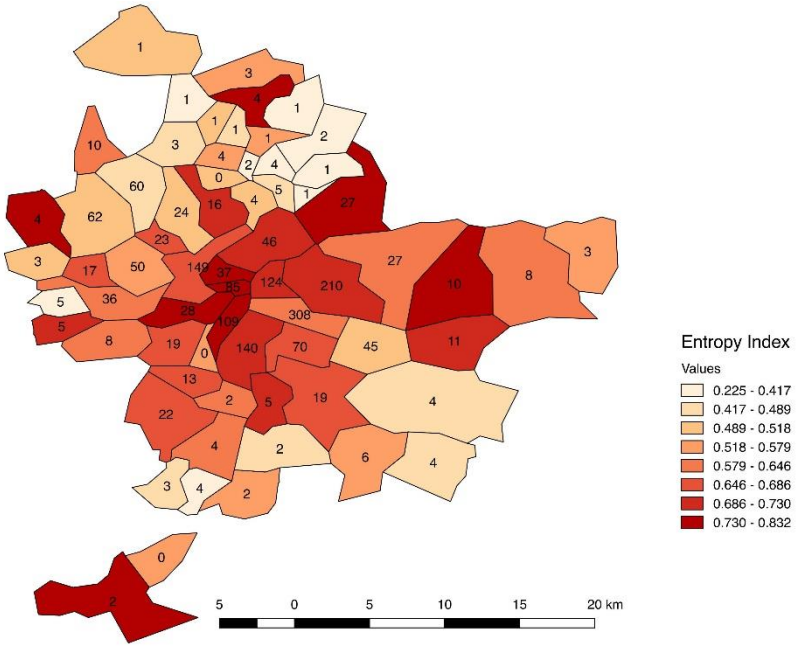
Horizontal axis units (r): meters. Source: Compiled by the authors.

Figure A1: Entropy Index and number of SVE Firms by region in the Metropolitan Area of Barcelona.



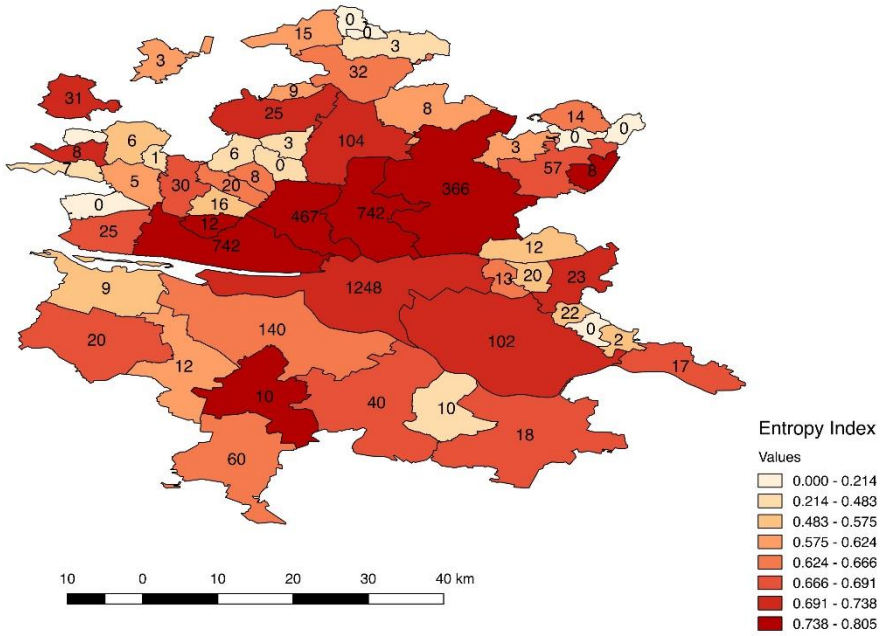
Note: Regions are municipalities and Barcelona city districts (10).
Source: Compiled by authors using Geo-Segregation Analyzer (Apparicio *et al.*, 2014).

Figure A2: Entropy Index and number of SVE Firms in the Metropolitan Area of Lyon.



Note: Regions are municipalities and Lyon city districts (9).
Source: Compiled by authors using Geo-Segregation Analyzer (Apparicio *et al*., 2014).

Figure A3: Entropy Index and number of SVE Firms in the Metropolitan Area of Hamburg.



Note: Regions are municipalities and Hamburg city districts (7).
Source: Compiled by authors using Geo-Segregation Analyzer (Apparicio *et al*., 2014).

Table 1: List of creative industries classification

Nº	Creative industries	Acronym	NACE 2009 Codes
1	Advertising and related services	ADV	731
2	Architecture and engineering	AE	711
3	Art and antiques trade	ART	4779
4	Craft and Performing Arts	CPA	90
5	Cultural Tourism and Recreational Services	TRS	93
6	Publishing	ED	581
7	Fashion	FA	14, 1511, 152
8	Graphic arts	GA	181
9	Heritage, cultural sites and recreational services	HE	91
10	Creative research and development	IDC	721, 722
11	Jewellery, musical instruments, toys and games	JEW	321, 322, 324
12	Music and music studies	MU	182, 592
13	Photography	PHO	742
14	Radio and TV	RTV	601, 602
15	Software, videogames and editing electronics	SVE	620, 582
	15.1 Software Firms	SOFT	620
	15.2 Videogames and Editing electronics Firms	VGE	582
16	Specialised services design	SSD	741
17	Video and film industries	VFI	591

Source: Compiled by the authors.

Table 2: Number of Creative industries at city and Metropolitana Area level.

		Barcelona			Lyon			Hamburg		
Nº	**CI Acronyms**	**City**	**MA**	**Total**	**City**	**MA**	**Total**	**City**	**MA**	**Total**
1	**ADV**	1924	367	2291	379	260	639	1479	226	1705
2	**AE**	2091	734	2825	1039	933	1972	1816	488	2304
3	**ART**	69	19	88	80	49	129	63	12	75
4	**CPA**	468	99	567	99	77	176	269	29	298
5	**TRS**	767	372	1139	119	138	257	1233	399	1632
6	**ED**	930	172	1102	125	65	190	514	85	599
7	**FA**	422	379	801	85	32	117	134	21	155
8	**GA**	869	675	1544	101	138	239	503	183	686
9	**HE**	41	10	51	0	2	2	58	10	68
10	**IDC**	225	93	318	97	88	185	272	67	339
11	**JEW**	141	42	183	93	38	131	82	17	99
12	**MU**	160	43	203	36	19	55	349	37	386
13	**PHO**	226	67	293	31	47	78	105	14	119
14	**RTV**	146	30	176	33	4	37	48	1	49
15	**SVE**	2346	801	3147	1046	864	1910	3810	746	4556
15.1	**SOFT**	*2241*	*779*	3020	*903*	*753*	1656	3765	741	3770
15.2	**VGE**	*105*	*22*	127	*143*	*111*	254	45	5	50
16	**SSD**	317	84	401	105	57	162	277	25	302
17	**VFI**	768	127	895	181	78	259	662	52	714
	Total	11910	4114	16024	3649	2889	6538	11674	2412	14086

Note: Creative industry acronyms can be found at Table 1. City refers to firms inside the city and MA refers to firms inside the Metropolitan Area.
Source: Compiled by the authors

Table 3

Table 3: Nearest Neighbour Index from Creatives, Software and Videogames Industry in Barcelona, Lyon and Hamburg (at City and Metropolitan Area level).

Barcelona	Metropolitan Area + City				Metropolitan Area				City			
	All creative	**SVE**	**SOFT**	**VGE**	**All creative**	**SVE**	**SOFT**	**VGE**	**All creative**	**SVE**	**SOFT**	**VGE**
AOD	35.661	91.262	93.688	505.944	80.245	205.367	208.282	1727.942	21.466	53.202	54.250	299.941
AED	140.815	311.768	318.258	1264.721	277.891	617.867	626.531	3038.681	77.782	136.516	139.679	429.999
NNI	0.253	0.293	0.294	0.400	0.289	0.332	0.332	0.569	0.276	0.390	0.388	0.698
N. Observations	16022	3146	3019	127	4114	801	779	22	11908	2345	2240	105
Z-Value	-180.827	-75.893	-74.171	-12.935	-87.273	-36.147	-35.644	-3.871	-151.148	-56.537	-55.377	-5.929
Lyon	**Metropolitan Area + City**				**Metropolitan Area**				**City**			
	All creative	**SVE**	**SOFT**	**VGE**	**All creative**	**SVE**	**SOFT**	**VGE**	**All creative**	**SVE**	**SOFT**	**VGE**
AOD	62.760	125.563	146.435	424.911	112.659	209.067	245.280	688.531	25.529	60.851	69.595	225.056
AED	254.400	421.785	452.979	879.705	382.677	627.121	671.755	1330.738	93.917	165.509	178.133	378.060
NNI	0.247	0.298	0.323	0.483	0.294	0.333	0.365	0.517	0.272	0.368	0.391	0.595
N. Observations	6537	1910	1656	254	2889	864	753	111	3648	1046	903	143
Z-Value	-116.517	-58.718	-52.684	-15.763	-72.555	-37.486	-33.328	-9.727	-84.138	-39.124	-35.028	-9.259
Hamburg	**Metropolitan Area + City**				**Metropolitan Area**				**City**			
	All creative	**SVE**	**SOFT**	**VGE**	**All creative**	**SVE**	**SOFT**	**VGE**	**All creative**	**SVE**	**SOFT**	**VGE**
AOD	88.646	174.253	175.126	3234.097	220.666	460.218	464.358	24600.318	62.262	122.404	122.394	1799.817
AED	320.268	558.072	561.160	4069.431	773.960	1379.154	1383.799	12478.974	238.434	411.866	408.112	2666.606
NNI	0.277	0.312	0.312	0.795	0.285	0.334	0.336	1.971	0.261	0.297	0.300	0.675
N. Observations	14086	4556	4506	50	2412	746	741	5	11674	3810	3765	45
Z-Value	-164.207	-88.809	-88.342	-2.777	-67.167	-34.816	-34.601	4.155	-152.725	-82.991	-82.181	-4.171

Note: AOD (Average Observed distance), AED (Average Expected Distance), NNI (Nearest Neighbour Index), SVE (Software, Videogames and Editing Electronics), SOFT (Software), and VGE (Videogames and Editing Electronics). All distances are in metres.
Source: Compiled by the authors.