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SPECIAL ISSUE PAPER

Digital entrepreneurship indicator (DEI): an analysis of the case of the greater Paris metropolitan area

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Abstract

The digital entrepreneurship indicator (DEI), which combines individual and institutional data, is designed to chart the vitality of metropolitan areas in terms of digital entrepreneurship on a suburban scale. In this study, we apply it to the case of the Greater Paris Metropolitan area. Using geographically weighted regression, we explore the spatial heterogeneity of the effect of digital entrepreneurial ecosystems on the location quotient of information and communication technology firms with fewer than 10 employees. The results highlight a positive link between the DEI and the location quotient of small ICT firms. In particular, the aspects of both ATTitudes and CAPacities (i.e., urbanization economies, Human Development Index, density of incubators, accounting and financial services, and fiber optic coverage) appear to have a significant effect on a suburban scale.

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1 Introduction

Information and communication technologies (ICTs) are particularly recognized for their innovative strengths (European Commission 2015). In the early 2000s, ICTs already became ubiquitous, "giving entrepreneurs opportunities to change to new business models, relationships, organization of production and consumer patterns" (McQuaid 2002, p. 10). Teruel Carrizosa et al. (2021) find that firms that adopt new digital technologies are also more likely to be internationalized. ICTs include the field of telematics, such as computers, audiovisuals, multimedia, internet, and telecommunication technologies. The creation of businesses based on these technological advances is usually called digital entrepreneurship (Kraus et al. 2019). In recent years, the United States has registered strong growth, partly due to the creation of firms in these sophisticated sectors, mainly derived from ICTs (Desruelle and Stančík 2014). Empirical research on the regional geography of ICTs shows that they are considerably more clustered than other employments. For example, the three Canadian metropolitan areas of Montreal, Toronto, and Vancouver represent 50% of all information technology-driven new-economy jobs in the country, compared with 36% of the total employment (Duvivier et al. 2018). In Europe, global cities such as London, Amsterdam, Berlin, and Paris are the main cities in terms of digital entrepreneurship (Bannerjee et al. 2016).

Such entrepreneurship occurs on two spatial scales: macro and micro. On a macro-level scale, cities are in competition due to different entrepreneurial ecosystems[1] (EEs) in terms of regulations, institutions and norms, infrastructure, city amenities, access to finance, and demand (Glaeser et al. 2014; Stam 2015; Ács et al. 2017). Urban centers are favorable to these firms because they feed on sectoral diversity, which is commonly specific to these areas (Duranton and Puga 2000; Glaeser et al. 2010; Bosma and Sternberg 2014). Indeed, ICTs are not always associated with advanced industries, unlike biotechnology, chemistry, and biochemistry, among others. They sometimes refer to software activities that consist simply of creating applications. Therefore, they do not always require a highly specialized workforce. In the ICT sector, digital entrepreneurial ecosystems[2] (DEEs) tend to be more favorable in large urban centers (Sussan and Ács 2017), and this may explain why startups created in these advanced technology sectors tend to be located in metropolitan areas with spatial and digital affordances (Autio et al. 2014). Moreover, the support for entrepreneurial activities generally occurs in urban areas, encouraging the growth of more opportunity-motivated entrepreneurial activities.[3] Using a

[1] The entrepreneurial ecosystem is an interconnected set of actors, organizations, institutions, and processes that combine in multiple ways within a local entrepreneurial environment (Isenberg 2010).

[2] Sussan and Ács (2017) defining DEEs as the combination of elements in a given region the objective of which is to support the development and growth of innovative startups seeking new opportunities offered by the digital world.

[3] In 1998, Maillat reported that urban areas are the most conducive to the development of innovative activities because they cover an over-representation of crucial resources to entrepreneurship. Cities effectively concentrate a critical mass of business-oriented tertiary activities, which are essential for the operation and development of an innovative system (research and development, technology, expertise, communication, training, finance, legal and managerial assistance, etc.).

sample of 70 European cities, Audretsch and Belitski (2017) show that variations in entrepreneurship exist between cities. They also highlight that the use of new technologies and IT contributes significantly to the development of quality entrepreneurship. These entrepreneurial activities feed on the "fertile environment" (Sorenson 2017) of such places. According to Adler et al. (2019, p. 122), "From the standpoint of an innovative firm in a new industry, a large city-region, represents a more hospitable environment for innovation because it is more likely to have a wider range of inputs–people, ideas, suppliers–that can be recombined to achieve breakthrough innovations (Duranton and Puga 2001; Glaeser et al. 1992)."

On a micro-level scale, what could be the most fertile environment for ICT startups? It is an environment that is conductive to opportunity entrepreneurship that assumes the presence of entrepreneurial skills, entrepreneurial experiences, and role models of successful entrepreneurs. Moreover, it is an environment that is favorable to social capital due to the presence of network organizations, highly educated people, and the spirit of innovation in the "air," similar to Marshall's atmosphere in industrial districts (Marshall 1920). It is preferable to be located "in" or "close to" rich and growing active districts, where savings, increasing power of consumers, and the youngness of the population (Duvivier et al. 2018) allow wide openness to innovation and easy expenses for new markets or ideas. Appropriate working spaces and meeting points in the locality, combined with an attractive ambiance of the area and the presence of infrastructures devoted to ICTs, serve as facilitators of ICT startups. Some specialization or "labeling" of areas in high-technology or highly specialized jobs in services (e.g., the financial "pôle" of La Défense) may serve as an aggregator mechanism, sometimes because of successful public policies.

In this article, we intend to measure the concept of DEEs by interweaving EEs and digital ecosystems (DEs) with a composite indicator called the digital entrepreneurship indicator (DEI). Specifically, DEEs are part of the Greater Paris Metropolitan (GPM) EEs. They are digitally enabled EEs and their output are measured using the location quotients of small ICTs firms at the municipality level. A composite indicator is a tool for assessing the performance of territories, as it provides a simple representation of complex and multidimensional phenomena. The use of a composite indicator is threefold: policy monitoring, public communication, and generation of rankings (Ács et al. 2017; Autio et al. 2018a). As they provide simple comparisons between spatial units (e.g., regions, districts, municipalities, etc.), indicators are increasingly used in the comparative analysis of territorial benchmarking (Saltelli 2007).

Some indexes have been developed to better understand and appraise digital entrepreneurship ecosystems. Autio et al. (2018a) have proposed a European index of digital entrepreneurship systems that assesses and monitors digital entrepreneurship support through an index based on four pillars (physical infrastructure, regulation and taxation, market conditions and culture). This index is computed at national level. We have also identified the European Digital Social Innovation Index which assesses how different European cities support digital social innovation (Marzano

2020).[4] These two indexes are computed either at the national or at the city level, but not at the suburban level. Our index was developed from the interaction of two concepts, the EE concept and the DE concept; while global digital cities can be ranked, their strength and performance are also a result of their ability to organize their multiple DEEs in space.[5] Therefore, the suburban scale appears a useful scale of analysis in terms of the implementation of public policies that support startups. Indeed, startups are far from being randomly located in a city because local social interactions reinforce local entrepreneurship in the form of peer effects, which enable a local culture favoring entrepreneurial behavior to develop and persist (Andersson and Larsson 2014). According to Andersson and Larsson (2014, p. 5), “the fraction of established entrepreneurs in a neighborhood has a positive and statistically significant effect on the probability that an individual leaves employment for entrepreneurship.”

In this context, based on previous studies having produced composite indices at others scales that the infra-urban one (European Index of Digital Entrepreneurship Systems (Autio et al. 2018a, b); Regional Entrepreneurship Development Index (REDI) (Szerb et al. 2013, 2017, 2020); Global Entrepreneurship Index (GEI) (Ács et al. 2017)), we develop the DEI to capture the DEEs of the GPM area and analyze how it can explain the spatial distribution of ICT startups. We use the GPM area as a case study because it belongs to the first innovative region in France[6] that has many structures that welcome digital entrepreneurs.[7] We collect data on the municipal scale to capture the heterogeneity of the infra-urban territory of the GPM.

To consider spatial heterogeneity on the infra-urban scale, we use a geographically weighted regression (GWR) model. With this model, we can explain the differences in functioning and relationships between variables on the infra-urban scale of municipalities, allowing us to modulate the relevance of the model as a function of local variations (Fotheringham et al. 1998; Bourdin 2019).

In this context, the originality of our contribution is threefold. First, this paper offers a new contribution to the growing literature recognizing that the drivers of digital entrepreneurship are frequently embedded in favorable ecosystems (i.e., the concept of DEEs interweaving EEs and DEs). From a theoretical point of view, we contribute to the development of the emerging concept of multi-site DEEs. In addition, we try to elucidate how DEEs help explain the localization of digital

[4] It includes issues related to funding, skills, civil society, collaboration, infrastructure and diversity and inclusion. For more information: https://www.nesta.org.uk/report/european-digital-social-innovation-index-methodology/.

[5] This index was developed as part of a doctoral thesis thanks to a *“Convention Industrielle de Formation par la Recherche”* (CIFRE) between the Centre d’Economie de la Sorbonne, Paris 1 Panthéon-Sorbonne and the City of Paris. This doctoral thesis "Entrepreneurial ecosystems in metropolitan territories" was defended by Dorine Cornet on January 18, 2021.

[6] The “capital region” accounts for about 18% of the total population and more than 30% of France’s gross domestic product. It employs over 40% of researchers in France (public and private research) (Aubry et al. 2015).

[7] The “Atelier Parisien d’URbanisme” (APUR) identifies the 110 places that support entrepreneurial and innovative activities (incubators, nurseries, accelerators) established in the GPM. https://www.apur.org/fr/nos-travaux/observatoire-jeunes-entreprises-innovantes-metropole-grand-paris.

entrepreneurship on a suburban scale. Second, from a methodological point of view, we build a composite indicator of quality digital entrepreneurship (DEI) on a sub-urban scale, an emerging sector that strongly contributes to territorial development (Malecki and Moriset 2007). This composite indicator appears relevant and can easily be used as a diagnostic tool or to support the public decision-making process in metropolitan areas across the world. Moreover, its subcomponents shed light on the multiscale spatial effect of the three dimensions of the indicator, with the ASPiration dimension playing a role in the entire area of the GPM. Third, from a methodological point of view, by using the GWR, we show that there is nonlinearity in the effects of DEEs on business creation in the ICT sector. In other words, some factors can significantly affect the emergence of startups in some areas but not in others.

In the following section, we present the theoretical framework on which the composite indicator is based (part 2) and the heterogeneity of the location of ICTs in the GPM (part 3). We then explain the methodology used (part 4), analyze the results (part 5), and present the conclusion (part 6).

2 Interweaving EEs and DEs to develop the DEI: a conceptual model

Recent studies have shed more light on the concept of EEs (Stam 2018). Based on biological analogy, EEs aim to encompass all the links that each institution of the ecosystem has in favor of sustainable and scalable innovative performance within a given area. Autio et al. (2014) explain that an EE is an area made up of institutions that promote the emergence of new businesses, comprising individuals with real innovation capacities that help develop entrepreneurship. These EEs are made up of a set of interconnected entrepreneurial actors (companies, business angels, universities, etc.) and entrepreneurial processes (rate of creation, entrepreneurial spirit, etc.) that formally or informally combine to foster performance within a local entrepreneurial environment (Autio et al. 2018b; Malecki 2018).

Although research on EEs is still in its infancy, several empirical studies have shown how a virtuous EE facilitates a high level of entrepreneurship, thereby creating further value on the regional scale (Fritsch 2013). For example, Mack and Mayer (2016) show how the few entrepreneurial ventures that began in Phoenix, Arizona, contributed to a virtuous EE based on visible success, a strong entrepreneurial culture, and supportive public policies. Similarly, Spigel's (2017) study of EEs in Waterloo and Calgary, Canada, suggests that although ecosystems may have different structures and origins, their success lies in their ability to create a cohesive social and economic system that supports the creation and growth of new businesses.

In the last 10 years, we have witnessed a spectacular growth of startups in ICTs, leading some researchers to discuss digital entrepreneurship (Kraus et al. 2019). The success of these digital startups relies not only on internal operations but also on the community that surrounds them (Autio et Fu 2015). Faced with the emergence of this type of startup, a new form of ecosystem is emerging, sharing common traits with and being conceptualized in relation to digital ecosystems. DEs are governed by infrastructures, technology, and governance and are constantly evolving. Technical characteristics, such as very high-speed broadband, are important for this type of ecosystem. Universities and research labs are also crucial to enhancing research and training skilled students in the ICT field (Kraus et al. 2019). The digital governance associated with DEs must be open, informal, and transparent from the outset. As DEs gain legitimacy, some new regulations and norms make them less attractive to EEs (Sussan and Ács 2017).

At the crossroads of these two types of ecosystems, EEs and DEs, another inter-organizational form has been implemented to support new businesses: DEEs.

DEEs are a combination of DEs and EEs that ensure a scalable innovative environment suitable for breakthrough innovations. The Silicon Valley model is a perfect example of a DEE. This DEE has been so successful in “pump-priming” new startup firms that Google, Apple, Facebook, Amazon, and Microsoft are now reducing their investment in research and development (R&D) and moving toward the acquisition and development of such startups.

DEEs differ from EEs (Spigel 2017) in that they involve proximity between stakeholders (Du et al. 2018) and users; the more they participate in the DEs, the more likely they are to favor entrepreneurial vocations (co-creation, startups). This relationship is mitigated by the openness of digital governance. The capacity to offer new products and services optimizes opportunity recognition and exploitation, and favors sustainable DEEs (Sussan and Ács 2017; Du et al. 2018).

In brief, a successful DEE encompasses four pillars: (1) a digital marketplace where new products and/or knowledge results from entrepreneurial activity and user participation; (2) a digital entrepreneurship that is not just technical entrepreneurship but rather the implementation of multi-sided platforms, networks, and systems to reduce transaction costs and improve the match between users and producers (matchmaker innovation); (3) a digital user citizenship, which implies the participation of citizens in building the ecosystem through legal and social contracts and (4) a permissive governance system and an entrepreneurial culture, especially with the support of venture capital.

“Cities play a critical role in overcoming institutional barriers to digital entrepreneurship. Institutions frequently need to be altered in order to enable the continued expansion of digital scale-ups and cities tend to provide the field conditions required for accomplishing institutional change.” (Geissinger, et al. 2019, p. 878). In particular, transaction costs are low, there exists a diverse collection of actors, policymakers are more accessible, and the markets are more diverse. Access to venture capital allows opportunity-driven entrepreneurs to scale up their startups. “The preponderance of entrepreneurial tech startups (measured as venture capital investment in high-tech startups) occurs in dense urban neighborhoods in significant global cities” (Adler et al. 2019, p.129).

Metropolitan areas are particularly suitable for measuring DEEs because they require some amenities, such as technical amenities with connected areas, cultural amenities with an entrepreneurial mindset, and economic and financial amenities with venture capital and service support (legal and accounting activities, business advice, and other management advice). Metropolitan DEEs constitute multiple sites where competition, complementarities, specialization, and agglomeration economies play a role. We consider each entity (among the 110 municipalities and 20 districts of the GPM) a priori to be a favored place to host ICTs. We have little information

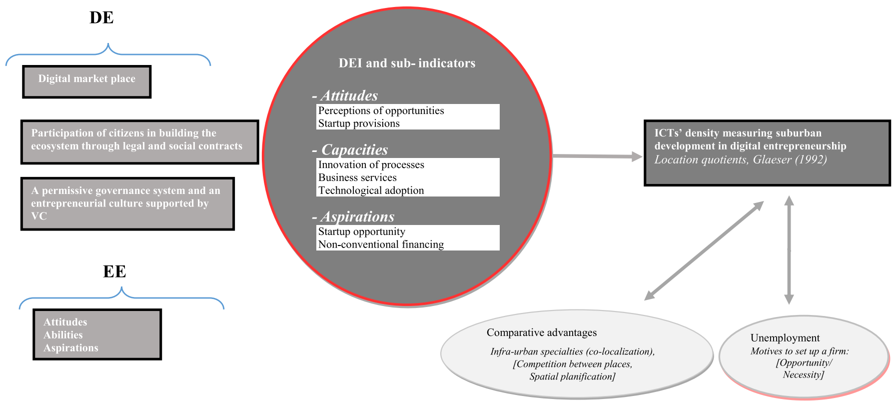


Fig. 1 Interweaving DE and EE to develop the DEI (inspired by REDI and EIDES)

about the underlying mechanisms that allow such a system to function. What spatialization and organization of the elements, characteristics, or determinants explain the localization of ICT startups in the entire metropolitan area?

From a theoretical and empirical perspective, very few papers have attempted to explain the spatial distribution of digital entrepreneurship on the infra-urban scale (Moriset 2003 in Lyon; Frenkel 2012 in Tel-Aviv; Duvivier et al. 2018, Duvivier and Polèse 2018 in a Canadian metropolis; Coll-Martínez et al. 2019 in Barcelona for creative industries). The indicator was developed to answer this question.

Indicators such as European Index of Digital Entrepreneurship Systems (EIDES) (Autio et al. 2018a, b), Regional Entrepreneurship Development Index (REDI) (Szerb et al. 2013, 2017, 2020), and Global Entrepreneurship Index (GEI) (Ács et al. 2017) inspired us to define the most suitable variables and proxies to measure contextual or individual elements promoting digital entrepreneurship in territories. We adjusted the indicator to measure spatial metropolitan features according to the available variables to reflect the spirit of these indicators as much as possible (Fig. 1).

3 Heterogeneity in ICTs in the GPM

The GPM gathered 7,026,765 inhabitants in 2016. It is an *Etablissement Public de Coopération Intercommunale*: a public cooperative of municipalities with its own fiscal system. The GPM gathers 12 different territorial public establishments (TPEs) (Fig. 2), which are public cooperatives of municipalities that do not have fiscal systems of their own. These TPEs, including Paris, belong to four departments: Paris, Hauts-de Seine, Seine-Saint-Denis, and Val-de-Marne (Fig. 3). Therefore, Paris is considered as a municipality (city of Paris), a TPE, and a department. Moreover, it gathers 20 "districts" called *arrondissements* in French, which have their own city hall. We took account of the 110 municipalities of the GPM plus the 20 districts of the city of Paris.

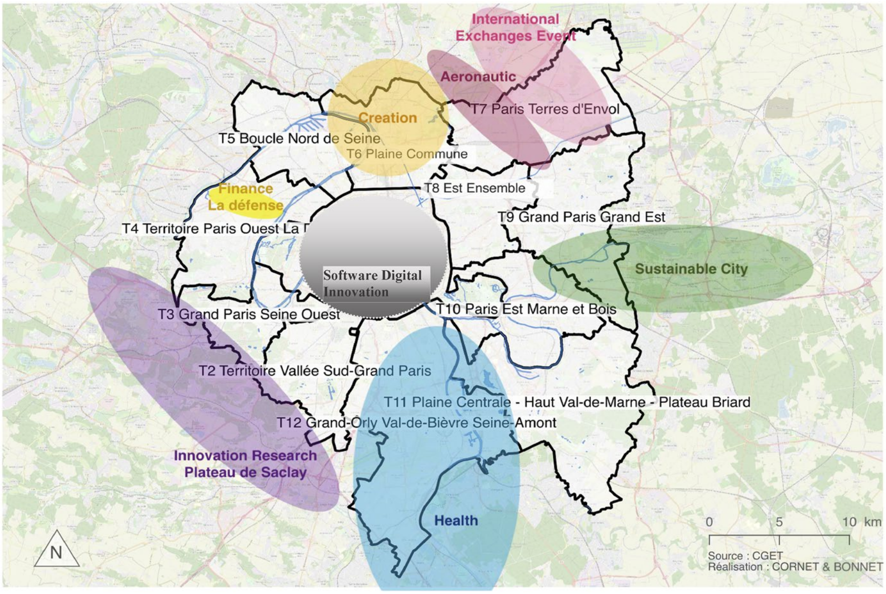


Fig. 2 TPEs and the specialties of ICTs

The suburban scale is interesting, we can emphasize some specificities in the partitioning of activities of the 130 entities of the GPM.

The French "*Pôle de Competitivité*" policy is structured around six clusters: the Plateau de Saclay (innovation and research hub), Roissy-Charles-de-Gaulle (center for international exchange events), Villejuif-Evry (health center), Plaine Commune (center for creation), La Défense (center for finance), and Marne la Vallée (sustainable city hub). We added Paris as a hub of software digital innovation, or what Adler et al. (2019) referred to as "tech-startup entrepreneurship."

Executives residing in the employment area of Paris[8] (T1) are over-represented compared with the executives' jobs available in the employment area (47% and 35%, respectively). The over-representation of this socio-professional category (SPC) in Paris makes it a cultural hub that promotes entrepreneurship and attracts talents, such as artists, who will be located in 75,011 ("creative class") (Florida 2002); attractiveness of the "coolness" of Paris, as identified for some boroughs of the center of Montréal (Duvivier 2018).

The Hauts-de-Seine department has a significant concentration of employment in financial services mainly located in T4, which tends to spread to other territories (75% increase for T2 between 2012 and 2017). This territory also belongs to the Seine Valley cluster, which includes business activities, industry, aeronautics, automotive, tourism, and logistics. Unlike the territories of Val-de-Marne or Paris, the productive sphere (40% for T2, 48% for T3, 50% for T4, and 45% for T5) is

[8] Representative of the first TPE of the GPM.

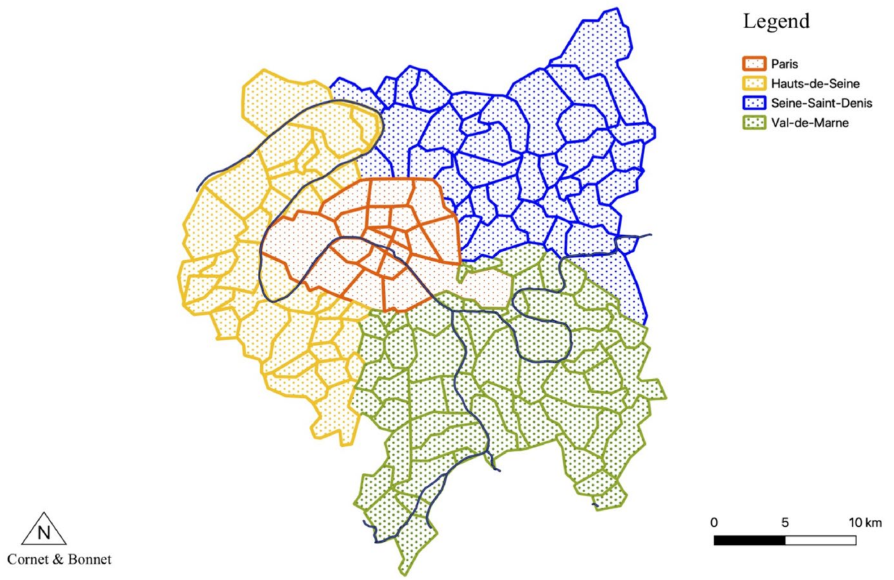


Fig. 3 Territorial units considered

over-represented, whereas the residential sphere (60% for T2, 52% for T3, 50% for T4, and 55% for T5) is underrepresented in the Hauts-de-Seine department compared with the rest of the GPM in 2015. The economic strength of this territory cannot be explained only by the concentration of skilled labor, suppliers, and information but also by a variety of regional institutions,[9] trade associations and organizations, local authorities, specialized firms, public relations, venture capital, and services, which tend to build a foundation of shared knowledge, uses, and codes.

The department of Seine Saint-Denis (T6, T7, T8, T9) holds a key intermediary role in urban metabolism, as it had many logistic activities and jobs in industry and construction in 2015 compared with other territories. Employment in these sectors saw the largest increase in 2012–2017 in transportation, warehousing, and construction. This territory is home to the *Cap Digital Competitiveness Cluster*,[10] which mainly comprises cultural and creative industry activities.[11] However, these TPEs attract higher SPCs than the other territories of the GPM, particularly

[9] A plethora of institutions of higher education, such as the université Paris Nanterre, Ecole d'Ingénieurs Paris-La Défense, IIM Paris–Grande École du Digital, Ascencia Business School, École de Finance & Management, ESAM, ESSEC, etc.

[10] Created in 2006 as a non-profit organization, Cap Digital is currently recognized as the biggest cluster in Europe and one of the largest innovators' collectives in the digital ecosystem.

[11] This place is trendy, close to the big names of art and luxury, such as the Thaddaeus Ropac Gallery, Chanel and its lab, and BETC (newly installed in the old general stores in Pantin). Fashion collections, including Soukmachines, are present and have taken over Hall Papin.

managers and intermediate professions, while the pool at the place of residence holds a higher share of employees and workers.

The department of Val-de-Marne (T10, T11) hosts two innovative clusters: in the northeast, the Marne-la-Vallée cluster invested in activities related to sustainable city and tourism; in the south, the Paris Biotech Vallée cluster invested in activities related to health and industry. The territory hosts executives at the place of residence who migrate to other territories through pendular mobility. The residential activities are over-represented in relation to productive activities compared with the rest of the GPM.

Therefore, the four departments show antagonistic underlying dynamics. The territories that currently show the lowest opportunity-motivated entrepreneurial activity rate are also those that have seen their economic situations improve the most in the last decade. Some form of catching-up effect seems to be developing between the western and eastern areas. The withdrawal of industrial activities and the development of telecommunications in particular contribute to this change.

4 Methodology

4.1 Data and variables

In our study, we attempt to understand the extent to which a favorable DEE explains the over-representation of ICT startups in some areas of the GPM area. The dependent variable is the location quotient of ICT firms with fewer than 10 employees (Table 1). Specialization, in which production costs are lower (e.g., availability of the right suppliers), accumulates advantages. One way to measure this accumulation over time is to use location quotients (Glaeser et al. 1992), which give a measure of localization economies. According to Pereyra (2019, p. 3), “Location quotients also provide empirical evidence of the geographical concentration of enterprise creation, as a way of accounting for entrepreneurship (Feldman and Audretsch 1999; Minniti and Lévesque 2008).” Additionally, “Economic decisions, actions and interactions of the past enable and constrain present activities of the economic agents. Moreover, they direct future intentions and actions to some extent (path-dependency)” (Welter et al. 2008, p. 111). Location quotients encompass a crystallization of past policies and economic advantages of the specific location at a multiscale level, agglomeration economies for the whole territory, and the economy of specialization (co-localization) for the place-based district. Even if the past plays a role, emerging places are always possible due to the localization factors of growing activities, local policies to equilibrate disparities (i.e., urban policy is oriented to the development of clusters as an economic tool [cf. see examples supra]), private investments by sponsors (e.g., free foundation[12]), and place opportunities. As small firms are generally relatively

[12] Xavier Niel, a French entrepreneur that founded Free, which is the fourth French operator in mobile smartphones, established “school 42” for ICT students. The programs concerned are computer programming, algorithms and artificial intelligence, graphics, innovation, web, technology integration, infrastructures, cyber security, big data and data, and parallel computing, which are based on peer-learning, a participatory pedagogy with no classes or teachers. The fist school created in Paris (17th district) was extended to Lyon, Angoulême, and Nice in 2021.

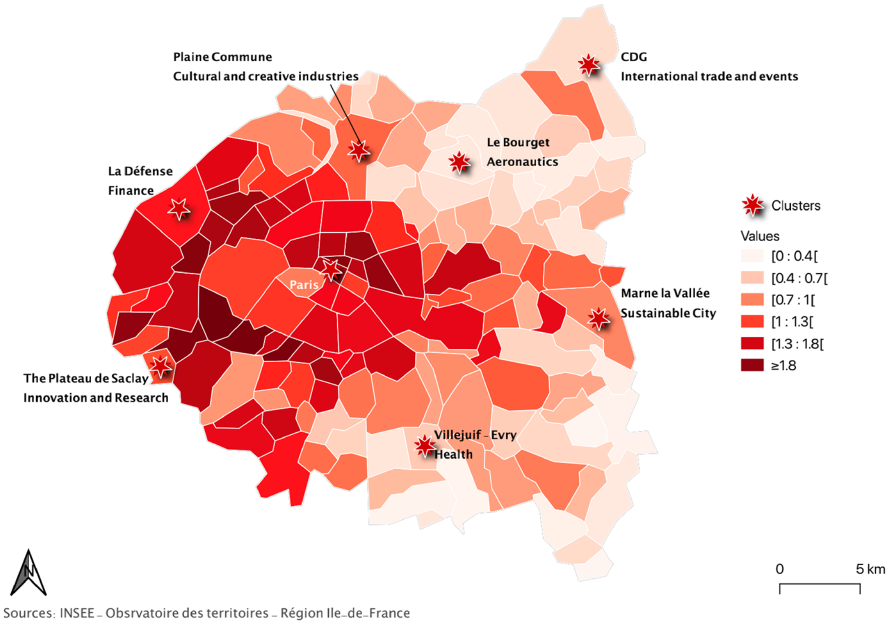


Fig. 4 Location quotient of small ICT firms

young (Klette and Kortum 2004), this location quotient effectively determines the vitality of young and small innovative ICT firms in our study area. The database we used comprises 130 municipalities from the GPM.

The location quotient of ICT firms appears to be more important in Paris and in the Hauts-de-Seine department (western Paris) than in the rest of the GPM (Fig. 4). The municipalities belonging to both departments are, on average, 1.5 times denser than the annual average of the GPM.

Regarding the explanatory variables, we developed the indicator based on sub-indicators inspired by REDI and EIDES:

- The sub-indicator ATTitudes represents collective and individual perceptions of opportunities (how to find and formulate an innovative idea).
- The sub-indicator CAPacities represents the collective and individual abilities to set up a firm in the ICT sector (what support and technical services are available for starting up a firm).
- The sub-indicator ASPirations represents the collective and individual willingness to disrupt and grow (how the environment favors new ventures with high potential).

Table 1 The dependent variable and explanatory variables

Dependent variable		Source
Location quotient of small ICT firms (LocQ ICTs)	Number of firms with < 10 ICT employees in a municipality *i*/ Total firms with < 10 employees in a municipality *i* ÷ Number of firms with < 10 ICT employees in the GPM/ Total firms with < 10 employees in the GPM	INSEE–CLAP (2015) *Sc: district/municipality*
Explanatory variables		
Entrepreneurial ATTitudes		
Perceptions of opportunities (PercOpp)	Urbanization indicator measured according to the density of the population	INSEE–demography studies (2013) *Sc: district/municipality*
Startup provisions (StartPro)	HDI-2 (health, education, and standard of living)	IdF Region–HDI-2 (2013) *Sc: district/municipality*
Entrepreneurial CAPacities		
Innovation of processes (InnovProcess)	Number of community structures* in a municipality/ Total number of community structures in the GPM	TechOnMap–IdF Region (2013) *Sc: district/municipality*
Business services (BusServ)	Number of legal and accounting activities in a municipality/Total number of legal and accounting activities in the GPM	SIREN–INSEE (2013) *Sc: district/municipality*
Technological adoption (TechnoAdopt)	Number of households connected to the municipality's fiber optic system/Total number of households in the municipality	Observatory of Local Communities (2020) *Sc: district/municipality*
Entrepreneurial ASPirations		
Startup opportunities (StartOpp)	Number of organizations involved in R&D activities in a municipality/Total number of organizations involved in R&D activities in the GPM	INSEE–SIREN (2013) *Sc: district/municipality*
Non-conventional financing (Fin)	Number of structures dedicated to risky investments in the municipality**/Total number of structures dedicated to risky investments in the GPM	TechOnMap–IdF Region and SIRENE *Sc: district/municipality*
Control variable		
Comparative advantages (CompAdv)	Inverse of the distance from the centroid of a municipality to the center of the nearest cluster	*Indicator calculated by the authors*
Unemployment (Unempl)	Number of unemployed/Active population in a municipality	INSEE– "Employment-Labor Force" (2013) *Sc: district/municipality*

CDT, Carnot institutes: Technology Diffusion Cells (known in French as Cellules de Diffusion Technologique [CDT]); CRT, Technological Resource Centers (known in French as Centres de Ressources Technologiques [CRT]); PEPITE, (structures to promote entrepreneurship among students); PFT, Technological Platforms (known in French as plateformes technologiques [PFT]); SATT, Technology Transfer Acceleration Companies (known in French as Société d'Accélération du Transfert de Technologies [SATT]); Coworking spaces: incubators, hackerspace, LivingLab, FabLab, makerSpace, pépinière, couveuse; CCI, Chambers of Commerce and Industry; Chambers of Trades and Crafts; ADIE, Associations for the Right to Economic Initiative (known in French as Association pour le Droit à l'Initiative Economiqu); BGE, Entrepreneurial Management Organizations (known in French as Boutique de Gestion); Entrepreneurial Networks (known in French as Réseau Entreprendre, France Active, etc.)

*Entrepreneurial community structures bring together the following:

**Risky investments: crowdfunding structures, venture capital

The ATT subcomponent aggregates a sub-indicator of (1) urbanization to capture the perception of opportunities (called "PercOpp") and (2) a Human Development Index (HDI) adapted to the Île-de-France (IdF) region[13] to measure the capacity for knowledge absorption (called "StartProv" for startup provision). The "PercOpp" indicator is calculated according to the population density (inhabitants/km^2). This can be considered a proxy for agglomeration economies and a measure of the collective nature of opportunity entrepreneurship (Bosma and Schutjens 2011). In terms of the "StartProv" indicator, which relies on a local HDI, Bosma and Sternberg (2014) introduced the hypothesis that a high standard of living improves entrepreneurial activity. Audretsch et al. (2006) argued that high human capital and standards of living lead to spillover effects on innovative activities. High human capital also provides intellectual resources for entrepreneurs to recognize and seize opportunities (Cohen and Levinthal 1990). It provides them with the skills to access available funding and learning opportunities to build their projects. As the literature has shown that the level of urbanization and the standard of living are correlated (Behrens et al. 2014), we decided to aggregate these variables, which help create environments suitable for building collaborative networks and supporting innovation. In addition, they facilitate the transfer and recombination of the knowledge necessary for the growth of EEs.

The CAP sub-indicator aggregates three variables: "InnovProcess" for the innovation process, "BuisServ" for business services, and "TechnoAdopt" for technology adoption. InnovProcess is a proxy for the presence of services offering strategic and technical skills to entrepreneurs, such as planning, accounting, and marketing. This variable divides the number of structures dedicated to the launch and development of young firms in each municipality by the total number of these same structures in the GPM. These structures (incubators, accelerators, etc.) embody the mediators of interorganizational networks that can stimulate interfirm synergies, triggering exploratory meetings, encouraging collaboration on the borders of existing industrial and technological sectors, and granting creators better access to private financing or business networks (Chabaud et al. 2004).

To consider support organizations dedicated to startups after their incubation phase (InnovProcess), we included BusServ, which measures the presence of specialized services facilitating the new firms' lifespan. This variable serves as a density proxy; that is, the ratio of the number of legal and accounting activities in a municipality to the total number of legal and accounting activities in the GPM.

To strengthen the collaborative aspect of these sub-components, we aggregated TechnoAdopt to measure the ability of startup networking using a proxy for internet connectivity. This variable measures the ratio of the number of households in a municipality connected to an optical fiber system based on the total number of households in the municipality. Audretsch and Belitski (2017) find that connectivity and internet access improve the entrepreneurial ecosystem. In fact, a positive link exists between broadband and firm location, especially in urban areas and in

[13] An index provided by the IdF region in 2013, derived from a combination the three sub-indices of education, health, and standard of living.

firms making advanced use of the internet (e-commerce, customer relationship management, company resource planning) (Duvivier 2019; Duvivier et al. 2021). Firm location theory considers that broadband access can enhance the location-specific profitability of firms in many ways. First, firms may increase sales by expanding their market and reducing transport costs, as they can find new suppliers and customers or sell services through digital media. Second, broadband internet makes access to information, knowledge, and ideas easier. Third, broadband access can enhance the match between firms and workers and abridge the hiring process (Autor 2001). These broadband networks are all the more important, as firms are located in urban centers, where businesses are confronted with congestion issues (Charlot and Duranton 2006). The authors explain that large cities offer more direct interaction opportunities, but they also make face-to-face meetings more expensive due to negative externalities, such as congestion costs. In terms of time, the opportunity cost is actually higher for employees in large cities because of the longer transport time compared with that for employees in less urbanized locations. Thus, even if there are more opportunities in large cities, the quality of face-to-face interactions may decline, increasing the need for effective networks. Therefore, this sub-component aggregates two proxies measuring the technical, strategic, and digital resources that can be mobilized by startups.

The ASP sub-component is essential to understand individuals' capacity to think outside the box and to challenge resistance to change. For this sub-component, we combined a proxy measuring R&D investment called "StartOpp" for startup opportunity and a proxy for unconventional financing called "Fin." The StartOpp variable is measured using the number of organizations involved in R&D activities in a municipality divided by the total number of organizations involved in R&D in the GPM. The Fin variable is measured using the number of structures dedicated to risky investments (capital venture, crowdfunding, etc.) in the district or municipality divided by the total number of structures dedicated to risky investments in the GPM. Entrepreneurial activities based on knowledge spillover may actually have a greater propensity for venture capital financing but a lower propensity for bank financing (Aghion and Bolton 1992; Brander et al. 2002). Therefore, the ASP sub-component aims to qualify the territorial determinants facilitating the penetration of new products and/or services and the launch of new production processes (R&D investments) by providing some entrepreneurs with resources to reduce risk perception (financial risk structures) (Acemoglu and Johnson 2005; Glaeser et al. 2010).

We added two control variables. The first control variable, "CompAdv," is a proxy measuring the presence of comparative advantages. We constructed this variable. The methodology is based on the inverse of the distance from the centroid of a municipality to the center of the nearest cluster.[14] We expect positive coefficients from this variable, as the literature has previously shown that "tech-startup entrepreneurship" is organized according to two distinct but related spatial scales that act on entrepreneurial activity through different mechanisms. Local diversity and local specialization can seem to simultaneously feed the innovation process (Adler

[14] We refer to the French "*Pôle de Competitivité*" policy: Six clusters plus Paris (cf. part 1).

et al. 2019). The second control variable, "Unempl," is related to the unemployment rate. We expect negative coefficients from this variable, as the literature has already shown that unemployment is negatively correlated with the presence of opportunity-motivated entrepreneurial activities (Nikolaev et al. 2018). Many studies have been conducted on the *Schumpeter* effects against refugee effects, demonstrating that the unemployed are pushed into entrepreneurship rather than pulled, especially in branches of activities with low barriers to entry (Aubry et al. 2015). Clearly, the knowledge spillover process is affected by the low capacity for knowledge absorption of this unemployed population.

4.2 Construction of the composite indicator and specification strategy

Two successive methodologies were applied to develop the DEI.

First, we performed a principal component analysis (PCA) to aggregate the indicator variables and overcome multicollinearity bias (see "Appendix"). We then estimated several GWR models to assess the effect of the DEI and the contribution of each axis (ATT, CAP, and ASP) on the share of ICT firms in 2015.[15]

As entrepreneurship varies significantly from one area to another (Glaeser et al. 2010; Bonnet et al. 2017), we needed to consider spatial heterogeneity in our model. The GWR allowed us to take the presence of non-stationarity into account through a local coefficient estimation. Therefore, explanatory variable coefficients vary, incorporating decreasing geographical weight with the distance from each observation *i* (Fotheringham et al. 1998). In our model, we considered the link between the DEI and its sub-indicators and the prevalence of young ICT firms. To remain consistent with the aim of the DEI, namely, to reveal the heterogeneity of the entrepreneurship ecosystem within the GPM area, we decided to implement a GWR. This method has already been used in previous studies in entrepreneurship. For example, Breitenecker and Harms (2010) applied GWR to estimate the factors affecting start-up activity for 96 Austrian counties. They highlighted the spatial variation of the effects of different variables on the exit rate.

The GWR is expressed as follows:

$$y_i = \beta_{i0}\left(u_i, v_i\right) + \sum_j x_{ij}\beta_j\left(u_i, v_i\right) + \varepsilon_i \quad with \quad \varepsilon = iid \tag{1}$$

where $(u_{i,}\ v_i)$ is the localization within a geographic space of the *i* observation (long-lat of the centroid of the municipality). In the calibration of the GWR model, observed data close to point *i* have more influence in the estimation process of the values $(u_{i,}\ v_i)$ than the data located far from *i*. In the GWR, an observation is weighted in accordance with its proximity to point *i*. Therefore, choosing the weighting regime implies that observations that are closest to the location $(u_i,\ v_i)$ have more influence on the parameters estimated at this location than observations

[15] Note that the explanatory variables are lagged in time (2 years) from the dependent variable to avoid endogeneity problems.

that are further away. Therefore, the weight $W_i(u_{i,}\ v_i)$ can be assimilated with a continuous, ever-decreasing function of distance (Bourdin 2019).

For our analysis, the definition of the weighting matrix is based on a Gaussian decline in weight:

$$W_{i,j} = \exp\left(\frac{-1}{2}\left(\frac{d_{i,j}}{h}\right)^2\right) \tag{2}$$

where h is the optimized distance with a fixed bandwidth value but with a flexible number of nearest neighbors. The method adopted to define the bandwidth value is based on the Akaike information criterion process (Cleveland 1979).[16] We report the bandwidth value of each model at the bottom of Table 2.

The GWR equation model is written as follows (Model 2 infra):

$$\begin{aligned} Y_i = {} & \beta_0(u_i, v_i) + \beta_1(u_i, v_i)\mathrm{ATT}_i + \beta_2(u_i, v_i)\mathrm{CAP}_i \\ & + \beta_3(u_i, v_i)\mathrm{ASP}_i + \beta_4(u_i, v_i)\mathrm{Unempl}_i \\ & + \beta_5(u_i, v_i)\mathrm{CompAdv}_i + \varepsilon_i \end{aligned} \tag{3}$$

where Y is the density of ICT firms with fewer than 10 employees for location i from a total number of firms with fewer than 10 employees for location i; ATTi, CAPi, and ASPi are the three main components of the DEI at location i; UNEMPLi is the unemployment rate; and CompAdv is the comparative advantage variable. We performed a Moran's I test on the residuals to test for robustness. Moran's I corrects the spatial autocorrelation effects in the errors. In the next section, we present the results obtained.

5 Results

Five GWRs estimate the DEI and each axis on the density of ICT firms with fewer than 10 employees in 2015. The first model relates to the global indicator, the second to the DEI's axes, and the following three models reduce the axes one by one:

The DEI provides relevant information on the presence of opportunity-motivated entrepreneurial activities in ICTs across the GPM territories. The DEI's coefficient of 0.526 is highly significant in the ordinary least square (OLS) regression. Nevertheless, R^2 remains low at 0.276. Using the GWR strongly improves the quality of the model (R^2 reaches 0.727) and justifies the existence of local variations in the influence of the DEI on the density of ICT firms. When the subcomponents of the indicator are used together, only the coefficients of ATTitudes and CAPacities are significant. In the simple models, the three coefficients are all significant, with the ASPiration coefficient being the most important.

[16] The determination of the bandwidth aims to minimize the residual spatial dependence of the GWR. We also implemented a robustness test using a variable bandwidth with a fixed distance and a variable number of nearest neighbors and obtained corroborating results.

Table 2 GWRs results of the DEI on the location quotients of ICTs firms with fewer than 10 employees

	Model 1				Model 2				Model 3				Model 4				Model 5			
	OLS	LQ	M	UQ	OLS	LQ	M	UQ	OLS	LQ	M	UQ	OLS	LQ	M	UQ	OLS	LQ	M	UQ
DEI	0.526***	0.092	0.172	0.243																
ATT					0.335***	0.064	0.104	0.146	0.506***	0.08	0.146	0.253								
CAP					0.267***	0.053	0.109	0.149					0.463***	0.084	0.175	0.231				
ASP					0.39	0.159	0.805	1.232									2.376***	0.596	1.282	1.592
CompAdv	0.025	− 0.07	− 0.04	0.025	0.019	− 0.08	− 0.49	0.01	0.016	− 0.07	− 0.04	0.019	0.089	− 0.07	− 0.02	0.033	0.105	− 0.07	− 0.02	0.035
Unempl	− 0.029	− 0.08	0.017	0.058	0.018	− 0.05	− 0.01	0.04	0.027	− 0.07	− 0.01	0.059	0.065	− 0.07	0.003	0.06	0.083	− 0.05	0.01	0.071
AICc		1225.14				1227.583				1223.319				1202.616				1202.616		
R^2	0.276	0.727			0.323	0.699			0.323	0.71			0.241	0.745			0.147	0.745		
F-value (Leung test 2)		2.369***				2.542***				2.597***				3.131***				3.131***		
Fixed bandwith in meters		4145.957				5513.803				4357.655				4266.572				4266.572		
130 Observations																				

The quartiles represent the magnitude of the variation in the coefficients of the variables. They can vary from negative to positive values, for example for the CompAdv and Unempl variables. This means that in local models, these variables can have a different influence. The significance of the coefficients, for the variables of interest, are presented in the following maps

OLS, ordinary least squares; LQ, lower quartile; M, median, UQ, upper quartile

***, **, *Statistically significant at the 0.1%, 1% and 5% respectively

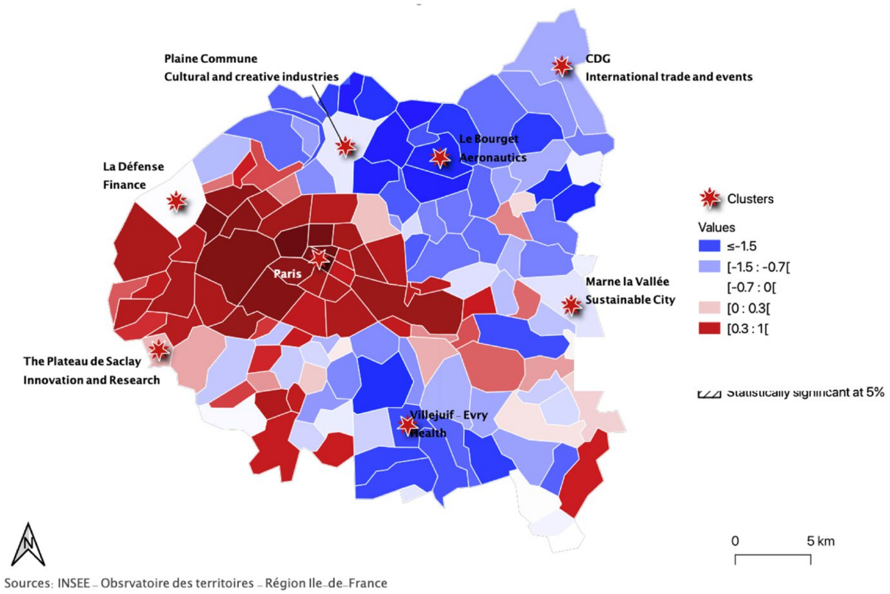


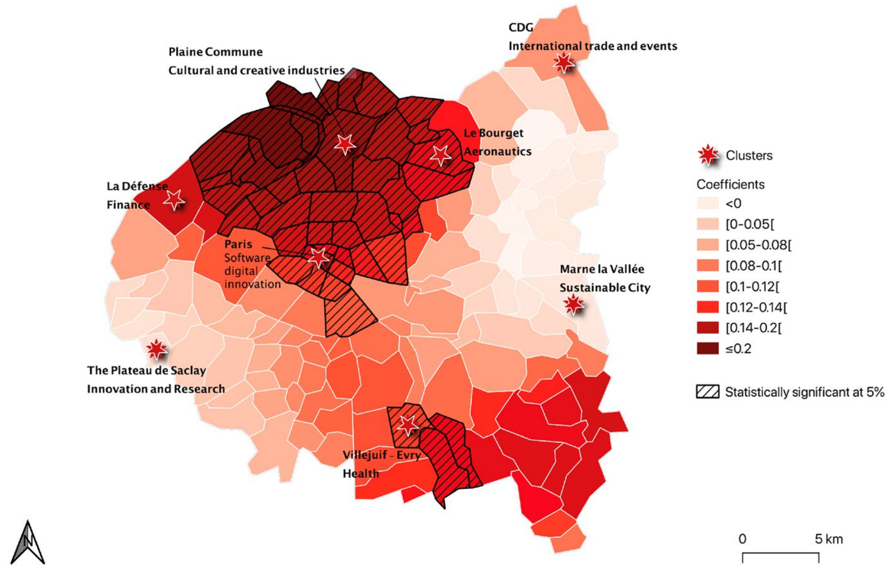
Fig. 5 DEI score over the GPM

The areas hosting opportunity entrepreneurship correspond to those areas with the highest DEI score, which correspond to two main clusters: the software digital innovation hub in Paris and the areas close to the finance cluster in La Défense (Fig. 5).

Furthermore, the GWRs help to identify high and significant DEI coefficients (Model 1), especially in the northeast area, Paris, and the southeast region of the GPM (Fig. 6). The high value of the coefficients obtained in the north (Seine-Saint-Denis department) reflects a strong correlation between the low values of the DEI and the density of ICT firms with fewer than 10 employees, which is rather low. This means that improving the indicator will have a good effect on the density of these small ICT firms. This territory has been subject to major public actions that mainly focus on fostering smart digital cities and artificial intelligence sectors by supporting innovative small and medium enterprises SMEs. The area hosted the first digital ecosystem and the largest business cluster, Cap Digital, in Europe since 2006. In 2020, the cluster hosted 60 large corporations, 790 PMEs, 77 schools and universities, 50 research labs, and 14 capital investors.[17] This can be an efficient way to improve the DEI indicator, even if the gap is still difficult to narrow in terms of the density of ICT firms with fewer than 10 employees.

Although the unemployment variable is not significant in the OLS model, the GWR of the DEI (Model 1) shows very strong heterogeneity with large negative

[17] Link to the Seine-Saint-Denis website: https://nouveau.seinesaintdenis.fr/Le-soutien-du-Conseil.html.



Sources: INSEE – Obsrvatoire des territoires – Région Ile-de-France

Fig. 6 Values and significance of DEI coefficients in the explanation of LocQ ICTs (Model 1)

significant coefficients in the Seine-Saint-Denis department.[18] Although the north has a digital cluster, it also has a high unemployment rate, which probably provides this population with fewer opportunities to surf the digital wave. A high share of executives and skilled workers comes from outside the department; thus, the social peer effect of Andersson and Larsson (2014) does not play a role. Similarly, Crescenzi and Rodríguez-Pose (2011) show that the process of knowledge diffusion is affected by the low knowledge absorption capacity of the unemployed population. A high proportion of unemployed individuals may also reflect the low levels of local demand and the unfavorable conditions for startups that mainly produce for the local market (Fritsch and Schroeter 2011).

Model 2 shows the three sub-indicators together. Nevertheless, the high value of the coefficients (Fig. 7) obtained in the north (Seine-Saint-Denis department) reflects a strong correlation between the low values of the ATT sub-indicator and the density of ICT firms with fewer than 10 employees, which is rather low. If the huge Cap Digital program directly participates in the development of ICTs, another efficient way to improve new startup firms in the ICT field, which are a real measure of an efficient DEE, is to improve the dimension attitudes of the indicator that would allow individuals to find and formulate an innovative idea. The same context applies to the Paris Biotech health cluster in the southeast of the GPM.

Figure 8 (Model 2) shows that the CAP axis obtains high and significant coefficients in Paris and the western GPM. This sector has a high marginal effect on

[18] The map is available upon request.

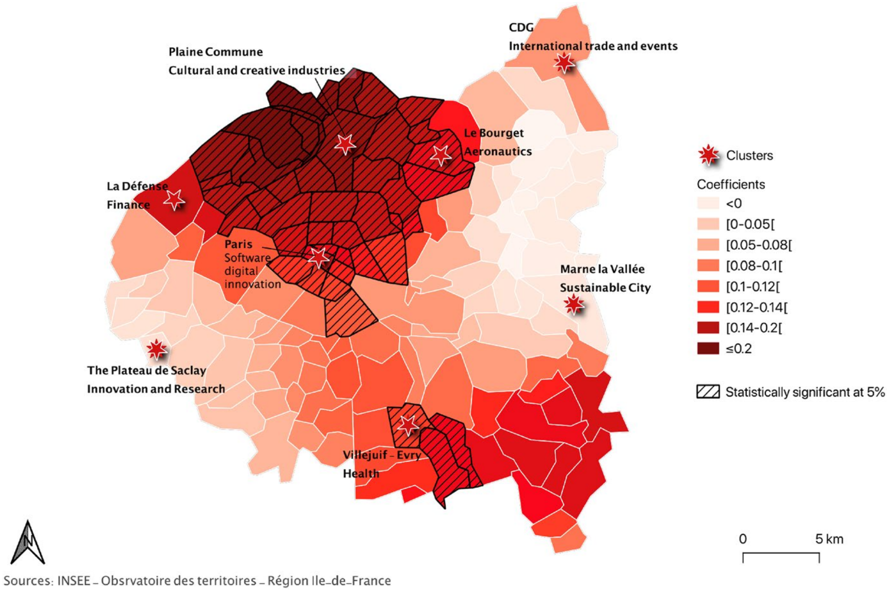


Fig. 7 Values and significance of ATT coefficients in the explanation of LocQ ICTs (Model 2)

opportunity entrepreneurship and can play a key role in the development of digital entrepreneurship in two kinds of areas. This finding is in accordance with the approach developed by Sussan and Ács (2017). In north Paris, the density of ICT

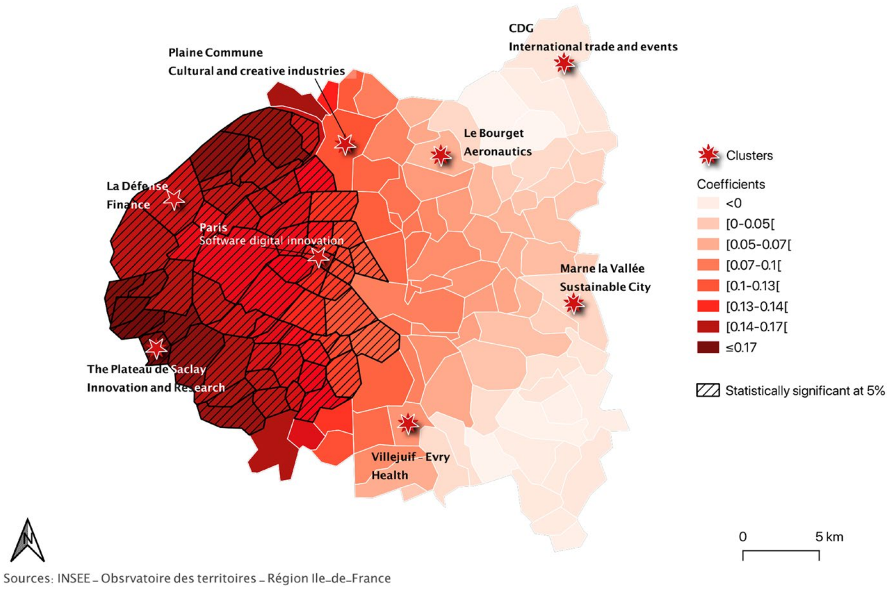


Fig. 8 Values and significance of CAP coefficients in the explanation of LocQ ICTs (Model 2)

firms is rather low for a CAP indicator, despite a good fiber optic coverage. Improving the CAP dimension of the indicator (i.e., by developing support and technical services) can improve the density of ICT startups.

In the "Plateau de Saclay" area and Paris, the density of ICT firms is rather high for a CAP indicator. We observe a kind of cumulative reinforcement of DEE. The marginal effects of the high levels of the CAP indicator remain strong and improve the high density of new startup firms in ICTs in these areas. We can assume that the broadband network and the presence of startup support structures allow them to consolidate their growth and expand their networks (Suire and Vicente 2015). This supports the specialization economics hypothesis. Another alternative is that the decision to set up a firm is also strongly linked to social networks (Sorenson 2018; Andersson et Larsson 2014). In areas where the location quotient of ICTs is strong, entrepreneurs serve as role models, and the localization of the potential entrepreneurs coming from an existing firm from these areas is also driven by the proximity of their relatives and friends if they live there and/or their work and social relationships. According to Sorenson (2018, p. 534), the benefits of co-location are not evident because "the negative effects of competition in the labor market and in the jockeying for business partners may simply outweigh any positive spillovers at the firm level."

The ASP axis is not significant when controlled by the two other axes (Model 2).[19] We can interpret this result through the fact that R&D and risky finance are mainly driven by the metropolis logic. In other words, what matters is the presence of these structures across the metropolitan area (Adler et al. 2019, for venture capital)[20] and not that much the district where an entrepreneur is located. R&D activities in a digital economy (i.e., scientific and technical services) tend to be located in the periphery of metropolitan areas. However, these structures are also essential at the macro-geographic level in the competition between cities where competition is bound to Jacobs-like mechanisms, such as the benefits of scale and diversity.

6 Conclusion and discussion

The objective of our article was to highlight that it exists polycentric organizations in DEEs and how these latter explain the localization of digital entrepreneurship within metropolises. Our paper contributes to the regional science literature by mobilizing a theoretical and empirical perspective to explain the spatial distribution of digital entrepreneurship at the suburban scale.

To do so, we built an original composite indicator of quality digital entrepreneurship (DEI) on a suburban scale. At the macro level, if the GPM compete with

[19] When implemented alone in a GWR, the ASP axis is strongly significant.

[20] Cities are most endowed with this crucial resource: Six cities in the United States rank first: San Francisco, San José, Boston, New York, Los Angeles, and San Diego, followed by London at seventh place and Paris only at 16th place (Adler et al. 2019). Not all districts of the same metropolis can host capital-backed startups: "Indeed, ten of the top twenty zip codes for digital venture capital startups are urban neighborhoods, with six mainly in around downtown San Francisco, and three in neighborhoods in New York City's Lower Manhattan" (Adler et al. 2019, p. 126).

other global cities, such as London, Stockholm, Amsterdam, Helsinki, Berlin, and Copenhagen, in terms of digital entrepreneurship (Bannerjee et al. 2016), at the micro level, disparities exist to host digital entrepreneurship. The GPM constitutes multiple sites where competition, complementarities, specialization, and agglomeration economies play a role. Based on the development of the DEI, the present study offers several geographical reading levels to interpret and understand the structure and organization of DEEs. It reveals greater heterogeneity in suburban areas based on IT distribution and sociological and demographic contexts. This original result highlights that some factors can significantly affect the emergence of start-ups in some areas but not in others, due to the heterogeneity of the DEE within the metropolis.

Paris, which has the highest DEI scores and a diverse economic sector, directly benefits from the presence of opportunity-motivated entrepreneurial activities in ICTs. Moreover, the sub-indicator CAP enabled us to find the self-reinforcement mechanisms in western GPM and Paris. However, on the whole, the distance from a cluster does not seem detrimental.

Entrepreneurial activity is a complex and systemic process that requires more than just financial services; innovation as an urban activity combines both localization and urban economies (Audretsch et al. 2006). However, great heterogeneity is revealed using the sub-indicator ATT according to the sociological and demographic contexts. In this case, the improvement of this sub-indicator is crucial in the northern area of the GPM as a CAP indicator. As Gill (2010) explains, the mismatch between the economic strategy of the policy and the socio-cultural context can have deleterious effects, as a gap remains between economic growth and local development. Consequently, recent studies have highlighted the interest in implementing more location-based policies that adapt to the specificities and characteristics of places (Duranton and Venables 2018). For example, in the case of Seine-Saint-Denis, a significant part of the population has insufficient skills, especially digital skills, because these territories combine signs of exclusion of growth: a high unemployment rate and a poor population that is not educated and is mainly of foreign origin (Chevrot et al. 2020; Bertaux et al. 2021). If we can observe over time a positive move from a part of this population on the social scale due to its creativity, dynamism, and spirit of entrepreneurship, this population will change location and be replaced by other new foreign origin entrants. It is then difficult for this territory to accumulate skills and escape its difficult trajectory. Durable place-based policies are needed to encourage not only positive social mobility but also a real anchorage of wealth in the territory (Reynaud 2020). These policies need to first reduce the educational gap between children from different socio-economic backgrounds and the long-term unemployment rate.

In the Hauts-de-Seine department and particularly in the "Plateau de Saclay" territory, the cumulative strengthening of DEE for the CAP indicator can be explained by the specialization of these territories in total ICTs employment (37% of total employment in ICTs for 16% of the total number of establishments—source: Camor et al. 2016). The presence of universities or prestigious engineering and business colleges and mainly large establishments favors the installation of small specialized establishments, working in collaboration with the largest ones, which constitutes a specialized entrepreneurial ICT culture.

If the presence of R&D activities appears to be a less crucial variable in the GPM compared with urban density indices (e.g., ATT axis), De Jong and Marsili (2010) associate disruptive innovations to R&D activities. Consequently, in this type of territory where R&D activities are lacking, there is a need to create conditions that favor disruptive innovations, such as constructing collaborative spaces (Boutillier et al. 2020), especially in the digital sector.

The DEI has a political dimension, as public authorities can use it as a decision-making support tool, contributing to the diagnostics and assessments of entrepreneurial policies and to the implementation of a stimulating and dynamic environment to promote opportunity-motivated entrepreneurial activities, as recommended by the literature (Chatterji et al. 2014). This is especially true in the digital economic sector where digital entrepreneurship drives the economic growth of OECD countries (Fernández-Portillo et al. 2020). In this way, the DEI can optimize and better mobilize district resources to improve local entrepreneurial ecosystems. By acting on the seven pillars of the DEI, policymakers will be able to implement policies at the suburban level to overcome local bottlenecks and stimulate business.

For example, in "arrondissement" 19 (city of Paris), the location quotient of small ICT firms (between 1 and 1.3) shows that there is a small amount of specialization. If the policymaker wants to further increase specialization, he or she should focus on the ATT dimension where the coefficient of the local model is positive and significant rather than the CAP dimension where the coefficient is positive but not significant. The variables that are easiest to implement in the ATT dimension are the variables that make up the HDI, education, health, and living standards. The policies that are tailored should then strengthen education, improve health and attract a wealthy population to the district.

The world has witnessed recent trends toward relocalization for a variety of reasons: agility for industries that had previously relocated to low-labor cost countries, sustainability with short food supply chains, independence and self-reliance with the maker movement.[21] All these trends are enabled by the development of what has been called the fourth industrial revolution thanks to new technologies.[22] COVID-19 has accelerated the adoption of Industry 4.0 technologies such as the use of ICTs, automation, AI, sensors and drones to minimize Covid-19 risks and localize value chains. It is then important to continue to invest in these new technologies (Aghion et al. 2020). New technologies also hold out the hope of helping to meet the ecological challenge to which France has committed itself to reduce its greenhouse gas (GHG) emissions since COP 21, whether through AI, big data, IOT or smart grids, etc. For example, the development of technologies makes it possible to optimize data storage on servers, to coordinate traffic lights to ease traffic jams, or

[21] Thanks to access to digital fabrication tools such as 3D printers, laser cutters, CAD software and computer numerical control (CNC) milling machines.

[22] These new technologies include biotech, nanotech, neuro-technologies, green and renewables, information and communication technology (ICT) and mobile communications, 3D, artificial intelligence (AI), robotics, sensoring, space technology, and drones.

to reduce commuting by enabling remote working, especially in the service sector. Nevertheless, estimates of electricity consumption for ICTs as a whole are around 10% of total consumption today, worldwide, and will probably increase in the future (Berthoud 2017). The role of public authorities will be more than ever essential in regulating this market so that technological performance serves energy sobriety and sobriety is associated with frugality of use. At a minimum, estimates of biodiversity and energy resources and GHG emissions required at each stage of the life of a new product or service (manufacturing, use, reuse and recycling) should be integrated into public policy decisions, via the definition of complex indicators for example, before subsidies are granted to startups. Experiments or other evaluations could also be generalized in order to appreciate the deleterious effects linked to uses such as rebound effects before committing to the allocation and public support for the emergence of new technologies. Moreover, while gentrification has long been associated with the emergence of a "creative class," the increased possibility of working from home may give rise to new forms of socio-spatial arrangements that challenge existing arrangements in the urban region's neighborhoods.[23] In the context of the COVID-19 crisis, where the return to the 'new normal' will involve a greater emphasis on the digital economy, digitization and flexibilization of work (Belitski et al 2021), the DEI we have developed may prove useful. Indeed, since it captures the heterogeneity of DEEs within a metropolis, it is possible to identify the weaknesses of certain features and thus to target policies to improve DEEs performance and the resilience of companies to prevent possible future shocks.

The major limitation of this indicator is its lack of temporal data. This can raise an issue about potential endogeneity in the dependent variable. An annual update of the data may allow a follow-up of the link between the DEI and digital entrepreneurship over time. For future research, given the fact that this study is based on data from 2016, it could be interesting to analyze how the Covid19 pandemic and the acceleration of the use of digital tools by companies to develop new opportunities can has affected the geography of the DEI. In terms of future research, this study could also be duplicated in other metropolitan areas for benchmarking purposes.

Appendix

The DEI score is calculated from the variables of Table 1 by the principal component analysis (PCA) method considering that the three sub-indicators are represented by three orthogonal axes: the ATT axis, the CAP axis and the ASP axis.

The number of common factors extracted to aggregate the DEI-GPM variable using the PCA, namely, the components generated from the linear combinations of the original variables, was determined from the Kaiser criterion.[24] These linear

[23] In France, following the health crisis, the confinements and curfews that marked it, as well as the trivialization of telecommuting, the desire of GPM inhabitants to locate has shifted towards medium-sized cities that has become more attractive.

[24] The extracted values are those whose initial eigenvalue is under 1.

combinations were weighted by inertia. Therefore, the PCA affects the weight of each variable in accordance with its statistical contribution to the PCA component. Thus, the DEI–GPM was aggregated by calculating the weighted average of the individuals' coordinates with respect to inertia (i.e., the associated eigenvalue divided by the sum of the eigenvalues considered). The mathematical formula for index I is given by

$$I = \sum_j^q W_i C_i,$$

With

$$W_i = \frac{\mu_i}{\sum_{j=1}^q \mu_j}$$

where C is the component, and μ is the eigenvalue. Note that the PCA adds some bias to the regression model because of the reduction of the variable, which *de facto* reduces the standard error. Nevertheless, we took care to retain a high eigenvalue to reduce this bias.

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