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Knowledge-based urban environments and entrepreneurship: Inside EU cities

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ABSTRACT

This paper aims to answer the following research question: does the knowledge city environment stimulate entrepreneurship? To answer this question, we develop a framework and multidimensional indexes to better explain the different dimensions of a 'knowledge city' and their relation to urban entrepreneurship, defined in terms of new and digital ventures. The analysis was performed on a sample of 60 cities, including all capital cities in the EU28 and 32 non-capital cities in the EU that are considered important knowledge hubs. The presence of cities from EU28 countries is important to foster the entrepreneurship attitude in each national context. Our study makes a significant contribution to the literature by providing a new approach to understand the factors affecting knowledge cities and to identify the city profiles that are key for the development of urban-level entrepreneurship, thus providing a number of important insights for academics and urban policy makers.

1. Introduction

In the knowledge economy, cities are characterized by a growing proportion of knowledge workers and by the service-orientation of economic activities. Moreover, the role of large cities tends to be reinforced as they become centres of governance in global networks (Clark, 2003; Glaeser & Gottlieb, 2006; Glaeser, Rosenthal, & Strange, 2010; Madon & Sahay, 2001; Sassen, 1991, 1994; Turok, 2008).

At the EU level, Lever (2002) finds a positive correlation between economic development and the 'knowledge attitude' in European cities. From this view, qualified human capital is seen as related to high local economic growth rates (Jacobs, 1961). Florida's proposal concerning the concentration of the so-called creative classes in some cities and regions (Florida, 2002; Florida, Mellander, & Stolarick, 2008), based on insights from Jacobs' works, has naturally moved to the core of the debate. In this vein, urban policies and governance should be oriented to nurture a strong 'people climate' to attract and retain talent in urban areas to form analytical, synthetic, and symbolic knowledge bases.

Knight (1995, 2008), Perry (2008), and Yigitcanlar (2011) define the concept of Knowledge Based Urban Development (KBUD) as a new development paradigm for the global knowledge economy, aimed at creating economic prosperity, socio-economic order, sustainability, and good governance for cities. The main goal is to construct a knowledge city (Carrillo, Yigitcanlar, Garcia, et al., 2014; Ergazakis, Metaxiotis, & Psarras, 2004). Accordingly, the literature has defined the key characteristics of the knowledge city (Carrillo et al., 2014; Edvardsson, Yigitcanlar, & Pancholi, 2016; Penco, 2015; Yigitcanlar & Bulu, 2015). The most recent view of KBUD defines a set of policies as '*targeting of building a place to form perfect climates for business, people, space/place and governance and emphasize on balance and integration of these climate*' (Yigitcanlar, 2014). Under this approach, the relationship between the paradigms characterizing the global 'knowledge city' and their effects on entrepreneurship did not explicitly emerge. More generally, the impact of the knowledge economy on urban development and the creation of 'new entrepreneurship' have not been properly addressed in the literature.

An analysis of the literature regarding the determinants and effects of entrepreneurship on economic development indicates that entrepreneurship has a national or regional perspective (e.g. Ács, Autio, & Szerb, 2014; Audretsch & Fritsch, 2002; Crescenzi, Rodriguez-Pose, & Storper, 2007; Glaeser et al., 2010; Glaeser, Ponzetto, & Tobio, 2014). The economic literature on city-level entrepreneurship is scarce: the main studies on urban entrepreneurship effects focus on North American or emerging-economy cities (Florida, 2002; Florida et al., 2008;

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Glaeser et al., 2010, 2014; Glaeser, Kallal, Scheinkman, et al., 1992), while only a few academic contributions address the economic and social effects of entrepreneurship (Audretsch, Belitski, & Desai, 2015) and the drivers of entrepreneurial ecosystems in European cities (Audretsch & Belitski, 2017).

This study focuses on the role of the urban environment in promoting entrepreneurship from a knowledge economy perspective with a focus on new and digital ventures. More specifically, we address the following research question (RQ):

RQ: is the knowledge city environment a stimulus for entrepreneurship? By analysing:

1. Which knowledge city profiles (i.e. built-in assets or public policies) enhance knowledge attitude;
2. Which knowledge city profiles (i.e. built-in assets or public policies) stimulate entrepreneurship the most.

Following the well-established KBUD model (Yigitcanlar, 2014; Yigitcanlar & Lönnqvist, 2013), we propose a new framework and an innovative multidimensional index, namely, the *Knowledge Based City Developing Entrepreneurship* (*KBCDE*), to better understand the different dimensions of a 'knowledge city'. A consolidated methodology that defines different stages in developing a composite index is used (Ivaldi, Bonatti, & Soliani, 2016a; Nardo, Saisana, Saltelli, et al., 2005; Salzman, 2003), based on a sample of 60 EU cities. This approach provides a number of advantages, such as aggregating variables expressed in different units of measurement, thereby eliminating the need to choose weights arbitrarily, as well as an appropriate treatment of missing values and duplicate information (Montero, Chasco, & Larraz, 2010; Somarriba & Pena, 2009). We compute the KBCDE index for each dimension of knowledge considered, as well as for an aggregate measure of knowledge (Ivaldi, Bonatti, & Soliani, 2016b). We use the same methodology to develop the composite index of Entrepreneurship (ENT) using two variables, namely, new business density and history of highly successful digital companies per capita.

Our study yields several insights. First, it is methodologically important to develop new indexes to understand the factors that affect the development of urban-level entrepreneurship. Second, on the basis of a set of sub-indexes, we study the relationship between each knowledge city profile and entrepreneurship within our sample in order to understand which profiles are more important for the development of urban-level entrepreneurship. Third, our work contributes to the debate on urban economic development and entrepreneurship by providing insights about knowledge city development valuable to both academics and urban policy makers.

The paper is organized as follows. Section 2 reviews literature on knowledge-based cities and entrepreneurship, provides the theoretical framework, and develops the research hypotheses. Section 3 explains the research design and method. Section 4 describes the construction of the indexes and presents the major empirical findings. Section 5 discusses the outcomes and implications for academics and practitioners. The last section concludes.

2. Theoretical background: knowledge-based cities and entrepreneurship

2.1. Cities in the knowledge economy

The debate about the emerging knowledge-based economy serves as a backdrop for introducing the most relevant characteristics that reinforce city-level entrepreneurial development. The knowledge economy is defined as production and services based on knowledge-intensive activities, which contribute to an accelerated pace of technological and scientific advance as well as equally rapid obsolescence (Powell & Snellman, 2004). The greater reliance of the knowledge economy on intangible assets such as intellectual capabilities rather than physical resources is well documented in the literature (Gershuny & Miles, 1983; Levitt, 1976). According to the Organization for Economic Cooperation and Development (Smith, 2002), a knowledge economy is 'an economy which is directly based on the production, distribution, and use of knowledge and information'. This change is reflected in the increasing contribution of intangible capital to the gross domestic product (Abramovitz & David, 1996).

The literature on knowledge economies focuses heavily on knowledge production, and concentrates on a number of important topics: the role of knowledge as a source of innovation (Bell, 1973; Romer, 1990); the new features of knowledge-based firms and their productive processes (Kochan & Barley, 1999); and knowledge management and the valorisation of knowledge transfer within and between organizations (Drucker, 1993; Nonaka & Takeuchi, 1995).

Studies on urbanization indicate that the role of large cities in the knowledge economy tends to be reinforced as they become centres of governance in global networks (Hendriks, 1999; Pancholi, Yigitcanlar, & Guaralda, 2017; Sassen, 1991, 1994).

The evolution of cities is becoming a topic attracting attention in itself due to the substantial increase in urbanization rates in both advanced and developing countries (Clark, 2003; Glaeser & Gottlieb, 2006; Madon & Sahay, 2001; Turok, 2008). Recent analyses by leading consulting companies confirm the trend towards an urban world, as the contributions of cities to the economy and global society—in terms of wealth creation and population concentration—have grown significantly over the last thirty years. In other words, the world is characterized by a level of urban development unprecedented in human history; moreover, since 2008, most of the world's population has been living in urban areas.

The relevance of this phenomenon has attracted the attention of researchers (mainly regional and industrial economists and urban planners), practitioners, and public administrators who have attempted not only to interpret explanatory factors and the path leading up to this phenomenon, but also to identify the social and economic effects of urban concentration.

There is rich literature exploring the relationship between cities and the knowledge economy by focusing on different city profiles. Several studies have analysed the role of knowledge-based activities in the creation of wealth and development at the urban level. In particular, universities contribute to regional economic development thanks to the creation of a knowledge-based environment in terms of creation of research, human capital through teaching, as well as technology development and transfer (Goldstein & Renault, 2004; Lawton Smith, 2003). The relevance of local knowledge spillovers in terms of stimulating innovation processes has been examined in the literature (Howells, 2002; Simmie, Sennett, Wood, & Hart, 2002). From this perspective, the topic of the development of knowledge-based clusters in cities and urban regions has also been explored (Van den Berg, Braun, & Van Winden, 2001).

Florida (2002) has attracted considerable attention in this debate by focusing on human capital in the urban economy, identifying the relevance of 'people climate' as a means of attracting and retaining talent in urban areas to form analytical, synthetic, and symbolic knowledge bases. This paper adopts the perspective focusing on urban governance issues related to the local knowledge economy (Knight, 1995). Consistent with this perspective, Carrillo (2004) introduces the concept of a 'knowledge city' to identify metropolitan areas that—similar to a production system—can facilitate knowledge creation. A knowledge city 'is a city that aims at a knowledge-based development, by continuously encouraging the KM (knowledge management) processes. This can be achieved through the continuous interaction between its knowledge

agents themselves and at the same time between them and other cities' knowledge agents. The city's appropriate design, ICT networks and infrastructures support these interactions' (Ergazakis et al., 2004; Pancholi et al., 2017). It has been found in the literature that knowledge cities are the most capable structure to foster sustainable economic growth.

The concept of knowledge city is different from other city concepts such as Smart city, Digital City, Virtual City, Information City, Wired City, Ubiquitous City, and Intelligent City. Let us first consider the concept of smart city as the number of academic contributions regarding this concept has significantly increased (Cocchia, 2014a, 2014b; Jucevičius, Patašienė, & Patašius, 2014). A smart city is a city with a significant presence of ICT applied to critical infrastructure components and services (Washburn et al., 2009). Nam and Pardo (2011) enlarged the definition of smart cities using a wider range of core factors such as technology, people (creativity, diversity, and education), and institutions (governance and policy). Several recent definitions have a secondary focus, namely, connecting the concept of smart city with the definition of ICT to promote sustainability, economic development, and quality of life (Giffinger et al., 2007).

The concepts of Digital city, Intelligent city, Ubiquitous city, Wired city, Hybrid city Information City are mainly concentrated on the digital representations and manifestations of cities and, in particular, on the design, implementation and governance of physical infrastructure, as well as smart and digital technologies (Nam & Pardo, 2011).

Unlike these city concepts, the concept of Knowledge City is focused on knowledge-based development that stimulates the creation and the renewal of knowledge, the key factor found in the knowledge-sharing culture (Ergazakis et al., 2004). This perspective aims to nurture the human dimension, for example, people, education, learning, and knowledge (March & Ribera-Fumaz, 2016).

Due to the extensive relationships between people, knowledge cities provide the most natural environment to search for evidence of the knowledge spillovers emphasized by endogenous growth theory. The concept of a knowledge city is intimately linked to the knowledge economy. In other words, a knowledge city is a 'learning city', and is linked to the 'knowledge economy' and to 'innovation' since IT networks and infrastructure support interactions among citizens.

The literature has defined frameworks and indicators to measure and monitor the development and the governance of urban contests in a knowledge city. Knight (1995, 2008), Perry (2008), and Yigitcanlar (2011) define the concept of KBUD as new development paradigms of the global knowledge economy aimed at creating economic prosperity, socio-economic order, sustainability, and good governance for a city. KBUD is therefore viewed as a vision/strategy to accompany the transformation of cities into knowledge cities and of economies into knowledge economies (Ardito, Ferraris, Petruzzelli, Bresciani, & Del Giudice, 2018; Yigitcanlar, O'connor, & Westerman, 2008).

KBUD comprises four main dimensions (Yigitcanlar, Velibeyoglu, & Martinez-Fernandez, 2008), each of which consists of two separate but inter-linked sub-categories. These dimensions and sub-categories include the following perspectives (Yigitcanlar, 2011; Yigitcanlar & Bulu, 2015; Yigitcanlar & Lönnqvist, 2013):

1. Economic development: (a) macro-economic foundations (gross domestic product (GDP) and foreign direct investments (FDI)); (b) knowledge economy foundations: research and development (R&D) expenditures and number of patents;
2. Socio-cultural (or societal) development: (a) human and social capital: public spending on education, educational attainment, and university rankings; (b) diversity and independence: ratio of people born abroad, unemployment and dependency ratios;
3. Enviro-urban (or spatial) development: (a) quality of life and place: cost of living and crimes against life and health; (b) environmental sustainability: CO2 emissions;
4. Institutional capacity and development: (a) governance and planning: electronic governance and city branding; (b) leadership (or support) and partnership: public grants for R&D and number of 'sister city' cooperation agreements.

The operationalisation of these variables is employed 'mutatis mutandis' in several empirical studies. KBUD provides a useful policy framework for the transformation of knowledge resources into local development that provides a basis for sustainable development. This is why several capital cities in the world have applied these principles to foster and accomplish urban development and/or urban economic renewal.

Following KBUD, Garcia (2012) introduced the MAKCi (Most Admired Knowledge City) framework. It comprises a knowledge-economy model that involves an assessment of the value base that enables future city development and includes eight knowledge capital dimensions: (1) identity capital; (2) intelligence capital; (3) financial capital; (4) relational capital; (5) human individual capital; (6) human collective capital; (7) instrumental-material capital; and (8) instrumental-knowledge capital.

Méndez and Moral (2011) identify the key components of a knowledge city by analysing the most important municipalities in Spain, based on 12 quantitative indicators divided into four dimensions (human capital; economic city specialisation in the knowledge economy, features of the local innovation system; digital network system).

López-Ruiz, Alfaro-Navarro, and Nevado-Peña (2014) analyse the most important variables used to assess and rank cities and also study the weaknesses and strengths of the most important urban indicators by producing several city profiles based on, for example, general or growth city indices, human development city indices, and sustainability city indices. They study the intellectual capital approach to understand the ability to transform knowledge and intangible resources into sustainable long-term wealth. The adopted Knowledge City Indicator (KCI) assesses not only sustainability and social wellbeing, but also intangible factors such as human development, economic structure, trade, image, and innovation. The KCI is made of 19 dimensions with 73 different indicators.

The knowledge-management literature defines the factors that foster the development of cities in the knowledge era, identifying strategic factors (e.g. political support, urban planning, financial incentives) and operational factors such as the presence of wireless networks, universities, and PR of the city (Carrillo, 2004; Ergazakis et al., 2004; Yigitcanlar, 2011). In light of these considerations, we argue that city development in the knowledge era is due to a mix of factors that could be broadly classified into two types (Penco, 2015):

- *built-in assets*, that regard the presence of knowledge-related activities and amenities in the 'DNA' of the cities;
- *public policies* aimed at promoting the city as a knowledge city.

Built-in assets are identified as the conditions that facilitate the spontaneous localization of companies and actors who produce knowledge. In this case, the presence of universities, research centres, large enterprises, or high-tech districts stimulates the agglomeration process and urban development. From a social perspective, urban development is mainly anchored to the 'knowledge atmosphere' that attracts and retains businesses and knowledge-workers. In addition, amenities, cultural, and entertainment operators facilitate the creation of a good quality of life (Musterd & Gritsai, 2013). Public policies can stimulate built-in asset factor growth. In fact, successful cities that have

a core infrastructure — such as the educational system, amenities for the quality of life (museums, theatres, cinemas, cultural events), a transport system, and the entrepreneurship vocation of the area — that requires a coherent vision of the necessary knowledge-related interventions and public policies needed to foster the creation of urban-level knowledge and an innovative system.

2.2. Urban system factors and entrepreneurship development

In recent decades, entrepreneurship has been extensively examined in economics and management studies as it is considered one of the most dynamic sources of job creation, healthy competition, economic growth, promotion of an 'inclusive' society, and innovation. According to Bruyat and Julien (2001), two basic perspectives are generally used to analyse entrepreneurship. According to the first perspective, the entrepreneur is the creator and the developer of new businesses of any kind, independently from the technological intensity and innovativeness of the business. The second perspective, which we adopt in this paper, is consistent with the Schumpeterian concept of entrepreneur as an 'innovator', namely, an individual that recognizes opportunities not just to create new ventures but to develop new technological innovations and business models that shape new industries and restructure the economy. Most of the economic and managerial literature has focused on Schumpeterian entrepreneurship, investigating the innovative and technological profiles of the entrepreneurial firm, taking in account the most important theories on innovation and technological changes (Solow, 1956). Moreover, several studies address the socio-economic and personality characteristics of entrepreneurs such as academic education and technical background (Koellinger, 2008; Shane, 2000). In this vein, academic contributions tend to identify the antecedents of entrepreneurial orientation, for example, the processes, practices, and decision-making activities used by entrepreneurs that lead to the creation of an entrepreneurial firm (Lumpkin & Dess, 1996). The typical conceptualizations of entrepreneurial orientation include three dimensions: proactiveness, risk taking, and innovativeness (Covin & Slevin, 1991; Wiklund & Shepherd, 2005; Zahra, 1991). This 'inclination' to become an entrepreneur, however, does not necessary imply the creation of new venture.

From an economic and regional studies perspective, there is considerable literature focusing on the territorial dimension of the entrepreneurship phenomenon, specifically the determinants and the impact of entrepreneurship on the economy and territory development (Acs, Braunerhjelm, Audretsch, & Carlsson, 2009; Andersson, 2011; Audretsch, 2003; Glaeser et al., 2010, 2014; Stam, Arzlanian, & Elfring, 2014). From this perspective, the predominant studies focus on the country or regional level (e.g. Ács et al., 2014; Audretsch & Fritsch, 2002; Crescenzi et al., 2007; Glaeser et al., 2010, 2014). For instance, the Global Entrepreneurship and Development Index (GEDI) (Ács et al., 2014) and Regional Entrepreneurship and Development Index (REDI) (Szerb, Ács, & Autio, 2013) aim to capture the interaction between individuals and the economic-structural environment at the national and regional levels.

Recent trends in entrepreneurship policy (e.g. UN Habitat and European Commission, 2016) and academic research (Audretsch & Belitski, 2017) focus not only on the national and regional perspectives to study entrepreneurship, but also on the local-urban perspective. Economic geography and urban economics studies have scrutinized the spatial organization of entrepreneurship and innovation, finding that entrepreneurial activity (especially the Schumpeterian type) is more concentrated and clustered than manufacturing industries (Adler, Florida, King, & Mellander, 2019).

Cities are an appropriate environment for entrepreneurship (Szerb et al., 2013), providing a relevant socio-economic and institutional context for the entrepreneurial ecosystem (Audretsch et al., 2015). The most important appeal of large metropolitan areas is linked to agglomeration economies (Chatterji, Glaeser, & Kerr, 2014) that enable a more significant and efficient sharing of complex knowledge along with higher externalities and spill-overs (Ghio, Guerini, Lehmann, et al., 2015), economies of scale, and incentives to innovation and growth (Szerb et al., 2013).

Different from Marshallian economies in industrial districts, urban agglomeration economies are 'knowledge agglomerations': they produce synergies due to the close transmission of knowledge between: (1) knowledge-intensive firms; (2) higher education, research, and development (universities); (3) complementary knowledge-intensive business services; financial intermediation, national and international public institutions; and (4) telecommunication networks that are placed in large metropolitan areas. An essential tool provided by knowledge agglomerations is the presence of research and training centres. Due to the clear importance of the human factor, the role of universities is crucial because of their dual research and training roles; universities have a fundamentally positive impact on the territory. To strengthen innovative and entrepreneurial supports, specific policies and interventions aimed at developing entrepreneurship are pursued at the city level (e.g. venture capital, incubators, and specific financial grants).

Moreover, cities provide amenities and infrastructure that are attractive to its high human capital residents (Glaeser & Gottlieb, 2006), stimulating the retention of talent for the development of entrepreneurship (Florida, 2002). Physical conditions such as infrastructure and amenities (green spaces, theatres, museums, cinemas, coffee shops, and art galleries) lead to increased social life and a perceived improvement in quality of life. In cities, downtown areas become places of consumption (accommodating multinational malls or megastores that replicate their service production system, labelled *servuction* by Eiglier and Langeard, in the main cities), increasingly populated by service companies and people who prefer to 'live in the city but work in the suburbs' (Benninson et al., 2007; Glaeser & Gottlieb, 2006; McKee & McKee, 2004; Padilla and Eastlick, 2008; Turok, 2008; Warnaby and Davies, 1997).

Transport may either foster or constrain the interaction between the agents of the entrepreneurial ecosystem: urban mobility (needed to connect major points of production services downtown, new office buildings, residential areas, and so on), the logistic accessibility to/from other international hubs, the presence of airports with many connections, high speed rail tracks, and a developed highway infrastructure network are important. In general, the larger the city, the better a firm's access to a deep labour pool, a large customer base, a choice of shared services and suppliers, and good external connections (Audretsch et al., 2015; Turok, 2008). Moreover, better home and neighbourhood Internet connectivity could be the ideal catalyst for exploiting the enormous potential of digital technologies in Europe, thus facilitating start-ups and high growth.

In the aforementioned frameworks, the relationship between the paradigm of the knowledge city and its effect on entrepreneurship does not emerge explicitly. Even if case histories of urban entrepreneurship are common (e.g. Bosma & Sternberg, 2014), its mechanisms remain under-examined (Beaudry & Schiffauerova, 2009). In Europe, these mechanisms have been made somewhat more explicit by the encouragement given by the European Urban Policy to urban policy makers to create supportive conditions that incentivise the creation, development, and maintenance of entrepreneurship.

Our study is related to the current literature as follows. Most studies of the effects of urban entrepreneurship tend to focus on North American or emerging economy cities (Andersson, 2011; Florida, 2002; Florida et al., 2008; Glaeser et al., 1992, 2010, 2014). On the other hand, the contemporary European urban context (Capello et al., 2008;

Dijkstra et al., 2013) has been significantly less studied (see Ács et al., 2014; Bosma & Sternberg, 2014). Moreover, the literature on knowledge-based cities does not explicitly reveal the relationship with the development of urban-level entrepreneurship attitude. Thus, entrepreneurship in the knowledge city context is not directly studied, even though the knowledge development context is commonly recognized as one of the most important features in entrepreneurship development. Consequently, our work follows the KBUD framework (Yigitcanlar, 2011; Yigitcanlar & Lönnqvist, 2013) and entrepreneurship research (Stam et al., 2014; Szerb et al., 2013) by connecting and extending these works in three ways. First, we create four domains of knowledge cities focusing on factors that are connected with the potential stimulus of the entrepreneurial activities at the urban level. Second, we create an innovative index for measuring urban-level entrepreneurship, taking in account the profiles of new businesses and the presence of unicorns. Third, we explain the relationship between each dimension of the knowledge city and the level of entrepreneurship to identify bottlenecks and derive policy implications.

3. Methodology

3.1. Cities identification

A sample of EU28 capital cities was constructed. The presence of cities from each EU28 country is important to foster the entrepreneurship attitude in each national context. We also included 32 non-capital cities in the EU that are important hubs, resulting in a sample of 60 cities (Bannerjee, Bone, & Finger, 2016).

3.2. Dimensions identification

An innovative multidimensional index (KBCDE—Knowledge Based City Developing Entrepreneurship) is developed to better explain the different dimensions of a 'knowledge city', following a consolidated methodology (Ivaldi et al., 2016a; Nardo et al., 2005; Salzman, 2003) that develops a composite index through different stages. A literature analysis enables an a priori derivation of the most suitable variables and the dimensions to include in the index (Yigitcanlar, Inkinen, & Makkonen, 2015), even if the choice is conditioned by both data availability and the purpose of the index. The selected dimensions are chosen to be sufficiently different to cover the multidimensional nature of 'knowledge' at city level.

The first dimension focuses on the social aspect, following the approach of Florida (2002) and Jacobs (1961). Its conditions are spontaneous and linked to the city's cultural and educational attitude.

Social and Talent-cultural perspective (STC):

- Multicultural diversity (foreign-born percentage of population);
- High education/graduates (population percentage aged 25–64 with tertiary level 5–8 education attainment);
- English language skills (population percentage who can communicate in English);
- Quality of research institutions (number of institutions in top 200-ranking);
- Size of potential mobile-based market (number of active mobile broadband subscriptions per 100 inhabitants):
- Culture & creativity (average scores attributed to diverse cultural facilities).

The second dimension identifies the economic conditions that facilitate entrepreneurship development while also considering the knowledge economy perspective. Certain built-in conditions in a city's economic structure can facilitate the production of new knowledge and entrepreneurs.

Economy and knowledge economy perspective (EKE);

- Labour costs (average salary for software developers, web designers, web developers, business developers, content marketers, sales managers, customer support personnel in € per annum; inverted variable);
- Time and costs associated with doing business (ranking);
- Cost of office space (average rental cost or price of commercial property—€/m^2/Year; inverted variable);
- Access to support employees in knowledge economy sectors (number of employees in legal and accounting activities; advertising and market research; office administrative, office support, and other business support activities relative to the working population);
- Number of employees in the ICT sector (relative to the working population in thousands);
- Online collaboration (number of hosting service users within the last 12 months per capita);
- Research & development intensity (thousands of Purchasing Power Standard—per capita).

The third dimension, although focused on the urban environmental and networking ability (Audretsch et al., 2015; Turok, 2008), nevertheless pertains to soft infrastructure (digitalisation level of the city) as well as hard infrastructure (transport, effectiveness of connection infrastructure for commuting). Public policies are needed to create physical conditions for knowledge transfer or dissemination through businesses and the educational system, and to attract new workers and entrepreneurs thanks to the high connectivity and living standards. Governments are more valuable if they are close to citizens, and that proximity supports the creation of an atmosphere of confidence and stability, thus acting as innovation catalysts.

Environmental and infrastructural perspective (ENI):

- Internet download/upload speed (MBps);
- Cost of broadband (fixed broadband subscription charge—$/Month inverted variable);
- Mobile internet download/upload speed (MBps);
- Standard of living (quality of life index score);
- Commute (average travel time and distance to work);
- Train connectivity (total population reachable within a 3-hour train commute);
- Airport connectivity (score based on number of flights from local airports).

The fourth component contains eight variables/indicators of the urban innovation system's innovative effort, in terms of institutions (Méndez & Moral, 2011). A top-level position in the knowledge economy is the direct consequence of public policies that facilitate financial resources for new venture creation, technological development, knowledge transfer, and various innovative projects, in both private and public institutions.

Urban innovation system perspective (UIS):

- Availability of early-stage funding (amount of seed and start-up funding raised—€ in thousands);
- Availability of later-stage funding (amount of later-stage funding raised—€ in thousands);
- Availability of business angels funding (amount of business angels funding—€ in millions);
- Availability of crowdfunding (amount pledged to successful campaigns through any model);
- Networking and mentoring events (number of meetup events in the last year per capita);
- Access to accelerators (number of accelerators per capita);

Table 1
Pearson correlation between the ENT and KBCDE dimensions.

		Social and talent-cultural perspective (STC)	Economy and context economy perspective (ECE)	Environmental and infrastructural perspective (ENI)	Urban innovation system perspective (UIS)	**KBCDE** Index	**ENT** Index
KBCDE Index	Pearson Correlation	0.915**	0.677**	0.479**	0.805**	1	0.534**
	Sig. (2-code)	0.00	0.00	0.00	0.00		0.00
	N	60	60	60	60	60	60
ENT Index	Pearson Correlation	0.645**	0.123	0.238	0.383**	0.534**	1
	Sig. (2-code)	0.000	0.349	0.067	0.003	0.000	
	N	60	60	60	60	60	60

- Availability of early-stage assistance (number of business angels per capita);
- Public sector information and openness of the data (public sector information score).

A composite index (ENT) was constructed to evaluate the entrepreneurship activity of the sampled cities, comprising the following measures: new business density (number of newly registered corporations per 1000 working-age people) and a history of highly successful digital companies (number of unicorns—billion-dollar start-ups). The first measure identifies new entrepreneurship at the city level, while the second underlines the presence of an 'elite' within the population of start-ups that has been able to scale-up, typically operating in a digital and platform business (Acs et al. 2016).

3.3. Aggregation of variables

The sub-indexes are based on currently available data from certified sources (Gordon & Pantazis, 1997; Ivaldi et al., 2016b). Data were drawn from composite sources, and refer to the years 2014–2017 (Table A1). Variables containing outliers were adjusted by transforming the largest/smallest value to be the same as the second largest/smallest value. All variables were normalised to the [0, 1] range by subtracting the minimum value and then dividing by the entire range of values, using the Min-Max normalisation method (Han, Kamber, & Pei, 2012). About 99% of the data was complete. Missing data were replaced by the mean of the other variables in that theme and city. For cities containing missing values, the theme scores obtained using imputed data were the same as those that would have been obtained, had the variables containing missing values been excluded from the index (Bannerjee et al., 2016). Finally, we opted for equal weighting because, even though it would be desirable to assign different weights to the various domains, there is no reliable basis for this practice (Nardo et al., 2005).

We carried out the study by *DP2 Distance* (Somarriba & Pena, 2009). This method considers variables as non-substitutable, and assumes no probability law for their distribution. The iterative procedure DP2 distance weighs partial indicators depending on their correlation with the global index (Munda & Nardo, 2005). The index we constructed solves several statistical issues, such as aggregating variables expressed in different units of measurement, using arbitrary weights, as well as providing an appropriate way to treat missing values, and duplicate information (Montero et al., 2010). Moreover, this method is considered more robust than traditional methods such as Principal Component Analysis and Data Envelopment Analysis, as demonstrated by Somarriba and Pena (2009).

The DP2 value aggregates the information contained in each dimension evaluated using the distances from a reference base corresponding to the theoretical area achieving the lowest value of the variables being studied (Somarriba, Zarzosa, & Pena, 2015).

We compute the index for each dimension, as well as for the aggregate global knowledge index (KBCDE) and use the same methodology to construct the Entrepreneurship index (ENT) by using two variables, namely, new business density, and history of highly successful digital companies (per capita).

A Pearson Correlation index between KBCDE and ENT was used to determine the association between knowledge cities and entrepreneurship. Lastly, we divided cities into classes to facilitate easier comparison between the two indices. We employ cluster analysis since it can be used to group city information meaningfully (Hartigan & Wong, 1979). Cluster analyses facilitate the attribution of greater importance to the KBCDE and ENT scores as a criterion to split classes, rather than a relative ranking position. In contrast with the use of quintiles, this approach allows the unit to distribute according to the score alone rather than to force classification into a specific class. In this analysis, we decided to apply a two-step cluster procedure to split countries into classes. This procedure involves two distinct stages: in the first stage, original cases are grouped into pre-clusters, which are then clustered using a hierarchical clustering algorithm in the second stage. Two-step cluster analysis is increasingly being employed in various fields (Tkaczynski, 2016). The SPSS Two Step Cluster extends the model-based distance measure used by Banfield and Raftery (1993) to situations with both continuous and categorical variables. It utilizes a two-step clustering approach similar to BIRCH (Zhang et al., 1996), and can automatically find the optimal number of clusters. We use these methods to create clusters for ENT, KBCDE, and for the sub-dimensions.

4. Results and discussion

A sensitivity analysis was performed to confirm the strength of the proposed index. It was recalculated using additive methods, and compared using the Spearman *rho* correlation (Ivaldi & Testi, 2011) to verify if the use of a different aggregation method involved a substantial change in the resulting rankings. The two different methodologies generated almost the same ranking for the 60 cities, as the value of Spearman's rho coefficient of very close to one (0.973), thus confirming a substantial robustness of the index. Therefore, we present the results for the DP2 distance index only. Indexes and sub-indexes are depicted in Table A2.

To answer the research question, the correlation matrix facilitates an understanding of which knowledge city profiles enhance the KBCDE level, and whether a high KBCDE level is a predictor of urban entrepreneurship (Table 1).

The Pearson correlation coefficient explains the contribution of each sub-index to KBCDE: KBCDE levels are positively correlated with the social and innovation system dimension since STC (0.915) and UIS (0.805) are significant. The presence of knowledge activities and amenities in the 'DNA' of the cities, and the formulation of public policies aimed at fostering new business and new entrepreneurship, are factors that positively contribute to an increase in rank.

Pearson's correlation for the relationship between KBCDE and ENT (Fig. 1) is moderately good (0.534). The findings demonstrate that a high KBCDE score is a valuable predictor of city-level ENT attitude, confirming that a knowledge city environment stimulates

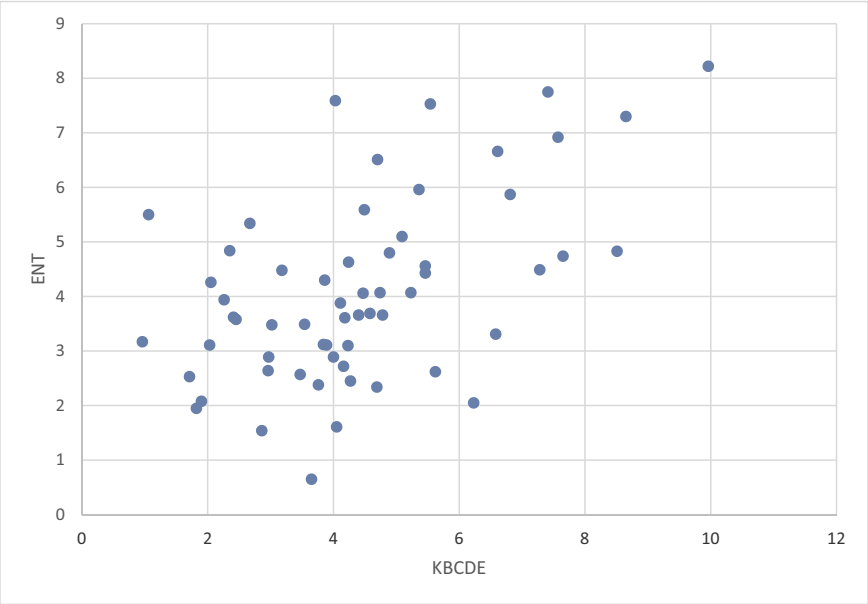


Fig. 1. Scatterplot for KBCDE and ENT.

entrepreneurship development.

To understand which profiles of knowledge cities are more effective for stimulating entrepreneurship, note that:

1. As the STC perspective helps to attract and retain talent, the empirical outcomes demonstrate a positive association between a good social environment and entrepreneurship attitude at the city level;
2. The outcomes test the relevant role of the creation of interventions and measures aimed at developing an UIS perspective to shape entrepreneurship.

The dimensions more correlated with the ENT Index are described by STC (0.645), and partially by UIS (0.383). It is interesting to note that entrepreneurship creation is more related to the built-in and spontaneous factors connected to STC than to the public policies aimed at nurturing entrepreneurship.

In particular, the correlation analysis explains that STC variables and indicators connected to the educational environment and the international/technical vocation of the population (i.e. graduate % of population, the English language skills % of population, the quality of research institutions, and the size of the potential mobile-based market) affect the level of entrepreneurship attitude more than the culture and recreation environment and the diversity of the city's population. Regarding UIS dimensions, factors and indicators connected to private or public funds for nurturing a positive environment for entrepreneurship development (availability of: BA investment, crowdfunding, early-stage funding, late-stage funding, and early-stage assistance) are more significant than other policies connected to the creation of a positive entrepreneurial environment in terms of services (networking and mentoring events, access to accelerators, and public sector information) (Table A3).

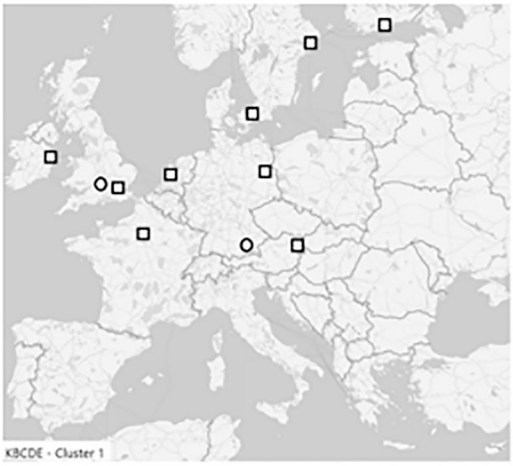
In order to better explain the relationship between KBCDE and ENT, a cluster analysis was performed on the basis of each index and subindex. A two-step analysis extracted three different clusters: cities of cluster 1 with a strong index value, cities of cluster 2 with a medium value, and cluster 3 with a weak value (Fig. 2).

KBCDE-Cluster 1 contains 11 cities, with a very high presence of STC and UIS. These include capital cities (9 out of 11) and cities that are relevant on the international city ranking (Oxford and Munich), especially for social and educational aspects. Consistent with the main literature (Ergazakis et al., 2004; Edvinsson et al., 2006), London has the best KBCDE rank, with best results in STC and UIS; Stockholm follows London in KBCDE (respectively 8.65 and 9.96), due to its second position in ECE (15.05), which is better than London (12.09). London and Stockholm are followed by Paris, Amsterdam, Copenhagen, Helsinki, and Oxford. It is not a coincidence that the top KBCDE cities have recently implemented public policies, making their government activities more coherent (Makkonen, Merisalo, & Inkinen, 2018). Some of these cities have implemented explicit policies to earn the 'status of knowledge cities'.

These policies aim to enhance competitiveness at the city and national levels, as well as to achieve a harmonious development with neighbouring areas. In the contemporary global economy, cities are essentially competing with each other in terms of attracting investments, businesses, inhabitants, tourists, as well as improving citizen satisfaction. Cities use different tools to compete: strategic planning, marketing strategies, city branding, for example. In particular, public policies contribute the following: (1) increased competitiveness, resulting in a positive impact on investment, jobs, inhabitants, visitors, and events; (2) higher returns on investment in real estate, infrastructure, and events; (3) coherent city development, as the physical, social, economic, and cultural aspects combine to deliver the brand promise; (4) and pride in the city as the inhabitants, businesses, and institutions experience a new sense of purpose and direction. Our results confirm that the top cities are located in Northern Countries. Policies aimed at enhancing the quality of social, economic, environment-sustainability, and supportive interventions for new firms have stimulated the creation of a knowledge-based context (Makkonen et al., 2018).

KBCDE-Cluster 1 (top KBCDE level) confirms that the seven top cities in STC are also KBCDE-Cluster 1 cities; Berlin, Munich, and Vienna are instead well positioned in other dimensions.

The KBCDE-Cluster 2 comprises 33 cities, characterized by a significantly different profile—although their scores on the first factor are



KBCDE-Cluster 1: London, **Stockholm**, Paris, Amsterdam, **Copenhagen**, **Helsinki**, Oxford, **Berlin**, **Dublin**, Munich, Vienna

ENT-Cluster 1: London, **Helsinki**, Luxembourg, Edinburgh, **Stockholm**, **Copenhagen**, **Dublin**, Tallinn, Bristol, **Berlin**

KBCDE-Cluster 2: Brussels, Edinburgh, Utrecht, **Cambridge**, Bristol, **Madrid**, **Manchester**, **Birmingham**, **Malmo**, **Uppsala**, Tallinn, Hamburg, **Eindhoven**, **Aarhus**, **Barcelona**, **The Hague**, Gothenburg, **Cardiff**, Frankfurt, **Riga**, Lisbon, **Bucharest**, Bratislava, Luxembourg, Cologne, Lyon, Glasgow, Vilnius, Karlsruhe, Budapest, **Stuttgart**, Prague, **Toulouse**

ENT-Cluster 2: Aarhus, Valletta, Bordeaux, **Manchester**, Lille, Paris, **Birmingham**, Amsterdam, **Cardiff**, Utrecht, Oxford, **Toulouse**, **Cambridge**, Glasgow, Nicosia, **Madrid**, **Uppsala**, **Barcelona**, Athens, **Bucharest**, **Eindhoven**, **The Hague**, **Malmo**, Valencia, **Riga**, Milan, **Stuttgart**, Sofia

KBCDE-Cluster 3: Sofia, **Dusseldorf**, **Warsaw**, **Ljubljana**, Bordeaux, Milan, Valencia, Lille, Athens, Nicosia, **Rome**, **Zagreb**, **Krakow**, **Dresden**, Valletta, Turin

ENT-Cluster 3: Munich, Turin, Vilnius, Lyon, **Rome**, Frankfurt, Cologne, **Dusseldorf**, Lisbon, **Warsaw**, Brussels, Prague, **Dresden**, Gothenburg, Karlsruhe, Hamburg, **Zagreb**, Vienna, **Krakow**, Bratislava, **Ljubljana**, Budapest

Legend : *cities in **bold** have the same ENT and KBCDE cluster level*.

(caption on next page)

Fig. 2. KBCDE and ENT clusters.

somewhat lower. KBCDE-Cluster 2 also includes capital cities in Spain, Portugal, and Eastern Europe, and metropolitan centres in the Northern Range. These cities have a good level of education/training associated with STC, but notable weaknesses in other UIS components.

KBCDE-Cluster 3 includes 16 cities, characterized by near-average values for each factor. Among them, seven capital cities are located in the Southern/Eastern range. Athens, Nicosia, Rome, and Valletta are Mediterranean capital Cities.

It is evident that the first KBCDE cluster is mainly corresponding to the ENT cluster, confirming the direct relationship between the urban-level knowledge-based attitude and entrepreneurship: Berlin, Copenhagen, Dublin, Helsinki, London, and Stockholm are knowledge-based cities with a high score of entrepreneurial activity.

The direct correspondence is less evident between KBCDE-Cluster 2 and ENT-Cluster 2 and, furthermore, between KBCDE-Cluster 3 and ENT-Cluster 3.

An additional control was applied to evaluate the correspondence between KBCDE and Entrepreneurship (ENT). The entrepreneurship values (ENT) were aggregated for each KBCDE-cluster (as a mean of the values of the cities), and the resulting three vectors of values were considered as new statistical units. Then, a new calculation of the DP2 distance was performed on the three cluster units. The results (Table 2) show that, considering the aggregated cities as a single big unit, the entrepreneurship trend seems to follow that of KBCDE. Note that improvement of the knowledge conditions, that is, going from the First to the Third cluster, is associated with a decrease in ENT calculated within each area. In other words, the level of ENT decreases when going from one class to another and from 2.40 in Cluster 1 to 0 in KBCDE-Cluster 3 (Table 2).

5. Conclusions

This study examines how specific variables (an STC perspective; EKE context perspective; ENI perspective; and UIS perspective) related to the concept of a knowledge-based city may affect urban-level entrepreneurship, measured by an index that takes into account new businesses and unicorns. The analysis was performed on a sample of 60 cities, including all capital cities in the EU28 and 32 non-capital cities in the EU that are considered as important knowledge hubs.

First, we demonstrate by means of a correlation analysis which knowledge city profiles (built-in asset or public policies) helped enhance the knowledge attitude level. The STC and the UIS dimensions are considered significant for constructing a strong knowledge-based urban environment. In this way, we demonstrate that a knowledge-based urban environment results from a mix of 'built-in asset' factors connected to the multicultural and social environment, along with policy-related factors aimed at enhancing the production of innovation and knowledge.

The findings reveal that a high KCBED score is a valuable predictor of ENT at the city level, confirming that a knowledge city environment stimulates the creation of new and innovative entrepreneurial activities.

Moreover, we tested which profiles of knowledge cities are more effective in stimulating this typology of entrepreneurship. First, as the STC perspective helps to attract and retain talent, the empirical outcomes corroborate the positive association between a good social and educational environment and city-level entrepreneurship attitude: the variables of the 'creative city' (e.g. young people's level of education; the quality of urban research institutions) drive new entrepreneurship development; multi-culturalism and the presence of cultural facilities are less correlated to the ENT profile.

Moreover, the outcomes show the relevant role of public policies, that is, the implementation of interventions and measures aimed at developing a UIS perspective in shaping entrepreneurship. The most important measures are connected to the creation of public/private funds aimed at supporting entrepreneurship. Therefore, the level of entrepreneurship results from a 'good' social environment and effective policies to create an urban-level innovation system.

Three different clusters of the sampled EU cities emerged from an evaluation of the regional distribution of the urban knowledge-based attitudes and the entrepreneurship attitudes. Regarding KBCDE, Cluster 1 comprising 11 cities is particularly interesting; London, which belongs to this cluster and is ranked higher than all the EU cities as a knowledge city, recently implemented public policies making its government activities more coherent—even if the presence of built-in assets factors are relevant. Thus, the city is oriented towards the implementation of tailor-made public policies aimed at enhancing its role as a centre of advanced services and a destination for tourism/cultural consumption, 'ensuring London sustains its success as the UK's only global city' (Turok, 2008). The city of Stockholm is implementing a knowledge city strategy, supported by a significant portion of its budget. In particular, strategic actions focus on developing high-tech businesses, attracting a highly educated and skilled workforce and providing a higher quality of life.

Some of these cities have implemented explicit policies to earn this 'status'; policies aim to enhance their competitiveness and that of the national system in which they are located, as well as to achieve harmonious development with neighbouring areas. Cities use different tools to remain competitive, for example, strategic planning, marketing strategies, and city branding.

Cities of the first cluster are mainly located in Northern Europe; policies to enhance the quality of social, economic, environment-sustainability, and supportive interventions for new firms have stimulated the creation of a knowledge-based context in that region. The first KBCDE cluster mainly corresponds to the ENT cluster, confirming the direct relationship between the urban-level knowledge-based attitude and the development of new entrepreneurship at the urban level.

Our study explores the theme of entrepreneurship in the urban context and contributes to the debate on urban economic development and entrepreneurship by providing useful insights to academics and urban policymakers. In terms of theoretical implications, this paper helps stimulate the debate on the role of cities in promoting entrepreneurship, which currently is an under-investigated topic, especially at the European level. Following the 'knowledge city' approach, this paper contributes to identify key factors that help stimulate innovative activities at the urban level.

In terms of practical implications, the paper may help explain to policy makers/city managers the importance of a knowledge-based context and the most important drivers for the creation of an attractive entrepreneurial environment. First, a good 'social environment' helps attract and retain talent, as seen empirically in the positive association between a good social and educational environment and city-level entrepreneurship. Moreover, the creation of an innovation system at the urban level is also important. Finally, the analysis of Cluster 1 has demonstrated the relevance of the implementation of urban strategies aimed at earning the 'status' of knowledge city that helps stimulate entrepreneurship. In order to enhance urban competitiveness, policymakers/city managers need to use different tools (e.g. strategic

Table 2
ENT trends in KBCDE clusters.

Cluster KBCDE	ENT Index
KBCDE-Cluster 1	2,40
KBCDE-Cluster 2	1,90
KBCDE-Cluster 3	0,00

planning, marketing strategies, and city branding).

In particular, public policies bring the following value: (1) increased competitiveness, resulting in a positive impact on investment, jobs, inhabitants, visitors, and events; (2) higher returns on investment in real estate, infrastructure, and events; (3) coherent city development, as the physical, social, economic, and cultural aspects combine to deliver the brand promise; and (4) pride in the city as the inhabitants, businesses, and institutions experience a new sense of purpose and direction.

This study has some inherent limitations to be addressed by future research. First, the investigation is performed on EU cities alone; further studies are required to enlarge the sample of cities, include other urban areas, and enable a comparison with other relevant countries (e.g. emerging/advanced economies). Second, our analysis, based on cross sectional data, cannot capture any causality between KBUD and Entrepreneurship, leaving this issue for future research. In addition, the number of variables and attributes that refer to each dimension may be expanded, embodying additional perspectives that could reasonably contribute towards a better understanding of the determinants affecting the development of urban-level entrepreneurship.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Lara Penco Enrico Ivaldi Carolina Bruzzi Enrico Musso.

Appendix A

Table A1
Variables and sources used.

Dimensions	Variable	Source (year)
Economy and knowledge economy perspective (EKE)	Ease of doing business (time and cost associated with doing business (distance to frontier score))	World Bank (2016)
	Cost of office space (average rental cost or price of commercial property (€/m^2/year))	Cushman-Wakefield (2016)
	Online collaboration (number of GitHub users within the last 12 months)	Ghtorrent (2016)
	Research & development intensity (expenditure on R&D (PPS, in thousands))	Eurostat (2013)
	Labour costs (average salary for: software developers, web designers, web developers, business developers, content marketing managers, sales managers, customer support specialists (€/year))	Teleport (2016)
	Access to ICT employees (number of employees in ICT sector/working population)	Eurostat (2015)
	Access to support employees (number of employees in: legal and accounting activities, advertising and market research, office administration, office support and other business support activities/working population)	Eurostat (2014)
Environmental and infrastructural perspective (ENI)	Internet download/upload speed (broadband speed (MB/s))	Ookla (2016)
	Cost of broadband (fixed broadband subscription charge ($/month))	ITU (2015)
	Mobile internet download/upload speed (Speed of mobile internet (MB/s))	Ookla (2016)
	Standard of living (quality of life index score)	Numbeo (2016)
	Commute (average travel time and distance to work)	Numbeo (2016)
	Train connectivity (total population that can be reached within 3 h of train travelling)	DG Regio (2014)
	Airport connectivity (score based on number of flights from local airports)	Teleport (2016)
Social and talent-cultural perspective (STC)	Multicultural diversity (percentage of population that are foreign-born)	European Statistical System: CensusHub2 (2011)
	Quality of research institutions (number of research intuitions in top 200)	QS University Rankings (2016)
	Culture & recreation (average scores attributed to diverse cultural facilities)	Teleport (2016)
	Size of potential mobile-based market (number of active mobile-broadband subscriptions per 100 inhabitants)	ITU (2015)
	Access to graduates (percentage of population aged 25–64 with tertiary (levels 5–8) education attainment)	Eurostat (2015)
	English language skills (percentage of the city population who can communicate in English)	Eurobarometer (2012)
Urban innovation system perspective (UIS)	Availability of early-stage funding in PPP (amount of seed and startup funding raised (€ in thousands))	European Venture Capital Association (2014)
	Availability of late-stage funding in PPP (amount of later-stage funding raised (€ in thousands))	European Venture Capital Association (2014)
	Availability of BA funding in PPP (amount of business angel funding (€ in millions))	European Business Angels Network (2015)
	Availability of crowdfunding (amount pledged to successful campaigns through any models)	Crowdsurfer (2016)
	Public sector information (public sector information score)	ePSI Platform (2014)
	Networking and mentoring events (number of meetup events in the last year per capita)	Meetup.com (2016)
	Access to accelerators (number of accelerators per capita)	Gust (2016) Open Axel (2016) Seed DB (2016)
	Availability of early-stage assistance (number of business angels per capita)	European Business Angels Network (2015)
Entrepreneurship (ENT)	Absence of negative perception of entrepreneurship (Percentage of people who answered “broadly favourable” to the question: “What is your overall opinion about the following groups of people? Entrepreneurs (self-employed, business owners)”)	Eurobarometer (2013)
	History of highly successful digital companies (number of unicorns (billion-dollar startups))	GP Bullhound (2016) CB Insights (2016)
	New-business density (number of newly registered corporations per 1000 working-age people)	World Bank (2014)

Table A2
Clusters and indices.

Social and talent-cultural perspective (*STC*)		*Economy and context economy perspective* (*ECE*)		*Environmental and infrastructural perspective* (*ENI*)		*Urban innovation system perspective* (*UIS*)		Knowledge-Based City Developing Entrepreneurship (**KBCDE**)		Entrepreneurship **(ENT)**	
London	16.80	Copenhagen	15.06	Oxford	14.59	London	6.05	*London*	*9.96*	*London*	*8.22*
Stockholm	13.80	Stockholm	15.05	Eindhoven	14.04	Berlin	5.82	*Stockholm*	*8.65*	*Helsinki*	*7.75*
Paris	13.65	Oxford	14.60	Bucharest	13.99	Paris	5.71	*Paris*	*8.51*	*Luxembourg*	*7.59*
Copenhagen	12.69	Bratislava	13.29	Utrecht	13.77	Amsterdam	5.40	*Amsterdam*	*7.65*	*Edinburgh*	*7.53*
Dublin	12.34	Helsinki	13.18	Amsterdam	13.46	Stockholm	4.52	*Copenhagen*	*7.57*	*Stockholm*	*7.30*
Helsinki	12.25	Munich	13.14	Riga	13.42	Dublin	4.09	*Helsinki*	*7.41*	*Copenhagen*	*6.92*
Amsterdam	11.22	Cambridge	12.65	Birmingham	13.08	Munich	4.04	*Oxford*	*7.28*	*Dublin*	*6.66*
Oxford	10.78	Hamburg	12.43	The Hague	12.98	Helsinki	3.89	*Berlin*	*6.81*	*Tallinn*	*6.51*
Edinburgh	10.64	Berlin	12.29	Paris	12.73	Hamburg	2.99	*Dublin*	*6.61*	*Bristol*	*5.96*
Brussels	10.41	Lisbon	12.25	Lille	12.36	Vienna	2.95	*Munich*	*6.58*	*Berlin*	*5.87*
Vienna	10.36	London	12.09	Luxembourg	12.08	Barcelona	2.74	*Vienna*	*6.23*	*Aarhus*	*5.59*
Gothenburg	10.11	Madrid	12.03	Vienna	12.02	Madrid	2.65	*Brussels*	*5.62*	*Valletta*	*5.50*
Berlin	10.01	Karlsruhe	11.87	Vilnius	11.98	Copenhagen	2.61	*Edinburgh*	*5.54*	*Bordeaux*	*5.34*
Munich	9.99	Stuttgart	11.32	Malmo	11.97	Lisbon	2.48	*Utrecht*	*5.46*	*Manchester*	*5.10*
Bristol	9.78	Bristol	11.17	Cambridge	11.67	Budapest	2.32	*Cambridge*	*5.46*	*Lille*	*4.84*
Manchester	9.75	Cologne	11.15	Aarhus	11.55	Frankfurt	1.96	*Bristol*	*5.36*	*Paris*	*4.83*
Birmingham	9.67	Bucharest	11.11	London	11.51	Brussels	1.87	*Madrid*	*5.23*	*Birmingham*	*4.80*
Glasgow	9.49	Sofia	11.06	Brussels	11.47	Cologne	1.87	*Manchester*	*5.09*	*Amsterdam*	*4.74*
Luxembourg	9.34	Prague	10.88	Manchester	11.36	Cambridge	1.80	*Birmingham*	*4.89*	*Cardiff*	*4.63*
Utrecht	9.29	Dublin	10.79	Lyon	11.27	Lyon	1.71	*Malmo*	*4.78*	*Utrecht*	*4.56*
Cardiff	9.25	Uppsala	10.68	Edinburgh	11.25	Manchester	1.68	*Uppsala*	*4.74*	*Oxford*	*4.49*
Malmo	9.11	Ljubljana	10.62	Bratislava	11.18	Bristol	1.45	*Tallinn*	*4.70*	*Toulouse*	*4.48*
Uppsala	9.03	Vienna	10.55	Uppsala	11.17	Tallinn	1.42	*Hamburg*	*4.69*	*Cambridge*	*4.43*
Aarhus	8.66	Edinburgh	10.49	Tallinn	10.78	Toulouse	1.37	*Eindhoven*	*4.58*	*Glasgow*	*4.30*
Tallinn	8.49	Tallinn	10.39	Bordeaux	10.78	Birmingham	1.30	*Aarhus*	*4.49*	*Nicosia*	*4.26*
Barcelona	8.40	Budapest	10.27	Bristol	10.77	Oxford	1.29	*Barcelona*	*4.47*	*Madrid*	*4.07*
Cambridge	8.22	Paris	10.27	Budapest	10.56	Edinburgh	1.21	*The Hague*	*4.40*	*Uppsala*	*4.07*
Madrid	8.20	Amsterdam	10.20	Cardiff	10.35	Eindhoven	1.19	*Gothenburg*	*4.27*	*Barcelona*	*4.06*
Nicosia	8.14	Utrecht	10.12	Prague	10.08	Lille	1.18	*Cardiff*	*4.24*	*Athens*	*3.94*
The Hague	7.90	Frankfurt	10.08	Dusseldorf	10.01	Valencia	1.15	*Frankfurt*	*4.23*	*Bucharest*	*3.88*
Hamburg	7.72	Brussels	10.00	Frankfurt	9.90	Utrecht	1.15	*Riga*	*4.18*	*Eindhoven*	*3.69*
Eindhoven	7.71	Warsaw	9.82	Copenhagen	9.89	Bordeaux	1.14	*Lisbon*	*4.16*	*The Hague*	*3.66*
Karlsruhe	7.44	Riga	9.45	Madrid	9.87	The Hague	1.13	*Bucharest*	*4.11*	*Malmo*	*3.66*
Frankfurt	7.37	Malmo	9.44	Valencia	9.83	Dusseldorf	1.07	*Bratislava*	*4.05*	*Valencia*	*3.62*
Lyon	7.22	Aarhus	9.39	Stockholm	9.81	Warsaw	1.07	*Luxembourg*	*4.03*	*Riga*	*3.61*

Riga	7.08	Gothenburg	9.25	Helsinki	9.78	Vilnius	1.01	*Cologne*	*4.00*	*Milan*	*3.58*
Stuttgart	7.07	Toulouse	9.19	Barcelona	9.69	Milan	1.01	*Lyon*	*3.89*	*Stuttgart*	*3.49*
Vilnius	6.95	Krakow	9.19	Toulouse	9.61	Karlsruhe	1.00	*Glasgow*	*3.86*	*Sofia*	*3.48*
Athens	6.61	Manchester	9.18	Munich	9.59	Gothenburg	0.98	*Vilnius*	*3.84*	*Munich*	*3.31*
Cologne	6.34	Rome	8.80	Cologne	9.56	Krakow	0.95	*Karlsruhe*	*3.76*	*Turin*	*3.17*
Ljubljana	6.02	Vilnius	8.69	Lisbon	9.47	Malmo	0.94	*Budapest*	*3.65*	*Vilnius*	*3.12*
Prague	5.95	Dresden	8.54	Warsaw	9.18	Glasgow	0.93	*Stuttgart*	*3.54*	*Lyon*	*3.11*
Dusseldorf	5.89	Eindhoven	8.52	Milan	8.95	Cardiff	0.91	*Prague*	*3.47*	*Rome*	*3.11*
Valencia	5.89	Barcelona	8.50	Glasgow	8.89	Aarhus	0.86	*Toulouse*	*3.18*	*Frankfurt*	*3.10*
Toulouse	5.83	The Hague	8.49	Berlin	8.51	Ljubljana	0.85	*Sofia*	*3.02*	*Cologne*	*2.89*
Milan	5.76	Cardiff	8.42	Sofia	8.24	Stuttgart	0.78	*Dusseldorf*	*2.97*	*Dusseldorf*	*2.89*
Sofia	5.75	Dusseldorf	8.30	Dublin	8.16	Bratislava	0.77	*Warsaw*	*2.96*	*Lisbon*	*2.72*
Lisbon	5.53	Lyon	8.03	Valletta	8.03	Luxembourg	0.70	*Ljubljana*	*2.86*	*Warsaw*	*2.64*
Bucharest	5.43	Zagreb	7.85	Krakow	7.97	Prague	0.68	*Bordeaux*	*2.67*	*Brussels*	*2.62*
Warsaw	5.37	Glasgow	7.68	Gothenburg	7.95	Dresden	0.68	*Milan*	*2.45*	*Prague*	*2.57*
Bratislava	5.28	Athens	7.51	Zagreb	7.85	Rome	0.63	*Valencia*	*2.41*	*Dresden*	*2.53*
Bordeaux	5.27	Birmingham	7.47	Stuttgart	7.79	Sofia	0.57	*Lille*	*2.35*	*Gothenburg*	*2.45*
Rome	5.24	Turin	7.38	Athens	7.39	Uppsala	0.57	*Athens*	*2.26*	*Karlsruhe*	*2.38*
Zagreb	5.21	Milan	7.33	Karlsruhe	7.22	Bucharest	0.53	*Nicosia*	*2.05*	*Hamburg*	*2.34*
Budapest	4.94	Bordeaux	7.16	Hamburg	7.10	Nicosia	0.52	*Rome*	*2.03*	*Zagreb*	*2.08*
Dresden	4.77	Lille	6.44	Ljubljana	7.05	Riga	0.50	*Zagreb*	*1.90*	*Vienna*	*2.05*
Valletta	4.57	Nicosia	6.27	Rome	6.85	Turin	0.45	*Krakow*	*1.82*	*Krakow*	*1.95*
Lille	3.93	Luxembourg	6.11	Dresden	6.35	Athens	0.40	*Dresden*	*1.71*	*Bratislava*	*1.61*
Turin	3.74	Valencia	5.93	Turin	6.27	Zagreb	0.33	*Valletta*	*1.06*	*Ljubljana*	*1.54*
Krakow	3.47	Valletta	5.42	Nicosia	4.90	Valletta	0.13	*Turin*	*0.96*	*Budapest*	*0.65*

Legend:

CLUSTER 1	
CLUSTER 2	
CLUSTER 3	

Italics is used for KBCDE and ENT.

Table A3
Correlation matrices.

Table A3.1 STC

		Correlations						
		ENT	STC multicultural diversity (% of population)	STC educational level - graduates (% of population)	STC English language skills (% of population)	STC quality of research institutions	STC size of potential mobile market	STC culture & recreation
ENT	Pearson correlation	1	0.264*	0.507**	0.435**	0.466**	0.551**	−0.003
	Sig. (2-tailed)		0.042	0.000	0.001	0.000	0.000	0.985
STC multicultural diversity	Pearson correlation	0.264*	1	0.221	0.152	0.320*	0.058	0.067
	Sig. (2-tailed)	0.042		0.090	0.245	0.013	0.659	0.609
STC educational level - graduates	Pearson correlation	0.507**	0.221	1	0.439**	0.458**	0.354**	0.190
	Sig. (2-tailed)	0.000	0.090		0.000	0.000	0.005	0.146
STC English language skills	Pearson correlation	0.435**	0.152	0.439**	1	0.384**	0.335**	−0.308*
	Sig. (2-tailed)	0.001	0.245	0.000		0.002	0.009	0.017
STC quality of research institutions	Pearson correlation	0.466**	0.320*	0.458**	0.384**	1	0.278*	0.318*
	Sig. (2-tailed)	0.000	0.013	0.000	0.002		0.031	0.013
STC size of potential mobile market	Pearson correlation	0.551**	0.058	0.354**	0.335**	0.278*	1	−0.227
	Sig. (2-tailed)	0.000	0.659	0.005	0.009	0.031		0.081
STC culture & recreation	Pearson correlation	−0.003	0.067	0.190	−0.308*	0.318*	−0.227	1
	Sig. (2-tailed)	0.985	0.609	0.146	0.017	0.013	0.081	

Table A3.2 EKE

		Correlations							
		ENT	EKE online collaboration (per capita)	EKE labour costs (€)	EKE access to ICT employees (per working population)	EKE access to support employees (per working population)	EKE ease of doing business	EKE cost of office space (€/m^2/year)	EKE research & development intensity (GERD: per capita)
ENT	Pearson correlation	1	0.365**	−0.393**	0.187	−0.061	0.259*	−0.564**	0.079
	Sig. (2-tailed)		0.004	0.002	0.153	0.641	0.045	0.000	0.547
EKE online collaboration	Pearson correlation	0.365**	1	−0.293*	0.314*	−0.149	0.509**	−0.361**	0.297*
	Sig. (2-tailed)	0.004		0.023	0.015	0.257	0.000	0.005	0.021
EKE labour costs	Pearson correlation	−0.393**	−0.293*	1	−0.032	−0.022	−0.469**	0.424**	−0.656**
	Sig. (2-tailed)	0.002	0.023		0.810	0.865	0.000	0.001	0.000
EKE access to ICT employees	Pearson correlation	0.187	0.314*	−0.032	1	0.481**	0.071	−0.313*	0.355**
	Sig. (2-tailed)	0.153	0.015	0.810		0.000	0.591	0.015	0.005
EKE access to support employees	Pearson correlation	−0.061	−0.149	−0.022	0.481**	1	−0.155	−0.250	0.033
	Sig. (2-tailed)	0.641	0.257	0.865	0.000		0.238	0.054	0.802
EKE ease of doing business	Pearson correlation	0.259*	0.509**	−0.469**	0.071	−0.155	1	−0.327*	0.369**
	Sig. (2-tailed)	0.045	0.000	0.000	0.591	0.238		0.011	0.004
EKE cost of office space	Pearson correlation	−0.564**	−0.361**	0.424**	−0.313*	−0.250	−0.327*	1	−0.186
	Sig. (2-tailed)	0.000	0.005	0.001	0.015	0.054	0.011		0.155

(*continued on next page*)

Table A3 (*continued*)

Table A3.2 EKE

		Correlations							
		ENT	EKE online collaboration (per capita)	EKE labour costs (€)	EKE access to ICT employees (per working population)	EKE access to support employees (per working population)	EKE ease of doing business	EKE cost of office space (€/m^2/year)	EKE research & development intensity (GERD: per capita)
EKE research & development intensity	Pearson correlation	0.079	0.297*	−0.656**	0.355**	0.033	0.369**	−0.186	1
	Sig. (2-tailed)	0.547	0.021	0.000	0.005	0.802	0.004	0.155	

Table A3.3 ENI

		Correlations							
		ENT	ENI Internet download/upload speed (MBps)	ENI cost of broadband ($)	ENI mobile Internet download/upload speed (MBps)	ENI standard of living	ENI commute	ENI train connectivity	ENI airport connectivity
ENT	Pearson correlation	1	0.198	−0.082	0.075	0.141	0.081	0.114	0.116
	Sig. (2-tailed)		0.129	0.535	0.570	0.282	0.540	0.386	0.378
ENI Internet download/upload speed	Pearson correlation	0.198	1	−0.032	0.457**	−0.030	0.239	−0.197	−0.026
	Sig. (2-tailed)	0.129		0.808	0.000	0.821	0.066	0.131	0.846
ENI cost of broadband	Pearson correlation	−0.082	−0.032	1	−0.120	−0.350**	0.113	0.071	−0.222
	Sig. (2-tailed)	0.535	0.808		0.362	0.006	0.388	0.589	0.089
ENI mobile Internet download/upload speed	Pearson correlation	0.075	0.457**	−0.120	1	0.056	0.082	0.015	0.034
	Sig. (2-tailed)	0.570	0.000	0.362		0.672	0.533	0.912	0.798
ENI standard of living	Pearson correlation	0.141	−0.030	−0.350**	0.056	1	−0.182	−0.013	−0.004
	Sig. (2-tailed)	0.282	0.821	0.006	0.672		0.164	0.919	0.976
ENI commute	Pearson correlation	0.081	0.239	0.113	0.082	−0.182	1	−0.183	−0.280*
	Sig. (2-tailed)	0.540	0.066	0.388	0.533	0.164		0.162	0.030
ENI train connectivity	Pearson correlation	0.114	−0.197	0.071	0.015	−0.013	−0.183	1	0.513**
	Sig. (2-tailed)	0.386	0.131	0.589	0.912	0.919	0.162		0.000
ENI airport connectivity	Pearson correlation	0.116	−0.026	−0.222	0.034	−0.004	−0.280*	0.513**	1
	Sig. (2-tailed)	0.378	0.846	0.089	0.798	0.976	0.030	0.000	

Table A3.4 UIS

		Correlations								
		ENT	UIS availability of early-stage funding	UIS availability of late-stage funding	UIS availability of BA investment	UIS availability of crowdfunding	UIS networking and mentoring events (per capita)	UIS access to accelerators (per capita)	UIS availability of early-stage assistance (per capita)	UIS public sector information
ENT	Pearson correlation	1	0.307*	0.296*	0.340**	0.420**	0.183	0.073	0.555**	0.288*
	Sig. (2-tailed)		0.017	0.022	0.008	0.001	0.161	0.578	0.000	0.026
UIS availability of early-stage funding	Pearson correlation	0.307*	1	0.933**	0.745**	0.729**	0.553**	0.252	0.185	0.104
	Sig. (2-tailed)	0.017		0.000	0.000	0.000	0.000	0.052	0.158	0.428
UIS availability of late-stage funding	Pearson correlation	0.296*	0.933**	1	0.718**	0.729**	0.538**	0.204	0.192	0.166
	Sig. (2-tailed)	0.022	0.000		0.000	0.000	0.000	0.118	0.141	0.206
		0.340**	0.745**	0.718**	1	0.644**	0.302*	0.408**	0.181	0.133

(*continued on next page*)

Table A3 (*continued*)

Table A3.4 UIS

		Correlations								
		ENT	UIS availability of early-stage funding	UIS availability of late-stage funding	UIS availability of BA investment	UIS availability of crowdfunding	UIS networking and mentoring events (per capita)	UIS access to accelerators (per capita)	UIS availability of early-stage assistance (per capita)	UIS public sector information
UIS availability of BA investment	Pearson correlation									
	Sig. (2-tailed)	0.008	0.000	0.000		0.000	0.019	0.001	0.166	0.311
UIS availability of crowdfunding	Pearson correlation	0.420**	0.729**	0.729**	0.644**	1	0.422**	0.236	0.192	0.247
	Sig. (2-tailed)	0.001	0.000	0.000	0.000		0.001	0.070	0.142	0.057
UIS networking and mentoring events	Pearson correlation	0.183	0.553**	0.538**	0.302*	0.422**	1	0.285*	0.224	0.185
	Sig. (2-tailed)	0.161	0.000	0.000	0.019	0.001		0.027	0.085	0.157
UIS access to accelerators	Pearson correlation	0.073	0.252	0.204	0.408**	0.236	0.285*	1	0.185	0.079
	Sig. (2-tailed)	0.578	0.052	0.118	0.001	0.070	0.027		0.158	0.547
UIS availability of early-stage assistance	Pearson correlation	0.555**	0.185	0.192	0.181	0.192	0.224	0.185	1	0.266*
	Sig. (2-tailed)	0.000	0.158	0.141	0.166	0.142	0.085	0.158		0.040
UIS public sector information	Pearson correlation	0.288*	0.104	0.166	0.133	0.247	0.185	0.079	0.266*	1
	Sig. (2-tailed)	0.026	0.428	0.206	0.311	0.057	0.157	0.547	0.040	

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

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