IRIS Utrecht presenteert:

Smart City Start-ups and Entrepreneurial Ecosystems

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Achtergrond/context van het rapport of product:
Vanwege urbanisatie en de druk op de kwaliteit van leven in steden die daarbij komt kijken, is het relevant om te weten hoe smart city-initiatieven gestimuleerd kunnen worden. Deze masterthesis bekijkt smart city startups vanuit het perspectief van *entrepreneurial ecosystems*.

Kernvraag:
Hoe dragen elementen van het *entrepreneurial ecosystem* bij aan de aanwezigheid van smart city startups, en wat betekent dit voor ecosystemen waarin meer smart city innovatie gewenst wordt?

Samenvatting/opbrengst:
In deze thesis zijn 273 NUTS 2 regio's geanalyseerd, met een totaal van 133 smart city startups verspreid over Europa. De analyse van de data laat zien dat de meeste elementen van het *entrepreneurial ecosystem* niet individueel gerelateerd zijn aan de aanwezigheid van smart city startups. Een uitzondering vormen de elementen "talent", dat een negatief effect heeft, en "ondersteunende diensten", die een positief effect hebben. Het effect van ondersteunende diensten is groter voor smart city startups dan voor startups in het algemeen. Dit betekent dat voor ecosystemen waarin meer smart city startups gewenst zijn, het raadzaam is om ondersteunende diensten te ontwikkelen.

Tags:
Smart Cities, Entrepreneurial Ecosystems, Europe, Startups

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Abstract

Over the last years, there has been increasing scholarly consideration to entrepreneurial ecosystems and smart cities, yet they have barely been looked at in combination. This thesis fills that gap in literature by examining how individual entrepreneurial ecosystem elements are related to smart city start-up presence and explores what this implies for ecosystems in which more smart city entrepreneurship is desired. I analyse start-up data from CrunchBase and Leendertse et al.'s (2020) dataset on entrepreneurial ecosystem elements for European NUTS 2 regions for the period 2015-2019. The results show that most ecosystem elements do not have individual effects on smart city start-up presence. Talent has a small negative effect on smart city entrepreneurship. Support services, however, are positively associated with smart city start-up presence, and the positive effect of support services is larger for smart city entrepreneurship than for non-smart city specific entrepreneurship. This implies that developing support services may stimulate smart city entrepreneurship.

1. Introduction

As the world's population is increasingly living in urban areas, pressure on the quality of urban life is mounting. Traffic gets jammed as urban transportation reaches its capacity limits, air quality deteriorates as a result of increased emissions of pollutants, and waste management systems become overburdened (Chourabi et al., 2012). Furthermore, the higher population density leads to increased strains on cities' natural resources, calling for solutions that address these problems and improve the quality of urban life, both environmentally as well as socially and economically (Manville et al., 2014). This goal of enhancing the living and working environment in cities is addressed by the so-called "smart city" (Hall et al., 2000). To achieve a smart city, there is a need for innovation, in which there is a role for entrepreneurs to play. This paper will look at smart city entrepreneurship from an entrepreneurial ecosystem perspective with the aim of identifying the ecosystem elements that are most important for the presence of smart city start-ups.

Academic involvement in the study of smart cities has emerged only recently, and the scholarly debate surrounding the topic is currently characterised by the coexistence of a variety of smart city definitions (Albino et al., 2015; Sarma & Sunny, 2017; Nilssen, 2019). Despite the multitude of definitions of the concept, smart cities are often understood to contribute to improving the quality of life in urban areas by means of deploying technology, with a special focus on information and communications technology (ICT) (De Jong et al., 2015; Harrison et al., 2010; Caragliu & Nijkamp, 2011; Hermse, Nijland & Picari, 2020). Entrepreneurial ecosystems constitute a relatively new field of academic interest as well, accompanied too by a lack of uniformity regarding the definition of the concept. This paper will use Stam's (2015, p. 1765) definition of the entrepreneurial ecosystem as "a set of interdependent actors and factors coordinated in such a way that they enable productive entrepreneurship". Entrepreneurial ecosystems are inherently geographically bounded systems within an entrepreneurial community (Cohen, 2006; Audretsch et al., 2019), although they may exist at multiple levels and may differ per firm. Entrepreneurial ecosystems are considered to consist of several factors that enable entrepreneurship, such as formal institutions, culture, physical infrastructure, demand, networks, leadership, finance, talent, knowledge, and support services (Stam, 2015; 2018).

To date, the paths of smart city and entrepreneurial ecosystems literature have barely crossed (Ooms et al., 2020). Given the current pressure on the quality of urban life, there is a need for innovation in the field of smart cities, which entrepreneurs can contribute to. This goes for start-ups in particular, as literature has argued that smaller firms are better positioned to pursue more radical innovations than larger and more established ones (Schaltegger & Wagner, 2011). Therefore, it is relevant to develop a better understanding of how entrepreneurial ecosystem elements are related to smart city start-up presence. This paper aims to answer the following research question: How do entrepreneurial ecosystem elements contribute to the presence of smart city start-ups, and what does this imply for ecosystems in which more smart city innovation is desired? This question bridges the gap between the smart city and entrepreneurial ecosystems literature by looking at how smart city entrepreneurship can be strengthened from an entrepreneurial ecosystem perspective. Knowing about which ecosystem factors stimulate smart city entrepreneurship offers policy opportunities for the development of specific entrepreneurial ecosystem elements. This provides a steppingstone for stimulating smart city entrepreneurship.

The importance of entrepreneurial ecosystem factors for smart city innovation is examined by assessing the data gathered by Leendertse et al. (2020), which includes information on a variety of entrepreneurial ecosystem factors for all European Union member states, as well as the United Kingdom, on a NUTS 2 level. The data analysis has an exploratory nature. As the relationship between entrepreneurial ecosystems and smart city entrepreneurship has not been studied before, this paper will examine each of the entrepreneurial ecosystem elements with regard to their effects on entrepreneurial activity, both in general and smart city specific. Then, the effects of each of the individual ecosystem elements can be compared between smart city-related and non-smart city-related firms. Such an analysis will yield insights into which ecosystem elements are particularly important in stimulating smart city entrepreneurial activity.

In this paper, I first consider and link the existing literature on entrepreneurial ecosystems and smart cities. Reviewing the literature will provide the theoretical starting point of this paper, as well as demonstrate current knowledge gaps with respect to the relationship between entrepreneurial ecosystems and smart cities. I will especially consider the current variety in definitions of entrepreneurial ecosystems and smart cities and look at the elements that constitute them. Then, I will examine both concepts in combination, that is, establish the overlap between both concepts as well as their differences. Thereby, this paper is positioned in both fields of research and adds to them by applying insights from both strands of literature to the relationship between smart city entrepreneurship and entrepreneurial ecosystems. Section 3 will take a closer look at the data for the European NUTS 2 regions, as well as at the operationalisation of the ecosystem elements. Next, section 4 will analyse and interpret the data by regressing start-up presence on entrepreneurial ecosystem elements. Thereby, I assess how the ecosystem elements are related to start-up presence and whether ecosystem elements are related to smart city start-ups differently than to non-smart city specific start-ups. Analysing Leendertse et al.'s (2020) and CrunchBase data, I find that most entrepreneurial ecosystem elements do not have an individual effect on smart city start-up presence. There are two ecosystem elements that are significantly related to smart city start-up presence, namely talent, which has a small negative effect, and support services, which is associated with smart city start-up presence positively. Furthermore, support services appear to have a larger positive effect on smart city start-up presence than on non-smart city specific entrepreneurial output. These results imply that for ecosystems in which more smart city entrepreneurship is desired, developing support services is advisable.

2. Theory

2.1. Entrepreneurial Ecosystems

Before looking at common definitions of entrepreneurial ecosystems, it is important to note that to this day, there has not been agreement on what exactly is an entrepreneurial ecosystem and what elements constitute it, nor on the approach to researching it (O'Connor et al., 2018). The main reason for this lack of clarity is the recent emergence of the field. The increase in scholarly attention to the topic has started about ten years ago, with discussions really starting to take off around five years ago (Stam, 2015; Audretsch & Belitski, 2017). The topic is receiving increasing consideration in academia, but there is still discussion on the definition of the entrepreneurial ecosystem (Daniel et al., 2018; Brown & Mason, 2017; Audretsch & Link, 2019).

Early work regarding the definition of entrepreneurial ecosystems is that of Van de Ven (1993) and Moore (1993). Moore (1993) was the first to use the word "ecosystem" in the context of business. While the concept originally stems from the biological discourse, he used the ecosystem perspective to draw attention to the role of the individual company not only within a single industry, but rather to the position of the firm as operating in an 'ecosystem' that is made up of a variety of industries. Van de Ven (1993) complements this view by moving away from concentrating solely on the characteristics of the individual firm. Instead, he argues that entrepreneurship is a collective rather than a purely individual achievement. Thus, both scholars put great emphasis on the context the individual firm is operating in. This attention to context constitutes one of the fundamental aspects of the entrepreneurial ecosystem.

The collective nature of the entrepreneurial ecosystem is widely acknowledged across literature. Daniel et al. (2018) refer to entrepreneurial ecosystems as a collective of various actors which are supported by institutional stakeholders. In fact, according to Audretsch et al. (2019), the entrepreneurial ecosystem derives its benefits from the notion that ecosystem agents are interrelated. They define the ecosystem as consisting of exogenously given components, the environment, and ecosystem agents which are interrelated, acting endogenously together as a system. Stam (2015, p. 1765) states that the entrepreneurial ecosystem is "a set of interdependent actors and factors coordinated in such a way that they enable productive entrepreneurship". Similarly, Spigel (2017) argues that entrepreneurial ecosystem elements support the development and growth of start-ups and stimulate taking on the risks of founding and assisting high-risk ventures, which can be regarded as the output of an entrepreneurial ecosystem. The collectiveness of the ecosystem means that apart from individual ecosystem element effects, as the elements work together, they also have joint and interacting effects.

Literature also argues that entrepreneurial ecosystems are inherently geographically bounded, in equivalence to the biological ecosystem (Audretsch et al., 2019). The local character of the entrepreneurial ecosystem has been discussed by Spigel (2017), Audretsch & Belitski (2017), and Audretsch & Link (2019), noting that geographical boundedness is a key feature in the entrepreneurial ecosystem concept. In his discussion of the entrepreneurial ecosystem concept, Cohen (2006) emphasizes that entrepreneurial ecosystem actors operate within a specific region. Brown & Mason (2017) note that geography and distance play a role in the entrepreneurial ecosystem, even if continuing globalisation and advancement in telecommunications may give rise to the belief that the importance of geography is declining. Given this focus on geographical boundedness in literature, I would like to note that entrepreneurial ecosystems are not separate entities, strictly isolated from other ecosystems. Rather, they can be embedded in and overlapping and each other (Bruns et al., 2017). For example, from a biological point of view, a tree may be an ecosystem overlapping with the forest ecosystem. Similarly, from an entrepreneurial perspective, there may be ecosystems on the city level, which are also embedded in a regional ecosystem. Consequently, from a conceptual standpoint, although the entrepreneurial ecosystem is geographically bounded, it does not have an absolute geographical size.

The fact that the entrepreneurial ecosystem does not have an absolute size is problematic from an empirical perspective when looking for the geographical level to apply to measuring ecosystems. Audretsch & Belitski (2017) approach this issue from the perspective of the entrepreneur, asking "[h]ow far geographically will an entrepreneur judge?" (p. 1034). Audretsch & Belitski (2017) regard the local level to be an appropriate ecosystem level as they consider it to be the level on which many entrepreneurial decisions are made. The level of entrepreneurial decision-making, however, rather depends on the type of entrepreneurship and is therefore not the same for each and every type of entrepreneurship. For example, the local bakery probably makes its entrepreneurial decisions on another geographical level than the entrepreneur who supplies IT services worldwide. This implies that for my analysis, it is not possible to set geographical boundaries for all start-ups in all places, given that the geographical reach of each firm may be different. I choose to use the NUTS 2 level, because most smart city start-ups have a local/regional focus and therefore, their entrepreneurial decisions are also likely taken on this level. Start-ups may not fully overlap with the NUTS 2 region they are assigned to, but on average the various ecosystem elements of a NUTS 2 region should be related to start-up presence. Not being able to fully capture the ecosystem size of each of the start-ups implies having a bias towards not finding any effects of ecosystem elements. For the analysis, this means the results I find are conservative, and that I may miss causal links because of this conservatism.

In order to avoid any confusion about the concept of the entrepreneurial ecosystem, it may be convenient to make an explicit distinction between entrepreneurial ecosystems and related concepts here. For example, the "business ecosystem" or "innovation ecosystem" focuses on a single industry or value chain, instead of the variety of businesses within a specific geographic region that the entrepreneurial ecosystem is concerned with (O'Connor et al., 2018). Besides that, the entrepreneurial ecosystem approach differs from established concepts such as "clusters" or "industrial districts" in that it views entrepreneurs instead of enterprises as the focal point (Stam, 2015).

The question now arises which elements the entrepreneurial ecosystem is composed of. Although the number of elements stated in literature varies widely, many elements mentioned are actually conceptionally overlapping. Isenberg (2010) notes that such elements are able to support entrepreneurship individually yet are not sufficient to sustain it when taken in isolation. However, he argues that when these elements are combined, they will stimulate new venture development and growth. More specifically, Audretsch & Belitski (2017) identify culture and norms as an element of the entrepreneurial ecosystem, just as physical infrastructure, formal institutions, and internet and IT services. Besides that, Fuentelsaz & Mata (2018) draw attention to the role of leadership, culture, capital markets, and open-minded consumers within the ecosystem. Nicotra et al. (2018) use broader element classifications. They argue that there are four factors that are supportive of entrepreneurial ecosystem output: financial capital, knowledge capital, institutional capital, and social capital. For financial capital, Nictora et al. (2018) propose a number of proxies, such as venture capital availability, access to debt, and angel investor availability, whereas knowledge capital includes factors such as entrepreneurship education and the local presence and quality of research universities. Institutional capital comprises both public and private institutions that support entrepreneurial activity, and social capital is mainly related to the cultural support of entrepreneurship and entrepreneurship networks. Spigel (2017) adopts categories that are more or less similar, distinguishing between economic, social, political, and cultural ecosystem elements. He includes variables such as cultural attitudes, social networks, worker talents, governance, investment capital, and universities. The importance of universities as elements of the entrepreneurial ecosystem is also highlighted by Malecki (2018), mentioning that universities have an important function in providing highly specialised and skilled talent. A more elaborate model stems from Cohen (2006), who describes eleven entrepreneurial ecosystem components, most of which apply to one of the aforementioned elements: both formal and informal networks, universities, governments, professional and support services, capital services, talent pools, large corporations, technology parks, physical infrastructure, and culture. Another extensive model of ecosystem elements, finally, is provided by Stam (2015; 2018), in which elements from both the less extensive models and the more extensive models as discussed above are integrated. His model includes ten entrepreneurial ecosystem elements: formal institutions, culture, physical infrastructure, demand, networks, leadership, finance, talent, knowledge, and support services. In this paper, Stam's (2015) model is used as it unites several ecosystem elements mentioned in literature. The individual ecosystem elements will be elaborated upon in more detail in section 3.2.

2.2. Smart Cities

Confusion about the definition of smart cities remains (Albino et al., 2015). This is in part due to the use of the word “smart” as a buzzword, complicating the clarification of what the smart city is (Angelidou, 2014). Sarma & Sunny (2017) label the present state of the definition development as pre-paradigmatic, which implies that there currently is a number of definitions that are coexisting, and that a final definition has yet to be agreed upon.

Despite the unclarity surrounding the definition of the smart city, however, some widely shared understandings of several aspects that make up the smart city can be derived from literature. First of all, there is strong consensus on the aims of the smart city. Currently, more than half of the world population lives in urban areas (Chourabi et al., 2012), and this share will continue to grow (Manville et al., 2014). As a result of the global urbanisation trend, cities are confronted with a range of challenges. In the light of both climate change and the problems encountered because of urbanisation, governments are planning to organise their cities in both more sustainable and smarter ways (Lee et al., 2014).

Most smart city definitions share a focus on improving the quality of life in urban areas by means of deploying technology, with a special emphasis on information and communications technology (ICT) (De Jong et al., 2015; Harrison et al., 2010; Caragliu & Nijkamp, 2011; Lazariou & Roscia, 2012; Manville et al., 2014). Examples for the use of technology in the smart city are real-time feedback for improving traffic streams and controlling public transport, using sensors to enhance waste collection and recycling by looking at the amount and type of waste, and improving air quality by employing sensors which observe air polluting particles (Appio et al., 2019).

As has been criticised in literature, however, a city's smartness depends on more factors than technology alone, so that technology may not be the most crucial factor in defining what a smart city is (Nilssen, 2019; Hollands, 2008). Ferraris et al. (2018), Manville et al. (2014), Angelidou (2014), and Sarma & Sunny (2017) stress that technology acts in cooperation with human and social capital to achieve a higher quality of urban life. In classifying smart city initiatives, Hermse et al. (2020) find a focus on technology and cities to be necessary conditions for a start-up to be considered a smart city firm. Nevertheless, according to them, there are other factors than just technology that determine the degree of intensity of smart city initiatives, namely a focus on ICT, citizens, environmental sustainability, quality of life, and the economy. Technology is thus considered to be a means in developing a smart city, amongst other factors.

Just as was the case with the factors constituting the entrepreneurial ecosystem, scholars vary broadly in the number of factors they attribute to the smart city but often hold shared views on which factors are important in creating smart cities. Many of these factors can be attributed to one of the following three factor categories: technology, social capital, and human capital. Caragliu & Nijkamp (2011) identify both human and social capital, and an infrastructural category which spans transport and ICT. Manville et al. (2014) distinguish three core factors of the smart city that deviate slightly from the previous three, namely technology factors, human factors, and institutional factors. Angelidou (2014) makes a distinction between 'hard' and 'soft' infrastructure. Transport, waste processing and energy systems are part of hard infrastructure, and soft infrastructure is composed of knowledge, inclusion, and social equity. Caragliu & Del Bo (2019) adhere to the same distinction between 'hard' and 'soft' infrastructure. According to them, hard infrastructure includes elements such as a fast internet connection, while soft infrastructure includes elements like human capital or the quality of governance.

Leadership and governance are also considered to be of essential importance to the smart city (Nam & Pardo, 2011). The most extensive smart city model presented is that of Chourabi et al. (2012), which includes eight smart city factors. They place governance at the core of smart city initiatives, which includes not only leadership, but also elements such as communication, transparency, and collaboration. Apart from governance, management and organisation, technology, policy, people and communities, the economy, infrastructure, and the natural environment are factors assumed to be essential in understanding smart city projects. The need for leadership and coordination is also addressed by Angelidou (2017), who argues that in smart city initiatives, all the resources needed in realising smart cities represent a challenge in controlling them. This issue has also been discussed by Lee et al. (2014) and Kraus et al. (2015), who reason that centralised governance enhances the coordination and control of smart city initiatives, as well as unites resources and stakeholders. Nilssen (2019) too not only mentions ICT and human resources as a factor in smart city success, but also highlights the role of participatory governance in guiding smart city development.

As I have demonstrated above, views on the exact definition of the smart city somewhat diverge. Nevertheless, the connection between them is that smart cities apply technology in working towards a higher quality of life, albeit that technology is not the only factor in creating a smart city. There is a range of other factors that are considered to stimulate smart city creation. In my analysis, I will examine the contributions of such factors to smart city start-up presence from an entrepreneurial ecosystem perspective, that is, I will look at how entrepreneurial ecosystem elements are associated with smart city start-up presence.

2.3. Combining Entrepreneurial Ecosystems and Smart Cities

So far, the strings of literature that are concerned with either entrepreneurial ecosystems or smart cities have barely interacted (Ooms et al., 2020). The following section aims at contributing to both fields of literature by looking at them in combination. It combines the insights from the literature on smart cities and entrepreneurial ecosystems by comparing both concepts and establishing their similarities and differences. In doing so, we finally identify a number of entrepreneurial ecosystem elements that may be relevant for smart city entrepreneurship. I will examine them more elaborately in the empirical analysis in section 3.

Entrepreneurial ecosystems are understood to be a set of interdependent actors and factors coordinated in such a way that they enable productive entrepreneurship (Stam, 2015, p. 1765). In looking at the elements that constitute the entrepreneurial ecosystem, I adopt the factors proposed by Stam (2015; 2018), as they reflect both the elements most often mentioned in literature, as well as cover the variety of factors mentioned literature-wide. These ecosystem elements include formal institutions, culture, physical infrastructure, demand, networks, leadership, finance, talent, knowledge, and support services. As regards smart cities, there is not yet a final smart city definition, although in literature overlapping perceptions of the smart city can be found. A widely shared view of the goal of smart cities is to improve living and working conditions by being a safe, environmentally green, and efficient living and working area (Hall et al., 2000). Technology is understood to play a major role in achieving these goals (Appio et al., 2019; Manville et al., 2014).

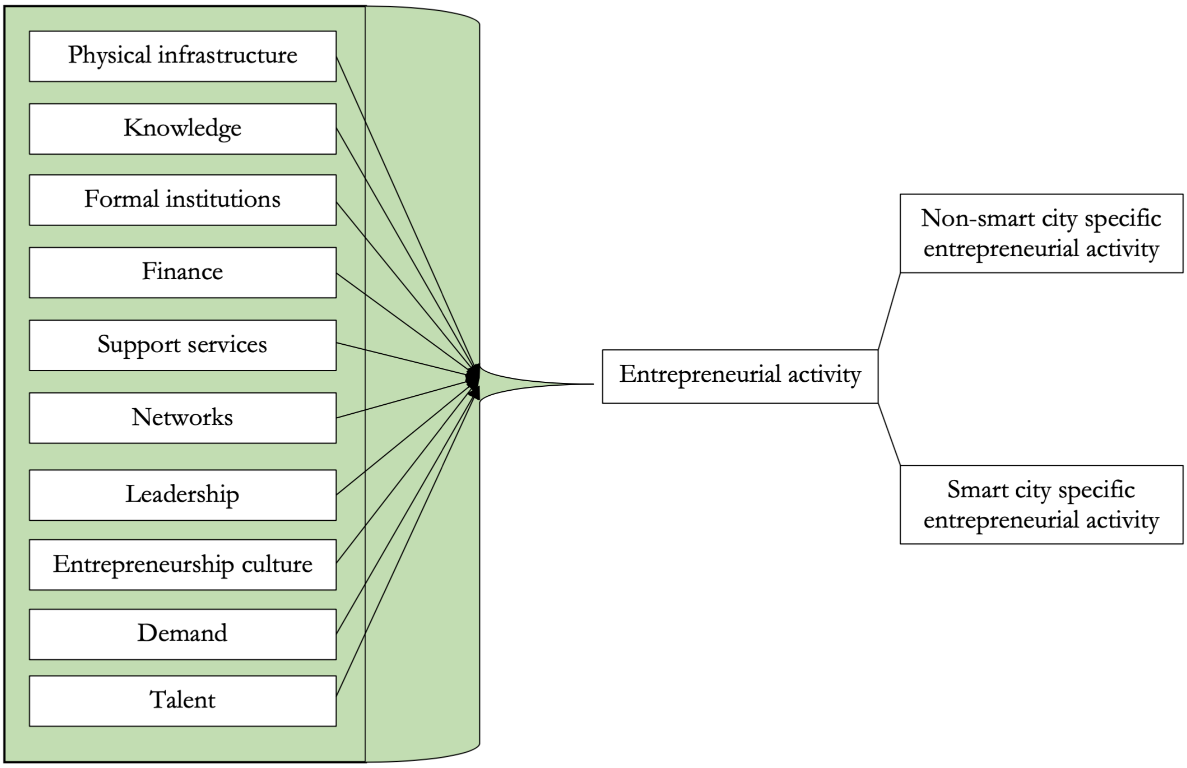
There is an overlap between the smart city and the entrepreneurial ecosystem concept. The entrepreneurial ecosystem has various elements acting together to produce entrepreneurial output. In the same way, for smart city innovations, multiple factors are important in stimulating smart city projects. In both cases, governance has a coordinating role and is important in stimulating entrepreneurial activity. However, not all smart city innovations have an entrepreneurial nature, and similarly, not all output of the entrepreneurial ecosystem is smart city related. Both concepts overlap where the entrepreneurial ecosystem produces entrepreneurial smart city output. In this thesis, I therefore leave non-entrepreneurial smart city initiatives out of consideration as they are no output of the entrepreneurial ecosystem, and instead compare entrepreneurship that is smart city focused to entrepreneurship that does not have a smart city focus.

As I noted above, smart cities aim at improving the quality of urban life through the use of technology, so that the focus is on the urban resident. Entrepreneurial ecosystems, however, enable entrepreneurship in general, and are thus not specifically concerned with smart city entrepreneurship. The entrepreneurial ecosystem approach focuses on the entrepreneur rather than the urban citizen (Stam, 2015).

Figure 1 shows a visualisation of how ecosystem elements are related to entrepreneurship. The individual ecosystem elements are embedded in the ecosystem as a whole (represented by the green box). The ecosystem elements individually affect entrepreneurial activity, which is displayed by the black arrows. The green bracket represents the joint effect of the ecosystem elements on entrepreneurial activity. We can then distinguish between two types of entrepreneurial activity; smart city specific entrepreneurial activity and entrepreneurial activity that is non-smart city specific.

Figure 1

Entrepreneurial ecosystem elements and outcome



Note: Figure adapted from Stam (2015; p.1765).

Obviously, some degree of overlap exists between the factors that make up the entrepreneurial ecosystem and those factors that are considered critical for smart city entrepreneurship. The question is whether ecosystem factors that drive entrepreneurship in general also stimulate smart city entrepreneurship. First of all, the physical infrastructure present in an entrepreneurial ecosystem overlaps with the role of technology in the smart city (Manville et al., 2014; Nilssen, 2019; Caragliu & Nijkamp, 2011). This applies especially to the ICT infrastructure present in a specific region. Secondly, there is an overlap between the entrepreneurial ecosystem factors talent and knowledge on the one hand, and the importance of human capital for smart city innovation on the other (Caragliu & Del Bo, 2019; Nilssen, 2019). Finally, two factors present in the entrepreneurial ecosystem that match with smart cities are formal institutions and leadership, as both good governance and leadership quality are deemed important in smart city literature (Lee et al., 2014; Kraus et al., 2015; Nam & Pardo, 2011).

Since there is only limited theory to build hypotheses concerning the effects of the individual entrepreneurial ecosystem elements on, I will not hypothesize about the effects of the individual elements here. Rather, in the analysis I will look at whether the individual entrepreneurial ecosystem elements are stronger or weaker related to smart city start-up presence than on non-smart city specific start-up presence.

3. Empirical strategy

3.1. Data collection

In order to find out how ecosystem elements contribute to the presence of smart city innovation, data on the ten entrepreneurial ecosystem elements are needed, as well as on the output of entrepreneurial ecosystems, distinguishing between smart city-related and non-smart city-related new enterprises. This means non-entrepreneurial smart city innovation is not considered here, as non-entrepreneurial smart city innovation is not an output of the entrepreneurial ecosystem. The first point of interest is the level on which entrepreneurial ecosystems are measured. As Stam & Van de Ven (2019) note, the ecosystem boundaries chosen are always arbitrary and can range between municipality and the national level. The boundaries selected when measuring the entrepreneurial ecosystem are regarded as arbitrary because the individual ecosystem elements all have a different spatial reach, with some elements having a higher spatial reach than others (Leendertse et al., 2020). Therefore, a clear-cut spatial line to entrepreneurial ecosystems cannot be drawn. This implies that ecosystem boundaries may range even further than the national level, with nations constituting an ecosystem within a global ecosystem. Nevertheless, although spatial ecosystem boundaries may be arbitrary, in this analysis I do suppose that the development of ecosystem elements in a given place at a given time is linked to entrepreneurial output in that location and time. From a European view, looking at the geographical radius that best approaches a regional level, Leendertse et al. (2020) propose to conduct the analysis on a NUTS 2 level. NUTS 2 levels are recognised in all member states of the European Union[1] and are defined by population size, with a NUTS 2 area covering 800,000 to 3 million inhabitants, and are also established by existing administrative units within the European Union (European Commission, 2018). Although data on national levels is more abundant than on regional levels, there is a relatively large amount of data available for European Union regional levels (Leendertse et al, 2020).

[1] Throughout this text, the European Union (EU) includes all 27 nations that are members of the EU in 2020, as well as its departing member, the United Kingdom.

Table 1

Operationalisation of the indicators of entrepreneurial ecosystem elements and output

Entrepreneurial ecosystem element	Description	Indicator(s)	Data source
Formal institutions	The rules of the game in society	Two composite indicators measuring the overall quality of government (consisting of scores for corruption, impartiality, rule of law) and the regulatory framework for starting a business (consisting of number of days to start a business, difficulties encountered when starting up a business, the ease of doing business index, and the barriers to entrepreneurship)	Quality of Government Survey and Regional Ecosystem Scoreboard
Entrepreneurship culture	The degree to which entrepreneurship is valued in a region	Composite indicator measuring regional entrepreneurship culture, consisting of entrepreneurial motivation, cultural and social norms, the importance to be innovative and creative, and trust in others	Regional Ecosystem Scoreboard
Physical infrastructure	Transportation and digital infrastructure	There are four components for infrastructure: accessibility by road, accessibility by railway, the number of passenger flights, and the percentage of households with access to internet	Regional Competitiveness Index
Demand	Potential regional market demand	Three components that capture disposable income per capita, potential market size in GRP, and potential market size in population. All components are relative to the EU average.	Regional Competitiveness Index
Networks	The connectedness of businesses for new value creation	Number of SMEs with innovation cooperation projects as a percentage of all SMEs within a region	Regional Innovation Scoreboard
Leadership	The presence of actors taking on a leadership role in the ecosystem	The number of coordinators on Horizon 2020 innovation projects per 1000 inhabitants	CORDIS (Community Research and Development Information Service)
Finance	The availability of venture capital and bank loans to firms	Two components: availability of venture capital and the availability of bank loans for capital investments	Regional Ecosystem Scoreboard

Talent	The prevalence of individuals with high levels of human capital, both in terms of formal education and skills	Consists of eight components: tertiary education, vocational training, lifelong learning, innovative skills training, entrepreneurship education, technical skills, creative skills, e-skills	Regional Ecosystem Scoreboard
Knowledge	Investments in new knowledge	Intramural R&D expenditure as a percentage of GRP	Eurostat
Support services	The supply and accessibility of intermediate business services	Two components: the percentage of employment in knowledge-intensive market services and the percentage of incubators/accelerators per 1000 inhabitants	Eurostat and CrunchBase
Output	Non-smart city specific entrepreneurial output	The number of CrunchBase listed firms founded between 2015-2019 per 100,000 inhabitants	CrunchBase
	Smart city entrepreneurial output	The number of CrunchBase listed smart city-focused firms founded between 2015-2019 per 100,000 inhabitants	CrunchBase

Source entrepreneurial ecosystem elements and non-smart city specific entrepreneurial output: Leendertse et al. (2020, pp. 10-11)

In this paper I work with Leendertse et al.'s (2020) data set for the data on the entrepreneurial ecosystem elements and non-smart city specific entrepreneurial output. The description of these data throughout section 3 is adapted from their paper, sometimes also verbatim. The data set is composed of three main sub datasets (see also Table 1). The first dataset is the Regional Competitiveness Index (RCI), which is composed by the European Union and assesses the competitive strengths and weaknesses of individual NUTS 2 regions. It covers topics related to regional competitiveness such as innovation, quality of institutions, measures of health, (digital) infrastructure, and human capital (Annoni & Dijkstra, 2013). The second main dataset is the Regional Ecosystem Scoreboard (RES), which is measured at NUTS 2 level for most countries and at NUTS 1 level for a minority of countries. Its goal is to assess and capture the quality of several components of the regional ecosystem. The RES consists of multiple indicators, grouped together in 6 main dimensions, which are collaboration and internationalisation, access to finance, knowledge basis and skills, demand conditions, entrepreneurial conditions, and the quality of governance (León et al., 2017, p.10). Thirdly, the Regional Innovation Scoreboard (RIS), which also examines European regions, focuses on the characteristics of regional innovation by looking at factors such as the availability of highly skilled workers, R&D expenditure by both public and private organisations, collaborations with other agents (such as other firms, universities, or other research institutes), and the number of patent applications (Domenech et al., 2016). Leendertse et al. (2020) combined these three main data sets with statistics from Eurostat to construct the entrepreneurial ecosystem elements.

The data source for the output is CrunchBase, a database on innovative businesses. It is gaining popularity in scholarly research, especially as an information provider on start-up activity and financing (Dalle et al., 2017). CrunchBase gets its data through its investor network, machine learning tools, community contributors, and its own data team (CrunchBase Staff, 2020). For each company in the database, CrunchBase offers information on the company size, founding date, location, company industry, and business activities, among other things. For this paper, the data for the output variable comes from CrunchBase. This concerns smart city and non-smart city specific start-ups within the EU for firms founded between 2015 and 2019.

3.2. Entrepreneurial ecosystem elements and output operationalisation

Leendertse et al. (2020) constructed seven out of ten entrepreneurial ecosystem factors with multiple indicators (see also Table 1). In order to ensure a proportionate impact of each of the indicators on the composite indicator, the authors standardised the scores on the individual indicators, with a mean of 0 and a standard deviation of 1. They then took the average of the standardised measures in order to arrive at the composite indicator (Leendertse et al., 2020, p. 12). For three measures (leadership, the number of incubators, and entrepreneurial output), the authors used the locations of individual organisations to construct the regional variables. By geocoding, they matched each organisation to the applicable NUTS 2 region, after which the authors divided the number of organisations in a NUTS 2 region by the population of that region to construct the final measure.

I will now cover each of the entrepreneurial ecosystem elements, as well as the output measures, and briefly discuss Leendertse et al.'s (2020) construction of those, as well as the smart city output measure I constructed myself. For a more detailed description of the ecosystem element variable construction, see also Leendertse et al. (2020).

Formal institutions are regarded as important for both the quality of entrepreneurial ecosystems as well as for smart city development (Ooms et al., 2020). In operationalising the formal institutions element of entrepreneurial ecosystems, Leendertse et al. (2020) assessed the quality of government and the regulatory framework regarding businesses. For the quality of government, the authors used the Quality of Government (QoG) study. The QoG index includes the degree of corruption, impartiality of public services, and rule of law in EU countries on both national and sub-national levels. The index score builds on citizen perception of the quality of government, which is measured by survey questions regarding the respondent's regional government (Charron et al., 2014). With regard to the regulatory framework, Leendertse et al. (2020, p. 13) used the composite indicator "regulatory framework for starting a business" from the RES, which is made up of four aspects: the number of days to start a business, the difficulties encountered when starting a business, the ease of doing business index, and the barriers to entrepreneurship.

Secondly comes entrepreneurship culture. More generally, culture is defined as a set of values of groups such as organisations, regions, and nations (George & Zahra, 2002). Extending this notion to entrepreneurship, entrepreneurship culture can be regarded as the way a population values the legitimacy of entrepreneurship as an economic behaviour (Stuetzer et al., 2018). The existence of a regional entrepreneurship culture has been found to be important for regional development and the persistence of regional entrepreneurship (Fritsch & Wyrwich, 2017). In operationalising entrepreneurship culture, Leendertse et al. (2020) used the RES indicator for entrepreneurship culture, which is composed of five components, namely entrepreneurial motivation, cultural and social norms, business and entrepreneurship education, the importance to be innovative and creative, and trust in others. The authors did not take entrepreneurship education into consideration as they deemed it more suitable for the talent ecosystem element. Besides that, at the core, culture is about values, whereas entrepreneurship education does not directly reflect the way society values entrepreneurship.

The third ecosystem element is physical infrastructure. Although literature on the link between physical infrastructure and entrepreneurial activity is still in its infancy (Bennett, 2019), an analysis by Audretsch et al. (2015) on German entrepreneurial activity finds that there is a positive relationship between infrastructure and start-up activity. Their study also includes the role of digital infrastructure, which they find to stimulate start-up activity. For the indicator for physical infrastructure, Leendertse et al. (2020) accounted for digital infrastructure, which they operationalised as the percentage of households having access to the internet. Furthermore, the authors followed the approach of the RCI by using the accessibility by both railway and road and including the number of passenger flights to measure a region's physical infrastructure.

Another ecosystem element is demand. Even though firms can be expected to serve markets outside their home region at a later stage, most new firms first serve their regional markets, which is why regional demand characteristics are important to the level of entrepreneurial activity (Bergmann & Sternberg, 2007). Leendertse et al. (2020, p. 18) used RCI data to measure market size by measuring regional disposable income per capita, and potential market size expressed in both GRP and in population.

Fifth, networks have been identified to contribute to entrepreneurial success, for example by securing resources, enabling the exchange of tacit knowledge, or by providing information and advice (Elfring & Hulsink, 2003; Hoang & Antoncic, 2003). To operationalise the connections between firms, Leendertse et al. (2020) looked at the cooperation projects firms have with regard to innovation. The authors argue they focus specifically on innovation projects because of the entrepreneurial focus of their research, but one can think of other types of cooperation projects which could stimulate entrepreneurial output. For example, regional interest groups could fuel connections to exchange best practices among entrepreneurs, thereby stimulating entrepreneurial output. Leendertse et al. (2020) measured networks as the number of small and medium enterprises (SMEs) with innovation cooperation projects as a percentage of all SMEs within a region, with the size of the SMEs ranging between 10 and 250 employees. The authors excluded larger firms from this measure as nearly all large firms participate in cooperative activities. Leendertse et al. (2020, p. 15) argue that therefore, including the cooperation projects of larger firms does not yield relevant information.

The sixth entrepreneurial ecosystem element is leadership. Innovative entrepreneurship and new ventures need their founders' leadership in order to define the mission of their organisations, set goals, and motivate and structure the efforts of their employees (Ensley et al., 2006). Leendertse et al. (2020) operationalised leadership as the number of project coordinators of Horizon 2020 innovation projects in a region. They constructed the leadership variable by calculating the number of innovation leaders per 1000 inhabitants in a region. The operationalisation of this ecosystem element is somewhat problematic as it only captures leadership related to Horizon 2020, which is an EU research and innovation programme (European Commission, n.d.). Thereby, it does not capture non-EU affiliated innovation leaders. Furthermore, besides the number of leaders in a region, the level of development of leadership skills may be of importance in order to not just measure leadership quantity but also quality. Operationalising the development of leadership skills for different cultures, however, may be difficult to generalise as leadership attributes are in part determined culturally and may thus differ between regions (Gupta et al., 2004). By employing Leendertse et al.'s (2020) operationalisation of leadership, my analysis does not take non-EU affiliated leadership and qualitative aspects of leadership into consideration, thereby only capturing a part of the concept. I am not creating a more comprehensive operationalisation of leadership as that is beyond the scope of my thesis. Nevertheless, for future research I recommend re-examining the current operationalisation and to employ an operationalisation that examines leadership more broadly.

Increases in the supply of venture capital have been found to be positively related with firm starts, employment, and aggregate income (Samila & Sorenson, 2011). Similarly, Léon (2019) finds that the provision of short-term capital is positively related with firm creation. To operationalise the finance ecosystem element, Leendertse et al. (2020) employed two indicators from the RES, namely the availability of venture capital and the availability of bank loans for capital investments.

Talent, or human capital, comprises the stock of knowledge and skills that resides within individuals, which can be developed over time and transferred between individuals (Wright et al., 2007). As has been observed by Armington & Acs (2002), a positive link exists between a region's level of human capital and new firm formation. Ucbasaran et al. (2008) distinguish between general human capital (including elements such as education) and entrepreneurship-specific human capital (including entrepreneurial and technical capabilities). Leendertse et al. (2020) applied the same distinction to the operationalisation of the human capital indicator, which includes both general human capital and entrepreneurship-specific human capital. The authors operationalised general human capital by looking at tertiary education, participation in education or training, and the share of companies providing vocational training. For the operationalisation of entrepreneurship-specific human capital, the inclusion of technical skills and e-skills in the operationalisation of talent is especially important here, since smart city innovation in general heavily involves IT (for more details on the operationalisation of talent, see Table 1).

Private and public R&D activities are regarded as sources of innovation since new knowledge provides entrepreneurial opportunities. Hence, a higher level of knowledge stock may lead to higher levels of entrepreneurship (Qian et al., 2013; Acs et al., 2009). Leendertse et al. (2020) operationalised knowledge, the ninth ecosystem element, as both private and public intramural R&D spending as a share of the total Gross Regional Product (GRP).

Finally, support services assist aspiring entrepreneurs to start a new firm, setting up business plans, arranging financing, and market their innovations, among other things (Gnyawali & Fogel, 1994). In operationalising support services, Leendertse et al. (2020) distinguished between a general and an entrepreneurship-specific measure, with the general measure operationalised as employment in knowledge-intensive market services, thereby representing the general availability of support services, and with the entrepreneurship-specific measure focusing on incubators and accelerators. Incubators and accelerators directly aim at emerging firms, providing them with assistance in enterprise development, for example by securing resources and developing products, and have been found to contribute to the success of start-ups (Grimaldi & Grandi, 2005; Cohen, 2013; Ayatse et al., 2017; Eveleens, 2019).

Leendertse et al. (2020) operationalised the output of the entrepreneurial ecosystem as the number of new CrunchBase listed enterprises founded less than 5 years ago. In scholarly research, CrunchBase particularly serves as an information provider on start-up activity and financing (Dalle et al., 2017) and is thus useful as a data source on entrepreneurial activity. Leendertse et al. (2020) selected the founding period of 2015-2019 so that the output measure matched the period in which most of the indicators of entrepreneurial ecosystem elements were measured. For smart city output, I look at the number of CrunchBase registered firms founded between 2015 and 2019 that have a focus on smart city. The data on smart city firms includes firms assigned to the "Smart Cities" industry category in CrunchBase, as well as firms that mention "Smart City" or "Smart Cities" in their CrunchBase company description, since not all smart city related firms have been labelled as such in their industry category. This is due to the way CrunchBase gets their data. CrunchBase's data contributors include its investor network, community contributors, AI and machine learning, and CrunchBase's data team (CrunchBase Staff, 2020). Since each data supplier adds the industry based on the type of firm by itself, data suppliers may assign firms to industries differently as there is no definition based upon which companies are systematically assigned to the "Smart Cities" industry. This could lead to not labelling firms as belonging to the "Smart Cities" industry, when in fact they have a smart city focus. In order to also trace firms that focus on smart cities yet are not labelled as such, I include firms that mention "Smart City" or "Smart Cities" in their company description, as an addition to the firms assigned to the "Smart Cities" industry. This yielded another 60 smart city firms on top of the 73 that were already assigned to the CrunchBase smart city category. These additional firms were located in mainly the same regions as start-ups that were assigned to the smart city industry category in CrunchBase. Firms that both fall in the "Smart Cities" CrunchBase industry category and mention "Smart City" or "Smart Cities" in their firm descriptions have not been double counted.

Admittedly, this procedure may well leave companies unnoticed that in fact do focus on improving the quality of urban life by means of deploying technology. This is because their company description or industry assignment does not explicitly state a smart city focus. Compared to being able to include all smart city firms, the current setup has an increased risk of type II errors. As likely not all smart city firms are included as such, the current setup has a risk of finding no effects of entrepreneurial ecosystem elements on smart city entrepreneurial output, when in fact such effects may exist. With regard to the coefficients on the entrepreneurial ecosystem elements, the current setup may lead to insignificant effects or smaller coefficient sizes as compared to including all smart city firms. I am attempting to lower these risks by also including firms that mention "Smart City" or "Smart Cities" in their firm descriptions, thereby detecting more smart city firms than by only looking at assignment to the "Smart Cities" industry. Yet, adding these firms does not fully take away the risk of type II errors and effects on coefficients. Thus, my current selection procedure entails bias against finding significant results, implying that any significant result I find could in fact be stronger if a more precise selection procedure is applied.

For future research, I would therefore recommend using a selection algorithm to detect smart city firms and to employ assignment criteria such as those formulated by Hermse et al. (2020) in order to be more precise in finding smart city firms. For now, as building a selection algorithm is beyond the scope of my thesis, I shall adhere to the selection process I described before, although acknowledging the future improvements that can be made.

3.3. Data analysis

In analysing the data, the goal is to examine how the individual entrepreneurial ecosystem elements are related to smart city-related entrepreneurial activity. The analysis has an exploratory approach. This implies that, given that there has been no empirical assessment of (the interactions of) individual entrepreneurial ecosystem effects yet which I can build hypotheses on, I will not be testing any hypotheses in this analysis. Analysing the effects on both smart city-related and non-smart city-related entrepreneurial activity provides the opportunity to compare the effects of individual ecosystem elements and see whether smart city entrepreneurship relies more heavily on a specific ecosystem element than entrepreneurship that is not specifically smart city related. The fact that I am examining the ecosystem elements individually means that I do not account for any interactions between them.

The proposed method of analysis is cross-sectional OLS regression analysis. The ten entrepreneurial ecosystem elements will be included as independent variables, and entrepreneurial output (both related and unrelated to smart city) will act as a dependent variable. The regression model examined in this paper thus looks as follows:

$$EE\ output_i = \beta_0 + \beta_1 institutions_i + \beta_2 culture_i + \beta_3 physical\ infrastructure_i + \beta_4 demand_i + \beta_5 networks_i + \beta_6 leadership_i + \beta_7 finance_i + \beta_8 talent_i + \beta_9 knowledge_i + \beta_{10} support\ services_i + e_i$$

Subscript "i" refers to the *i*th NUTS 2 region. "EE output" refers to the number of CrunchBase registered firms founded between 2015 and 2019, per 100,000 inhabitants of a NUTS 2 region, and concerns either smart city specific entrepreneurial ecosystem output or non-smart city specific output. In order to find out how ecosystem elements are related to start-up presence individually, I included each of the ecosystem elements as an independent variable. Furthermore, both smart city and non-smart city specific start-up presence have been normalised by taking the number of (smart city) start-ups per 100,000 inhabitants and subtracting the mean, and then dividing this number by the standard deviation. With all ecosystem elements added as independent variables, normalising the output allows for a comparison between the effects of individual entrepreneurial ecosystem elements on smart city and non-smart city output. This is necessary to determine whether the ecosystem elements are related differently to smart city start-up presence than to non-smart city specific start-up presence.

The descriptive statistics of the smart city CrunchBase output per 100,000 inhabitants, non-smart city specific CrunchBase output per 100,000 inhabitants, and the ten entrepreneurial ecosystem elements are shown in Table 2. Both types of entrepreneurial output are not standardised in Table 2 yet. There are 274 NUTS 2 regions, of which 273 are included in the analysis. This is because data on some of the entrepreneurial ecosystem elements were not available for Åland (FI20), a NUTS 2 region in Finland (Leendertse et al., 2020, pp. 22-23).

Table 2

Descriptive statistics

	n	Mean	Standard deviation	Minimum	Maximum
Smart city CrunchBase output per 100,000 inhabitants	273	0.024	0.079	0	0.955
CrunchBase output per 100,000 inhabitants	273	6.417	36.643	0	600.743
Formal institutions	273	0.992	0.768	0.071	3.333
Entrepreneurship culture	273	0.973	0.921	0.013	5.000 (10.229)
Physical infrastructure	273	0.907	1.065	0.058	5.000 (8.411)
Demand	273	1.003	0.939	0.032	4.667
Networks	273	0.984	1.142	0.117	5.000 (6.070)
Leadership	273	0.596	0.993	0.154	5.000 (49.816)
Finance	273	1.003	0.770	0.067	5.000 (5.061)
Talent	273	0.956	1.004	0.029	5.000 (10.902)
Knowledge	273	0.724	1.032	0.108	5.000 (33.480)
Support services	273	0.575	0.852	0.060	5.000 (101.880)

The score Leendertse et al. (2020) assigned to the ecosystem elements ranges from 1 to 5. The authors capped the maximum score at 5 in order to avoid disproportionate influences of outliers.

The uncapped scores are reported between brackets in Table 2. Leendertse et al. (2020, p. 23) standardised all ecosystem elements relative to the EU average in order to account for the different scales of measures. For smart city CrunchBase output, there are 66 out of 273 NUTS 2 regions that have at least one smart city firm. The other regions do not host any CrunchBase listed smart city firms founded between 2015 and 2019. For non-smart city specific CrunchBase output, only 3 NUTS 2 regions do not have any output. This goes for Северозападен (Severozapaden, BG31), a region in north Bulgaria, Δυτική Μακεδονία (Dutikè Makedonia, EL53), a region in the north of Greece, and Valle d'Aosta (ITC2), an Italian region adjacent to France. Across the EU, there are 133 CrunchBase-listed smart city firms, out of a total of 31,236 CrunchBase-listed firms founded between 2015 and 2019 in the EU. This amounts to 0.43% of the total CrunchBase output. As I used a rather coarse selection procedure in classifying smart city firms, analyses that use a more refined method to select smart city firms will likely yield a higher share of smart city start-ups compared to the total.

Figure 2

Map of NUTS 2 regions showing smart city CrunchBase output per 100,000 inhabitants (firm founded date 2015-2019)

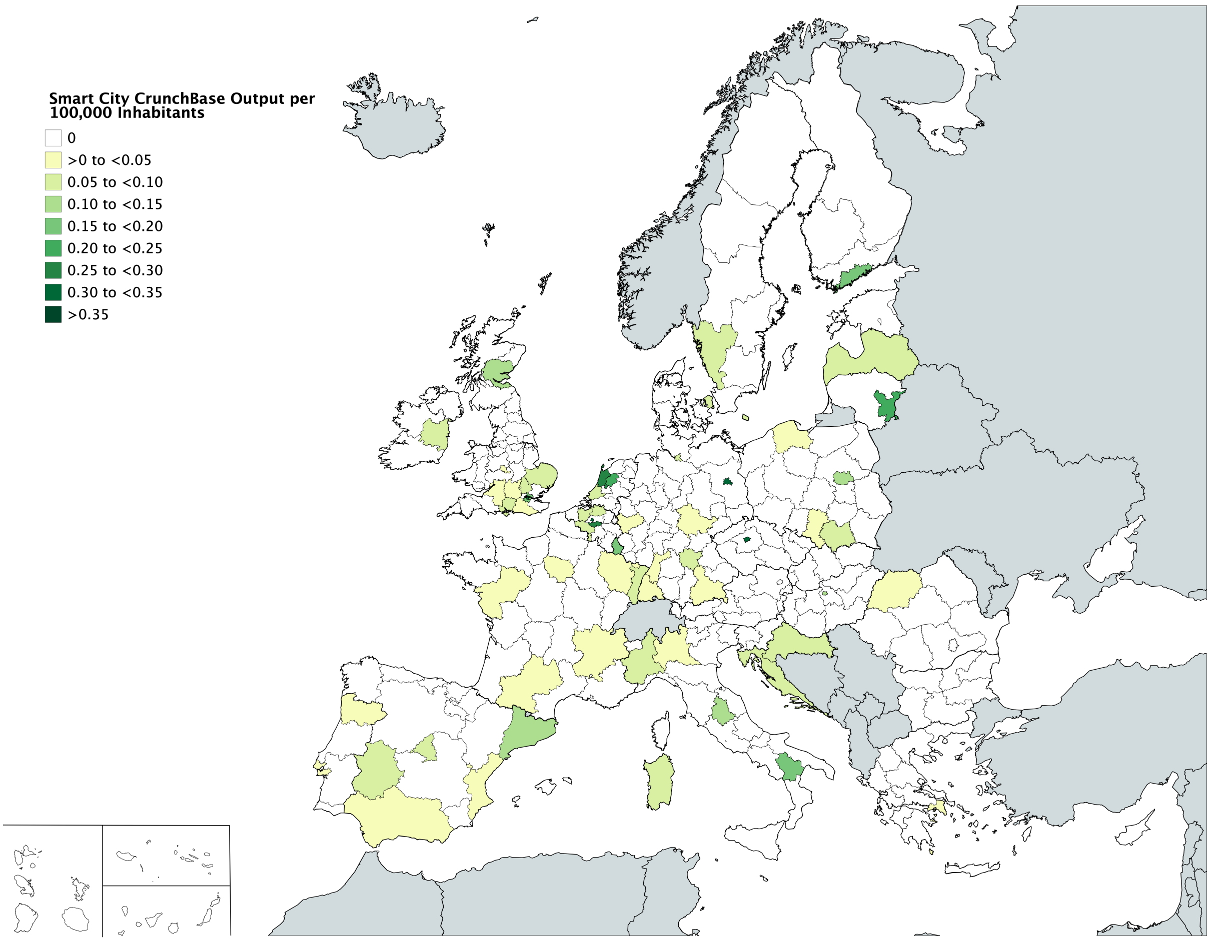


Figure 2 shows a map with the number of smart city firms founded between 2015 and 2019 and listed in CrunchBase per 100,000 inhabitants of the NUTS 2 region in question. The map shows that smart city entrepreneurial activity is present across Europe. The regions with the relatively highest number of smart city firms generally are capital regions. This applies especially to the UK, the Netherlands, Belgium, Germany, the Czech Republic, Finland, Poland, Greece, Hungary, Ireland, and Lithuania. Smart city entrepreneurial activity is concentrated on their capital regions, with none or relatively fewer smart city firms present outside their capital regions. For most NUTS 2 regions, the number of smart city CrunchBase listed firms per 100,000 inhabitants ranges between 0 and 0.30. There is one region with a much higher concentration of smart city firms, however. This is Inner London – West (NUTS 2 region UKI3), which has 0.92 smart city firms per 100,000 inhabitants. The ten NUTS 2 regions with the highest smart city output relative to the number of inhabitants are (in descending order) Inner London – West (UKI3), Brussels Hoofdstedelijk Gewest (BE10), Praha (CZ01), Berlin (DE30), Inner London – East (UKI4), Province du Brabant wallon (BE31), Sostinės regionas (LT01), Noord-Holland (NL32), Flevoland (NL23), and Helsinki-Uusimaa (FI1B). Inner London – West (UKI3), Noord-Holland (NL32), Helsinki-Uusimaa (FI1B) and Berlin (DE30) appear in both the smart city and general entrepreneurial output top ten. The rest of the top ten for general CrunchBase output is comprised of Stockholm (SE11), Eastern and Midland (IE06), Eesti (EE00), Hovedstaden (DK01), Malta (MT00), and Luxembourg (LU00).

Table 3 reports the correlations between the variables. Smart city entrepreneurial output is significantly correlated to five out of the ten entrepreneurial ecosystem elements, namely physical infrastructure (p=0.0000), demand (p=0.0000), networks (p=0.0385), leadership (p=0.0000), and support services (p=0.0000). This largely corresponds with non-smart city specific start-up presence, which is significantly correlated with physical infrastructure (p=0.0000), demand (p=0.0000), leadership (p=0.0000), and support services (p=0.0000). These entrepreneurial ecosystem elements are more strongly related to smart city start-up presence than to non-smart city specific entrepreneurial activity, however. Most ecosystem elements are correlated among themselves, so that one of the potential problems with assessing entrepreneurial ecosystem elements individually is multicollinearity. One may expect that regions with high scores on one of the elements will also have high scores on other elements, as the region in question is more developed. As all ecosystem elements are theoretically relevant in entrepreneurial ecosystems literature, however, there are no redundant variables that can be dropped.

Table 3
Correlations among variables

Variable	Smart City CrunchBase output per 100,000 inhabitants	CrunchBase output per 100,000 inhabitants	Formal institutions	Entrepreneurship culture	Physical infrastructure	Demand	Networks	Leadership	Finance	Talent	Knowledge	Support services
Smart City CrunchBase output per 100,000 inhabitants	1.0000											
CrunchBase output per 1,000 inhabitants	**0.7613**	1.0000										
	(0.0000)											
Formal institutions	0.0817	0.1041	1.0000									
	(0.1782)	(0.0861)										
Entrepreneurship culture	0.0895	0.1083	**0.7134**	1.0000								
	(0.1402)	(0.0739)	(0.0000)									
Physical infrastructure	**0.3921**	**0.2844**	**0.5056**	**0.3720**	1.0000							
	(0.0000)	(0.0000)	(0.0000)	(0.0000)								
Demand	**0.3707**	**0.2614**	**0.4283**	**0.2270**	**0.8523**	1.000						
	(0.0000)	(0.0000)	(0.0000)	(0.0002)	(0.0000)							
Networks	**0.1257**	0.0867	**0.4144**	0.0254	**0.3617**	**0.3909**	1.0000					
	(0.0379)	(0.1529)	(0.0000)	(0.6765)	(0.0000)	(0.0000)						
Leadership	**0.3847**	**0.3575**	**0.2177**	**0.2358**	**0.3146**	**0.2272**	**0.1709**	1.0000				
	(0.0000)	(0.0000)	(0.0003)	(0.0001)	(0.0000)	(0.0002)	(0.0046)					
Finance	0.0569	-0.0185	0.0229	0.0809	0.0684	0.0776	**-0.1354**	0.0492	1.0000			
	(0.3490)	(0.7605)	(0.7066)	(0.1826)	(0.2598)	(0.2012)	(0.0253)	(0.4180)				
Talent	-0.0157	0.0352	**0.3593**	**0.2978**	**0.1364**	0.0673	**0.2025**	**0.2394**	**0.2245**	1.0000		
	(0.7963)	(0.5621)	(0.0000)	(0.0000)	(0.0242)	(0.2681)	(0.0008)	(0.0001)	(0.0002)			
Knowledge	0.0587	0.0228	**0.2856**	**0.2249**	**0.1931**	**0.2487**	0.0576	**0.3414**	**0.1929**	**0.3469**	1.000	
	(0.3335)	(0.7072)	(0.0000)	(0.0002)	(0.0013)	(0.0000)	(0.3434)	(0.0000)	(0.0014)	(0.0000)		
Support services	**0.6686**	**0.4250**	**0.2606**	**0.3025**	**0.5952**	**0.4980**	**0.1578**	**0.4771**	0.1048	**0.1890**	**0.1977**	1.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0090)	(0.0000)	(0.0841)	(0.0017)	(0.0010)	

Note: *p*-values between parentheses. Significant correlations ($p<0.05$) are reported in bold.

4. Results and interpretation

Table 4 reports the regression results of normalised smart city and normalised non-smart city specific CrunchBase output per 100,000 inhabitants of a NUTS 2 region on the entrepreneurial ecosystem elements.[2] I use normalised CrunchBase output to be able to compare the effects of entrepreneurial ecosystem elements between smart city output and non-smart city specific output. As there is heteroskedasticity present, I use heteroskedasticity-robust standard errors for each regression.

Besides looking at normalised CrunchBase output (in the second and third columns of Table 4), I also examine normalised CrunchBase output that excludes the 1st and 99th percentiles (see also the final two columns of Table 4). This is because one NUTS 2 region, which is Inner London – West (UKI3), represents a special case because of its very high CrunchBase output compared to the output of other NUTS 2 regions. I shall discuss this region in more detail later.

Table 4

Regression results of normalised smart city and non-smart city specific CrunchBase output per 100,000 inhabitants on entrepreneurial ecosystem elements

	Normalised smart city output per 100,000 inhabitants	Normalised non-smart city specific output per 100,000 inhabitants	Normalised smart city output per 100,000 inhabitants (excl. 1st and 99th percentiles)	Normalised non-smart city specific output per 100,000 inhabitants (excl. 1st and 99th percentiles)
Formal institutions	-0.0353	0.0249	-0.0142	0.0291**
	(0.1179)	(0.0516)	(0.1143)	(0.0129)
Entrepreneurship culture	-0.0692	-0.0341	-0.0591	-0.0164
	(0.0799)	(0.0413)	(0.0712)	(0.0106)
Physical infrastructure	-0.1004	-0.0662	-0.0163	0.0070
	(0.0884)	(0.0907)	(0.0745)	(0.0162)
Demand	0.1572	0.1747	-0.0048	-0.0465**
	(0.1418)	(0.2115)	(0.0787)	(0.0184)
Networks	0.0230	-0.0418	0.0308	0.0015
	(0.0451)	(0.0432)	(0.0401)	(0.0063)
Leadership	0.1492	0.2611	-0.0056	0.0572***
	(0.1301)	(0.1961)	(0.0518)	(0.0136)
Finance	0.0392	-0.0623	0.0573	0.0077
	(0.0647)	(0.0772)	(0.0488)	(0.0081)
Talent	-0.1249**	-0.0184	-0.1032**	0.0145
	(0.0605)	(0.0458)	(0.0430)	(0.0111)
Knowledge	-0.0751	-0.1307	0.0096	0.0025
	(0.0778)	(0.1209)	(0.0300)	(0.0085)

[2] For the results of regressions that include control variables as well, see Tables A1-A6 in the Appendix.

Support services	0.7598***	0.3623*	0.5964***	0.1213***
	(0.1670)	(0.2158)	(0.1187)	(0.0024)
F-statistic	5.23***	1.22	7.99***	13.99***
	(df=10; 262)	(df=10; 262)	(df=10; 260)	(df=10; 256)
N	273	273	271	267
R^2	0.4962	0.2376	0.4478	0.5588

Note: standard errors in parentheses. * = p <0.10; ** = p <0.05; *** = p <0.01

With regard to normalised smart city entrepreneurial output per 100,000 inhabitants, the majority of entrepreneurial ecosystem elements does not have a statistically significant effect. This applies to formal institutions, entrepreneurship culture, physical infrastructure, demand, networks, leadership, finance, and knowledge. Surprisingly, keeping all other variables constant, an increase in the score on talent has a negative effect on smart city output (p=0.040). The effect is relatively small, however. A one standard deviation increase in the score on talent reduces smart city CrunchBase output by approximately 0.12 standard deviations. For support services, the effects are larger. A one standard deviation increase in the score on support services is associated with 0.76 standard deviations increase in smart city CrunchBase output (p=0.000). To test the robustness of these results, I also ran regressions that included a number of control variables. When controlling for non-smart city specific entrepreneurial output, density, and country, as well as working with subsets of the ecosystem elements, the coefficient size on support services decreases somewhat, to around 0.40-0.60 standard deviations increase in smart city start-up presence for each standard deviation increase in the support services score.[3] To further investigate the results on talent and support services, I also looked at a regression of the share of smart city start-ups as part of the total number of start-ups on the entrepreneurial ecosystem elements.[4] None of the entrepreneurial ecosystem elements was statistically significantly related to the share of smart city start-ups. This implies that although talent is associated with lower and support services are associated with higher smart city start-up presence, they are not significantly related to the *share* of smart city start-ups.

For normalised non-smart city specific start-up presence, the ecosystem elements do not have a jointly statistically significant effect, and none of the ecosystem elements has a statistically significant individual effect (p <0.05). This however includes extreme values, the most notable of which is Inner London – West.

Besides looking at the normalised entrepreneurial ecosystem output, in the final two columns of Table 4, I further include regression results that do not take the 1st and 99th percentiles of the normalised output into consideration. This is because entrepreneurial output, for both smart

[3] See also Tables A1-A2 in the Appendix.
[4] For the regression results, see Table A6 in the Appendix.

city and non-smart city ventures, is very high in Inner London – West (UKI3). This region has 0.96 CrunchBase-listed smart city firms founded between 2015 and 2019 per 100,000 inhabitants, compared to 0.33 in Brussels Hoofdstedelijk Gewest (BE10), which is the second-highest score on smart city output. An even larger difference between Inner London – West and other regions can be found with regard to non-smart city specific start-ups. Inner London – West hosts 600.7 CrunchBase-listed firms founded between 2015 and 2019 per 100,000 inhabitants, whereas Berlin (DE30), which comes next, has 42.4 such firms per 100,000 inhabitants. Inner London –West thus is a special case compared to other NUTS 2 regions. An explanation for the relatively very high entrepreneurial output in Inner London – West is the fact that within the UK, London acts as a cluster of entrepreneurial activity (Sanders et al., 2020). By excluding the 1st and 99th percentiles, Inner London – West's entrepreneurial output is not taken into consideration. This prevents the region from driving the regression results for other regions, which have a more moderate entrepreneurial output.

The effects of ecosystem elements on normalised smart city output that excludes the 1st and 99th percentiles correspond with smart city output that includes the 1st and 99th percentile in terms of statistical significance. The size of the effects is roughly the same as well. Here, too, formal institutions, entrepreneurship culture, physical infrastructure, demand, networks, leadership, finance, and knowledge do not have a statistically significant effect on smart city output. For talent, the effect on smart city output is again negative (p=0.017), although slightly smaller in size. A one standard deviation increase in the score on talent is associated with a decrease in smart city start-up presence by 0.10 standard deviations. The effects of an increase in the score on support services are somewhat smaller here as well (p=0.000). For the regression that does not exclude the 1st and 99th percentiles, this implies that the more extreme values bias the coefficients up. Keeping all other variables constant, increasing the score on support services with one standard deviation yields 0.60 standard deviations increase in smart city entrepreneurial output. With control variables included, the coefficient sizes of talent and support services remain roughly the same.[5]

Compared to normalised non-smart city specific CrunchBase output, using normalised non-smart city specific output that does not include the 1st and 99th percentiles increases the R^2 from 0.2376 to 0.5588. Here, entrepreneurship culture, talent, physical infrastructure, networks, finance, and knowledge do not have a statistically significant effect. This does not correspond to findings in literature. For example, a study by Audretsch et al. (2015) on German entrepreneurial activity finds that there is a positive relationship between infrastructure and start-up activity. Similarly, findings by Acs et al. (2009) suggest that "entrepreneurial activity tends to be greater where

[5] See also Table A4 in the Appendix.

knowledge is more prevalent" (p. 23). For finance, Samila & Sorenson (2011) find that increases in the supply of venture capital are positively associated with firm starts. Table 4 shows that formal institutions, demand, and leadership all have statistically significant yet minor effects on non-smart city specific entrepreneurial output. For a one standard deviation increase in the score on formal institutions, we see an increase in non-smart city specific entrepreneurial output of 0.03 standard deviations (p =0.025). An increase in the score on demand has a negative effect on non-smart city specific output (p=0.012), although the size of the effect also is relatively small. An increase of one standard deviation on the demand score is associated with 0.05 standard deviations lower non-smart city specific output. Leadership, or really the relative number of Horizon 2020 innovation project coordinators present in a NUTS 2 region, has a positive effect on non-smart city specific output (p=0.000), with an increase in non-smart city specific output of 0.06 standard deviations for an increase in the leadership score of one standard deviation. Talent also has a small yet statistically significant effect on non-smart city specific output (p=0.011). A one standard deviation increase in the score on talent is associated with 0.01 standard deviations increase in non-smart city specific output. With regard to support services, for a one standard deviation increase in the score, non-smart city specific CrunchBase output increases by 0.12 standard deviations (p=0.000).

A comparison of the regression results between normalised smart city output and non-smart city specific output (excluding 1st and 99th percentiles) shows that the main differences concern the effects of talent and support services. For smart city entrepreneurial activity, an increase in the talent score has a negative effect, whereas there is no such effect for non-smart city specific entrepreneurial activity. For smart city output, a one standard deviation increase in the talent score is associated with a 0.10 standard deviations lower output (p=0.017), meaning the size of the effect is rather small. The negative effect of talent is surprising as in literature, each ecosystem element is understood to contribute to entrepreneurial activity, rather than inhibit it (Audretsch & Belitski, 2017; Fuentelsaz & Mata, 2018; Nicotra et al., 2018; Spigel, 2017; Stam, 2015). The negative coefficient may be explained by the operationalisation of talent, which measures skills and trainings both related and unrelated to entrepreneurship that may not be that relevant for start-ups (such as lifelong learning). This also asks for a critical review of the operationalisation of support services and its relation to start-ups. Part of the operationalisation of support services focuses explicitly on newly founded firms, as it takes the relative number of incubators and accelerators within a region into account. The operationalisation of the support services ecosystem element thus is directly related to entrepreneurship, and start-ups in particular.

Support services have a larger positive effect on smart city entrepreneurial output than on non-smart city specific entrepreneurial activity. Smart city start-up presence increases by 0.60

standard deviations (p=0.000) for each standard deviation increase in the ecosystem score on support services, whereas for non-smart city specific output, the increase in entrepreneurial output from a one standard deviation increase in the support services score amounts to 0.12 standard deviations (p=0.000). This implies that support services are particularly relevant for smart city start-up presence as compared to non-smart city specific start-ups. Finally, some ecosystem elements have relatively small yet statistically significant effects on non-smart city specific entrepreneurial activity only. This concerns formal institutions, demand, and leadership.

The main result of the analysis thus concerns the effects of support services, which are larger for smart city start-up presence than for non-smart city specific start-up presence. Furthermore, support services are the only entrepreneurial ecosystem element which has an individually positive effect on smart city start-up presence.

5. Discussion and conclusion

The aim of this thesis was to identify the entrepreneurial ecosystem elements that are most important for the presence of smart city start-ups. As research on smart cities and entrepreneurial ecosystems is fairly young and there is still discussion around the definitions of both concepts (Stam, 2015; Audretsch & Belitski, 2017), this thesis is an exploration of the topic, examining the effects of each of the entrepreneurial ecosystem elements on smart city start-up presence. It contributes to existing literature by combining two strands of literature that have barely interacted to date (Ooms et al., 2020).

Looking at the number of (smart city) start-ups registered in CrunchBase relative to the number of inhabitants of NUTS 2 regions, I found that most entrepreneurial ecosystem elements do not have a statistically significant individual effect. Only talent and support services are significantly related to smart city entrepreneurship. When comparing smart city entrepreneurship to non-smart city specific entrepreneurship, support services have a larger positive effect. Talent is negatively associated with smart city start-up presence, as opposed to start-ups in general, which are not significantly related with talent. The coefficient sizes and significance remain roughly the same when controlling for country, density, or non-smart city specific start-ups.[6] Although the coefficient size is only small, the results for the talent ecosystem element call for further investigation and discussion as they do not match the view expressed in literature, according to which each of the ecosystem elements supports entrepreneurship.

[6] See Appendix Tables A1, A2, and A4.

In literature each of the entrepreneurial ecosystem elements considered in this analysis has been considered to contribute to the entrepreneurial ecosystem, thereby stimulating entrepreneurial output (Audretsch & Belitski, 2017; Fuentelsaz & Mata, 2018; Nicotra et al., 2018; Spigel, 2017; Stam, 2015). So far, however, there has been little empirical analysis of such relations (Nicotra et al., 2018). For both smart city and non-smart city specific start-ups, I have found only limited individual effects, with only support services being positively associated with smart city and non-smart city specific start-up presence. Talent had a small negative effect on smart city entrepreneurship. This does not correspond with previous findings in literature on the relationship between human capital and entrepreneurship in general, which finds a positive relationship between the two (Armington & Acs, 2002; Qian et al., 2013). Thus, the results of this analysis raise questions and call for further investigation, not only concerning the negative coefficient on talent with respect to smart city start-up presence, but also on the role of the other ecosystem elements, of which many were statistically insignificant.

Smart city start-ups may help find solutions that tackle problems which are associated with increasing urbanisation, such as pollution, transportation capacity limits, or exhaustion of natural resources (Chourabi et al., 2012; Manville et al., 2014). Therefore, more insight into how entrepreneurial ecosystem elements stimulate the presence of smart city start-ups is desirable. This thesis has shown that an improvement of an ecosystem's support services is associated with higher smart city related start-up presence. Thus, for ecosystems in which more smart city entrepreneurship is desired, it is relevant to pay attention to developing the ecosystem's support services. For policy purposes, developing support services can be regarded as a tool in stimulating smart city entrepreneurship.

This study has a number of limitations. First, the selection method of smart city start-ups that I applied could have been more elaborate and precise. In this study, I classified a start-up as being a smart city firm when it was assigned to the "Smart Cities" industry in CrunchBase, or when its company description stated "Smart City" or "Smart Cities". This may arguably leave smart city start-ups not being classified as such. When a firm had a focus on improving the quality of urban life, yet its company description did not state "Smart City"/ "Smart Cities" or was not assigned to the "Smart Cities" industry, it would not have been classified as a smart city firm in my sample. Thus, there are likely more smart city firms than the ones I included in the sample. This leads to a bias against not finding any significant results, implying that the effects I found could well be stronger if a more precise selection procedure is followed. A solution to this problem could be using a selection algorithm that scouts the CrunchBase website and classifies start-ups as smart city firms if they match certain selection criteria, such as the procedure described by Hermse et al.

(2020), so as to select smart city firms more precisely. As creating a selection algorithm was beyond the scope of my thesis, I have not employed such an algorithm here. Secondly, in measuring the ecosystem, I used NUTS 2 regions, which probably do not fully correspond with the geographical boundaries of the ecosystems of all start-ups. This implies there is a bias towards not finding any effects of ecosystem elements. This means the results I find are conservative, and that I may not have found causal links because of this conservatism. Finally, the operationalisation of some of the entrepreneurial ecosystem elements by Leendertse et al. (2020) could have been more elaborate. This applies especially to leadership and networks. The current operationalisation of leadership only captures a very limited part of the concept, with leadership being operationalised as the number of project coordinators of Horizon 2020 innovation projects per 1000 inhabitants of a region. This does not capture non-EU affiliated leadership, nor does it take leadership quality into account. Thereby, the current operationalisation is not accounting for leadership traits that may be of relevance for entrepreneurship. As for networks, the operationalisation could have been more complete by also including forms of interactions other than innovation projects only. For example, local entrepreneurship associations may provide assistance to aspiring entrepreneurs and introduce them to other entrepreneurs. Excluding such forms of networks could lead to not finding any effects of networks, when in fact networks may have an effect, if adopting a more extensive operationalisation of networks.

All in all, my findings show that an improvement of an ecosystem's support services is positively related to the presence of smart city start-ups. On the other hand, I found an ecosystem's increase of talent to be negatively associated with smart city start-up presence. The other entrepreneurial ecosystem elements are not significantly related to the presence of smart city start-ups individually. These findings imply that in ecosystems in which more smart city entrepreneurship is desired, developing the ecosystem's support services is recommended. As far as I know, my thesis is the first study to assess the effects of individual ecosystem elements on smart city start-up presence. Therefore, for future research I suggest taking the analysis further and not only assess the individual ecosystem elements, but to also consider the effects of interactions among entrepreneurial ecosystem elements. Finally, the results of this analysis demonstrate the need for further discussion and empirical analysis of entrepreneurial ecosystems.

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Appendix

Table A1

Regression results of normalised smart city (SC) CrunchBase output per 100,000 inhabitants on entrepreneurial ecosystem elements, including control variables

	Normalised SC output per 100,000 inhabitants	Normalised SC output per 100,000 inhabitants	Normalised SC output per 100,000 inhabitants	Normalised SC output per 100,000 inhabitants	Normalised SC output per 100,000 inhabitants	Normalised SC output per 100,000 inhabitants
Formal institutions	-0.0335	-0.0243	-0.0498	-0.0236	-0.0022	-0.0394
	(0.1158)	(0.1196)	(0.1157)	(0.1170)	(0.1210)	(0.1173)
Entrepreneurship culture	-0.0357	-0.0600	-0.0496	-0.0217	-0.0213	-0.0352
	(0.0714)	(0.0782)	(0.0734)	(0.0727)	(-0.0806)	(0.0737)
Physical infrastructure	-0.0346	-0.0821	-0.0622	-0.0246	-0.0483	-0.0516
	(0.0716)	(0.0921)	(0.0751)	(0.0675)	(0.0765)	(0.0695)
Demand	0.0010	0.1266	0.0565	-0.0583	-0.0618	-0.0132
	(0.0758)	(0.1561)	(0.0755)	(0.0787)	(0.0927)	(0.0766)
Networks	0.0759*	0.0422	0.0471	0.0709	0.0370	0.0426
	(0.0441)	(0.0514)	(0.0412)	(0.0441)	(0.0549)	(0.0419)
Leadership	-0.0143	0.1414	-0.0014	-0.0154	0.1074	-0.0027
	(0.0575)	(0.1328)	(0.0602)	(0.0532)	(0.1036)	(0.0550)
Finance	0.0791	0.0417	0.0751	0.0799*	0.0509	0.0759
	(0.0514)	(0.0652)	(0.0527)	(0.0475)	(0.0593)	(0.0488)
Talent	-0.1472***	-0.1471**	-0.1143**	-0.1425**	0.1356**	-0.1100**
	(0.0500)	(0.0649)	(0.0456)	(0.0471)	(0.0634)	(0.0441)
Knowledge	-0.0080	-0.0811	0.0002	0.0139	-0.0133	0.0223
	(0.0317)	(0.0760)	(0.0316)	(0.0281)	(0.0369)	(0.0280)
Support services	0.5728***	0.7757***	0.5508***	0.4641***	0.4721***	0.4414***
	(0.1145)	(0.1592)	(0.1204)	(0.1256)	(0.1425)	(0.1331)
Country	-0.0111**	-0.0074		-0.0109**	-0.0077	
	(0.0046)	(0.0058)		(0.0042)	(0.0048)	
Density[7]				0.0001**	0.0004*	0.0002**
				(0.0001)	(0.0002)	(0.0001)
Non-smart city specific entrepreneurial output	0.5818***		0.5767***	0.5332***		0.5277***
	(0.0276)		(0.0284)	(0.0324)		(0.0342)
F-statistic	2495.91***	6.01***	2721.08***	2008.12***	7.70***	1781.96***
	(df=12; 260)	(df=11; 261)	(df=11; 261)	(df=13; 259)	(df=12; 260)	(df=12; 260)
N	273	273	273	273	273	273
R^2	0.7567	0.4993	0.7498	0.7688	0.5806	0.7622

Note: standard errors in parentheses. * = p <0.10; ** = p <0.05; *** = p <0.01

[7] Data source Density: https://ec.europa.eu/eurostat/databrowser/view/tgs00024/default/table?lang=en

Table A2

Regression results of normalised smart city (SC) CrunchBase output per 100,000 inhabitants on entrepreneurial ecosystem elements, including control variables

	Normalised SC output per 100,000 inhabitants	Normalised SC output per 100,000 inhabitants	Normalised SC output per 100,000 inhabitants	Normalised SC output per 100,000 inhabitants	Normalised SC output per 100,000 inhabitants
Formal institutions	-0.0391		0.0202		0.0340
	(0.1174)		(0.0944)		(0.0961)
Entrepreneurship culture	-0.0355		-0.0593		-0.0658
	(0.0732)		(0.0601)		(0.0608)
Physical infrastructure	-0.0521		-0.0303	-0.0435	-0.0291
	(0.0685)		(0.0667)	(0.0730)	(0.0666)
Demand	-0.0125		-0.0238	-0.0519	-0.0300
	(0.0745)		(0.0796)	(0.0721)	(0.0799)
Networks	0.0422			0.0699*	
	(0.0432)			(0.0361)	
Leadership					
Finance	0.0760			0.0824*	0.0654
	(0.0484)			(0.0473)	(0.0444)
Talent	-0.1101**	-0.1218***	-0.1130**	-0.1531***	-0.1235**
	(0.0443)	(0.0367)	(0.0483)	(0.0424)	(0.0491)
Knowledge	0.0215		0.0110	0.0055	0.0052
	(0.0270)		(0.0275)	(0.0261)	(0.0271)
Support services	0.4405***	0.4230***	0.4578***	0.4558***	0.4544***
	(0.1243)	(0.1037)	(0.1188)	(0.1155)	(0.1185)
Country		-0.0098**	-0.0086**	-0.0115***	-0.0086**
		(0.0038)	(0.0040)	(0.0043)	(0.0039)
Density	0.0002**	0.0001**	0.0002**	0.0002**	0.0002**
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Non-smart city specific entrepreneurial output	0.5271*** (0.0311)	0.5262*** (0.0328)	0.5249*** (0.0318)	0.5286*** (0.0294)	0.5278*** (0.0310)
F-statistic	1936.02***	2633.01***	1956.61***	2543.22***	2153.91***
	(df=11; 261)	(df=5; 267)	(df=10; 262)	(df=10; 262)	(df=11; 261)
N	273	273	273	273	273
R^2	0.7622	0.7593	0.7630	0.7678	0.7653

Note: standard errors in parentheses. * = *p* <0.10; ** = *p* <0.05; *** = *p* <0.01

Table A3

Regression results of normalised non-smart city specific CrunchBase output per 100,000 inhabitants on entrepreneurial ecosystem elements, including control variables

	Normalised non-smart city specific output per 100,000 inhabitants	Normalised non-smart city specific output per 100,000 inhabitants
Formal institutions	0.0157 (0.0556)	0.0401 (0.0462)
Entrepreneurship culture	-0.0418 (0.0441)	0.0008 (0.0517)
Physical infrastructure	-0.0816 (0.1015)	-0.0445 (0.0769)
Demand	0.2004 (0.2352)	-0.0066 (0.0726)
Networks	-0.0579 (0.0578)	-0.0636 (0.0644)
Leadership	0.2677 (0.2013)	0.2303 (0.1630)
Finance	-0.0644 (0.0787)	-0.0543 (0.0791)
Talent	0.0003 (0.0435)	0.0129 (0.0560)
Knowledge	-0.1256 (0.1164)	-0.0511 (0.0482)
Support services	-0.3488* (0.2049)	0.0151 (0.1333)
Country	0.0063 (0.0065)	0.0060 (0.0059)
Density		0.0004 (0.0004)
F-statistic	1.09 (df=11; 261)	3.77*** (df=12; 260)
N	273	273
R^2	0.2398	0.3380

Note: standard errors in parentheses. * = p <0.10; ** = p <0.05; *** = p <0.01

Table A4

Regression results of normalised smart city CrunchBase output per 100,000 inhabitants on entrepreneurial ecosystem elements, excluding 1st and 99th percentiles, and including control variables

	Normalised smart city output per 100,000 inhabitants (excl. 1st and 99th percentiles)	Normalised smart city output per 100,000 inhabitants (excl. 1st and 99th percentiles)	Normalised smart city output per 100,000 inhabitants (excl. 1st and 99th percentiles)	Normalised SC output per 100,000 inhabitants (excl. 1st and 99th percentiles)	Normalised SC output per 100,000 inhabitants (excl. 1st and 99th percentiles)
Formal institutions	-0.0300 (0.1146)	-0.0143 (0.1137)	-0.0467 (0.1144)	-0.0539 (0.1181)	-0.0313 (0.1156)
Entrepreneurship culture	-0.0264 (0.0693)	-0.0353 (0.0691)	-0.0324 (0.0698)	-0.0172 (0.0731)	-0.0333 (0.0721)
Physical infrastructure	-0.0111 (0.0704)	-0.0073 (0.0714)	-0.0308 (0.0726)	-0.0324 (0.0711)	-0.0270 (0.0731)
Demand	0.0088 (0.0801)	-0.0164 (0.0825)	0.0494 (0.0769)	0.0177 (0.0767)	-0.0055 (0.0788)
Networks	0.0516 (0.0432)	.0524 (0.0437)	0.0284 (0.0399)	0.0292 (0.0416)	0.0300 (0.0412)
Leadership	-0.0347 (0.0599)	-0.0037 (0.0531)	-0.0270 (0.0595)	-0.0378 (0.0609)	0.0057 (0.0534)
Finance	0.0365 (0.0452)	0.0407 (0.0450)	0.0260 (0.0438)	0.0306 (0.0443)	0.0346 (0.0439)
Talent	-0.1272*** (0.0464)	-0.1194*** (0.0453)	-0.0986** (0.0340)	-0.0995** (0.0412)	-0.0890** (0.0390)
Knowledge	-0.0023 (0.0301)	-0.0009 (0.0300)	0.0033 (0.0300)	0.0170 (0.0285)	0.0147 (0.0292)
Support services	0.5118*** (0.1433)	0.5575*** (0.1402)	0.4803*** (0.1435)	0.3713** (0.1646)	0.4891*** (0.1644)
Country	-0.0085* (0.0047)	-0.0085* (0.0047)			
Density				0.0001 (0.0001)	0.0001 (0.0001)
Non-smart city specific entrepreneurial output (excl. 1st and 99th percentiles)	0.5417 (0.5117)		0.5419 (0.5119)	0.7715 (0.5148)	
F-statistic	4.51*** (df=12; 254)	4.61*** (df=11; 255)	4.74*** (df=11; 255)	4.90*** (df=12; 254)	5.19*** (df=11; 255)
N	267	267	267	267	267
R^2	0.3817	0.3740	0.3717	0.3858	0.3716

Note: standard errors in parentheses. * = p <0.10; ** = p <0.05; *** = p<0.01

Table A5

Regression results of normalised non-smart city specific CrunchBase output per 100,000 inhabitants on entrepreneurial ecosystem elements, excluding 1st and 99th percentiles, including control variables

	Normalised non-smart city specific output per 100,000 inhabitants (excl. 1st and 99th percentiles)	Normalised non-smart city specific output per 100,000 inhabitants (excl. 1st and 99th percentiles)
Formal institutions	0.0291** (0.0130)	0.0291** (0.0133)
Entrepreneurship culture	-0.0164 (0.0106)	-0.0209* (0.0109)
Physical infrastructure	0.0070 (0.0167)	0.0068 (0.0172)
Demand	-0.0466** (0.0201)	-0.0297 (0.0214)
Networks	0.0015 (0.0070)	0.0008 (0.0069)
Leadership	0.0572*** (0.0136)	0.0564*** (0.0133)
Finance	0.0077 (0.0084)	0.0051 (0.0081)
Talent	0.0145 (0.0118)	0.0138 (0.0118)
Knowledge	0.0025 (0.0085)	-.0030 (0.0087)
Support services	0.1213*** (0.0250)	0.1525*** (0.0180)
Country	0.0000 (0.0008)	0.0001 (0.0008)
Density		-0.0000*** (0.0000)
F-statistic	14.21*** (df=11; 255)	19.58*** (df=12; 254)
N	267	267
R^2	0.5588	0.5981

Note: standard errors in parentheses. * = *p* <0.10; ** = *p* <0.05; *** = *p* <0.01

Table A6

Regression results of share of smart city start-ups in total number of start-ups on entrepreneurial ecosystem elements, including control variables

	Share of smart city start-ups in total number of start-ups
Formal institutions	-2.5390 (2.2952)
Entrepreneurship culture	1.8591 (1.9194)
Physical infrastructure	0.4442 (0.7597)
Demand	-0.7359 (1.0189)
Networks	0.2654 (0.3251)
Leadership	-0.2843 (0.2337)
Finance	-0.7085 (0.5315)
Talent	-0.1702 (0.1878)
Knowledge	0.0033 (0.0955)
Support services	-0.3467 (0.3223)
Country	-0.0319 (0.0418)
Density	0.0002 (0.0002)
F-statistic	0.17 (df=12; 257)
N	270
R^2	0.0218

Note: standard errors in parentheses.