Utrecht University

School of Economics

Measure Twice, Cut Once.

Entrepreneurial Ecosystem Metrics

Jip Leendertse, Mirella Schrijvers & Erik Stam

U.S.E. Working Paper Series nr: 20-01

Utrecht University School of Economics

U.S.E. Research Institute
Working Paper Series 20-01

Measure Twice, Cut Once. Entrepreneurial Ecosystem Metrics

Jip Leendertse[1], Mirella T. Schrijvers[2], Erik Stam[2]
1: Innovation Studies, Copernicus Institute of Sustainable Development
Utrecht University
2: Utrecht University School of Economics
Utrecht University

February 2020

Abstract
An entrepreneurial ecosystem comprises a set of interdependent actors and factors that are governed in such a way that they enable productive entrepreneurship within a particular territory. While the entrepreneurial ecosystem approach is useful to think about regional economies, it currently lacks full-fledged metrics to enable policy. In this paper, we bridge this gap by quantifying and qualifying regional economies using the entrepreneurial ecosystem approach. We operationalize ten elements of entrepreneurial ecosystems for 274 regions in the 28 countries of the European Union. The ecosystem elements show strong and positive correlations between them, confirming the systemic nature of entrepreneurial economies, and the need for a complex systems perspective. Our results show that formal institutions and physical infrastructure take a central position in the interdependence web, providing a first indication of these elements as fundamental conditions of entrepreneurial ecosystems. We then use the elements to calculate an index that measures the quality of entrepreneurial ecosystems. This index is robust and performs well in regressions to predict entrepreneurial output, which we measure using novel data on productive entrepreneurship.

Keywords: entrepreneurial ecosystem; regional dynamics; entrepreneurship; economic development; economic policy; entrepreneurship policy

JEL classification: D2, E02, L26, M13, O43, P00, R1, R58

Comments welcomed to: e.stam@uu.nl

Measure Twice, Cut Once

Entrepreneurial Ecosystem Metrics

1. Introduction

An entrepreneurial ecosystem comprises a set of interdependent actors and factors that are governed in such a way that they enable productive entrepreneurship within a particular territory (Stam, 2015; Stam and Spigel, 2018). The entrepreneurial ecosystem approach has become popular in economic policy because of the recent shift from managerial economies to entrepreneurial economies (Thurik et al., 2013). In these entrepreneurial economies entrepreneurship is a key driver of economic change (Schumpeter, 1911). For scientific research on the entrepreneurial economy to be relevant for economic policy, it needs to provide a sound understanding of how the economy works and provide an actionable framework that guides policymaking. The entrepreneurial ecosystem approach has the promise of providing such an actionable framework. It offers a lens to empirically trace the systemness of entrepreneurial economies and the degree to which economic systems produce entrepreneurship, as an emergent property of the system (Brown and Mason, 2014; Isenberg, 2010; Stam, 2015). It is especially useful to synthesize and integrate a large variety and quantity of data to measure the (changing) nature, outputs and outcomes of (regional) economies (Stam, 2015).

Economic policy often fails to achieve its objectives. One cause of this failure is a lack of diagnosis and monitoring in the policy cycle. We develop entrepreneurial ecosystem metrics to better measure entrepreneurial economies. These metrics enable adequate diagnosis of entrepreneurial economies and monitoring of economic change affected by policy and other dynamics. This paper takes heed of the old carpenter's adage "measure twice, cut once", reducing policy failures with better measurement tools. Even though the academic literature on entrepreneurial ecosystems has been flourishing recently, it does not yet provide an actionable framework for economic policy.

In this paper we address this gap in the literature by developing and extending the entrepreneurial ecosystem framework as a tool to analyse and improve entrepreneurial economies. The objective

of this paper is to quantify and qualify regional economies with an entrepreneurial ecosystem approach. Quantification involves measuring its key elements with a wide range of data sources. Qualification involves developing a methodology that provides insight into the extent to which the elements are interdependent, into the overall quality of the entrepreneurial economy, and relate this to entrepreneurial outputs. We have three main research questions. First, how can we compose a harmonized data set with which the quality of key elements of entrepreneurial economies can be measured? We develop a universal set of constructs for each element of entrepreneurial economies and compose a harmonized data set to measure these constructs in the context of 274 regions in the 28 countries of the European Union. The European Union provides an excellent laboratory for analysing entrepreneurial economies because it contains a large number of regions that exhibit striking variation in socio-economic conditions, entrepreneurial activity, and economic growth. Second, to what extent and how are the elements of entrepreneurial economies interdependent? Can entrepreneurial economies be seen as complex systems, with strong interdependencies between the elements? Interdependence is a key aspect of complex systems, we show with multiple statistical methods to what extent and how the elements of entrepreneurial economies are interdependent. Third, how can we determine the quality of entrepreneurial economies? We will answer this question by composing an entrepreneurial ecosystem index and analysing its relation to entrepreneurial outputs. Entrepreneurial output, realizing large scale innovations, is an indicator of the emergent property of the entrepreneurial economy as a complex system. We use multiple data sources and metrics to determine entrepreneurial outputs at the regional level. We do this with novel methods including web scraping and geocoding to determine the entrepreneurial outputs in the form of the number of (Crunchbase listed) innovative new firms and unicorns - young private firms with a valuation of more than $1 billion - in a region.

The outline of our paper is as follows. First, we discuss the key measures and mechanisms that explain entrepreneurship and economic development, and provide a new, complex systems methodology of understanding regional economies. Second, we discuss the measures that are needed to approximate the key elements of entrepreneurial economies and that allow us to quantify these elements and to qualify entrepreneurial economies, and relate this to entrepreneurial outputs. Third, we use these measures to quantify and qualify entrepreneurial economies in Europe. The

final section concludes, reflects on the findings, policy implications, and sets out an agenda for further research.

2. Entrepreneurship and economic development

The empirical literature on entrepreneurship and (regional) economic development can be divided in the entrepreneurship growth literature, focusing on the aggregate economic effects of entrepreneurship, and the geography of entrepreneurship literature, focusing on the causes of the spatial heterogeneity of entrepreneurship. In the next two sections we summarize the insights from these two literatures.

2.1 Entrepreneurship and economic growth

The role of entrepreneurship in economic development has been studied for a long time, going back to Schumpeter (1934), Leibenstein (1968) and Baumol (1990). The entrepreneurship growth literature is mainly concerned with the question how and to what extent entrepreneurship affects economic growth. Even though the entrepreneurship and economic growth literatures do not provide full consensus on the positive effects of entrepreneurship, there seems to be more evidence in favour of than against positive (causal) effects of entrepreneurship on economic growth (Audretsch et al., 2006; Bosma et al., 2018; Carree and Thurik, 2010; Fritsch, 2013). Key causal mechanisms being the creation and diffusion of innovations, and competition created by entrepreneurs (Bosma et al., 2018). The direction and strength of the effect of entrepreneurship on economic growth depends on the type of context and type of entrepreneurship: ambitious, opportunity and growth oriented types of entrepreneurship are more likely to lead to economic growth than self-employed, necessity based entrepreneurship (Bosma et al., 2018, 2011; Fritsch, 2013; Stam et al., 2011; Stam and Van Stel, 2011). In addition, entrepreneurship is most productive in conditions of inclusive and growth enhancing institutions (Bosma et al., 2018; Sobel, 2008). Entrepreneurship does not occur in a vacuum, but is very much a local event (Feldman, 2001). There is also substantial regional variation in the prevalence of entrepreneurship, with underlying causes being very much spatially bound.

2.2 The geography of entrepreneurship

The geography of entrepreneurship literature has provided numerous insights into the role of different factors enhancing the prevalence of entrepreneurship in regions (Bosma et al., 2011; Stam, 2010; Stam and Spigel, 2018; Sternberg, 2009). We summarize the empirical geography of entrepreneurship literature with ten elements affecting the prevalence of entrepreneurship (cf. Stam and Van de Ven, 2020). The first element, institutions, provides the fundamental preconditions for economic action (Granovetter, 1992) and for resources to be used productively (Acemoglu et al., 2005). Institutions are not only a precondition for economic action to take place, they also affect the way entrepreneurship is pursued and the welfare consequences of entrepreneurship (Baumol, 1990). Informal institutions also have strong effects on the prevalence of entrepreneurship, one example being entrepreneurship culture, reflecting the degree to which entrepreneurship is valued in society (Fritsch and Wyrwich, 2014). Networks of entrepreneurs provide an information flow, enabling an effective distribution of knowledge, labour and capital (Malecki, 1997). Leadership provides direction for the entrepreneurial ecosystem. This leadership is critical in building and maintaining a healthy ecosystem (Feldman, 2014). This involves a set of 'visible' entrepreneurial leaders who are committed to the region (Feldman and Zoller, 2012). The high levels of commitment and public spirit of regional leaders might be a reflection of underlying norms dominant in a region (Olberding, 2002). A highly developed physical infrastructure (including both traditional transportation infrastructure and digital infrastructure) is a key element of the context to enable economic interaction and entrepreneurship in particular (Audretsch et al., 2015). Access to financing—preferably provided by investors with entrepreneurial knowledge—is crucial for investments in uncertain entrepreneurial projects with a long-term horizon (see e.g. Kerr and Nanda, 2009). Perhaps the most important condition for entrepreneurship is the presence of a diverse and skilled group of workers ('talent': see e.g. Acs and Armington, 2004; Lee et al., 2004; Qian et al., 2013). An important source of opportunities for entrepreneurship can be found in knowledge, from both public and private organizations (see e.g. Audretsch and Lehmann, 2005). The supply of support services by a variety of intermediaries can substantially lower entry barriers for new entrepreneurial projects, and reduce the time to market of innovations (see e.g. Clayton et al., 2018; Howells, 2006; Zhang and Li, 2010). Finally, the presence of financial means in the

population to purchase goods and services—preferably locally, but possibly also on a further distance—is essential for entrepreneurship to occur at all. The presence of demand thus is an important element of the entrepreneurial ecosystem. Income and purchasing power in a region is both a cause and an effect of entrepreneurship in a region (Berkowitz and DeJong, 2005), already hinting at the role of feedback effects in the evolution of entrepreneurial ecosystems.

2.3 An entrepreneurial ecosystem framework

The empirical literatures on the geography of entrepreneurship and economic growth reveal several factors to be of relevance in explaining the spatial heterogeneity in entrepreneurship. This suggests that there is a limited set of factors, or elements that affects the prevalence of entrepreneurship in a region. We integrate the insights from the empirical literatures on the geography of entrepreneurship and economic growth into one figure, reflecting an entrepreneurial ecosystem framework with ten elements (see Fig. 1). This framework with ten elements provides a compromise between other frameworks with five (Vedula and Kim, 2019), six (Isenberg and Onyemah, 2016) and 14 elements (Ács et al., 2014). We build on these frameworks and develop them further by separating inputs and outputs of the system, providing an academically grounded set of elements, and using empirical indicators more closely reflecting productive entrepreneurship.

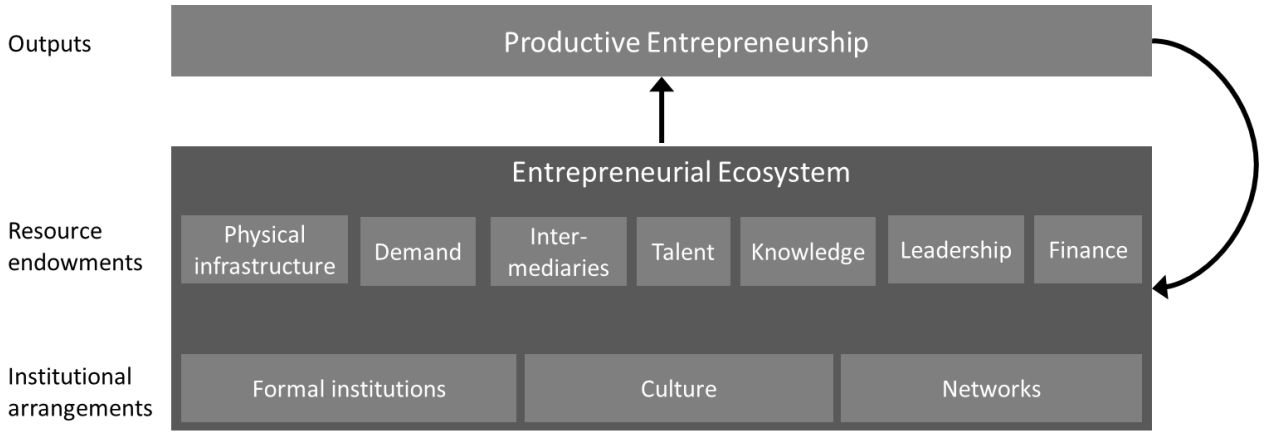


Fig. 1. Elements and outputs of the entrepreneurial ecosystem (adapted from Stam and Van de Ven, 2020).

2.4 Understanding entrepreneurial economies as complex systems

To understand the long-term development of (regional) economies and the role of entrepreneurship, the approaches of entrepreneurship and economic growth and geography of entrepreneurship need to be combined. Entrepreneurship plays a double role: it is the output variable in the geography of entrepreneurship approach, and it is the input variable in the entrepreneurship and economic growth approach. To complicate matters even more, entrepreneurship and economic growth also affect the inputs of the geography of entrepreneurship approach, for example with serial entrepreneurs becoming venture capitalists and creating networks; and with economic growth leading to growth in demand, investments in knowledge, and congestion effects in the physical environment. One solution to these conceptual complications is to build on complex systems approaches (Arthur, 2013; Hidalgo and Hausmann, 2009; Ostrom, 2010; Simon, 1962) to develop and use a complex systems perspective on the evolution of entrepreneurial economies (Roundy et al., 2018; Stam and Van de Ven, 2020). A complex systems perspective is able to integrate the geography of entrepreneurship (environmental conditions of entrepreneurship) and the entrepreneurship and economic growth literature (the conditions and effects of productive entrepreneurship). We build on the integrative model of entrepreneurial ecosystems by Stam and Van de Ven (2020), which includes institutional arrangement and resource endowment elements (see Fig. 1). They focus on three key mechanisms: interdependence and coevolution of elements, upward causation of the ecosystem on entrepreneurship, and downward causation of entrepreneurial outputs on the quality of the ecosystem (Stam and Van de Ven, 2020).

Entrepreneurial eco(logical) systems do not exist as such, in contrast to economies that do exist, and can be more or less complex, systemic, and entrepreneurial. Systemic in the sense of elements interacting with each other, and complex in the sense of creating distinct properties that arise from these interactions (including nonlinearity, emergence, adaptation, and feedback loops). In this paper we focus on emergence, and conceptualise economies as complex systems from which transformative innovations can emerge. Transformative innovations are the product of interacting agents, enabled by interdependent components of the system in which they act (Arthur, 2013). Complex systems have distinct properties that arise from interdependencies, such as nonlinearity, emergence, tipping-points, spontaneous order, adaptation, and feedback loops. A complex systems

perspective on the evolution of entrepreneurial economies can provide new answers and new questions to the literature on entrepreneurship and economic development. We take a complexity perspective to better understand the dynamics of economic systems and the interdependencies between the elements of a system. Our complexity approach provides the tools for tracing nonlinear dynamics. Small changes in the conditions of an ecosystem can have big effects: just like the introduction of a wolf can change a whole natural ecosystem, the introduction of a new law or a new actor can change a whole economic system. Also, when a threshold (tipping point) is reached in producing scale-ups in a particular territory, this might trigger a virtuous cycle of successful exits that provide a fertile breeding ground for next generations of scale-ups, as these successfully exited entrepreneurs may become venture capitalists, role models, and network builders in their home-region (Mason and Harrison, 2006). Such analyses provide novel insights into the recursive causal connections between entrepreneurship and elements in the economic system such as venture capital (Lerner, 2012) and culture (Minniti, 2005).

3. Measuring entrepreneurial ecosystems

The ecosystem framework discussed above identifies ten key elements of an entrepreneurial ecosystem. In this section we operationalize these elements into measurable variables at the appropriate geographical level. First, we discuss the boundaries of an ecosystem to determine the relevant level of analysis. Then we shortly illustrate the main data sources and describe the operational measure of each ecosystem element (for an overview see Table 1).

3.1 Level of analysis

The outputs and outcomes of entrepreneurial ecosystems are the result of a complex set of actors and factors that occur in a temporal and varying regional setting. As Feldman and Lowe (2015, p. 1785) rightly state there is often a disconnect "between the theoretical definition of a region as integrated contiguous space and the political and census geography for which data are readily available." In addition, since ecosystems are continuously evolving and are not limited to a specific sector, it is hard to precisely determine their boundaries (Stam and Van de Ven, 2020). The primary

demarcation criterium should be the spatial reach of the causal mechanisms involved. This does not lead to one straightforward unit or spatial level of analysis. First, given the multiplicity of causal mechanisms involved in nurturing entrepreneurship, there will be different spatial reaches: for talent it may be the daily urban system (within a 50 mile radius), while for credits it may be the local bank, and for venture capital a two hour drive radius (which may overlap with the regional level in large countries, but may be beyond the national level for small countries). Second, there is a spatial nestedness of contexts: formal institutions at the municipal, regional, national and supranational level may be important context conditions. These first two considerations make it difficult to delineate the spatial boundary of entrepreneurial ecosystems, from a causal mechanism point of view. From a practitioners', the stakeholders of entrepreneurial ecosystems, point of view the relevant boundaries will again be different depending on their role in the ecosystem. For civil servants it will be a particular jurisdiction, while for entrepreneurs it may be a multiplicity of layered (regional, national) or connected ecosystems (different city-regions). To determine the spatial level of analysis (although almost always imperfect) we therefore search for a common spatial denominator in combination with data availability (to allow for comparisons). It should nevertheless also be kept in mind that even though we choose a spatial unit to represent the entrepreneurial ecosystem, entrepreneurial ecosystems are not closed containers, but open systems.

In the European context, the most relevant spatial level of analysis is likely to be between the municipal and national level, since the spatial reaches of the different elements are most likely to overlap with regional boundaries (e.g. the 50 mile radius for talent). The regional level in Europe is best defined through the NUTS 2 classification, which identifies 281 geographical regions over the 28 member states. Hence, we use the NUTS 2 level as the level of analysis. The boundaries of these areas are based on existing administrative boundaries and population thresholds. The population of a NUTS 2 unit is roughly between 800,000 and 3 million people (European Commission, 2018). By defining entrepreneurial ecosystems at the NUTS 2 level we use the same region size as the recent study by Stam and Van de Ven (2020). Our study looks at a larger set of observations than Stam and Van de Ven (2020) since we include all countries in the European Union instead of only one. This also results in a substantial larger variety in our data. Studying regions instead of countries allows us to look at entrepreneurial at a more detailed and appropriate scale. A disadvantage of looking at regions instead of countries is that data on a regional level is

scarcer than national data. However, the European Union performs several large data collection exercises on regional level to inform regional policy, this results in the availability of a fairly large amount of regional data. Furthermore, we use a number of novel methodologies to create new metrics at the NUTS 2 level. Finally, we use several national measures to account for the aforementioned spatial nestedness of for example institutions. This combination of data on different geographical levels is discussed in detail for each element below and summarized in Table A1 in the appendix.

3.2 Data sources

To measure entrepreneurial ecosystem elements we combine three datasets from studies executed by the European Commission and complement this with data from other sources as well as new data we collected using innovative data analytics. The three main datasets are all available for NUTS 2 units in the European Union. The Regional Competitiveness Index (RCI) is a large study performed every three years (Annoni and Dijkstra, 2019). It uses multiple data sets to construct indicators for areas such as infrastructure, human capital and innovation, and subsequently computes an index that is said to reflect the competitiveness of a region. A related dataset that is more explicitly focused on entrepreneurship is the Regional Ecosystem Scoreboard (RES) (Léon et al., 2016). In addition to combining several statistical sources, this study also performs its own survey among cluster organizations and regional development agencies. The data used in the RES is mainly from the 2010-2015 period and we obtained this through web scraping. Finally, we also take data from the Regional Innovation Scoreboard (RIS) which is a smaller dataset solely focused on the innovation performance of regions (Hollanders et al., 2019). This is the regional version of the European Innovation Scoreboard (EIS) and measures for instance R&D expenditure, innovation by SMEs and human capital. These main data sources are combined with several statistics from Eurostat. For some indicators data is only available at the NUTS 1 level in certain countries. In those cases we follow the approach of the original datasets and impute the NUTS 1 for the NUTS 2 regions (Annoni and Dijkstra, 2019; Hollanders et al., 2019; Léon et al., 2016). Table 1 provides an overview of the data source for each measure while a more detailed version, including all original data sources, can be found in Table A1 in the appendix.

Table 1.

Operationalisation of the indicators of entrepreneurial ecosystem elements and output.

Elements	**Description**	**Empirical indicators**	**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, accountability, and impartiality) and the regulatory framework for entrepreneurship (number of days to start a business, difficulties encountered when starting a business, the barriers to entrepreneurship and the ease of doing business)	Quality of Government Survey and the Regional Ecosystem Scoreboard
Entrepreneurship culture	The degree to which entrepreneurship is valued in a region	A composite measure capturing the regional entrepreneurial culture, consisting of entrepreneurial motivation, cultural and social norms, importance to be innovative and trust in others	Regional Ecosystem Scoreboard
Networks	The connectedness of businesses for new value creation	Percentage of SMEs that engage in innovative collaborations as a percentage of all SMEs in the business population	Regional Innovation Scoreboard
Physical Infrastructure	Transportation infrastructure and digital infrastructure	Four components in which the transportation infrastructure is measured as the accessibility by road, accessibility by railway and number of passenger flights and digital infrastructure is measured by the percentage of households with access to internet	Regional Competitiveness Index
Finance	The availability of venture capital and bank loans to firms	Two components: availability of venture capital, availability of bank loans for capital investments	Regional Ecosystem Scoreboard

Leadership	The presence of actors taking a leadership role in the ecosystem	The number of coordinators on H2020 innovation projects per 1000 inhabitants	CORDIS (Community Research and Development Information Service)
Talent	The prevalence of individuals with high levels of human capital, both in terms of formal education and skills	Eight components: tertiary education, vocational training, lifelong learning, innovative skills training, entrepreneurship education, technical skills, creative skills, e-skills	Regional Ecosystem Scoreboard
New Knowledge	Investments in new knowledge	Intramural R&D expenditure as percentage of Gross Regional Product	Eurostat
Demand	Potential market demand	Three components: disposable income per capita, potential market size expressed in GRP, potential market size in population. All relative to EU average.	Regional Competitiveness Index
Intermediate 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	Entrepreneurial output	The number of Crunchbase firms founded in the past 5 year per 1000 inhabitants	Crunchbase
	Unicorn output	The absolute number of unicorns in the region	CB Insights

3.3 Element construction

Seven of the ten elements are constructed through multiple indicators. For these elements we calculate the element score by first standardizing the individual measures (mean as 0 and standard deviation of 1). This ensures that the different measures each have a proportionate influence on the composite indicator. We then take the average of the standardized measures. In section 3.14 we go into more detail on how the different elements are used to calculate an index for the entrepreneurial ecosystem.

To measure four of our variables, leadership, the number of incubators, and both output measures we use the location of individual organizations to determine our regional variables. We here explain the methodology of geocoding and region allocation which we use in all four occasions. First, we use the nominatim package in R to geocode the given locations using OpenStreetMap (OpenStreetMap, 2019; Rudis, 2019). This is an online map which allows users to pass a list of locations into the software and obtain their coordinates. For the few regions without a match in this procedure we manually search and add its coordinates. With this procedure we obtained the coordinates for all organization. Subsequently, we used Eurostat shapefiles to determine in which NUTS 2 region these coordinates are located. The shapefiles contain an exact overview of the NUTS 2 boundaries (Eurostat, 2019). We then use the rgdal package in R to assign the coordinates to the corresponding NUTS 2 region (Bivand et al., 2019; Eurostat, 2019). Through this we are able to assign all except for about 0.1% of the organizations to a region. We filled in the remaining geocodes through the browser tool of Open Street Map. After this we were able to assign all organizations for each of the four variables to a region. For each of the four variables we then count the number of organizations/firms in each NUTS 2 region and divide this by the population of the region to obtain our final measure.

3.4 Formal institutions

Well-functioning institutions are essential for any entrepreneurship to take place at all (Granovetter, 1992). Even when fundamental conditions of the institutional framework, e.g. property rights, are in place, the quality of these institutions will affect entrepreneurship (Baumol, 1996; Boudreaux

and Nikolaev, 2019; Webb et al., 2019). To operationalize this element, we use a generic and an entrepreneurship specific indicator. These indicators cover two different aspects of the institutional environment, namely the quality of government and the regulatory framework for businesses. To operationalize the general quality of government we use the Quality of Government study (QOG), which is the largest sub national governance study that has been performed (Charron et al., 2019a). The quality of government indicator consists of three components: corruption, accountability and impartiality. These are each measured by a large citizen survey in each European region and complemented by the World Governance Indicators on a national level. The survey questions measure both experiences and perceptions of citizens and ask for example about the quality of public education in their region or corruption in the police force in their area (Charron et al., 2019b).[1] It is important to note that all questions specifically refer to the region of the respondent. One potential threat is that some of the NUTS areas do not precisely coincide with local administrative units and in some countries local administrative units may not be very powerful. However, NUTS 2 regions are devised to overlap with administrative regions as much as possible and even in more centralized countries previous studies found substantial regional variation. This measure thus accounts for the nestedness of the regional variation in quality of governance within national institutions.

To measure the entrepreneurship specific regulatory framework we use the composite indicator 'Regulatory framework for starting a business' from the RES (Léon et al., 2016). This consists of the following four measures: number of days to start a business, difficulties encountered when starting a business, the barriers to entrepreneurship, and the ease of doing business index (for a more detailed overview of all the indicators see Table A1 in the appendix). Using a combination of general and entrepreneurship specific institutions is a significant improvement over the operationalization of formal institutions as implemented by Stam and Van de Ven (2020).

3.5 Entrepreneurship culture

[1] Whenever possible the word for region in the survey was replaced by the relevant administrative region in the country e.g. Bundesland in Germany.

The next element of entrepreneurial ecosystems, culture, represents an informal institution. Specifically, how much entrepreneurship is valued and stimulated in a society (Fritsch and Wyrwich, 2014). The cultural context can have a substantial effect on entrepreneurship by influencing the aspirations of entrepreneurs and whether people are likely to become an entrepreneur at all (Hayton et al., 2002). To measure entrepreneurship culture we use the RES indicator for entrepreneurial culture, which consists of five components: entrepreneurial motivation, cultural and social norms, business and entrepreneurship education, importance to be innovative and creative, and trust in others. However, we exclude the entrepreneurship education measure as we deem this measure to be more fitting for the talent element. These components were measured by two large surveys: the Global Entrepreneurship Monitor (Bosma and Kelley, 2019) and the European Social Survey (Norwegian Center for Research Data, 2014).[2]

3.6 Networks

When actors in a region are well connected in networks this allows information, labour and knowledge to flow to firms which can use it most effectively (Malecki, 1997). Networks are essential for entrants as it helps new firms to build social capital, which firms can leverage to get access to resources, information and knowledge (Eveleens et al., 2017; van Rijnsoever, 2020). The connections between firms can be measured through their cooperation projects. Our focus on entrepreneurship entails that we specifically want to measure cooperation on innovative projects. Therefore, we measure networks as the number of Small and Medium Enterprises (SMEs) with innovation cooperation activities as percentage of all SMEs in a specific region. The focus on innovation projects means this measure captures the kind of productive collaboration that is likely to contribute to entrepreneurial output. In addition, the size of SMEs (enterprises with between 10 and 250 employees) matches with our focus on entrepreneurial growth since it does not include micro firms (less than 10 employees) which are less relevant for our output measure. Larger firms

[2] Stam and Van de Ven (2020) use the number of new firms per 1000 inhabitants as an alternative measure of culture. We initially aimed to combine our current indicator with this data. However, there is (not yet) a harmonized dataset on this variable for all European NUTS 2 regions and we thus had to use a combination of OECD, Eurostat, and national statistics offices to construct this variable (see Table A1). These data sources were not consistent in their definitions and data demarcations. Hence, we deemed the validity of this alternative measure to be questionable and we excluded this measure from our analyses. We did perform a robustness test in which we combined the birth rate of new firms with our current culture measure. The results of our analyses remained largely identical.

are also excluded from this measure, mainly because almost all large firms participate in some cooperation activities so this does not provide relevant information. Stam and Van de Ven (2020) use a similar measure in their study. We use the data from the RIS, complemented with the European Innovation Scoreboard for countries with only one NUTS 2 region. The RIS and EIS base their data on the Community Innovation Survey (Arundel and Smith, 2013).

3.7 Physical infrastructure

Infrastructure is essential for economic interaction between actors and thus essential for entrepreneurship (Audretsch et al., 2015). In this highly digital world not only physical infrastructure enables this interaction but also digital infrastructure. Digital infrastructure provides the opportunity to meet other actors, even if they are not in close physical proximity. Therefore, it is important to include this when creating an empirical measure of infrastructure. For our indicator we follow the approach of the RCI which uses the accessibility by road, accessibility by railway and number of passenger flights to measure the physical (transportation) infrastructure of a region (for details see Table A1). To this we add a measure for the digital infrastructure of a region, which is the percentage of households with access to internet and also available in the RCI (Annoni and Dijkstra, 2019).

3.8 Finance

An important condition for starting a new firm and growing an existing firm is access to capital (see e.g. Kerr and Nanda, 2009; Samila and Sorenson, 2010). We measure the availability of capital with two indicators from the Regional Ecosystem Scoreboard (RES): the availability of venture capital and the availability of bank loans for capital investments (Léon et al., 2016). The data is taken from the RES survey which measures the perceived availability of capital on a 5-point scale. Venture capital is defined as equity not noted on the stock market including replacements and buyouts. It would arguably be better to have the actual amount of venture capital in a region.

However, although this data is available on a national level from the EIS, there is not sufficient regional data on the actual availability of venture capital.[3]

3.9 Leadership

Leadership in an entrepreneurial ecosystem is necessary to provide the actors in the ecosystem a certain direction or vision to work towards and can make the ecosystem function more effectively (Normann, 2013). Leadership can be provided by individual leaders but also by collaborative efforts that try to guide the system in a certain direction. Since leadership is such an intangible concept it is quite hard to measure and remains understudied (Sotarauta et al., 2017). In our study we operationalize leadership as the number of project coordinators of Horizon2020 innovation projects in a region. We thus follow the approach of Stam and Van de Ven (2020) who use the number of innovation project leaders as their operationalization for leadership. To construct this variable we use the CORDIS database which, after removing duplicates, contains data on 23,693 innovation projects that are subsidized as part of the Horizon 2020 program of the European Union (CORDIS, 2019; European Commission, 2019). We then use the geocoding approach outlined in section 3.3 to create our leadership indicator, the number of innovation leaders per 1000 inhabitants.

3.10 Talent

Human capital (or talent) encompasses the skills, knowledge and experience possessed by individuals (Stam and Van de Ven, 2020). Human capital is a critical input for entrepreneurship and has been shown to be linked to new firm formation (see e.g. Acs and Armington, 2004). It is clearly quite a broad concept which asks for several empirical measures to properly cover the different facets. We break human capital down into two different components, general human capital and entrepreneurship-specific human capital (Becker, 1964; Rauch and Rijsdijk, 2013). General human capital is not directly related to a certain job (Rauch and Rijsdijk, 2013). To compute the human capital indicator we use data from the RES which offers an extensive measure

[3] To test the robustness of our measure we performed a correlation between the actual venture capital data for the UK and DE with the RES data which results in a correlation of 0.40.

of education and skills (Léon et al., 2016). The general indicator includes the percentage of population having completed tertiary education, the percentage share of companies providing vocational training and the percentage of population aged 25-64 that participates in education or training (lifelong learning).

Entrepreneurship specific human capital is directly related to start-up activities (Brüderl et al., 1992; Rauch & Rijsdijk, 2013). We include five measures, measuring entrepreneurship and business education, innovative skills training given at companies, creative skills, technical skills, and e-skills. The inclusion of digital skills is highly relevant since digital literacy is almost essential for working in any type of enterprise in the current digital society. In addition, a lot of innovation nowadays involves some digital aspect. The talent measure we use is a significant improvement over earlier papers which almost solely focused on formal education.

3.11 Knowledge

The creation of new knowledge by either private or public organizations provides new business opportunities (Kim et al., 2012; Qian et al., 2013). It is therefore an important source of entrepreneurship. We measure this element with intra-mural R&D expenditure as a share of the total Gross Regional Product (GRP). This measure includes R&D spending in both public and private sectors. The data for this variable is available in both the Regional Competitiveness Index (Annoni and Dijkstra, 2019) and Regional Innovation Scoreboard (Hollanders et al., 2019). We chose to use the data from the RCI as this is available at the NUTS 2 level for a larger number of regions.

3.12 Demand

The purchasing power and potential demand for goods and services is important for entrepreneurs, since it will only be interesting to market new products if the population has the financial means to buy them. Several studies have shown that market growth increases firm entry (Eckhardt and Shane, 2003). Even though most firms nowadays serve larger markets than just those in their own region, it will be important for start-ups to have a potential regional market which they can easily

access (Cortright, 2002; Reynolds et al., 1994; Schutjens and Stam, 2003). We measure the demand using data from the RCI which combines three measures to create an indicator for market size (Annoni and Dijkstra, 2019). The measures are disposable income per capita, potential market size expressed in GRP and potential market size expressed in population.

3.13 Intermediate services

Intermediate services or producer services can help producers to start a new enterprise and market an innovation. The supply of support can substantially lower entry barriers of new entrepreneurial projects and speed up the introduction of innovations (Howells, 2006; Zhang and Li, 2010). For this element we compose an indicator based on two measures. Similar to the talent and formal institutions element we combine a general and a specific measure. We operationalize the general measure as employment in knowledge intensive market services, which represents the general availability of intermediate services. The required data is available in Eurostat.

For the specific measure we look at incubators and accelerators as intermediate service providers. These are organizations specifically aimed at helping people with innovative ideas start their own companies. Incubators and accelerators normally provide various services such as access to networks of entrepreneurs and training in business skills (Cohen et al., 2019; Eveleens et al., 2017; van Weele et al., 2017). In addition, incubators are an important form of intermediate services since they also act as developers of entrepreneurial ecosystems (Van Rijnsoever, 2020). To identify the population of incubators we scraped a total of 1,005 incubators and accelerators from the Crunchbase website. We then use the geocoding approach outlined in section 3.3 to determine the number of incubators per 1000 inhabitants.

Several studies have shown that incubators and accelerators can significantly contribute to the success of start-ups (see for recent reviews Ayatse et al. (2017) and Eveleens et al. (2017)). Since these organizations are put in place to support entrepreneurs and can improve the performance of new firms, it is important to include this in the analysis. Including incubators/accelerators in addition to general intermediate services is therefore a significant improvement of our understanding of how support services can contribute to a successful ecosystem. Note that we

measure the prevalence of intermediate services in general, and incubators/accelerators in particular, but not the quality of these services per se.

3.14 Entrepreneurial Ecosystem Index

The ten elements of the entrepreneurial ecosystem which we have operationalized in the previous sections are then used to calculate an index. This is done using the same method as applied in Stam and Van de Ven (2020). We have first standardized the composite indicators which we have calculated. This ensures that all elements get similar weights in the creation of the index. So the calculation of the index is based on the assumption that all ten elements are of equal importance in the ecosystem. Future research could investigate whether the index can be improved by giving certain elements more weight than others. Subsequently, we take the inverse natural log of the indicators and then normalize them by setting the European average of each element to 1 and by letting all other regional values deviate from this. If an element in a region performs less than average this results in a value between 0 and 1, above average performing regions have a value above 1. This allows us to compute an index value based on the ten elements and compare the quality of different entrepreneurial ecosystems. We calculate the index values in three ways. First, in an additive way where (E1 + E2 +…En). Regions with an average value on each element will thus score an index value of 10. Second, to better account for the complex system nature of the entrepreneurial ecosystem we also calculate the index in a multiplicative manner (E1*E2*…En). The disadvantage of the multiplicative index is that values above 1 have a stronger effect on the index than below average values (which are between 0 and 1). We therefore take the natural logarithm to let the values oscillate symmetrically around 0, this logarithmic way (log(E1) + log(E2) +….log(En)) is our third index value.

3.15 Output

The output of the entrepreneurial ecosystem is productive entrepreneurship (see Fig. 1). This kind of entrepreneurship contributes to net output of the economy and consequently leads to aggregate value creation, which is the outcome of the system (Baumol, 1990). Previous research has shown that productive entrepreneurship indeed has a strong effect on economic growth and job creation

(Criscuolo et al., 2014; Haltiwanger et al., 2013; Stam et al., 2011; Wong et al., 2005). Productive entrepreneurship is a subset of total entrepreneurship and thus requires another measure than, for example, the total number of new firms.

In this study we take the number of new enterprises, founded less than 5 years ago, that are registered in Crunchbase as our measure for entrepreneurial output (Crunchbase, 2019; Dalle et al., 2017). Crunchbase predominantly captures venture capital oriented/innovative entrepreneurial firms and largely ignores companies without a growth ambition and is thus a good source for data on productive entrepreneurship (Dalle et al., 2017). We choose this specific timeframe to ensure that we select firms who experience their growth phase during the same time period (2015-2019) as most of our indicators are measured (see Table A1). The data on Crunchbase mostly comes from two channels, a community of contributors and a large investor network. In addition, the data is validated with other data sources using AI and machine-learning algorithms. A limitation of the Crunchbase dataset is that it is uncertain if the coverage of start-ups is equal among the different countries. However, we found no evidence that this was the case. We further acknowledge that not all start-up entrepreneurs are innovative (cf. Autio et al., 2014), and are also aware that our measure of entrepreneurial output does not capture all innovative activity in the economy, nevertheless Crunchbase is currently the most comprehensive dataset available to measure high growth entrepreneurship as an entrepreneurial output (Dalle et al., 2017). While Crunchbase is increasingly used by scholars for different purposes (Dalle et al., 2017) we are, to the best of our knowledge the first to employ this dataset to measure the output of entrepreneurial ecosystems. We also explored using the ORBIS data of Bureau Van Dijk as an alternative (Bureau van Dijk, 2020; Dalle et al., 2017). However, we elected not to do this because we found relatively low serial correlation between the different years in the database and found disproportionally large differences between countries which were hard to render and thus influenced our ability to perform cross country regional comparisons.

In addition to the Crunchbase output measure we use a measure for extreme entrepreneurial output in the form of unicorns, which are entrepreneurial ventures valued above $1 billion. We used the 2018 CB Insights unicorn dataset and identified a total of 24 unicorns in Europe (CBInsights, 2018). We then used the geocoding procedure to allocate these unicorns to a total of 17 NUTS 2

regions. As such, unicorns are a very rare and selective form of high growth entrepreneurship that is only present in a small number of regions.

3.16 Outliers

Since the European Union covers a large and diverse set of regions, the data show a lot of variety. In particular for the measures of knowledge, intermediate services, leadership and output there are a few regions that have very high values (up to 50 times the standard deviation). Even though this variation is realistic, these outliers do disproportionally influence the correlation results and regression results. Most importantly, for the regions that score extremely high on one particular indicator, the index for the quality of the Entrepreneurial Ecosystem is disproportionally influenced by one indicator. This does not reflect the systemic nature of entrepreneurial ecosystems as argued in the existing theory (Spigel, 2017; Stam, 2015). Therefore, we performed two transformations on the data to provide better interpretable results. First, before the standardization of the composite indicators we cap the maximum value at four standard deviations of the mean (for more information on the standardization procedure see the section on index calculation). In practice this means that we change the values for DE30 (Berlin) for the Crunchbase output measure, UKI3 (Inner London-West) for the Crunchbase output, leadership, and intermediate services, DE91 (Braunschweig) for knowledge (as a result of the high R&D intensity), and DK01 (Hovenstaden) for leadership. Second, we set the maximum score for any single element to 5 in order to prevent a disproportionate influence of strong performing ecosystem elements on the overall index. We perform a number of robustness checks on the construction of our index which we discuss in section 4.5.

4. Quantifying and qualifying entrepreneurial ecosystems in Europe

4.1 Descriptive statistics

The descriptive statistics of the empirical measures for the ten ecosystem elements, entrepreneurial outputs, and the index scores are shown in Table 2. In total our data covers 274 NUTS 2 regions divided over the 28 EU member states.

Table 2

Descriptive statistics

	n	Mean	Standard Deviation	Minimum	Maximum
Crunchbase output	274	0.378	0.898	0.111	5.000 (58.162)
Unicorn output	274	0.088	0.436	0.000	5.000
Formal institutions	274	1.000	0.778	0.071	3.333
Culture	274	0.977	0.922	0.013	5.000 (10.229)
Networks	273	0.984	1.142	0.117	5.000 (6.070)
Physical Infrastructure	273	0.907	1.065	0.058	5.000 (8.411)
Finance	274	1.000	0.770	0.067	5.000 (5.061)
Leadership	274	0.594	0.991	0.154	5.000 (49.816)
Talent	274	0.955	1.002	0.029	5.000 (10.902)
Knowledge	274	0.721	1.031	0.108	5.000 (33.48)
Demand	274	1.000	0.939	0.032	4.667
Intermediate services	274	0.585	0.887	0.060	5.000 (101.880)
EE index additive	273	8.707	5.510	0.989	30.905
EE index mult	273	49.843	534.354	0.000	8657.341
EE index log	273	-6.352	6.435	-24.487	9.066

Notes: The uncorrected maximum value of each element is presented between brackets. We do not have data for all elements for Aland, a small island region of Finland, so the total number of regions for which we calculate the index is 273.

We standardize all variables relative to the EU average to account for the different scales of measures. The mean is calculated based on the corrected maximum values and can therefore be below one. We also see a large variation around the mean for several variables, from regions with less than 2 percent of the EU average to regions who have over 160 times the average value. These findings are nevertheless in line with our expectations since we study regions across different countries and levels of development. Looking at the three index values that we calculated using the methods of Stam and Van de Ven (2020), we find that the difference between the smallest and largest value for the multiplicate index is a factor 10^{14}. This difference is disproportionately large in comparison with the actual variation in the data as a result of the multiplicative way of calculating the index. Hence, we deem the external validity of the multiplicative index to be insufficient and instead use the additive index in our further analyses with the logarithmic index as a robustness check.

4.2. Entrepreneurial Ecosystem Index

To provide a closer insight in the strongest and weakest regions in Europe according to the Entrepreneurial Ecosystem Index, we display the scores for the ten highest (Fig. 2) and lowest ranking (Fig. 3) regions. The highest scoring regions are, as expected, mainly Western European and densely populated while the lowest scoring regions are mainly Bulgarian and Greek rural regions. To look at the different Entrepreneurial Ecosystems in more detail, Fig. 4 shows the map of Europe with all NUTS 2 regions colored based on the value of the Entrepreneurial Ecosystem Index. The highest index values can be found in European capital regions, such as Berlin, Paris, Vienna and London. Many regions in Eastern Europe show very low index values as do some of the more rural areas in Spain. The map supports the claim that there is a substantial difference between urban and rural areas. Most of the high-scoring regions include large cities. In addition, we see the Northern European countries scoring very high.

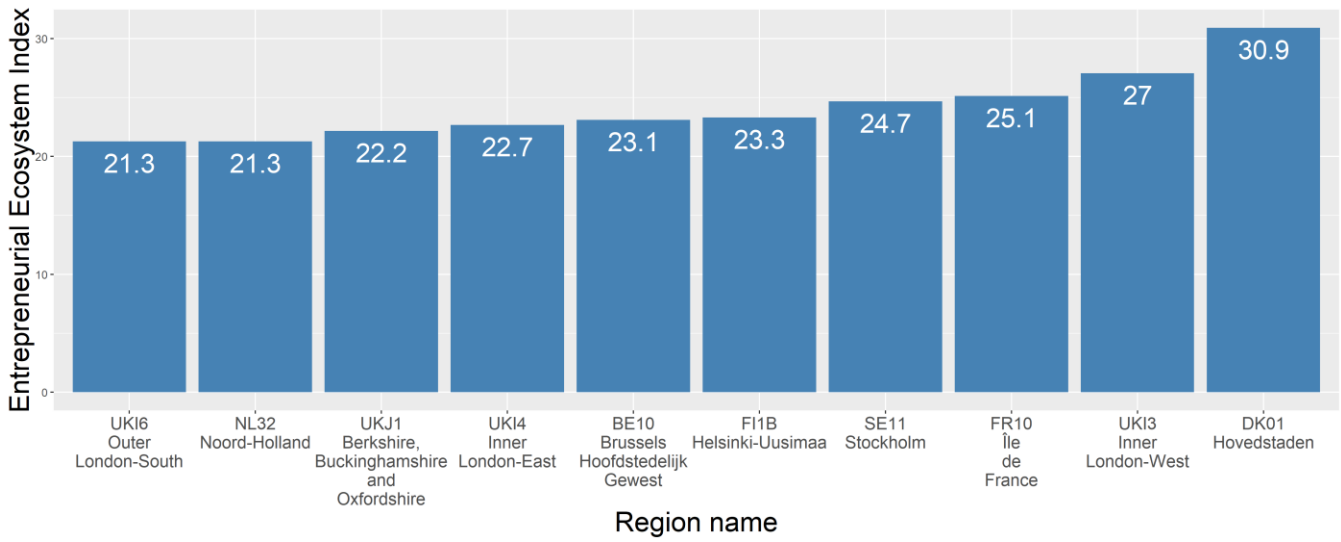


Fig. 2

NUTS 2 regions with the highest Entrepreneurial Ecosystem Index scores.

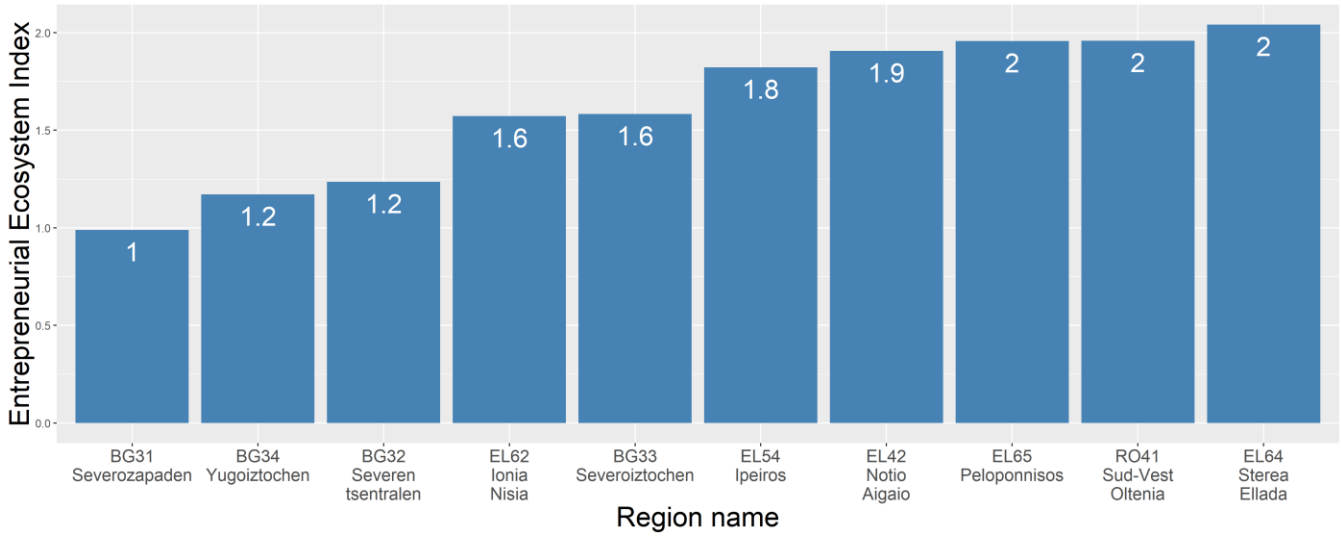


Fig. 3

NUTS 2 regions with the lowest Entrepreneurial Ecosystem Index scores.

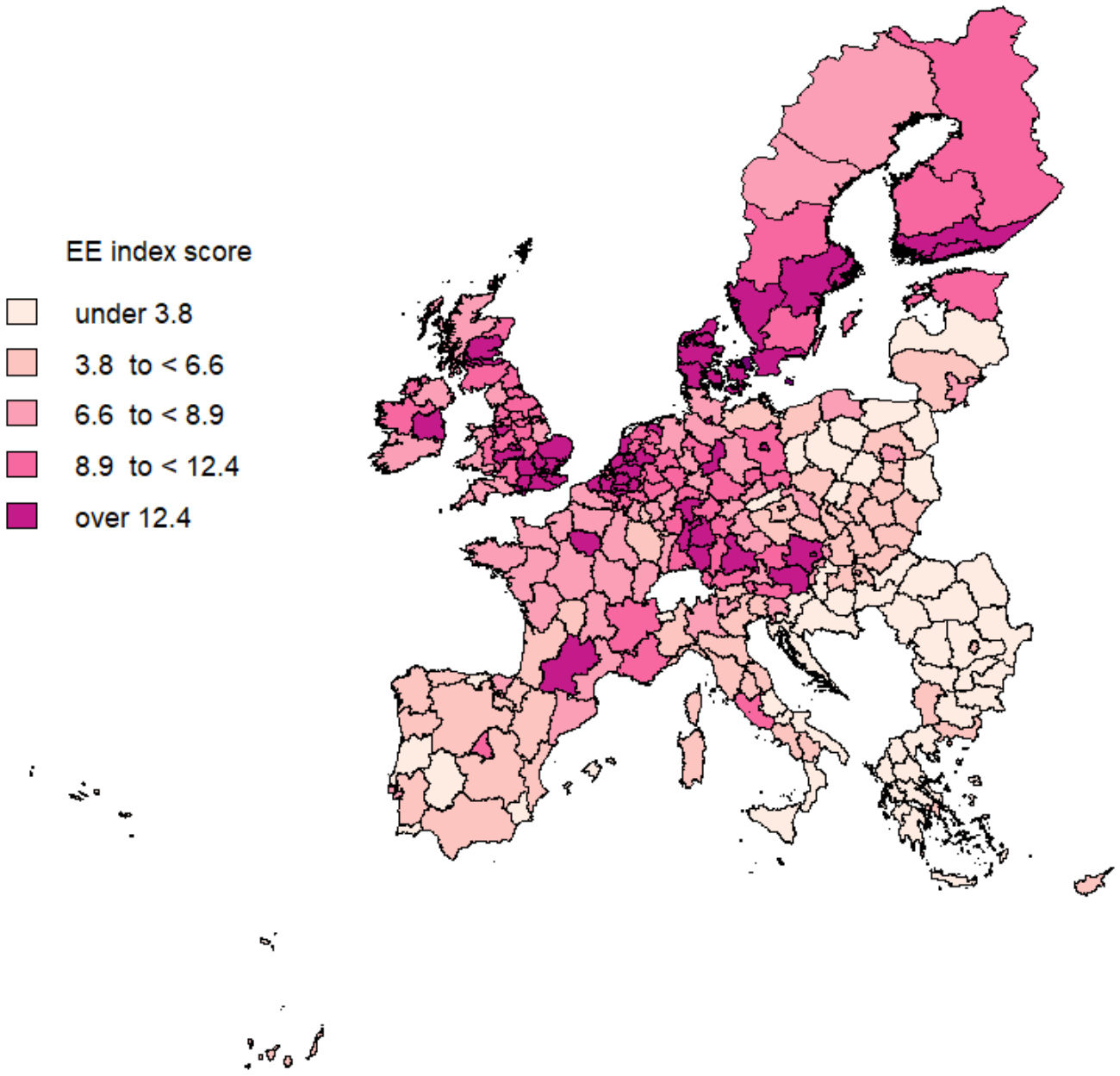


Fig 4.

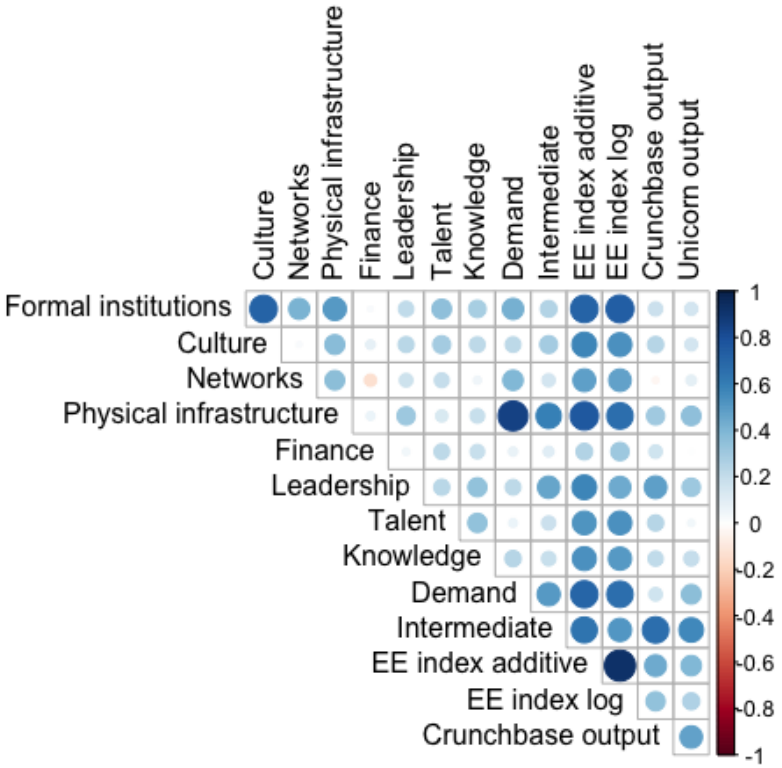
Map of NUTS 2 regions showing Entrepreneurial Ecosystem Index (273 regions are divided among groups of equal size).

4.3. Interdependence between entrepreneurial ecosystem elements

Table 3 shows the correlations between the different elements of the entrepreneurial ecosystem, the outputs and the index. In general, we see high, positive and significant correlations between almost all of the elements of the ecosystem.[4] Only for finance there are two small negative correlations. The strong positive correlations illustrate the interdependencies in the entrepreneurial ecosystem. This corresponds to the results shown in Stam and Van de Ven (2020) and confirms the complex system nature of entrepreneurial ecosystems. Considering the entrepreneurial output measures, we see positive and significant correlations with almost all elements, and with the entrepreneurial ecosystem indices we constructed. This supports the proposition regarding upwards causation, stating that the ecosystem elements influence the occurrence of productive entrepreneurship.

Table 3.

Correlation matrix (correlation coefficient is indicated by colour and the significance level by size, only correlations that are significant at 5% level are shown)



[4] For an overview of the numeric correlation coefficients with p-values see Table A2.

The interdependencies between the ten elements are shown in the form of a network plot in Fig. 5. Physical infrastructure, formal institutions and also demand take the most central position in the interdependence web. This central role is supported by the finding that when looking at interdependencies with a correlation above 0.5 where physical infrastructure and formal institutions each have five interdependencies (Fig. 6a), and again confirmed by the interdependency web with correlations above 0.6 (Fig. 6b). This provides an indication for a potential role of these elements as fundamental conditions of the entrepreneurial ecosystem.

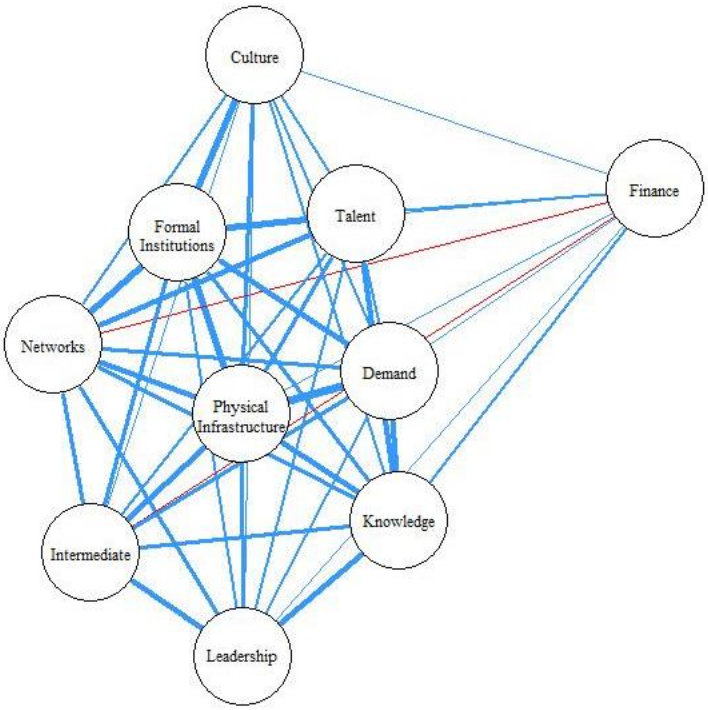


Fig. 5.

Interdependence webs of entrepreneurial ecosystem elements with blue lines showing positive and red lines negative correlations. The edge weight is defined based on the correlation strength

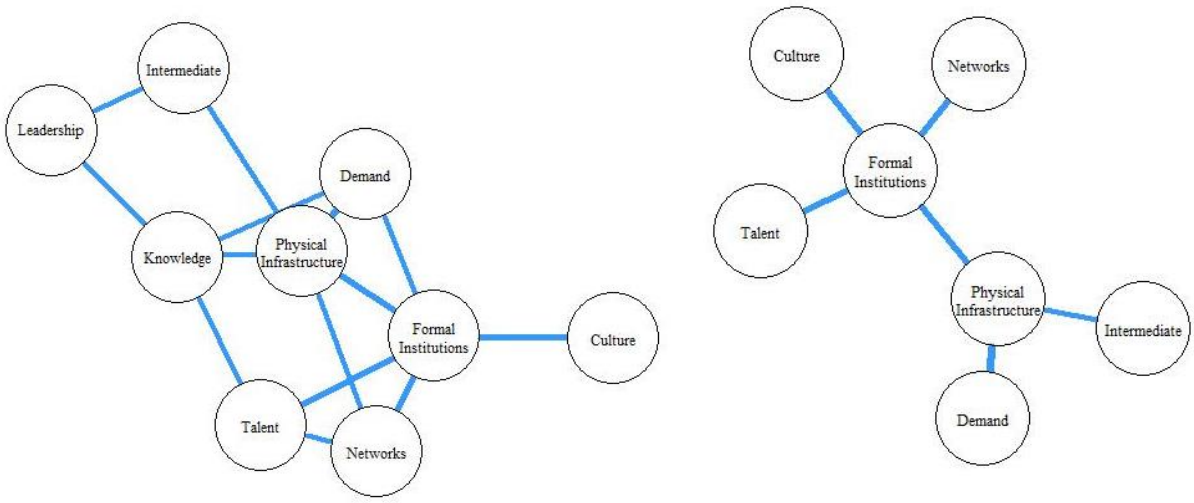


Fig. 6a. and 6b.

Interdependence webs of entrepreneurial ecosystem elements with correlations above 0.5 (left) and 0.6 (right)

To further explore the interdependencies and to test the reliability of using the sum scores method to calculate the index, we performed principal component analyses (PCA) on the 10 individual elements. The results are presented in Table 4, the first component explains 36.1% and has loadings of 0.23 or higher for all components except finance (0.08). The three elements with the highest loadings are physical infrastructure (0.44), formal institutions (0.40), and demand (0.40). This result confirms our findings from the interdependency graphs which show a strongly connected set of elements with a central role for these elements. The second component, which explains an additional 14.6% of the variation, has loadings of 0.25 or higher for all components except leadership (0.14), intermediate services (0.11), and formal institutions (0.07). Similarly, for the third component six elements have loadings above 0.30 while physical infrastructure (0.15), talent (0.19), knowledge (0.142) and demand (0.19) have lower loadings. We thus find that the elements have relatively balanced loadings across the first three principal components. The results of the PCA thus confirm the strong interdependencies between the entrepreneurial ecosystem elements and thereby validates our approach of building an index.

Table 4.

Principal components analysis

	PC1	PC2	PC3
Proportion of Variance	0.361	0.146	0.117
Standard Deviation	1.900	1.207	1.083
Cumulative Variance	0.361	0.507	0.624
Formal institutions	-0.396	0.070	-0.493
Culture	-0.324	0.248	-0.365
Networks	-0.245	-0.325	-0.318
Physical infrastructure	-0.435	-0.310	0.147
Finance	-0.082	0.432	0.393
Leadership	-0.284	0.137	0.303
Talent	-0.234	0.476	-0.191
Knowledge	-0.247	0.403	0.142
Demand	-0.397	-0.355	0.188
Intermediate	-0.356	-0.108	0.404

As a second alternative approach to classify regional economies we perform a cluster analysis on the ten ecosystem elements. We use the k-means clustering method which minimizes the total intra-cluster variation (sum of squared errors) using Euclidean distance measures for an a priori fixed number of clusters (Tan et al., 2018). The K-means clustering technique is the most popular clustering technique and was originally proposed by MacQueen (1967). The number of clusters is a parameter that has to be set by the user. After considering the total intra-cluster variation, the average silhouette of clusters, the gap statistic, and the interpretability of the outcomes we selected the approach with three clusters. The results show a small first cluster which consists of high performing regions including Berlin, London, and Brussels. The second cluster forms a middle group and includes Manchester, Cologne and North Brabant (including Eindhoven). Finally, the third cluster contains the low-performers and forms the largest group, including Athens, Budapest and Sicily. The average index values for these three clusters are, as shown in Table 5, in line with

our expectations. A particularly interesting finding is that the regions in the first cluster have clearly higher outputs than the middle and laggard group, both in terms of Crunchbase and unicorn output.

Table 5.

Summary statistics of index and output by cluster

	Cluster 1 (n=26)	Cluster 2 (n=95)	Cluster 3 (n=152)	Overall (n=273)
EE index additive				
Mean (SD)	20.4 (4.02)	11.5 (2.55)	4.93 (2.24)	8.71 (5.51)
Median [Min, Max]	19.8 [12.0, 30.9]	11.0 [7.64, 18.1]	4.27 [0.989, 10.2]	8.09 [0.989, 30.9]
EE index log				
Mean (SD)	3.76 (2.43)	-2.13 (2.46)	-10.7 (4.67)	-6.35 (6.44)
Median [Min, Max]	3.53 [-1.13, 9.07]	-2.25 [-7.59, 3.37]	-10.5 [-24.5, -2.37]	-5.31 [-24.5, 9.07]
Crunchbase output				
Mean (SD)	1.77 (2.07)	0.281 (0.700)	0.203 (0.268)	0.379 (0.899)
Median [Min, Max]	0.793 [0.111, 5.00]	0.142 [0.111, 5.00]	0.133 [0.111, 2.15]	0.139 [0.111, 5.00]
Unicorns				
Mean (SD)	0.615 (1.17)	0.0632 (0.285)	0.0132 (0.114)	0.0879 (0.437)
Median [Min, Max]	0.00 [0.00, 5.00]	0.00 [0.00, 2.00]	0.00 [0.00, 1.00]	0.00 [0.00, 5.00]

4.4. Entrepreneurial Ecosystem Index and entrepreneurial output

After discussing the creation and reliability of the Entrepreneurial Ecosystem Index we now use regression analysis to study if regions with better ecosystems indeed have higher entrepreneurial outputs. The results of the regressions with the indices as independent variable and the Crunchbase output as dependent variable are shown in Table 6 and graphically displayed in Fig. 7.[5] The results of the regression analyses with the unicorn output as dependent variable are consistent with the findings reported in Table 6. However, we chose not to report these results because of the limited number of regions with unicorn observations (17 out of 274). In all regressions the index has a

[5] As an additional robustness test, we also performed the regression analyses using the principal components (see section 4.3). The results of these regressions showed nearly identical results, serving as evidence for the robustness of our results.

positive and significant coefficient ($p<0.001$) on the entrepreneurial output. The R^2 is higher for the regression with the additive index at 0.198. The graph in Fig. 7 shows that the relation between the index and entrepreneurial output does not appear to be linear, since an increase in performance on the index goes together with a disproportionate increase in high growth entrepreneurial ventures. To capture this nonlinearity in the relation between the quality of an entrepreneurial ecosystem and its entrepreneurial outputs, we added quadratic effects to the model. This resulted in a significant improvement of the model as the non-linear effect is also significant ($p<0.001$) and increases the R^2 to 0.319.

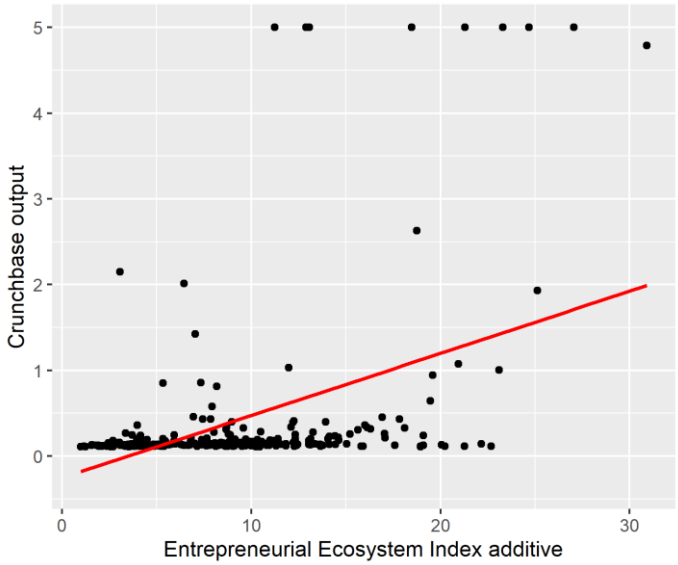


Fig. 7. Entrepreneurial Ecosystem Index and entrepreneurial outputs

Table 6.

Regression results of the additive and logarithmic index on the Crunchbase output variable including non-linear effects

	Crunchbase output			
	(1)	(2)	(3)	(4)
EE index additive	0.073***	-0.101***		
	(0.009)	(0.026)		
EE index additive squared		0.007***		
		(0.001)		
EE index log			0.048***	0.140***
			(0.008)	(0.015)
EE index log squared				0.007***
				(0.001)
Constant	-0.253**	0.468***	0.685***	0.733***
	(0.091)	(0.134)	(0.072)	(0.067)
Observations	273	273	273	273
R^2	0.198	0.319	0.119	0.253
Adjusted R^2	0.195	0.314	0.116	0.247
F Statistic	66.884*** (df = 1; 271)	63.197*** (df = 2; 270)	36.588*** (df = 1; 271)	45.660*** (df = 2; 270)

Note: *p<0.05; **p<0.01; ***p<0.001

Since we compare regions in different countries, it is important to check whether the index does not just capture between country differences but also has explanatory power within countries. We therefore run a multilevel analysis with country-specific intercepts and our Entrepreneurial Ecosystem Index. The results of the multilevel analysis are presented in Table 7. The index variables still show a significant and positive relation with the entrepreneurial output ($p<0.001$). Adding country specific intercepts improves the model as evidenced by an increased R^2 as well as the likelihood ratio tests. The random effects in the bottom of the table show the regional variation

(σ^2) and the variation between countries (τ_{00}). The strong coefficient estimates for the index show that even when we compare regions within countries the regions with a higher index value have a significantly higher entrepreneurial output. The high regional variation in entrepreneurial output and index values supports our choice to focus on the regional level when studying entrepreneurial ecosystem performance.

Table 7.

Multilevel analysis

	Crunchbase output	
	(1)	(2)
EE index additive	0.11 ***	
	(0.01)	
EE index log		0.08 ***
		(0.01)
Intercept	-0.49 ***	0.97 ***
	(0.13)	(0.12)
Random Effects		
σ^2	0.47	0.55
τ_{00}	0.13 $_{country}$	0.11 $_{country}$
ICC	0.22	0.17
N	23 $_{country}$	23 $_{country}$
Observations	268	268
Marginal R^2 / Conditional R^2	0.386 / 0.522	0.281 / 0.403

Notes: This regression excludes countries that exist of only a single NUTS 2 region, which are Luxembourg, Malta, Estonia, Cyprus and Latvia. * p<0.05; ** p<0.01; *** p<0.001

We find that many of the top performing regions are regions in which a capital region is located (Fig. 3). To test whether the explanatory power of our index holds after controlling for the influence of capital cities on the output variable we run the regressions with a capital city indicator added, which is a dummy variable indicating whether a region contains a capital city (no = 0, yes = 1). The results are displayed in Table A2 and confirm that capital regions perform significantly better than non-capital regions ($p<0.001$). Nevertheless, the linear and quadratic effect of the Entrepreneurial Ecosystem Index remain significant ($p<0.001$) and only show a small decrease in coefficients.

4.5. Robustness to outliers

In addition, we performed three robustness checks on the sensitivity of our index to outliers. The results of which are presented in Table A4-6. First, we do not conduct the modifications outlined in section 3.16. This robustness test actually results in an R2 of 0.99. However, the results are now strongly influenced by the outlier regions that we discussed in the methodology. Therefore, we performed a second robustness test which removes those regions with a value higher (or lower) than one standard deviation of the second highest values. This concerned Inner London-West (as a result of a high number of incubators and Crunchbase start-ups per population), Braunschweig (as a result of the high R&D intensity) in Germany, and Hovenstaden in Denmark. Since we prefer not to discard observations of which the data is reliably measured, we also performed the regression with all observation after transforming the data. For the variables with a huge range of variation (standard deviations above 10) we transformed the data using the Tukey transformation (Tukey, 1957). The result of this transformation is a distribution of data which is close to a normal distribution, thus reducing the standard deviations from the variables with outliers. All three robustness tests show findings qualitatively similar to those presented in the main analysis, indicating the robustness of our index to outliers.

5. Discussion and conclusions

This paper discussed and applied new methodologies and metrics to quantify and qualify entrepreneurial economies, applying this to European regions. The objective of this paper was to quantify and qualify regional economies with an entrepreneurial ecosystem approach. Quantification involves measuring its ten key elements with a wide range of data sources. Qualification involved developing a network methodology that provides insight into the extent to which the elements are interdependent, the construction of an Entrepreneurial Ecosystem Index to capture the overall quality of entrepreneurial economies, and relating this to entrepreneurial outputs.

We have answered three main research questions. First, how can we compose a harmonized data set with which the quality of key elements of entrepreneurial economies can be measured? We built on prior entrepreneurial ecosystem research that developed a universal set of constructs for each element of entrepreneurial economies, and composed a harmonized data set to measure these constructs in the context of 274 regions in the 28 countries of the European Union. We sourced a wide variety of data and constructed a rich dataset. However, not all elements could be measured in a fully satisfactory way. Often, more adequate data is available, but not at the same regional level or for all regions. An example is the data we used for the finance element: we prefer to have a composite indicator that includes objective data on the supply of different types of finance, including bank loans for SMEs, debt and equity crowdfunding, and regular equity funding. This is not yet available for all European regions. Another example is the data we used for the networks element. Even though the data provided on the engagement of SMEs in innovative collaborations is very informative, additional network data on collaborative networks and influencer networks, for example based on twitter data, could enrich the diagnosis of entrepreneurial ecosystems. This kind of network data would also allow for more refined measures of network diversity and density. For some elements there is no straightforward data available and new variables had to be constructed. This is the case for leadership, for which others (Stam and Van de Ven 2020) have constructed country specific indicators, and we have created a pan-European indicator. However, even though this indicator provides information of the prevalence of (public-private) leadership behaviour in regions, improvements can be made to measure leadership that is relevant for the

quality of entrepreneurial economies, for example with the prevalence of public-private leadership in regional partnerships (see Olberding, 2002). Overall, there is a significant trade-off between getting richer context-specific data (often only available in a relatively small number of regions) and getting widely available, harmonized data, which enables comparisons between regions.

Second, to what extent and how are the elements of entrepreneurial economies interdependent? We performed correlation analyses, principal component analyses, and developed a network methodology to visualize the interdependencies between elements. These analyses revealed that entrepreneurial economies are systems with elements that are highly interdependent, and are not a collection of isolated factors and actors. Our analyses also showed that in particular formal institutions and physical infrastructure provide foundational conditions for entrepreneurial economic systems.

Third, how can we determine the quality of entrepreneurial economies? We answered this question by composing an entrepreneurial ecosystem index and analysing its relation to entrepreneurial outputs. We used multiple data sources and metrics to determine entrepreneurial outputs at the regional level. We also used novel methods including web scraping and geocoding to determine the entrepreneurial outputs in the form of the number of high-growth firms in a region. We have shown that it is possible to measure the quality of entrepreneurial economies, in a way that has external validity: showing a ranking of European regions and range of variation that is credible. Our analyses reveal the wide-ranging quality of entrepreneurial ecosystems in Europe, showing a large group of substantially lagging regions, while a smaller group of leading regions is clearly ahead of the European average. We also tested the internal validity using the fact that high quality entrepreneurial economic systems are more likely to produce emergent properties, which we measured with indicators of productive entrepreneurship. The prevalence of innovative new firms is strongly positively and statistically significantly related to quality of entrepreneurial ecosystems, as captured with differently constructed entrepreneurial ecosystem indices. This upward causation confirms earlier findings of Stam and Van de Ven (2020) and Vedula and Kim (2019). This internal validity should be tested more carefully, in particular with other (more direct) tests of causality, with longer time lags between changes in the quality of entrepreneurial ecosystems and the resulting entrepreneurial outputs, and with some quasi-natural experiments in which a set of

similar regions is confronted with substantially different changes in one or a few elements. Other methods, including qualitative comparative analysis, could also play an important role in improving our understanding of the workings of ecosystem.

Did we fulfil the policy promise of the entrepreneurial ecosystem approach? We developed entrepreneurial ecosystem metrics to better measure entrepreneurial economies. These metrics enable adequate diagnosis of (regional) entrepreneurial economies and also enables monitoring economic change after policy interventions and other dynamics have changed the system. This paper thus takes heed of the old carpenter's adage "measure twice, cut once", reducing policy failures with better measurement tools.

There are nevertheless many opportunities for improvement of these metrics. Two directions deserve substantial attention in follow-up research. First, we need to move from a comparative static analysis to a dynamic analysis, and for this we need longitudinal datasets. This would make it possible to better trace processes within entrepreneurial ecosystems (Spigel and Harrison, 2018), and allow us to measure the distinct properties of complex systems that arise from interdependencies, such as nonlinearity, emergence, tipping-points, spontaneous order, adaptation, and feedback loops. Second, even though the European Union provides a wide variety of regions to develop and test our entrepreneurial ecosystem metrics, these metrics need to be developed and tested in other contexts as well, in large sets of regions in the US, Asia, Africa, and Latin America. Statistical regions are not always overlapping with either the relevant jurisdictions or the spatial reach of the causal mechanisms involved (for example as related to culture and the provision of finance). Developing tailor made spatial units and taking into account the nestedness of elements (cities, in regions, in countries) and neighbourhood effects is also a task for future research.

Scientific progress and societal impact are often achieved with better tools. In this paper we developed entrepreneurial ecosystem metrics, with which entrepreneurial economies can be quantified and qualified. These metrics enables researchers and practitioners to gain insight in, and a better understanding of, these economies. Using measurement tools to capture and comprehend the current state of the economy is a necessary condition for effective policy.

References

Acemoglu, D., Johnson, S., Robinson, J.A., 2005. Chapter 6 Institutions as a Fundamental Cause of Long-Run Growth. Handb. Econ. Growth. https://doi.org/10.1016/S1574-0684(05)01006-3

Acs, Z.J., Armington, C., 2004. The impact of geographic differences in human capital on service firm formation rates. J. Urban Econ. 56, 244–278. https://doi.org/10.1016/j.jue.2004.03.008

Ács, Z.J., Autio, E., Szerb, L., 2014. National Systems of Entrepreneurship: Measurement issues and policy implications. Res. Policy 43, 476–494. https://doi.org/10.1016/j.respol.2013.08.016

Annoni, P., Dijkstra, L., 2019. The EU Regional Competitiveness Index.

Arthur, W.B., 2013. Complexity Economics. Oxford University Press, Oxford.

Arundel, A., Smith, K., 2013. History of the Community Innovation Survey, in: Gault, F. (Ed.), Handbook of Innovation Indicators and Measurement. Edward Elgar, Cheltenham, pp. 60–87.

Audretsch, D.B., Heger, D., Veith, T., 2015. Infrastructure and entrepreneurship. Small Bus. Econ. 44, 219–230. https://doi.org/10.1007/s11187-014-9600-6

Audretsch, D.B., Keilbach, M.C., Lehmann, E.E., 2006. Entrepreneurship and Economic Growth. Oxford University Press, Oxford.

Audretsch, D.B., Lehmann, E.E., 2005. Does the knowledge spillover theory of entrepreneurship hold for regions? Res. Policy 34, 1191–1202. https://doi.org/10.1016/j.respol.2005.03.012

Autio, E., Kenney, M., Mustar, P., Siegel, D., Wright, M., 2014. Entrepreneurial innovation: The importance of context. Res. Policy 43, 1097–1108. https://doi.org/10.1016/j.respol.2014.01.015

Ayatse, F.A., Kwahar, N., Iyortsuun, A.S., 2017. Business incubation process and firm performance: an empirical review. J. Glob. Entrep. Res. 7, 2. https://doi.org/10.1186/s40497-016-0059-6

Baumol, W.J., 1996. Entrepreneurship: Productive, unproductive, and destructive. J. Bus. Ventur. 11, 3–22. https://doi.org/10.1016/0883-9026(94)00014-X

Baumol, W.J., 1990. Entrepreneurship: Productive, Unproductive, and Destructive. J. Polit. Econ. 98, 893–921. https://doi.org/10.1086/261712

Becker, G.S., 1964. Human capital. New York.

Berkowitz, D., DeJong, D.N., 2005. Entrepreneurship and Post-socialist Growth. Oxf. Bull. Econ. Stat. 67, 25–46. https://doi.org/10.1111/j.1468-0084.2005.00108.x

Bivand, R., Keitt, T., Rowlingson, B., 2019. rgdal: Bindings for the "Geospatial" Data Abstraction Library. R package version 1.4-7. Cran 0.

Bosma, N., Content, J., Sanders, M., Stam, E., 2018. Institutions, entrepreneurship, and economic growth in Europe. Small Bus. Econ. 51, 483–499. https://doi.org/10.1007/s11187-018-0012-x

Bosma, N., Kelley, D., 2019. Global Entrepreneurship Monitor.

Bosma, N., Stam, E., Schutjens, V., 2011. Creative destruction and regional productivity growth: Evidence from the Dutch manufacturing and services industries. Small Bus. Econ. 36, 401–418. https://doi.org/10.1007/s11187-009-9257-8

Boudreaux, C.J., Nikolaev, B., 2019. Capital is not enough: opportunity entrepreneurship and formal institutions. Small Bus. Econ. 53, 709–738. https://doi.org/10.1007/s11187-018-0068-7

Brown, R., Mason, C., 2014. Inside the high-tech black box: A critique of technology entrepreneurship policy. Technovation 34, 773–784. https://doi.org/10.1016/j.technovation.2014.07.013

Brüderl, J., Preisendörfer, P., Ziegler, R., 1992. Survival Chances of Newly Founded Business Organizations. Am. Sociol. Rev. 57, 227–242.

Bureau van Dijk, 2020. Bureau van Dijk | Private company information – Orbis [WWW Document]. URL https://www.bvdinfo.com/en-gb (accessed 1.10.20).

Carree, M.A., Thurik, A.R., 2010. The Impact of Entrepreneurship on Economic Growth, in: Handbook of Entrepreneurship Research. Springer New York, pp. 557–594. https://doi.org/10.1007/978-1-4419-1191-9_20

CBInsights, 2018. The Global Unicorn Club [WWW Document].

Charron, N., Lapuente, V., Annoni, P., 2019a. Measuring quality of government in EU regions across space and time. Pap. Reg. Sci. 98, 1925–1953. https://doi.org/10.1111/pirs.12437

Charron, N., Lapuente, V., Rothstein, B., 2019b. Measuring the quality of Government at the subnational level and comparing results with previous studies.

Clayton, P., Feldman, M., Lowe, N., 2018. Behind the scenes: Intermediary organizations that

facilitate science commercialization through entrepreneurship, in: Academy of Management Perspectives. Academy of Management, pp. 104–124. https://doi.org/10.5465/amp.2016.0133

Cohen, S., Fehder, D.C., Hochberg, Y. V., Murray, F., 2019. The design of startup accelerators. Res. Policy 48, 1781–1797. https://doi.org/10.1016/j.respol.2019.04.003

Commission, E., 2018. Regulation (EC) No 1059/2003 of the European Parliament and of the Council of 26 May 2003 on the establishment of a common classification of territorial units for statistics (NUTS).

CORDIS, 2019. EU research projects under Horizon 2020 (2014-2020) - Datasets [WWW Document]. URL https://data.europa.eu/euodp/en/data/dataset/cordisH2020projects (accessed 12.19.19).

Cortright, J., 2002. The Economic Importance of Being Different: Regional Variations in Tastes, Increasing Returns, and the Dynamics of Development. Econ. Dev. Q. 16, 3–16. https://doi.org/10.1177/0891242402016001001

Criscuolo, C., Gal, P.N., Menon, C., 2014. The Dynamics of Employment Growth. OECD Sci. Technol. Ind. Policy Pap. 96. https://doi.org/10.1787/5jz417hj6hg6-en

Crunchbase, 2019. Crunchbase [WWW Document].

Dalle, J.-M., Den Besten, M., Menon, C., 2017. Using Crunchbase for economic and managerial research Using Crunchbase for Economic and Managerial Research Matthijs den Besten †. https://doi.org/10.1787/6c418d60-en

Eckhardt, J.T., Shane, S.A., 2003. Opportunities and Entrepreneurship. J. Manage. 29, 333–349. https://doi.org/10.1177/014920630302900304

European Commission, 2019. Horizon 2020 | The EU Framework Programme for Research and Innovation [WWW Document]. URL https://ec.europa.eu/programmes/horizon2020/en (accessed 12.19.19).

Eurostat, 2019. Eurostat [WWW Document]. URL ttps://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/nuts (accessed 11.26.19).

Eveleens, C.P., van Rijnsoever, F.J., Niesten, E.M.M.I., 2017. How network-based incubation helps start-up performance: a systematic review against the background of management theories. J. Technol. Transf. 42, 676–713. https://doi.org/10.1007/s10961-016-9510-7

Feldman, M., Lowe, N., 2015. Triangulating regional economies: Realizing the promise of digital data. Res. Policy 44, 1785–1793. https://doi.org/10.1016/j.respol.2015.01.015

Feldman, M., Zoller, T.D., 2012. Dealmakers in Place: Social Capital Connections in Regional Entrepreneurial Economies. Reg. Stud. 46, 23–37. https://doi.org/10.1080/00343404.2011.607808

Feldman, M.P., 2014. The character of innovative places: Entrepreneurial strategy, economic development, and prosperity. Small Bus. Econ. 43, 9–20. https://doi.org/10.1007/s11187-014-9574-4

Feldman, M.P., 2001. The Entrepreneurial Event Revisited: Firm Formation in a Regional Context. Ind. Corp. Chang. 10, 861–891. https://doi.org/10.1093/icc/10.4.861

Fritsch, M., 2013. New business formation and regional development: A survey and assessment of the evidence. Found. Trends Entrep. https://doi.org/10.1561/0300000043

Fritsch, M., Wyrwich, M., 2014. The Long Persistence of Regional Levels of Entrepreneurship: Germany, 1925–2005. Reg. Stud. 48, 955–973. https://doi.org/10.1080/00343404.2013.816414

Granovetter, M., 1992. Economic Institutions as Social Constructions: A Framework for Analysis. Acta Sociol. 35, 3–11. https://doi.org/10.1177/000169939203500101

Haltiwanger, J., Jarmin, R.S., Miranda, J., 2013. Who creates jobs? Small versus large versus young. Rev. Econ. Stat. https://doi.org/10.1162/REST_a_00288

Hidalgo, C.A., Hausmann, R., 2009. The building blocks of economic complexity. Proc. Natl. Acad. Sci. U. S. A. 106, 10570–10575. https://doi.org/10.1073/pnas.0900943106

Hollanders, H., Es-Sadki, N., Merkelbach, I., 2019. Regional Innovation Scoreboard 2019.

Howells, J., 2006. Intermediation and the role of intermediaries in innovation. Res. Policy 35, 715–728. https://doi.org/10.1016/j.respol.2006.03.005

Isenberg, D., Onyemah, V., 2016. Fostering scaleup ecosystems for regional economic growth (innovations case narrative: Manizales-Mas and Scale Up Milwaukee. Innov. Technol. Governance, Glob. 11, 60–79.

Isenberg, D.J., 2010. How to start an entrepreneurial revolution. Harv. Bus. Rev. 88, 41–50.

Kerr, W.R., Nanda, R., 2009. Democratizing entry: Banking deregulations, financing constraints, and entrepreneurship. J. financ. econ. 94, 124–149. https://doi.org/10.1016/j.jfineco.2008.12.003

Kim, Y., Kim, W., Yang, T., 2012. The effect of the triple helix system and habitat on regional entrepreneurship: Empirical evidence from the U.S. Res. Policy 41, 154–166. https://doi.org/10.1016/j.respol.2011.08.003

Lee, S.Y., Florida, R., Acs, Z.J., 2004. Creativity and entrepreneurship: A regional analysis of new firm formation. Reg. Stud. 38, 879–891. https://doi.org/10.1080/0034340042000280910

Leibenstein, H., 1968. Entrepreneurship and Development. Am. Econ. Rev. 58, 72–83.

Léon, L.R., Izsak, K., Bougas, K., Soto, V., 2016. Regional Ecosystem Scoreboard.

Lerner, J., 2012. Boulevard of broken dreams: why public efforts to boost entrepreneurship and venture capital have failed--and what to do about it. Princeton University Press.

MacQueen, J., 1967. Some methods for classification and analysis of multivariate observations. Proc. fifth Berkeley Symp. Math. Stat. Probab. 1, 281–297.

Malecki, E.J., 1997. Entrepreneurs, networks, and economic development: A review of recent research, in: Katz, J.A. (Ed.), Advances in Entrepreneurship, Firm Emergence and Growth. CT:JAI Press, Greenwich.

Mason, C.M., Harrison, R.T., 2006. After the exit: Acquisitions, entrepreneurial recycling and regional economic development. Reg. Stud. 40, 55–73. https://doi.org/10.1080/00343400500450059

Minniti, M., 2005. Entrepreneurship and network externalities. J. Econ. Behav. Organ. 57, 1–27. https://doi.org/10.1016/j.jebo.2004.10.002

Normann, R., 2013. Regional Leadership: A Systemic View. Syst. Pract. Action Res. 26, 23–38. https://doi.org/10.1007/s11213-012-9268-2

Norwegian Center for Research Data, 2014. ESS Round 7: European Social Survey Round 7 Data, Data file edition 2.2.

Olberding, J.C., 2002. Does Regionalism Beget Regionalism? The Relationship between Norms and Regional Partnerships for Economic Development. Public Adm. Rev. 62, 480–491. https://doi.org/10.1111/0033-3352.00201

OpenStreetMap, 2019. OpenStreetMap [WWW Document]. URL https://www.openstreetmap.org/ (accessed 11.22.19).

Ostrom, E., 2010. Beyond markets and states: Polycentric governance of complex economic systems. Am. Econ. Rev. 100, 641–672. https://doi.org/10.1257/aer.100.3.641

Qian, H., Acs, Z.J., Stough, R.R., 2013. Regional systems of entrepreneurship: The nexus of human capital, knowledge and new firm formation. J. Econ. Geogr. 13, 559–587. https://doi.org/10.1093/jeg/lbs009

Rauch, A., Rijsdijk, S.A., 2013. The Effects of General and Specific Human Capital on Long-Term Growth and Failure of Newly Founded Businesses. Entrep. Theory Pract. 37, 923–941. https://doi.org/10.1111/j.1540-6520.2011.00487.x

Reynolds, P., Storey, D.J., Westhead, P., 1994. Cross-national Comparisons of the Variation in New Firm Formation Rates. Reg. Stud. 28, 443–456. https://doi.org/10.1080/00343409412331348386

Roundy, P.T., Bradshaw, M., Brockman, B.K., 2018. The emergence of entrepreneurial ecosystems: A complex adaptive systems approach. J. Bus. Res. 86, 1–10. https://doi.org/10.1016/j.jbusres.2018.01.032

Rudis, B., 2019. nominatim: Tools for Working with the "Nominatim" API. R package version 0.2.2.9000.

Samila, S., Sorenson, O., 2010. Venture capital as a catalyst to commercialization. Res. Policy 39, 1348–1360. https://doi.org/10.1016/j.respol.2010.08.006

Schumpeter, J., 1911. The Theory of Economic Development, Harvard Ec. ed. Harvard University Press, Cambridge, MA.

Schutjens, V., Stam, E., 2003. The Evolution and Nature of Young Firm Networks: A Longitudinal Perspective, in: Small Business Economics. pp. 115–134. https://doi.org/10.1023/A:1025093611364

Simon, H.A., 1962. The Architecture of Complexity. Proc. Am. Philos. Soc. 106, 467–482.

Sobel, R.S., 2008. Testing Baumol: Institutional quality and the productivity of entrepreneurship. J. Bus. Ventur. 23, 641–655. https://doi.org/10.1016/j.jbusvent.2008.01.004

Sotarauta, M., Beer, A., Gibney, J., 2017. Making sense of leadership in urban and regional development. Reg. Stud. https://doi.org/10.1080/00343404.2016.1267340

Spigel, B., 2017. The Relational Organization of Entrepreneurial Ecosystems. Entrep. Theory Pract. 41, 49–72. https://doi.org/10.1111/etap.12167

Spigel, B., Harrison, R., 2018. Toward a process theory of entrepreneurial ecosystems. Strateg. Entrep. J. 12, 151–168.

Stam, E., 2015. Entrepreneurial Ecosystems and Regional Policy: A Sympathetic Critique. Eur.

Plan. Stud. 23, 1759–1769. https://doi.org/10.1080/09654313.2015.1061484

Stam, E., 2010. Entrepreneurship, Evolution and Geography, in: Boschma, R., Martin, R.L. (Eds.), The Handbook of Evolutionary Economic Geography. Edward Elgar, Cheltenham, pp. 307–348.

Stam, E., Hartog, C., Van Stel, A., Thurik, R., 2011. Ambitious entrepreneurship and macro-economic growth, in: Minniti, M. (Ed.), The Dynamics of Entrepreneurship. Evidence from the Global Entrepreneurship Monitor Data. Oxford University Press, Oxford, pp. 231–249.

Stam, E., Spigel, B., 2018. Entrepreneurial ecosystems, in: Blackburn, R., De Clerq, C., Heinonen, J. (Eds.), The SAGE Handbook of Small Business and Entrepreneurship. SAGE, London, pp. 407–422.

Stam, E., Van de Ven, A., 2020. Entrepreneurial Ecosystem Elements. Small Bus. Econ. 1–24.

Stam, E., Van Stel, A., 2011. Types of Entrepreneurship and Economic Growth, in: Szirmai, A., Naudé, W., Goedhuys, M. (Eds.), Entrepreneurship, Innovation, and Economic Development. Oxford University Press, Oxford.

Sternberg, R., 2009. Regional dimensions of entrepreneurship. Found. Trends Entrep. 5, 211–340. https://doi.org/10.1561/0300000024

Tan, P., Steinbach, M., Kumar, V., Karpatne, A., 2018. Introduction to data mining, Second. ed. Pearson Education.

Thurik, A.R., Stam, E., Audretsch, D.B., 2013. The rise of the entrepreneurial economy and the future of dynamic capitalism. Technovation 33, 302–310. https://doi.org/10.1016/j.technovation.2013.07.003

Tukey, J.W., 1957. On the Comparative Anatomy of Transformations. Ann. Math. Stat. 28, 602–632. https://doi.org/10.1214/aoms/1177706875

van Rijnsoever, F.J., 2020. Meeting, mating, and intermediating: How incubators can overcome weak network problems in entrepreneurial ecosystems, in: Research Policy. Elsevier B.V. https://doi.org/10.1016/j.respol.2019.103884

van Weele, M., van Rijnsoever, F.J., Nauta, F., 2017. You can't always get what you want: How entrepreneur's perceived resource needs affect the incubator's assertiveness. Technovation 59, 18–33. https://doi.org/10.1016/j.technovation.2016.08.004

Vedula, S., Kim, P.H., 2019. Gimme shelter or fade away: The impact of regional entrepreneurial ecosystem quality on venture survival. Ind. Corp. Chang. 28, 827–854.

https://doi.org/10.1093/icc/dtz032

Webb, J.W., Khoury, T.A., Hitt, M.A., 2019. The Influence of Formal and Informal Institutional Voids on Entrepreneurship. Entrep. Theory Pract. 104225871983031. https://doi.org/10.1177/1042258719830310

Wong, P.K., Ho, Y.P., Autio, E., 2005. Entrepreneurship, innovation and economic growth: Evidence from GEM data. Small Bus. Econ. 24, 335–350. https://doi.org/10.1007/s11187-005-2000-1

Zhang, Y., Li, H., 2010. Innovation search of new ventures in a technology cluster: the role of ties with service intermediaries. Strateg. Manag. J. 31, 88–109. https://doi.org/10.1002/smj.806

Appendix

Table A1.

Description of indicator data sources

Element	Indicators	Measurement and description	Source	Geographical level	Year
Formal institutions	Corruption	z-score based on survey answers	Quality of Government Index	Country-level IE and LT, NUTS 1: BE, DE, EL, SE, UK, others NUTS 2	2017
Formal institutions	Quality and accountability	z-score based on survey answers	Quality of Government Index	Country-level IE and LT, NUTS 1: BE, DE, EL, SE, UK, others NUTS 2	2017
Formal institutions	Impartiality	z-score based on survey answers	Quality of Government Index	Country-level IE and LT, NUTS 1: BE, DE, EL, SE, UK, others NUTS 2	2017
Formal institutions	Number of days for starting a business	Absolute values	World Bank	Country	2015
Formal institutions	Difficulties encountered when starting a business	Growth rate between 2009-2012	Flash Eurobarometer	Country	2012

Formal institutions	Barriers to entrepreneurship	Composite indicator (complexity of regulatory procedures, administrative burden, protection of incumbents)	OECD	Country	2013
Formal institutions	Ease of doing business index	Index based on several dimensions: starting a business, dealing with permits, registering property, credit access, protecting investors, taxes, trade, contract enforcement and closing a business	World Bank Doing Business Report	Country	2011
Entrepreneurship culture	Entrepreneurial motivation	Percentage of early stage entrepreneurs motivated by a desire to improve their income or a desire for independence	Global Entrepreneurship Monitor	Country	2014
Entrepreneurship culture	Cultural and social norms	Rating: 1=highly insufficient, 5=highly sufficient	Global Entrepreneurship Monitor	Country	2014
Entrepreneurship culture	Innovative and creative	Percentage of respondents that agree to: it is important to think of new ideas and be creative	European Social Survey	NUTS 2	2014
Entrepreneurship culture	Trust	Survey question on scale 0-1: Most people can be trusted	European Social Survey	NUTS 2	2014
Entrepreneurship culture robustness	Birth of new firms	Number of new firms per 1,000 inhabitants	Eurostat, OECD and national statistics offices	Country-level EL, CY, MT, LU, NUTS 1: DE, UK, others NUTS 2	2010-2016

Networks	Innovative SMEs collaborating with others	Percentage of innovative SMEs in SME business population collaborating with others	RIS & EIS (for countries which are a NUTS 2 region) (also available in RCI)	NUTS 1 for BE, UK, FR and AT, others NUTS 2	2016
Physical Infrastructure	Accessibility via road	Population accessible within 1h30 by road, as share of the population in a neighbourhood of 120 km radius	DG Regio	NUTS 2	2016
Physical Infrastructure	Accessibility via rail	Population accessible within 1h30 by rail (using optimal connections), as share of the population in a neighbourhood of 120 km radius	DG Regio	NUTS 2	2014
Physical Infrastructure	Number of passenger flights	Daily number of passenger flights accessible in 90 min drive	Eurostat / Eurogeographics / National Statistical Institutes	NUTS 2	2016
Physical Infrastructure	Household access to internet	Percentage of households with access to internet	Eurostat	NUTS 2	2018
Finance	Availability of venture capital	Survey question: In the last 2 years, access to venture capital in my region has been. [1 extremely difficult to 5 extremely easy]	Survey RES	NUTS 2	2015
Finance	Availability of bank loans	Survey question: In the last 2 years, access to bank loans for capital investments for members of my cluster has been. [1 extremely difficult to 5 extremely easy]	Survey RES	NUTS 2	2015

Leadership	The presence of actors taking a leadership role in the ecosystem	The number of coordinators on H2020 innovation projects per 1,000 inhabitants	CORDIS (Community Research and Development Information Service)	NUTS 2	2014-2019
Talent	Tertiary education	Percentage of total population that completed tertiary education	Eurostat	NUTS 1 for BE, GER, UK , others NUTS 2	2013
Talent	Vocational training	Percentage of companies that provide initial vocational training	Eurostat	Country	2010
Talent	Lifelong learning	Percentage of population aged 25-64 participating in education and training	Eurostat	NUTS 1 for BE, GER, UK , others NUTS 2	2013
Talent	Innovative skills training	Availability of innovation training and innovative skills coaching programs in last two years	RES	NUTS 2	2015
Talent	Business and entrepreneurship education	Rating: 1=highly insufficient, 5=highly sufficient	Global Entrepreneurship Monitor	Country	2014
Talent	Technical skills	Percentage of private enterprises with employees with technical skills	RES	Country	2010
Talent	Creative skills	Percentage of private enterprises with employees with creative skills	RES	Country	2010
Talent	E-skills	Percentage of individuals in active population with high levels of e-skills	Eurostat	Country	2014

New knowledge	R&D expenditure	Intramural R&D expenditure as percentage of Gross Regional Product	Eurostat	NUTS 2	2015
Demand	Disposable income per capita	Net adjusted disposable household income in PPCS per capita (index EU average=100)	Eurostat	NUTS 2	2014
Demand	Potential market size in GRP	Index GRP PPS (EU population-weighted average=100)	Eurostat	NUTS 2	2016
Demand	Potential market size in population	Index population (EU average=100)	Eurostat	NUTS 2	2018
Intermediate services	Incubators	Percentage of incubators in total business population	Own data	NUTS 2	2019
Intermediate services	Knowledge intensive services	Percentage employment in knowledge-intensive market services	Eurostat	NUTS 2	2018
Productive entrepreneurship	Innovative new firms	Number of new firms registered in Crunchbase in the last five years per 1,000 inhabitants	Crunchbase	NUTS 2	2019
Productive entrepreneurship	High-value new firms (unicorns)	Absolute number of entrepreneurial firms valued above $1 billion	CB Insights	NUTS 2	2019

Table A2.

Correlation table

	Institutions	Culture	Networks	Infrastructure	Finance	Leadership	Talent	Knowledge	Demand	Intermediate	EE_index_add	EE_index_log	Crunchbase_output
Institutions													
Culture	0.71****												
Networks	0.41****	0.03											
Infrastructure	0.51****	0.37****	0.36****										
Finance	0.02	0.08	-0.14*	0.07									
Leadership	0.22***	0.24****	0.17**	0.31****	0.05								
Talent	0.36****	0.30****	0.20***	0.14*	0.22***	0.24****							
Knowledge	0.29****	0.22***	0.06	0.19**	0.19**	0.34****	0.35****						
Demand	0.43****	0.23***	0.39****	0.85****	0.08	0.23***	0.07	0.25****					
Intermediate	0.26****	0.30****	0.16**	0.60****	0.10	0.47****	0.18**	0.19**	0.50****				
EE_index_add	0.72****	0.58****	0.49****	0.77****	0.26****	0.57****	0.53****	0.54****	0.70****	0.64****			
EE_index_log	0.74****	0.53****	0.48****	0.66****	0.31****	0.45****	0.53****	0.51****	0.66****	0.51****	0.93****		
Crunchbase_output	0.18**	0.25****	-0.04	0.31****	0.17**	0.48****	0.24****	0.22***	0.17**	0.66****	0.44****	0.34****	
Unicorns	0.16**	0.15*	0.10	0.36****	0.01	0.32****	0.05	0.20***	0.36****	0.57****	0.39****	0.27****	0.48****

Note: *p<0.05; **p<0.01; ***p<0.001; ****p<0.0001

Table A3.

Regression with dummies for capital cities

	Crunchbase output					
	(1)	(2)	(3)	(4)	(5)	(6)
EE index add	0.073***	-0.101***	-0.091***			
	(0.009)	(0.026)	(0.026)			
EE index add squared		0.007***	0.006***			
		(0.001)	(0.001)			
Capital city			0.472**			0.654***
			(0.150)			(0.148)
EE index log				0.048***	0.140***	0.113***
				(0.008)	(0.015)	(0.016)
EE index log squared					0.007***	0.005***
					(0.001)	(0.001)
Constant	-0.253**	0.468***	0.417**	0.685***	0.733***	0.567***
	(0.091)	(0.134)	(0.133)	(0.072)	(0.067)	(0.075)
Observations	273	273	273	273	273	273
R^2	0.198	0.319	0.343	0.119	0.253	0.303
Adjusted R^2	0.195	0.314	0.336	0.116	0.247	0.295

F Statistic	66.884*** (df = 1; 271)	63.197*** (df = 2; 270)	46.803*** (df = 3; 269)	36.588*** (df = 1; 271)	45.660*** (df = 2; 270)	39.016*** (df = 3; 269)

Note: *p<0.05; **p<0.01; ***p<0.001

Table A4.

Regression with no transformation of outlier values

	Crunchbase output			
	(1)	(2)	(3)	(4)
EE index add	0.393***	-0.236***		
	(0.010)	(0.010)		
EE index add squared		0.001***		
		(0.00002)		
EE index log			0.689***	5.841***
			(0.139)	(0.291)
EE index log squared				0.156***
				(0.008)
Constant	-2.925***	1.642***	12.718***	48.833***
	(0.375)	(0.120)	(2.529)	(2.563)
Observations	273	273	273	273
R^2	0.852	0.990	0.083	0.599
Adjusted R^2	0.851	0.990	0.080	0.596
F Statistic	1,558.041*** (df = 1; 271)	13,915.330*** (df = 2; 270)	24.558*** (df = 1; 271)	201.510*** (df = 2; 270)

Note: *p<0.05; **p<0.01; ***p<0.001

Table A5.

Regression excluding observations with outlier values

	Crunchbase output			
	(1)	(2)	(3)	(4)
EE index add	0.250***	0.296**		
	(0.044)	(0.095)		
EE index add squared		-0.001		
		(0.002)		
EE index log			0.223***	0.639***
			(0.060)	(0.106)
EE index log squared				0.033***
				(0.007)
Constant	-1.495*	-1.786*	2.291***	2.156***
	(0.584)	(0.791)	(0.522)	(0.503)
Observations	269	269	269	269
R^2	0.106	0.107	0.050	0.123
Adjusted R^2	0.103	0.100	0.046	0.116
F Statistic	31.654*** (df = 1; 267)	15.936*** (df = 2; 266)	13.911*** (df = 1; 267)	18.568*** (df = 2; 266)

Note: *p<0.05; **p<0.01; ***p<0.001

Table A6.

Regression including Tukey transformation to outliers

	Crunchbase output			
	(1)	(2)	(3)	(4)
EE index add	0.173***	0.078***		
	(0.009)	(0.018)		
EE index add squared		0.001***		
		(0.0001)		
EE index log			0.118***	0.315***
			(0.020)	(0.033)
EE index log squared				0.016***
				(0.002)
Constant	-0.727***	0.046	1.616***	1.509***
	(0.133)	(0.177)	(0.169)	(0.156)
Observations	273	273	273	273
R^2	0.559	0.613	0.116	0.254
Adjusted R^2	0.558	0.610	0.113	0.248
F Statistic	343.704*** (df = 1; 271)	213.908*** (df = 2; 270)	35.641*** (df = 1; 271)	45.889*** (df = 2; 270)
Note:	*p<0.05; **p<0.01; ***p<0.001			