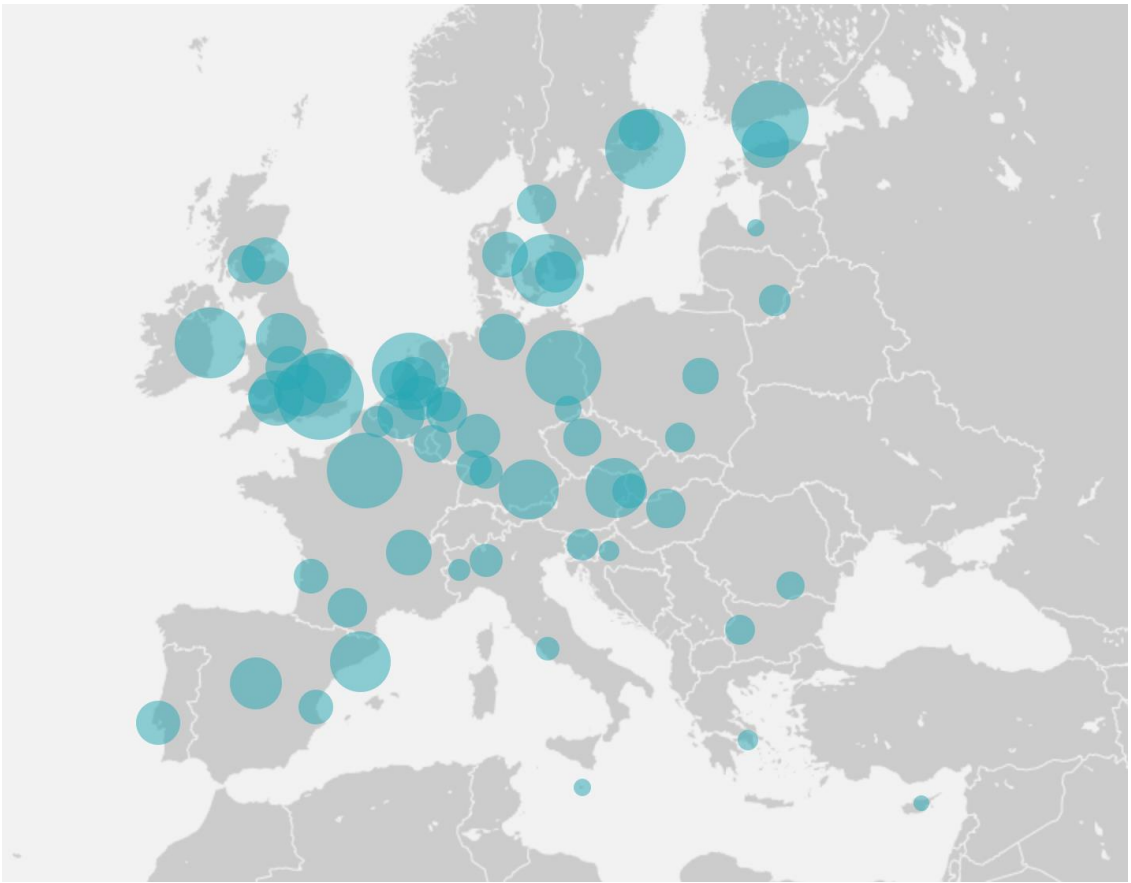
European Digital City Index

Methodology Report



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2016

Title European Digital City Index Methodology Report

Abstract

This report describes the methodological steps taken to compile the European Digital City Index. The purpose of this composite Index is to provide entrepreneurs, policymakers and researchers a tool for measuring the readiness or receptiveness of city-level ecosystems for both digital startups, as well as scale-ups. To capture and measure this concept, we chose ten themes on which to focus: Access to capital, Business Environment, Digital infrastructure, Entrepreneurial Culture, Knowledge spillovers, Lifestyle, Market, Mentoring, Non-digital infrastructure and Skills. Each of these themes contain between two and eight variables and a set of indicators to operationalise them. The themes, variables, measurement metrics and weighting scales were all selected based primarily on expert interviews and secondarily on literature reviews. By following the best practices laid out in the OECD/JRC 10-step approach to constructing composite indicators, this report hopes to contribute a methodologically robust approach towards the relatively underdeveloped body of literature around the measurement of city-level digital entrepreneurship.

European Digital City Index: https://digitalcityindex.eu/

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About the European Digital Forum

The European Digital Forum is a think tank led by the Lisbon Council and Nesta, in collaboration with the European Commission's Startup Europe Initiative. It is dedicated to empowering tech entrepreneurs and growing Europe's digital economy.

Disclaimer

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1. Executive Summary

This executive summary provides a brief overview of the steps we took to compile the 2016 European Digital City Index.

1.1 Introduction

The European Digital City Index (EDCi) contains composite indicators describing how well different European cities support digital entrepreneurship. These indicators examine key factors such as the availability of sufficient and appropriate finance, the skillset of the workforce in the area and the quality of the supporting infrastructure and networks. The ultimate purpose of EDCi is to support digital entrepreneurship by providing a holistic and local view across Europe by describing what ecosystem factors are most conducive to digital startups. To that end, it includes indicators which relate to various policy, economic, social/cultural, and technological factors.

1.2 Changes from 2015 → 2016

We piloted the European Digital City Index in 2015 with a launch at the Innovate Connect Transform (ICT: 2015) conference organised by the European Commission's DG CONNECT programme. The response to the EDCi was promising as stakeholders felt that the Index filled a gap in the ecosystem knowledge by reliably describing how well different European cities support digital entrepreneurship. Based on widespread demand from cities, the improved availability of data and as a result of a methodological audit carried out by the Joint Research Centre's Composite Indicators Unit, we made some significant changes to our Index (see table below for a summary of changes in data collection and methodology). Taken together, the addition of new cities and the changes in data collection and methodology mean that a direct comparison between the 2015 composite Index and its 2016 variant is not possible.

New Variables	Improved Indicator Sources	Improved Methodological Soundness (JRC Audit)
Availability of business angels funding Total Business Angels Investments European Early Stage Market Statistics	***Availability of crowdfunding*** Amount pledged towards crowdfunded projects (including money pledged through equity, debt, rewards and donations based crowdfunding across hundreds of platforms) Crowdsurfer	***Standardisation*** • Denominated variables – National level variables in the Access to Finance theme were estimated at the city level using the number of startups in the city
Training to start a business Score based on basic and post school entrepreneurial education and training Global Entrepreneurship Monitor	***Online collaboration*** Number of new active Github Users within the last 12 months Ghtorrent	***Normalisation*** • Outliers – all outliers are now capped at the variable-appropriate level, rather than at 95% across all variables
Digital Market Size Aggregate revenue in the 'e-commerce' and 'e-services' national market Statista	***Access to accelerators*** Number of accelerators in each city Compiled through: Seed DB, Gust, Open Axel	***Correlation Structures*** • Correlation structure of indicators/themes explored to determine if any are either collinear or similar enough to be considered cosmetic additions
Culture & Recreation Popularity scores, based on Foursquare data, on cultural venues Teleport	***Labour Cost*** Average salary for relevant startup skills Teleport	***Statistical Tests*** • Principal Component Analysis (PCA) – the increase in number of cities means we can conduct PCA to explore the underlying data structure
Train Connectivity Total population that can be reached within 3h of train travel DG Regio	***Airport connectivity*** Score based on number of flights to/from city's airport Teleport	***Conceptual Choice of Weighting and Aggregation*** • Aggregation – we have switched to a linear (variables) / geometric (themes) aggregation technique (from geometric (variables) / geometric (themes) in 2015) • Weighting – theme weights have been slightly updated; variable weights have been moved from a 2-point (low, high) to 4-point (not applied, low, medium and high) scale to fine tune rankings

Table 1 Changes 2015 -2016.

1.3 Geographic Coverage

The Index includes all capital cities in the EU28. The presence of cities from every EU28 country will allow all member states to use the Index to inform and assess their digital entrepreneurship policies. Additionally, it includes 32 non-capital cities in the EU that are important hubs of digital entrepreneurship; these extra cities were chosen by reference to other indicators of digital activity or entrepreneurship.

Below is the list of all 60 cities we deemed essential for inclusion in the Index:

1. Aarhus (Denmark)	**21. Eindhoven (Netherlands)**	**41. Oxford (UK)**
2. Amsterdam (Netherlands)	**22. Frankfurt (Germany)**	**42. Paris (France)**
3. Athens (Greece)	**23. Glasgow (UK)**	**43. Prague (Czech Republic)**
4. Barcelona (Spain)	**24. Gothenburg (Sweden)**	**44. Riga Latvia**
5. Berlin (Germany)	**25. Hamburg (Germany)**	**45. Rome (Italy)**
6. Birmingham (UK)	**26. Helsinki (Finland)**	**46. Sofia (Bulgaria)**
7. Bordeaux (France)	**27. Karlsruhe (Germany)**	**47. Stockholm (Sweden)**
8. Bratislava (Slovakia)	**28. Kraków (Poland)**	**48. Stuttgart (Germany)**
9. Bristol (UK)	**29. Lille (France)**	**49. Tallinn (Estonia)**
10. Brussel (Belgium)	**30. Lisbon (Portugal)**	**50. The Hague (Netherlands)**
11. Bucharest (Romania)	**31. Ljubljana (Slovenia)**	**51. Toulouse (France)**
12. Budapest (Hungary)	**32. London (UK)**	**52. Turin (Italy)**
13. Cambridge (UK)	**33. Luxembourg**	**53. Uppsala (Sweden)**
14. Cardiff (UK)	**34. Lyon (France)**	**54. Utrecht (Netherlands)**
15. Cologne (Germany)	**35. Madrid (Spain)**	**55. Valencia (Spain)**
16. Copenhagen (Denmark)	**36. Malmö (Sweden)**	**56. Valletta (Malta)**
17. Dresden (Germany)	**37. Manchester (UK)**	**57. Vienna (Austria)**
18. Dublin (Ireland)	**38. Milan (Italy)**	**58. Vilnius (Lithuania)**
19. Dusseldorf (Germany)	**39. Munich (Germany)**	**59. Warsaw (Poland)**
20. Edinburgh (UK)	**40. Nicosia (Cyprus)**	**60. Zagreb (Croatia)**

Table 2 List of cities in the Index

1.4 Process for EDC Index construction

Below are the construction steps and our method/process for each phase.
We have adhered to the 'ideal sequence' of steps detailed in the JRC/OECD Handbook on constructing composite indicators to guide our process, and these are illustrated (Figure 1) and described briefly below.

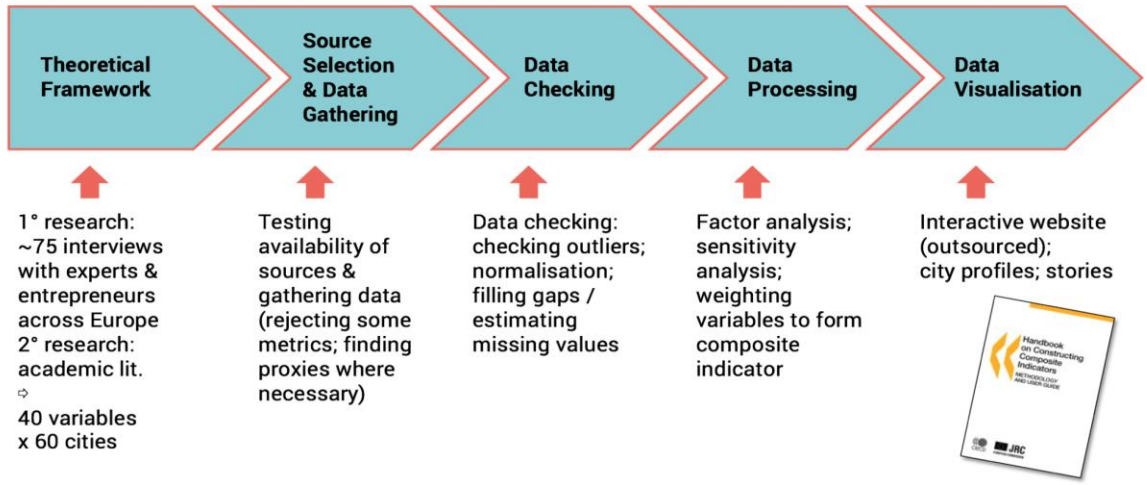


Figure 1 Flow diagram illustrating the ideal sequence steps for the construction of composite indicators as suggested by the JRC/OECD handbook.

1.5 Theoretical framework

The theoretical framework for the Index was built based on several months of interviews with experts and digital entrepreneurs across Europe. Combined with the burgeoning academic literature and existing policy reports, this primary research was distilled to give a clear understanding and definition of the phenomenon of 'digital readiness' (or receptiveness at the city level) to digital entrepreneurs and used to structure the ten dimensions or themes, and their subsidiary variables. We deliberately aimed to include some novel metrics that we felt provided an interesting, but under-utilised, indicator of digital activity.

1.6 Source selection & data gathering

The indicators were selected using a combination of interviews with digital experts and a review of existing, recent indices. We developed a crowdsourcing platform that allowed digital experts to recommend data sources. The sources include both hard (Eurostat, World Bank, OECD, ITU) as well as innovatively sourced soft data (scraping of Meetup APIs, Ookla, Teleport, Statista, and non-public databases such as commercial venture capital and angel investment databases). Where specific direct data was not available or easily compiled, we have used proxy measures (for example, number of Tweets originating from the city which have specific startup related keywords as a proxy for level of digital engagement from Follow the Hashtag). For about a dozen indicators, we were forced to use national data as a proxy where city or NUTS2 level data was not available. We have denominated this data accordingly (either by population, GDP or number of startups) in order to make the comparisons across different sized cities meaningful.

1.7 Data structure

- 60 European cities in 28 European countries, including all capital cities in the EU.
- 40 indicators grouped into 10 buckets: Access to Capital, Entrepreneurial Culture, Mentoring & Managerial Assistance, Skills, Business Environment, Digital Infrastructure, Knowledge Spillovers, Market, Lifestyle, Non-digital Infrastructure.

1.8 Data checking

1.8.1 Outliers/Capping

Variables containing outliers were identified as those having distributions with a kurtosis greater than 3.5 and absolute skewness greater than 2. Variables containing outliers were treated by winsorization. For variables with upper-end outliers, the largest value was transformed to have the same value as the second largest value and for those with lower-end outliers, the smallest value was transformed to have the same value as the second smallest value. This process was iterated until the variable's skewness and kurtosis fell within the acceptable limits.

1.8.2 Normalisation

We utilized a Min-Max normalisation method which normalises the indicators to within an identical [0,1] range by subtracting the minimum value and then dividing by the entire range of values for that indicator. For comparison purposes, we also employed the distance to reference normalisation method which involves dividing each value by the reference level.

1.8.3 Missing Values

99% of the data was complete from the initial data gathering exercise, these gaps were scattered across multiple indicators and cities. In order to work with a complete dataset, missing data were replaced with the mean of the other variables in that theme obtained for that city. This means that for cities containing missing values, the theme scores obtained using imputed data were the same as those that would have been obtained had the variables containing missing values been excluded from the Index.

1.9 Data Processing

1.9.1 Multivariate Analysis

Principal Components Analysis was used to explore the underlying structure of the data, particularly how different variables change in relation to each other

and how they are associated.

1.9.2 Weighting and Aggregation

Since our Index is pertinent to both startups and scale-ups, we weighted both datasets based on criteria defined by experts and the existing entrepreneurship literature. The weighting was carried out first at the variable level, and then subsequently at the theme level to ensure the most differentiated possible outcome.

Variables were aggregated using a weighted arithmetic mean to create theme scores (linear aggregation). Theme scores were then aggregated using a weighted geometric mean to produce the overall index score. Using geometric aggregation meant that compensability is lower for theme scores with low value, so a city with a low score for one theme will need a much higher score on the others to improve its score. We believe that this matches reality because our research suggested that all themes included in the Index are important to the entrepreneurial ecosystem. For comparison with the 2015 EDCi, we also tested the effect of aggregating both variables and theme scores using a weighted geometric mean.

1.9.3 Robustness and Sensitivity Analysis

The robustness and sensitivity analysis checked the effect of removing each variable in turn from the Index to ascertain whether this has an unduly large (or small) influence on the remaining variables and the composite Index as a whole.

1.10 Data visualisation

We worked in partnership with our platform developers DIAS to represent the Index in intuitive and interactive ways, allowing users to view & customize the final index according to their choices. The city rankings and variable scores are displayed graphically on a map of Europe alongside an 'Index Customiser', which allows users to create their own version of the Index based on what they deem to be the most important factors.

2. Background

The European Digital City Index (EDCi) contains composite indicators describing how well different European cities support digital entrepreneurship. These indicators examine key factors such as the availability of sufficient and appropriate finance, the skillset of the workforce in the area and the quality of the supporting infrastructure and networks. The ultimate purpose of EDCi is to support digital entrepreneurship by providing both a holistic local view across Europe by describing what ecosystem factors are most conducive to attracting and retaining digital startups. To that end, it includes indicators which relate to various policy, economic, social/cultural, and technological factors. Since our Index is pertinent to both startups and scale-ups (defined as companies beyond the startup phase, who have typically undergone several years of strong growth), we allow users to view the Index from the perspective of either a startup or a scale-up by differentially weighting the influence of these composite indicators.

The number of indices measuring social, political environmental and economic indicators has grown rapidly in the past few years.[1] Unfortunately, the growing popularity of composite indices has not been in line with the development of objective methodological rigour. This is partly because of the lack of transparency in the construction of composite indices, which require several subjective decisions (for example in terms of data selection and weighting of component variables), but also due to the lack of emphasis on documentation and collection of metadata. To design, develop and disseminate our Index, we have therefore strived to be as transparent as possible, but have also put special emphasis on the preparation of relevant documentation at the end of each phase in order to ensure the coherence of the overall process as well as to avoid any data manipulation and misrepresentation issues. In practice, this has meant adhering to the 'ideal sequence' of ten steps detailed in the JRC/OECD Handbook on constructing composite indicators to guide our process (Figure 1, in Executive Summary).

[1] A quick Google search for 'composite indicators' yields 114,000 results.

3. Aim of the Index

The principal purpose of EDCi is to support digital entrepreneurship and digital startups across Europe by describing what environmental factors matter to startups. We are aware that other indices exist which touch on this area. This Index is not intended to replicate those, but instead will provide a complementary angle by considering all the factors that cities have implemented in their attempt to attract digital entrepreneurs. A summary table that depicts the similarities and differences between this proposed index and other projects – such as the Digital Entrepreneurship Monitor (DEM), the Digital Economy and Society Index (DESI) and the Atlas of ICT Poles of Excellence (EIPE) – that look at digital entrepreneurship in the European and global context is provided in appendix 10.1.

Ultimately, our aim is to situate this Index alongside other work packages within the broader EDFx project so as to complement the Index from a policy perspective. These work packages are, specifically, the *Startup Manifesto Policy Tracker* , the *Scale Up Europe Manifesto* and the *Repository of Best Practice*. Taken together, these projects will provide policymakers with a menu of policies they can implement which would boost their ranking on Nesta's Index. This interplay between the Index and policy will ensure that it becomes a relevant and important policy tool.

3.1 Intended Audience

We anticipate a variety of audiences. For startups, the Index will provide information about the strengths and weaknesses of local ecosystems, allowing them to plan accordingly and consider where they may need to devote more resources. For scale-ups, the Index may additionally assist with expansion plans. For policymakers aiming to encourage digital entrepreneurship in their own city or country, it will assist in identifying existing and promising hubs of activity, in order to learn from their practices and provide inspiration and support when implementing similar approaches in their own ecosystems; additionally, it will allow them to benchmark their performance against other European hubs and help identify which policy areas they should prioritise.

3.2 Defining the Concept

In terms of definition, we note the description of digital entrepreneurship (the receptiveness at the city-level which we are trying to measure and compare) provided by the European Commission, as follows:

"Digital entrepreneurship embraces all new ventures and the transformation of existing businesses by creating and using novel digital technologies. Digital enterprises are characterised by a high intensity of utilisation of novel digital technologies (particularly social, big data, mobile and cloud solutions) to improve business operations, invent new business models, sharpen business intelligence, and engage with customers and stakeholders."

- European Commission - "Fuelling Digital Entrepreneurship in Europe"

In terms of our own working definition, we have taken 'digital entrepreneurship' as referring to startups and scale-ups that incorporate novel digital technology as a vital component of their business model and which *could not feasibly operate without the internet*. This would therefore include businesses working on the 'internet of things', and online retailers such as Amazon, but exclude retailers who have a physical presence on the high-street. We believe that this definition complements the Commission's description above, but provides a simpler term of reference.

3.3 Geographical Coverage

The Index includes all capital cities in the EU. This satisfies two main aims: firstly, the presence of cities from all EU countries will allow all member states to use the Index to inform and assess digital entrepreneurship policies; secondly, most EU capital cities perform highly in measures of digital excellence and entrepreneurship - either relative to cities in other member states, or relative to cities in their own country (and in some cases, both).

Additionally, as well as covering capitals, the Index also includes a number of other cities in the EU that are important hubs of digital entrepreneurship activity (see Table 2). In order to justify the further selection of non-capital cities, extensive secondary research has been conducted into existing indices and data sources that are relevant to the prevalence of digital excellence, entrepreneurship and cluster formation. Since this Index is covering new ground and there are no existing sources dedicated specifically to the performance of digital entrepreneurship in cities, the secondary research was focused on identifying cities with substantial ICT, digital, or web presence on the one hand, and substantial entrepreneurial presence on the other. We used the following sources for this process: *European ICT Poles of Excellence (EIPE), The Global Entrepreneurship and Development Index (GEDI), The Innovation Cities Program, Global City Competitiveness Index, Fortune.com's 7 best new global cities for startups, Nestas' Manifesto for the Creative Economy, City Initiatives for Technology, Innovation and Entrepreneurship, The European ICT Clusters and Start-up Cities 2014.*

There were some existing indices that proved to be more useful than others for this task. Considering this, sources were subjectively tiered in terms of their influence when selecting cities. This ranking depended on the relevance of both the aims of indices and any indicators used to measure digital entrepreneurship. For example, the 2014 Cities in Motion Index, created by IESE, aims to support city-level strategic planning. While the majority of the indicators are not entirely relevant, information on educational attainment and broadband penetration are included and, as such, were given a medium tier. In contrast, the European ICT Poles of Excellence was deemed to be a more relevant source because it describes and highlights high performing agglomerations of ICT production, R&D and innovation initiatives within the EU.

A city's performance in terms of ICT excellence was identified and cross referenced against existing sources that explore the extent and quality of entrepreneurship. Cities that feature strongly in both are deemed 'essential' for the Index. Proceeding in this manner mitigates the risk of including cities that perform well in terms of ICT excellence but only due to the presence of a cluster of large ICT firms and not digital entrepreneurs. It is vital that the Index focuses primarily on high-performing cities as, from a policy perspective, this will provide policymakers with an insight into which areas they need to improve upon to create the best possible digital startup ecosystem in the city.

Quantitative and qualitative research were then combined to select cities that had digital startup ecosystems comparable to many of the capitals that dominated the rankings. Because of this, 32 non-capital cities were selected in 2016 (up from just 7 in 2015), with the selection method focused on formal indices and informal data sources which could be used to identify the presence of a strong digital startup ecosystem.

Some of the cities identified were on the borderline for inclusion. When this was the case, our objective method, described above, was combined with qualitative research which attempted to ascertain the likely prominence and support for a digital ecosystem. While there are many European cities with non-insignificant digital startup ecosystems, it was important for the city-selection procedure to be rigorous and methodical, meaning that cities which performed averagely or poorly in the indices that were investigated had to be excluded. Alternatively, cities that scored highly in ICT indices as a result of high levels of 'hard tech' (hardware rather than digital services) were also considered less relevant for the purposes of this Index.

Due to capacity constraints and because it was our pilot year, we had to limit the number of cities which we could consider for inclusion in the 2015 version of the Index to 35 in total. But, based on positive feedback, a large demand from entrepreneurs and city officials, and the availability of comparable data, we were

able to include 25 additional cities in the 2016 version, bringing the total up to 60.

Below is the list of all 60 cities we deemed essential for inclusion in the Index:

Aarhus (Denmark)	Copenhagen (Denmark)	Ljubljana (Slovenia)	Sofia (Bulgaria)
Amsterdam (Netherlands)	Dresden (Germany)	London (UK)	Stockholm (Sweden)
Athens (Greece)	Dublin (Ireland)	Luxembourg	Stuttgart (Germany)
Barcelona (Spain)	Dusseldorf (Germany)	Lyon (France)	Tallinn (Estonia)
Berlin (Germany)	Edinburgh (UK)	Madrid (Spain)	The Hague (Netherlands)
Birmingham (UK)	Eindhoven (Netherlands)	Malmö (Sweden)	Toulouse (France)
Bordeaux (France)	Frankfurt (Germany)	Manchester (UK)	Turin (Italy)
Bratislava (Slovakia)	Glasgow (UK)	Milan (Italy)	Uppsala (Sweden)
Bristol (UK)	Gothenburg (Sweden)	Munich (Germany)	Utrecht (Netherlands)
Brussel (Belgium)	Hamburg (Germany)	Nicosia (Cyprus)	Valencia (Spain)
Bucharest (Romania)	Helsinki (Finland)	Oxford (UK)	Valletta (Malta)
Budapest (Hungary)	Karlsruhe (Germany)	Paris (France)	Vienna (Austria)
Cambridge (UK)	Kraków (Poland)	Prague (Czech Republic)	Vilnius (Lithuania)
Cardiff (UK)	Lille (France)	Riga Latvia	Warsaw (Poland)
Cologne (Germany)	Lisbon (Portugal)	Rome (Italy)	Zagreb (Croatia)

Table 3 List of 28 EU Capitals + 32 selected hub cities.
New cities in green.

4. Theoretical Framework

The theoretical framework for the Index was built based on several months of interviews with experts and digital entrepreneurs across Europe (a list of whom is provided in the Appendix 10.3). Combined with the burgeoning academic literature and existing policy reports, this primary research was distilled to give a clear understanding and definition of the phenomenon of 'digital readiness' (or receptiveness at the city level) to digital entrepreneurs and used to structure the ten dimensions or 'themes' and subsequently their subsidiary variables. We deliberately aimed to include some novel metrics that we felt provided an interesting, but under-utilised, indicator of digital activity.

4.1 Composition of the Index

The Index is comprised of a number of composite indicators, or 'themes' that summarise the external political, economic, social and technical environment of a given city, insofar as this relates to digital entrepreneurship (Table 4)[2]. Each of these themes is composed of a number of mostly input, some output, and a few process variables that capture different aspects of the category (**Error! eference source not found.**). Input variables refer to the resources needed for the implementation of an activity (e.g. entrepreneurship), whereas outputs refer to the product of the activity and processes refer to variables that measure whether planned activities took place.

For example, the 'Business Environment' theme contains variables describing the ease of doing business and the availability of public sector information and openness of data (process variables) as well as the cost of office space and availability of coworking spaces (input variables). These factors are measured using different metrics. The Index was weighted at both the variable and then subsequently at the theme level. Thus, inside a theme, certain variables were more influential than others and certain themes were more influential than others in determining the final index score. For ease of understanding, the structure of the Index has been graphically visualised below (Figure 2).

[2] Three potential themes were considered but later rejected. These were 'Data Protection & Regulation', 'Success Stories' and 'Agglomeration':

Data Policy, Protection and Regulation is Priority 4 of the Startup Manifesto and, as such, was originally considered for inclusion as a theme. However, neither existing indices of Digital/ICT excellence nor indices of entrepreneurship measure it, and only one of the expert interviewees brought up the issue. Moreover, in a separate study which Nesta conducted, relatively few startups cited data-related issues as inhibiting growth (tech.eu, Nesta & The Lisbon Council, 2015). For this reason, it was subsumed within the 'Business Environment' theme. In doing so, we emphasize that the Index does not in any way reject the Startup Manifesto: initiatives that simplify and harmonise data regulation, and which make government data available to the public are welcome. However, from the very specific perspective of research on creating a city-level environment conducive to the growth of digital startups, it does not seem to have sufficient prominence to warrant being a major category at this time.

Success Stories - the visible presence of successful startups which might serve as role models or inspiration - were consistently considered to be of medium-to-High importance. However, the main benefits were typically described as being a network externality effect for Access to Finance and Mentoring and Managerial Assistance, as well as a more positive cultural approach to startup foundation. After discussion, we concluded that these benefits were adequately captured in the measures constructed for 'Access to Finance', 'Mentoring and Managerial Assistance' and 'Entrepreneurial Culture' and hence did not warrant their own 'theme'.

Agglomeration – defined by the presence of an ICT cluster – was also removed from the list. This is because interviewees, whilst consistently citing this theme as important, thought that its main benefits came in the form of the concentration of skilled workers in a given location and the presence of mentors and networks. Both of these factors were already being measured as part of 'Skills' and 'Mentoring & Managerial Assistance', so Agglomeration was removed in order to avoid unnecessary duplication.

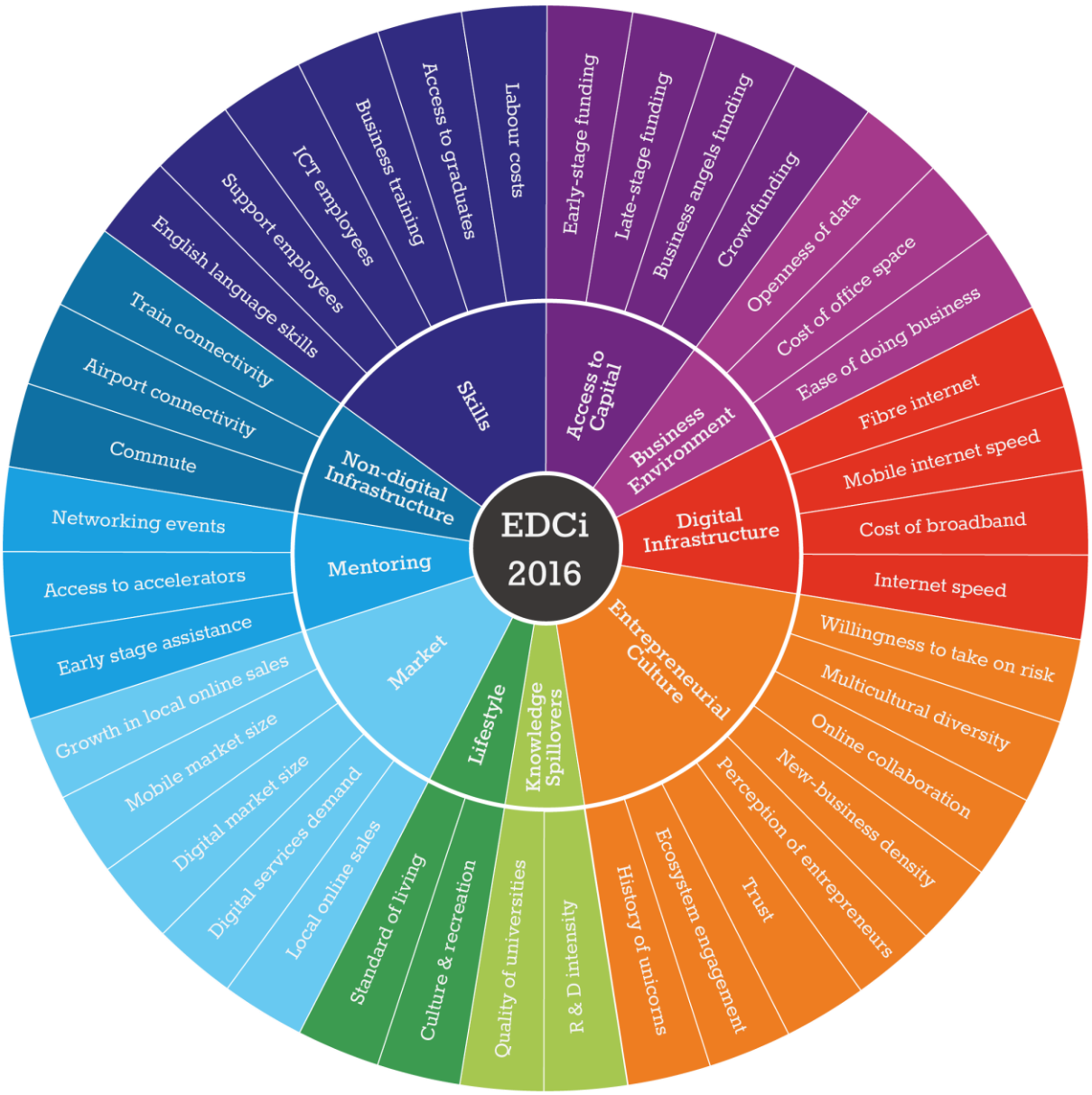


Figure 2 Graphical representation of the Index structure.

4.2 Secondary Research

To inform the primary research, a review was undertaken of existing, recent indices that gauge different aspects of European and worldwide city performance vis-à-vis entrepreneurship. Further, the academic and think-tank literature on digital and ICT startup formation and performance was also reviewed to provide additional information about the factors which contribute to digital startup formation. This literature review was used to inform the questions which were asked in the interviews which constituted the primary research phase of the project and can be found in Appendix 10.3. As that table shows, there is

academic disagreement about the most important environmental factors. Nevertheless, we believe that all the prominent factors identified by the academic literature are present in our Index to some degree.

When conducting this secondary research, conceptual overlap with priorities areas outlined in the Startup Manifesto was considered. The five priorities outlined in the Startup Manifesto were as follows:

1) Educational & Skills
2) Access to Talent
3) Access to Capital
4) Data Policy, Protection and Privacy
5) Thought Leadership

Nesta did not *assume* that overlap would exist, as it was important to maintain the methodological rigour of the Index. If neither expert interviewees nor the secondary research highlighted issues outlined in the Startup Manifesto, then they were not included in the framework for the Index. Conceptual overlap was strong between our theoretical framework and Priority 1, 2, and 3 of the Startup Manifesto. To reflect this, the themes related to skills and capital were named to echo Priorities 1, 2 and 3. The research also suggested that there were partial overlap issues important for growing digital businesses and Priority 5 - 'Thought Leadership'. The theme related to whether the culture of a city was conducive to creation and growth of startups, which had only partial overlap with Priority 5, was called 'Entrepreneurial Culture'.

4.3 Primary Research

The general aim of the primary research phase was to make the Index as substantive and robust as possible. To this end, we conducted over 70 expert interviews with 'digital experts' from across the EU and US, a list of whom can be found in Appendix 10.3. Experts were defined as stakeholders with an in-depth knowledge of the digital entrepreneurship space through experience in industry associations, startup support intermediaries, co-founding digital startups, within academia and so on. The expert interviews aimed to identify the consensus view on what factors are most important in driving the growth and creation of digital startups. These insights were used to choose the themes, variables and weightings our Index would include and employ.

Theme	Description	Reason for inclusion and weight
Access to Capital	The amount of funding that digital startups have access to at various stages in their development.	Interviewees consistently rated this factor highly. As there was disagreement regarding the importance of investors being located in the same city as the startup, the data was gathered on the basis of the location of portfolio companies, thus representing the overall accessibility of capital in each city.
Business Environment	The extent to which the regulatory/policy environment in a city is conducive to the growth of digital startups. It also measures startup access to office space and access to public sector data.	Interviewees consistently rated this factor as having medium importance. This was because, although the regulatory and cost environment that exists in different cities is a problem for digital startups, it was considered to be easy to overcome and in many cases, less of an issue than for non-digital startups.
Digital Infrastructure	Internet speed and penetration, both in broadband and mobile, as well as the cost of broadband.	Digital Infrastructure was consistently considered to be of medium-to-high importance. However, interviewees also consistently said this was not a differentiating factor and that, whilst it was important, it was at the required level in every major EU city. As such, the factor was given a 'Medium' rather than 'High' weighting. Within digital infrastructure, the quality of the mobile network was considered most important.
Entrepreneurial Culture	The risk tolerance of a city's residents, perceptions of entrepreneurs, the engagement of the local ecosystem, online collaboration, multiculturalism, language skills, trust and history of successful digital startups from the city.	A range of opinions was given on the importance of culture, which averaged at interviewees considering it to be of medium importance. However, interviewees were initially asked about 'Success Stories' separately to 'Entrepreneurial Culture', and the decision to make 'History of Successful Digital Startups' a component of 'Entrepreneurial Culture' required an increase in its weighting. On the other hand, it was considered that once a startup reaches a certain stage, culture becomes less relevant.
Knowledge Spillovers	The importance of knowledge spillovers for digital startups working in industries on the technological frontier. The variables measured cover the quality of research institutions, and the intensity of R&D in the city.	This factor had by far the highest levels of disagreement. On average, interviewees gave it low importance. However, the high variance of this factor meant that the average score was not necessarily a useful indicator of the importance of knowledge spillovers. Thus, the interviewee responses were analysed and it was decided that, as the Index should also measure the ability of cities to support startups operating in the major growth areas of the digital sector, the weighting on this factor should be raised to medium.

Lifestyle	The standard of living that digital entrepreneurs and their employees can enjoy in a city, as well as the extent to which a city offers a highly differentiated and exciting (or alternatively highly differentiated and boring) lifestyle to its citizens.	A range of opinions was given about this factor. Some secondary literature (e.g. Morris 2013) ranks this very highly, but the majority of interviewees attached a low level of importance.
Market	The level of online (in the form of e-commerce) and offline (in the form of procurement) demand for the products produced by digital startups, both at the regional and national level. It also measures projected growth rates of online and offline demand and the aggregate national size of the e-commerce and e-services market.	A range of opinions was given on the importance of Market, which averaged at interviewees considering it to be of low importance during the early stage of development and then of medium relevance for scale-ups. This was considered to be an appropriate weighting because digital startups often focus on the global marketplace. However, it was also thought that local market conditions were important for the testing and feedback that occurs in a digital startup's early stages, and could also be important for sales of B2C software.
Mentoring & Managerial Assistance	The number of networking events, accelerators, and business angels.	Interviewees consistently rated this factor highly. Many also commented on the importance of mentoring & managerial assistance when asked about agglomeration (which was previously considered a potential theme, as explained earlier). Considering that the indicators are principally measuring early stage assistance, the weighting was lowered for later stage companies.
Non-Digital Infrastructure	The quality and prevalence of public transport as well as the connectedness of a city via air and rail links.	There was some disagreement on the importance of non-digital infrastructure. Some secondary literature suggests that it is important (e.g. as an enabler of access to talent and capital) but answers from interviewees tended to suggest an overall low importance.
Skills	The access that digital startups have to an appropriate talent pool. The variables in this theme assess the quality and abundance labour force with relevant skills as well as the cost of labour.	Interviewees consistently considered this to be of high importance for any venture in phase of expansion. In this regard, it tended to be rated as the most important factor. On the other hand, this was considered to be much less relevant in the early stage of startup development.

Table 4 Description of the ten selected 'themes', and the reasons for their inclusion.

4.4 Variable / Indicator Selection

The primary and secondary research described above, as well as extensive internal discussion, culminated in the development of an initial framework for the Index consisting of a list of themes and a weighting system for those different themes. Follow-up interviews and research, along with internal deliberations and external roundtables were then used to determine relevant, analytically sound, timely and accessible measurement metrics and indicators for these variables. A list of ten themes and 40 measurable variables were thus identified (Table 4). Where specific direct data was not available or easily compiled, we have used proxy measures. For example, we used the number of Tweets, which include specific entrepreneurship keywords, originating from the city as a proxy for level of digital engagement with the online ecosystem. It is worth noting that while some indicators that have been selected are not necessarily targeted at digital entrepreneurs specifically (or solely), they do benefit from them.

A further issue that we tackled is regarding the comparison of indicators in relative rather than absolute terms. For instance, Paris and London each have 10 times the population of Bratislava and Nicosia, therefore, standardising absolute values by the respective city population was a step necessary to make these cities comparable along the same scale. Most of our data is at the NUTS2 level, but certain information was only available at the national or city level, and we have used these as a proxy, after denominating them by the appropriate standardisation metric (GDP per capita, population or number of startups, see Table 5 below for a full account of these).

Theme	Variable	Indicator	Coverage level	Data Type	Source
Access to Capital	Availability of early-stage funding	Amount of seed and startup funding raised (standardised by purchasing power parity; PPP)	City*	Input	European Venture Capital Association (2015)
	Availability of late-stage funding	Amount of later-stage funding raised (standardised by PPP)	City*	Input	European Venture Capital Association (2015)
	Availability of business angels funding	Amount of business angels funding raised (standardised by PPP)	City*	Input	EBAN (2015)
	Availability of crowdfunding	Amount pledged towards crowdfunded projects (standardised by PPP)	City	Input	Crowdsurfer (2016)
Business Environment	Openness of data	Public Sector Information Score	National	Process	ePSI Platform (2014)
	Cost of office space	Average rental cost or price of commercial property (inverted)	City	Input	Cushman-Wakefield (2016)
	Ease of doing business	Time and cost associated with doing business	National	Process	World Bank - Ease of doing business business ranking (2016)
Digital Infrastructure	Availability of fibre internet	Number of fibre-to-the-home/building Internet subscriptions (standardised by number of households)	National	Input	ITU (2014)
	Mobile internet speed	Mobile internet upload/download speed of (MB/Sec)	City	Input/ Process	Ookla (2016)
	Cost of broadband	Average fixed broadband subscription charge ($ / Month)	National	Input	ITU (2015)
	Internet speed	Broadband upload/download speed (MB/Sec)	City	Input	Ookla (2016)
Entrepreneurial Culture	Willingness to take on risk	Response to question about whether one should start a business if there is a risk it might fail	NUTS2	Input	Eurobarometer (2013)
	Multicultural diversity	Percentage of population that are foreigners	NUTS2	Input	European Statistical System (2011)

	Online collaboration	Number of GitHub Users within the last 12 months (standardised by city level population)	City	Input	Ghtorrent (2016)
	New-business density	Number of newly registered corporations per 1,000 working-age people	National	Input/ Output	World Bank (2014)
	Perception of entrepreneurs	Response to question about participants overall opinion of entrepreneurs	NUTS2	Input/ Output	Eurobarometer (2013)
	Trust	Response to question about whether most people can be trusted	NUTS2	Input	Eurobarometer (2013)
	Online engagement with startup ecosystem	Number of tweets with selected startup related keywords in the last year (standardised by city level population)	City	Process	Follow the Hashtag (2016)
	History of highly successful startups	Number of unicorns (standardised by city level population)	City	Input/ Output	GP Bullhound / CB Insights (2016)
Knowledge Spillovers	Research and development intensity	Number of research institutions in top 200	NUTS2	Input	QS University Ranking (2016)
	Quality of research institutions	Expenditure on R&D (€ / Inhabitant)	City	Input	Eurostat (2013)
Lifestyle	Culture & recreation	Average scores attributed to diverse cultural facilities	City	Input	Teleport (2016)
	Standard of living	Quality of life index score	City	Input	Numbeo (2016)
Market	Local online sales	Percentage of internet users who bought or ordered goods or services for private use over the internet in the past 12 months	NUTS2	Input	Eurostat (2015)
	National demand for digital services	Percentage of Enterprises' total turnover from e-commerce for all enterprises, without financial sector (10 persons employed or more)	National	Input	Eurostat (2015)
	Digital market size	Aggregate revenue in the 'e-commerce' and 'e-services' sectors	National	Input	Statista (2015)

	Mobile market size	Active mobile-broadband subscriptions per 100 inhabitants	National	Input	ITU (2015)
	Growth in local online sales	Difference in the percentage of individuals who have purchased online from 2013-2015	NUTS2	Input	Eurostat (2015)
Mentoring & Managerial Assistance	Availability of early stage assistance	Number of Business Angels (standardised by national population)	National	Input	EBAN (2015)
	Access to accelerators	Number of accelerators (standardise by city level population)	City	Input	Gust / Seed DB / Open Axel (2015)
	Networking and mentoring events	Number of meetups/networking events per month in city (standardised by city level population)	City	Process	Meetups (2016)
Non-digital infrastructure	Commute	Average travel time and distance to work	City	Input/ Process	Numbeo (2016)
	Airport connectivity	Score based on number of flights from local airport	City	Input/ Process	Teleport (2016)
	Train connectivity	Total population that can be reached within 3h of train travelling	City	Input/ Process	DG Regio (2014)
Skills	English language skills	Percentage of city's population who can communicate in English	NUTS2	Input	Eurobarometer (2012)
	Access to support employees	Number of employees in selected startup relevant sectors (standardized by city level working population)	NUTS2	Input	Eurostat (2015)
	Access to ICT employees	Number of employees in ICT sector (standardized by city level working population)	NUTS2	Input	Eurostat (2015)
	Business training	Basic and post school entrepreneurial training	National	Input	World Economic Forum (2015)
	Access to graduates	Population aged 25-64 with tertiary (level 5 - 8) education attainment	NUTS2	Input	Eurostat (2015)
	Labour costs	Average salary for selected startup relevant profession (inverted)	City	Input	Teleport (2016)

Table 5 Variables for each theme, indicators associated with variables, coverage level, data type and source.

* City level data was estimated by multiplying national level data by the proportion of national startups coming from that city

4.5 Data Collection

The next stage in the research was the data gathering phase. We had resolved from the start that the Index would use many sources of reliable secondary data selected on the basis of their relevance, analytical soundness, timeliness, accessibility etc. These included 'hard' data from internationally comparable quantitative public sources such as: The World Bank, Eurostat and the OECD. In addition to public sources, the Index also utilized some non-public databases such as commercial venture capital databases (e.g. European Venture Capital Association).

Beyond constructing the indicators based on existing 'hard' data sources, the Index also used novel data gathering techniques to explore areas of interest not covered in the existing data sources. For this, we partnered with businesses to collect bespoke, non-public data, for example with Teleport for lifestyle and salary data, Ookla for digital download/upload speeds, Statista for digital market size and Follow the Hashtag for Twitter data aggregation. In addition, technologies such as web scraping and API queries were used to gain insights that are difficult to obtain from other sources (for example from Meetup and GitHub). These were used to, for example, identify social media use in a particular geography, and the interest that those social media users have in digital ecosystems.

To aid this process, we adopted an innovative crowdsourced approach to data gathering in line with Nesta's commitment to collaborative research. During the primary research phase, a number of our digital experts provisionally agreed to provide assistance in supplying specific information either on a city, or sectoral level, along with other potentially useful data sources. The way we have operationalized this is by creating a data-gathering tool in collaboration with Open Evidence. This bespoke portal (Figure 3) allowed our selected experts, as well as National Champions we have identified, to input data either theme-wise or by choosing a particular city. It also enabled experts to challenge the measures which we have proposed, and to suggest alternative metrics.

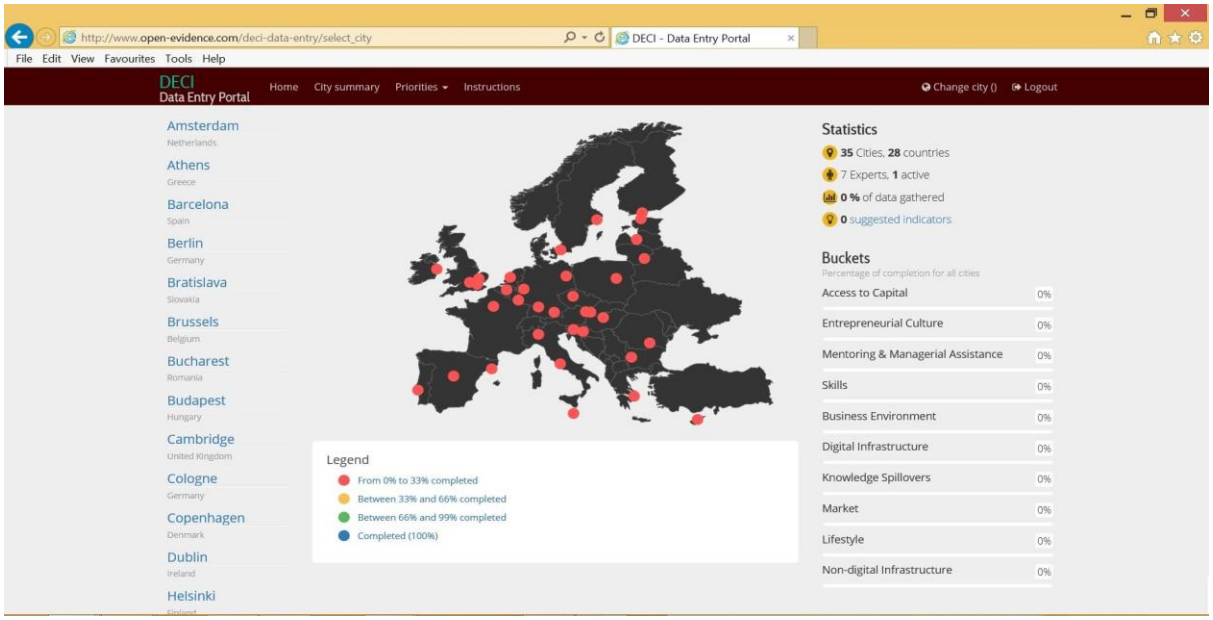


Figure 3 City selection page of our data-gathering tool.

Once users had selected the relevant city, a new page listing the subsidiary variables and measurement metrics opened (Figure 4) and where they could enter a value (of a specified data type), provide a source for the information and add any additional comments they thought were relevant. This tool served a dual purpose as it could also be used to highlight any interesting practices or policies that they have encountered, which we included in our [Idea Bank for local policy makers](#).

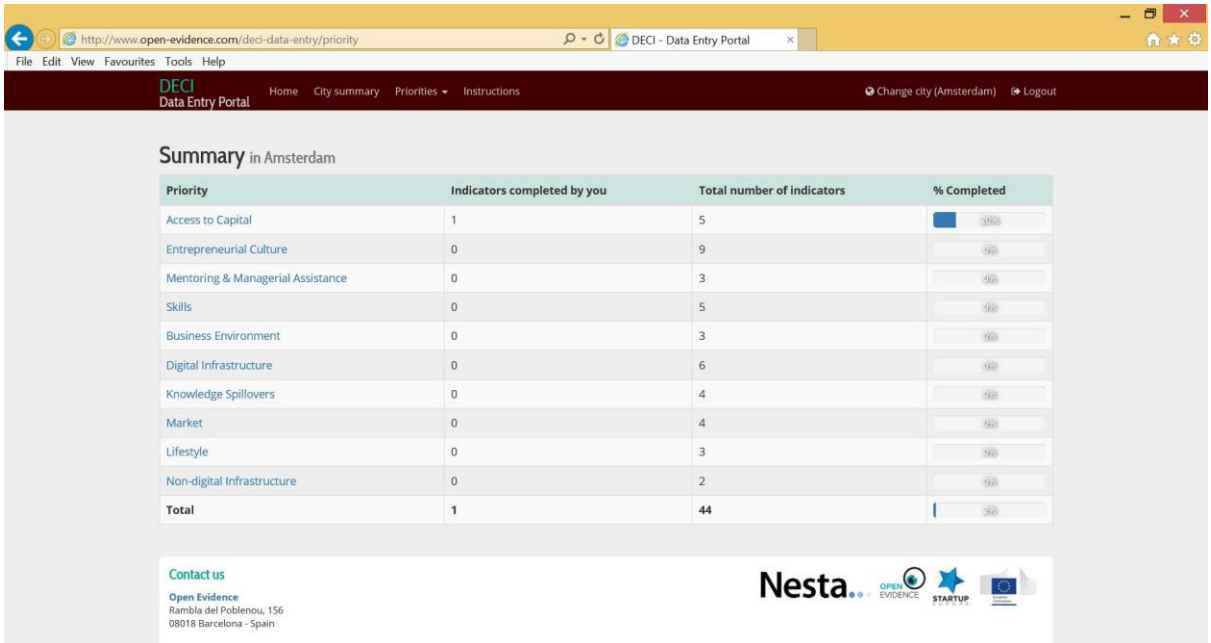


Figure 4 Theme selection page of our data-gathering tool.

4.6 In-house data gathering and processing

At Nesta, we are fortunate to have as members of staff, many highly skilled data scientists. We could collaborate with these colleagues to source and process interesting and relevant data sets to generate bespoke variables that are not normally part of other composite indices. We elaborate on three such examples: Twitter data, Meetup attendance/popularity and GitHub usage.

4.6.1 Twitter

We collected data on the number of Tweets containing specific startup related keywords[3] originating from each city as a proxy for digital engagement with the startup ecosystem. Our data partner Follow the Hashtag collected all tweets that were published over the previous 365 days and that contained at least one of the chosen keywords using the Twitter API. Tweets were assigned to cities based on the location given by the user in their profile and then standardised by the city level population. Although it is optional for users to state their location, most do. An alternative method of assigning tweets to cities is by looking at geotags attached to tweets which give the precise latitude and longitude at which the tweet was sent. However, we decided against this because most twitter users do not geotag their tweets meaning that the sample of tweets we could use would be substantially reduced.

4.6.2 Meetup

For each of the European cities included in the Index, we used Google's geocoding API to gather the estimated latitude and longitude of the city's centroid, as well as the points, in latitude and longitude, of a bounding box that envelops the city. We then used Meetup's API (Version 3) to gather data on Meetup groups classed as 'Tech' groups, for each of these cities, using Meetup's 'smart radius' filter to identify whether a group was within a city's area.

For each of the groups in each city, we gathered data on the individual events they had held over the last 12 months. These events were then filtered based on their geolocation, and whether this was within the bounding box of the relevant

[3] We collected tweets containing the following keywords: #startup, #startups,"Petite entreprise", "nouvelle entreprise", avviare, "piccola impresa", Kleinbetrieb, Neugeschäft, "pequeños negocios", "nuevo negocio", yrittäjä, "uutta liiketoimintaa", "lille virksomhed", "ny virksomhed", "μικρή επιχείρηση", "νέων επιχειρήσεων", "Nieuw bedrijf", "startende onderneming", "petits negocis", "noun egoci", "malý biznis", "nové obchody", "afaceri mici", "afaceri nou", "pequeno negócio", "novo negócio", "mala podjetja", "nov poslovni", "mazo uzņēmumu", "jauns bizness", "smulkus verslas", "naujos verslo", "kezdő vállalkozás", "kis vállalkozás", Girişim , yeniiş, "malé podniky", "nový podnikání", "малък бизнес", "нов бизнес", "litet företag", "nya affärer", väikeettevõte, "uute ettevõtete", "mały biznes", "nowy biznes", "negozji żgħar", "negozju ġdid"

city for that event's group. The remaining events data were used to sum the total number of events held in each city.

4.6.3 GitHub

The data from GitHub was collected through the GHTorrent project. This project monitors the GitHub public event timeline, collecting information about users and their collaboration for open source projects. User information includes the location they choose to be shown as part of their public profile. We used SQL to query that piece of information to understand how many active users are located in each city[4].

In conclusion, it is important to note that the establishment of the EDCi theoretical framework was an iterative process. The extent to which data was readily available on our preferred variables was, over time, thoroughly understood and ultimately dictated which variables could be included. In light of this, there were regular internal discussions regarding possible correlations between variables and alternative measures and proxies to ensure that the effects of variables we were unable to include are captured elsewhere within the Index.

[4] The SQL query we used is "`select u.city, u.country_code, count(*) from users u where u.country_code in ('at', 'be', 'bg', 'hr', 'cy', 'cz', 'dk', 'ee', 'fi', 'fr', 'de', 'gr', 'hu', 'ie', 'it', 'lv', 'lt', 'lu', 'mt', 'nl', 'pl', 'pt', 'ro', 'sk', 'si', 'es', 'se', 'gb', 'ch') group by u.city;`". We then filtered the results for the relevant cities.

5. Data Checking

5.1 Treatment of Outliers

Index building is based on a benchmarking principle where baseline values considerably influence both a city's index score as well as its rank. The presence of outliers may result in inappropriate benchmarks and must therefore be dealt with before the index can be constructed.

Variables containing outliers were identified as those having a distribution with a kurtosis greater than 3.5 and absolute skewness greater than 2; a skewness of greater than +2 indicated the presence of upper-end outliers whereas a skewness of less than -2 indicated lower-end outliers. This threshold is based on Groeneveld and Meeden (1984), which sets the criteria for a normal distribution as having an absolute skewness less than 1 and kurtosis less than 3.5. We relaxed Groeneveld and Meeden (1984)'s skewness criterion to greater than absolute 2 to account for the relatively small sample of 60 cities.

Variables identified to contain outliers were treated by winsorization. For variables with top-end outliers, the largest value was transformed to have the same value as the second largest value and for those with low-end outliers, the smallest value was transformed to have the same value as the second smallest value. This process was iterated until the variable's skewness and kurtois fell within the acceptable limits. Winsorized data is highlighted in the downloadable data file. After winsorization, according to Tukey's (1977), rather conservative, rule that values of more than Q3 + (1.5 x Inter Quartile Range) can be counted as outliers, several outliers still existed (Figure 5). However, since the data now falls within the acceptable range of kurtosis and skewness, we decided that this is satisfactory for the use of the data in this Index.

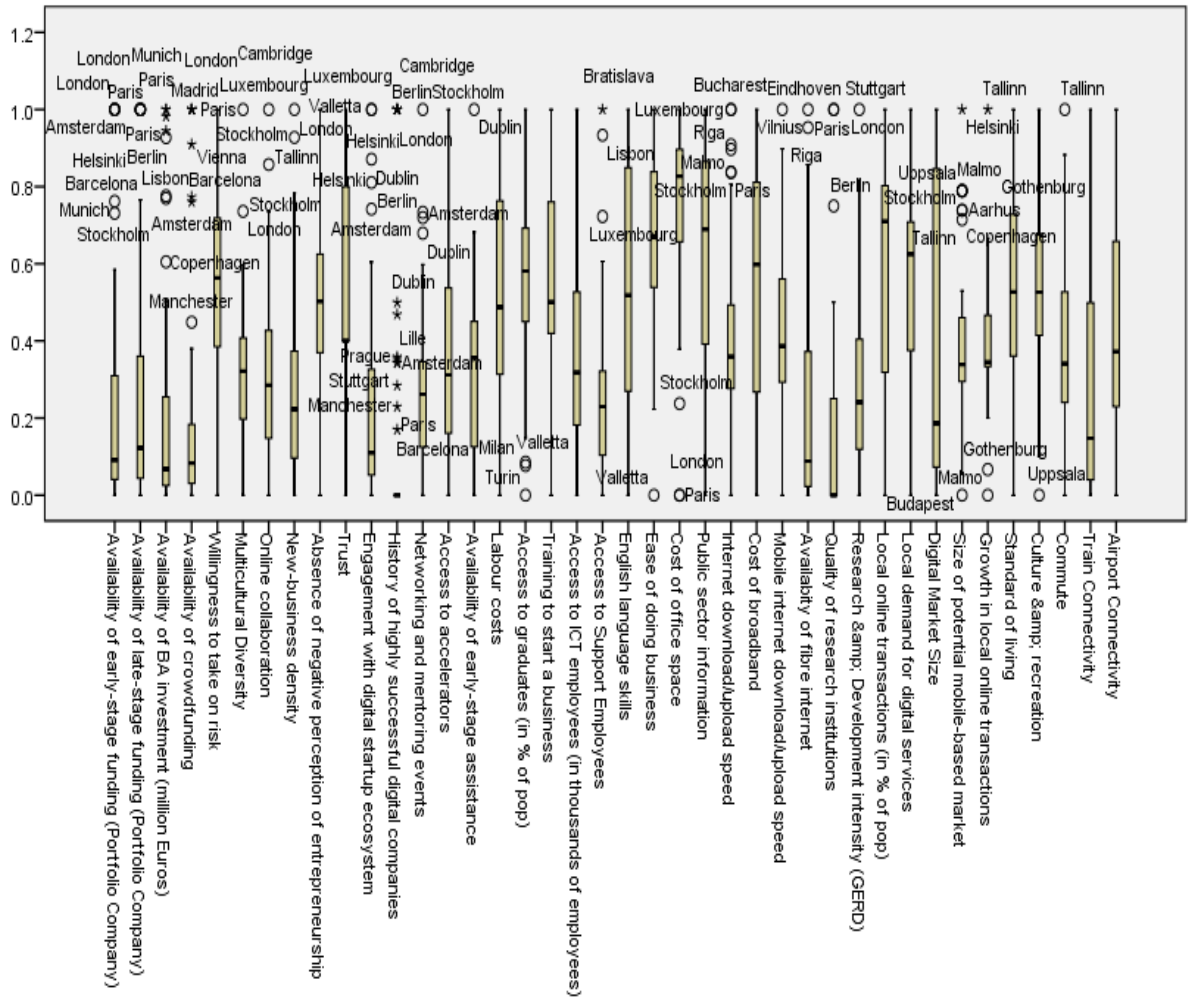


Figure 5 Box and whisker diagram showing data after min-max normalisation.
Box = interquartile range (IQR); bar = median; whiskers = box ± 1.5 x IQR; small circles = outliers (below Q1 – 1.5 × IQR or above Q3 + 1.5 × IQR); Stars = extreme outliers (below Q1 – 3

5.2 Normalisation

Normalisation procedures were required on our dataset because indicators had different measurement units and scales of magnitude. The normalisation methods considered were: ranking, z-score standardisation, min-max, and distance to a reference point. The ranking normalisation method, although the simplest, was dismissed as an option on the grounds that we did want to lose information on the absolute performance of cities. We then looked at the z-score method of converting indicators to a common scale. A salient feature of this method is that it exaggerates the influence of extreme values which therefore have a bigger net effect on the overall composite index. We decided that this would be an undesirable feature for this Index because we did not want to privilege a few exceptional results over a high number of average scores.

We therefore decided to utilise a min-max normalisation method (used in the Human Development Index (HDI); see Equation 1) which normalises the

indicators to within an identical [0,1] range by subtracting the minimum value and then dividing by the entire range of values for that indicator. This method has the advantage of increasing the differences between values, even if real deviations are minimal, allowing us to differentiate cities based on their scores.

Equation 1 Min-max Normalisation

$$z_{i,j} = \frac{x_{i,j} - min(x_j)}{max(x_j) - min(x_j)}$$

where $z_{i,j}$ is the normalized value for city i and variable j
$x_{i,j}$ is the original value for city i and variable j
$max(x_j)$ is the maximum value for variable j
$min(x_j)$ is the minimum value for variable j

For comparison, we also employed the distance to reference normalisation method. This approach involves dividing each value by the reference level. Applying this method preserves the relative differences among the values recorded in each of the cities. The reference level chosen was the maximum value recorded for that variable across all the cities (as in the Regional Entrepreneurship and Development Index (REDI); see Equation 2).

Equation 2 Distance to Reference Normalisation

$$z_{i,j} = \frac{x_{i,j}}{max(x_j)} \quad (2)$$

where $z_{i,j}$ is the normalized value for city i and variable j
$x_{i,j}$ is the original value for city i and variable j
$max(x_j)$ is the maximum value for variable j

5.3 Imputation of Missing Data

Economic and demographic datasets are often incompletely reported across regions or nations. Consequently, the presence of missing values poses a significant problem for researchers aiming to make geographical comparisons based on pre-existing data sources. Although the number of overall missing values was generally low (1.4 %; Figure 6), of the 40 variables included, 12 variables (30%) had missing data for at least one of the 60 cities. To work with a complete dataset, missing data were replaced with the mean of the other variables in that theme obtained for that city. This meant that for cities containing missing values, the theme scores obtained using imputed data were the same as those that would have been obtained had the variables containing missing values been excluded from the Index (hereafter this method will be referred to as 'theme mean imputation'). We decided to use theme mean imputation rather than multiple imputation (Rubin 1987), as used in the 2015

EDCi, because the former allows simpler interpretation of which indicators are driving a city's performance. However, for comparison, we also tested the effect of instead using multiple imputation. Details of this analysis can be found in the 'Robustness and Sensitivity Analysis' section of this document. Imputed data is highlighted in the downloadable data file.

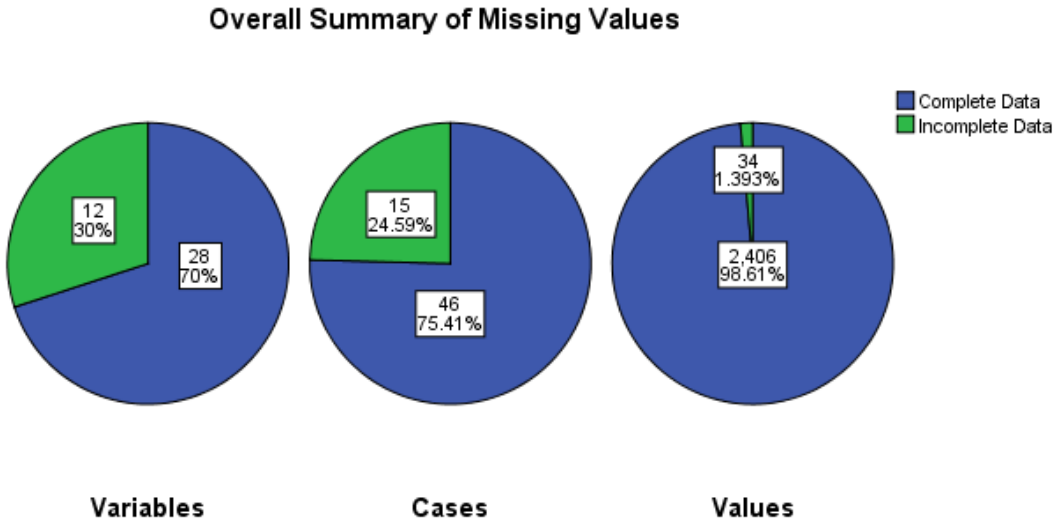


Figure 6 Overall Summary of Missing Values.
Pie charts represent the number and percentage of variables, cases (i.e. cities), and values with complete (blue) and incomplete (green) data.

6. Data Processing

6.1 Multivariate Analysis

When constructing a composite index, it is important to carefully assess the suitability of the data by investigating the overall structure of the proposed indicators and the interrelationships between them. Failing to consider the underlying structure of the data can result in indices which confuse and mislead rather than provide valuable insight into the phenomenon in question.

We explored the structure of our data using principal components analysis (PCA) to assess between-variable correlation. The number of principal components used to describe the data was chosen using the Kaiser criterion which selects those with an eigenvalue of 1 or more. This gave us 11 principal components which together explained 81% of the data (Table 6). Only component loadings of more than 0.4 were considered high enough to be taken into consideration when interpreting the results.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10.406	26.016	26.016	10.406	26.016	26.016
2	5.026	12.565	38.581	5.026	12.565	38.581
3	3.782	9.454	48.035	3.782	9.454	48.035
4	3.071	7.677	55.712	3.071	7.677	55.712
5	2.189	5.473	61.186	2.189	5.473	61.186
6	1.769	4.422	65.608	1.769	4.422	65.608
7	1.537	3.843	69.451	1.537	3.843	69.451
8	1.346	3.366	72.816	1.346	3.366	72.816
9	1.167	2.919	75.735	1.167	2.919	75.735
10	1.110	2.776	78.511	1.110	2.776	78.511
11	1.005	2.513	81.024	1.005	2.513	81.024
12	.883	2.209	83.232			
13	.753	1.882	85.114			
14	.709	1.773	86.886			
15	.661	1.652	88.539			
16	.631	1.578	90.117			
17	.478	1.194	91.311			
18	.453	1.132	92.443			
19	.386	.965	93.409			
20	.361	.901	94.310			
21	.346	.864	95.174			
22	.248	.619	95.793			
23	.220	.549	96.342			
24	.191	.477	96.818			
25	.183	.458	97.277			
26	.165	.412	97.688			
27	.130	.326	98.014			
28	.120	.299	98.313			
29	.108	.271	98.584			
30	.098	.245	98.829			
31	.089	.222	99.051			
32	.082	.204	99.256			
33	.065	.163	99.419			
34	.061	.152	99.571			
35	.049	.123	99.694			
36	.038	.096	99.790			
37	.034	.085	99.875			
38	.024	.060	99.935			
39	.015	.037	99.972			
40	.011	.028	100.000			

Table 6 The variance explained by the initial solution, extracted components and rotated components of PCA.

PCA results confirm some (but not all) aspects of our conceptual framework for measuring support of digital entrepreneurism. For example, all 5 indicators in the 'Access to capital' theme were included in the first and second component,

and both indicators in the 'Lifestyle' theme, and both indicators in the 'Knowledge Spill overs' theme were also included in the first component (see downloadable date file for matrix of component loadings).

Moreover, all but one variable, 'Access to accelerators', from the 'Mentoring and Managerial Assistance' theme was included in the first component. This variable was not included in any of the principal components suggesting that most of the variation in the data can be explained without it. In addition, all but one variable, 'Training to start a business', in the 'Skills' theme and all but the 'Public sector information' variable from the 'Digital Infrastructure' theme were included in the first component. Furthermore, all but the 'Cost of broadband' variable from the 'Digital Infrastructure' theme was included in the third component.

The results of the PCA fitted less closely with our conceptual framework for the 'Entrepreneurial Culture', 'Market' and 'Non-Digital Infrastructure' themes. However, since we think their subsidiary indicators are vital components in trying to understand and explain the city-level readiness for digital entrepreneurship, and because they do not fit well theoretically into any of the other themes, they were left unchanged.

Several themes were included in the first principal component suggesting that these themes could be combined. However, interviews with experts coupled with rigorous research suggested that each of the 10 themes are important for their own separate reasons, so we decided that they should not be combined.

Although PCA can be used to decide how indicators are weighted when aggregated, we have decided to choose weightings based on those suggested by interviewed experts, along with a review of the extant literature.

6.2 Weighting and Aggregation

The next phase was deciding on how our individual variables would be weighted and aggregated to produce an overall index score. We decided to aggregate our variables first at the theme level, producing theme scores, and then aggregate theme scores to produce a final index score. This meant that themes that contain more variables were not automatically more influential to the final index score than those with fewer variables.

Most composite indicators rely on equal weighting, meaning that indicators are equally influential on their final index score. However, interviews with experts and a review of the extant entrepreneurship literature suggested that some themes are likely to be more important to the index score than others. In addition, secondary research suggested that some of our chosen indicators are more important to their theme than others. Therefore, we decided to

differentially weight our indicators and themes based on the opinions of experts and secondary research. This approach also allowed us to vary the weightings of the composite indicators such that users could view the Index from the perspective of either a startup or a scale-up.

One possible method of deciding on weightings for variables is the budget allocation approach. Using this approach, experts are given a budget of points, which they can split between the individual variables; those that are given more points, receive a higher weighting (as in Moldan et al., 1997). This process however, did not lend itself to our Index because it was thought that the high number of indicators would induce serious cognitive stress in the experts who are asked to allocate the budget. Instead, insights generated from initial interviews, along with a short survey circulated amongst a knowledgeable cohort, were used to place the themes into categories of importance (Low, Medium, High), which correspond to a discrete, three-tiered weighting of the Index. These expert weightings were modified, based on secondary research, to produce different weightings for startups and scale-ups.

As with the theme weights, individual variables were differentially weighted for startups and scale-ups based on secondary research but with a four-tiered, rather than a three-tiered, weighting system (Not Applicable, Low, Medium and High). We used a four-tiered approach (compared to the previous year's two-tiered weighting system) for the variables because we could conduct further secondary research along with an expert survey to ascertain a more precise ranking scheme. These weights were incorporated during the aggregation of the variables and themes. For the variable weights, we used the weighting factors: not applicable = 0, low = 0.3333, medium = 0.6666 and high = 1; and for the theme weights we used the weighting values: low = 0.3333, medium = 0.6666 and high = 1.

We then considered aggregating our data using both a linear and a geometric method. The linear method involved taking the weighted arithmetic mean of the variables in each theme (see Equation 3), producing theme scores, and then taking the weighted arithmetic mean of the theme scores (see Equation 4). The geometric method was much the same but involved using weighted geometric means (see Equation 5 & 6) rather than weighted arithmetic means.

We were aware that such a methodology can contain significant biases and therefore undertook an analysis of the correlation structure of both the variables and themes to test the influence of the weighting scheme used on our final rankings and elaborate on this in the section below

Theme name	Theme weight startup	Theme weight scale-up	Variable name	Variable weight startup	Variable weight scale-up
Access to Capital	High	High	Availability of early-stage funding	High	Not applicable
			Availability of late-stage funding	Not applicable	High
			Availability of Business Angels funding	High	Low
			Availability of crowdfunding	Medium	Low
Business Environment	Medium	Medium	Ease of doing business	High	High
			Cost of office space	Medium	Medium
			Public sector information and openness of data	Low	Low
Digital Infrastructure	Medium	Medium	Internet download/upload speed	High	High
			Cost of broadband	Low	Low
			Mobile internet speed	Medium	Medium
			Availability of fibre internet	Low	Low
Entrepreneurial Culture	High	Low	Willingness to take on risk	High	High
			Multicultural diversity	Low	Low
			Online collaboration	Low	Low
			New-business density	High	Low
			Trust	Low	Low
			Absence of negative perception of entrepreneurship	High	Low
			Engagement with digital startup ecosystem	Low	Low
			History of Highly successful digital companies	Medium	Low

Knowledge Spillovers	Medium	Medium	Quality of research institutions	Medium	Medium
			Research & Development intensity	High	High
Lifestyle	Low	Low	Standard of living	High	High
			Culture & Recreation	Low	Low
Market	Low	Medium	Local online transactions	High	Medium
			National demand for digital services	High	High
			Digital market size	Medium	High
			Size of potential mobile-based market	Medium	High
			Growth in local online transactions	Low	Low
Mentoring & Managerial Assistance	High	Medium	Networking and mentoring events	High	Medium
			Access to accelerators	Medium	Low
			Availability of early-stage assistance	Medium	Low
Non-Digital Infrastructure	Low	Low	Commute	Medium	Medium
			Train connectivity	Medium	High
			Airport connectivity	Low	High
Skills	Low	Medium	Labour costs	Medium	High
			Access to graduates	Medium	Medium
			Training to start a business	Medium	Not applicable
			Access to ICT employees	High	High
			Access to Support (Finance/Insurance/Legal) employees	Low	Medium
			English language skills	High	High

Table 7 Weights assigned to themes and variables.

6.2.1 Aggregation

Geometric and linear aggregation each have their own benefits, while in a linear aggregation, the compensability is constant, with geometric aggregations, compensability is lower for the composite indicator or themes with low values. This means that when using a geometric aggregation, a city with a low score for one indicator or theme will need a much higher score on the others to improve its score.

In the original 2015 Index, the variables within a theme were aggregated geometrically (Equation 5). However, since it is not possible to compute a logarithm of zero (which, due to the min-max normalisation, there was at least one per variable), we added 0.001 to each value in the dataset. The themes were then aggregated geometrically themselves (Equation 6).

Our research has suggested that all the themes included in this Index are important to the entrepreneurial ecosystem. We therefore do not believe that having a higher score in one completely negates the absence of another. The importance and compensability for variables within themes, however, is less clear. In addition, there are several individual variables which we believe may be less robust than others.

For these reasons, in the revised 2016 Index, we decided that a better approach would be to use a combination of linear aggregation within the themes to create theme scores (Equation 3), followed by geometric aggregation across the themes to produce the overall index score (Equation 6). This captures the non-compensability across themes without making the Index too sensitive to individual variables for which the importance, robustness and compensability is less clear. This also means that we did not have to add the largely arbitrary 0.001 constant to each value to produce theme scores.[5] The city rankings obtained after aggregation for startups and scale-ups can be found in Table 8.

For comparison with the 2015 EDCi, we tested the effect of aggregating both variables and theme scores using the geometric mean. Details of this analysis can be found in the 'Robustness and Sensitivity Analysis' section of this document.

Equation 3 Linear Aggregation for Theme Scores

$$TS_{i,k} = \frac{\sum_{j=1}^{J} w_j z_{i,j}}{\sum_{j=1}^{J} w_j}$$

[5] We did, however, add 0.001 to each cities 'Knowledge Spillovers' theme score because Riga scored 0 for this theme meaning that without this addition it would not have been possible to use a geometric mean to aggregate themes into the overall Index score.

where $TS_{i,k}$ is the aggregated theme score for city i and theme k

w_j is the weight given to variable j=1,…,J

$z_{i,j}$ is the normalised value for city i and variable j=1,…,J

Equation 4 Linear Aggregation for Index Score

$$IS_i = \frac{\sum_{k=1}^{K} w_k TS_{i,k}}{\sum_{k=1}^{K} w_k}$$

where IS_i is the aggregated index score for city i

w_k is the weight given to theme k=1,…,K

$TS_{i,k}$ is the aggregated theme score for city i and theme k =1,…,K

Equation 5 Geometric Aggregation for Theme Scores

$$TS_{i,k} = \left(\prod_{j=1}^{J} z_{i,j}^{\ w_j}\right)^{1/\sum_{j=1}^{J} w_j}$$

where $TS_{i,k}$ is the aggregated theme score for city i and theme k

w_j is the weight given to variable j=1,…,J

$z_{i,j}$ is the normalised value for city i and variable j=1,…,J

Equation 6 Geometric Aggregation for Index Scores

$$IS_i = \left(\prod_{k=1}^{K} TS_{i,k}^{\ w_k}\right)^{1/\sum_{k=1}^{K} w_k}$$

where IS_i is the aggregated Index score for city i

w_k is the weight given to theme k=1,…,K

$TS_{i,k}$ is the aggregated theme score for city i and theme k =1,…,K

Ranking	Startup	Scale-up	Ranking	Startup	Scale-up
1	London	London	**31**	Toulouse	Eindhoven
2	Stockholm	Stockholm	**32**	The Hague	Uppsala
3	Amsterdam	Paris	**33**	Budapest	Budapest
4	Helsinki	Helsinki	**34**	Gothenburg	Glasgow
5	Paris	Amsterdam	**35**	Luxembourg	Karlsruhe
6	Berlin	Copenhagen	**36**	Glasgow	Stuttgart
7	Copenhagen	Berlin	**37**	Prague	Cardiff
8	Dublin	Munich	**38**	Warsaw	The Hague
9	Barcelona	Dublin	**39**	Karlsruhe	Dusseldorf
10	Vienna	Vienna	**40**	Cardiff	Prague
11	Munich	Cambridge	**41**	Bratislava	Warsaw
12	Cambridge	Oxford	**42**	Valencia	Bordeaux
13	Bristol	Barcelona	**43**	Bordeaux	Bratislava
14	Madrid	Madrid	**44**	Dusseldorf	Luxembourg
15	Oxford	Hamburg	**45**	Stuttgart	Milan
16	Manchester	Bristol	**46**	Milan	Lille
17	Brussels	Manchester	**47**	Ljubljana	Valencia
18	Tallinn	Brussels	**48**	Lille	Vilnius
19	Edinburgh	Lyon	**49**	Vilnius	Ljubljana
20	Hamburg	Frankfurt	**50**	Sofia	Dresden
21	Lyon	Cologne	**51**	Krakow	Bucharest
22	Aarhus	Edinburgh	**52**	Bucharest	Krakow
23	Birmingham	Birmingham	**53**	Dresden	Sofia
24	Lisbon	Malmo	**54**	Rome	Rome
25	Frankfurt	Utrecht	**55**	Turin	Turin
26	Eindhoven	Gothenburg	**56**	Athens	Athens
27	Utrecht	Toulouse	**57**	Zagreb	Zagreb
28	Cologne	Tallinn	**58**	Riga	Valletta
29	Malmo	Lisbon	**59**	Valletta	Riga
30	Uppsala	Aarhus	**60**	Nicosia	Nicosia

Table 8 EDCi 2016 city rankings for startups and scale-ups.

6.2.2 Variable-variable correlation

The variable-variable correlation matrix can be found in downloadable data spreadsheet tab 'Correlations'. Based in part on this matrix and in part on PCA analysis (described later in this document), we decided to move 'New-business density' variable to the 'Business Environment' theme. This made sense on a conceptual level, but also increased the coherence of the 'Entrepreneurial Culture' theme.

Before this analysis, we had already discussed that the potential weakness of the 'Access to Mentors' variable because it was collected using a simple search for the word 'Mentor' amongst LinkedIn user profiles and therefore would count users describing themselves as being mentors of any description (not solely in a business sense). Thus it also included people who were mentors at a school or who act as mentors to young adults from troubled backgrounds etc. The correlation matrix showed that it also did not correlate strongly with other variables in its theme. Based on these two factors, we decided to remove this variable entirely from the Index.

The second standardisation version (standardised by number of startups) of the 'Access to Accelerators' and 'Access to early-stage Assistance' variables was negatively correlated with other variables in the 'Mentoring and Managerial Assistance' theme; whereas, the first standardisation version (standardised by city-level population) of these variables was not. As there are conceptual arguments in favour of both standardisation versions, we decided to use the first version to maintain the maximum possible statistical coherence within the 'Mentoring and Managerial Assistance' theme.

The 'Correlations' spreadsheet tab shows the variable-variable correlation matrix after these changes were made. As you can see, there is a good level of coherence within 'Access to Capital', 'Entrepreneurial Culture' and 'Mentoring and Managerial Assistance'.

However, within other themes, there were still some cases where variables did not correlate strongly with others in the same theme. But, as these variables were chosen based on what experts in the field (i.e. digital entrepreneurs themselves) had deemed important, we felt that they needed to remain.

There were also instances where variables correlated negatively with others in the same theme. We also believe that these negative correlations reflect important real world trade-offs. For example, for a startup looking for skilled employees, there is a trade-off between going to a more affluent country/city, which typically have higher labour costs but more skilled workers, and going to a less affluent country/city, where labour costs may be lower, but the talent pool

is also concomitantly smaller. This trade-off is reflected by the negative correlation within the skills theme.

We also noted that in several cases the 'high/medium/low' weighting of the variables is not confirmed by the statistical associations. This is because the weighting of specific variables was chosen based on a review of literature and on the opinions of experts who we interviewed, rather than on pure statistical analysis. In this sense, we have made a judgement call to blend and balance the 'real-world' experiences of our target population with statistical coherence.

6.2.3 Variable-theme correlation

The variable-theme correlation matrix can be found in the 'arith-geo startup' and 'arith-geo scaleup' tabs of the downloadable data file. As with the individual variables, the differences between the themes' weighting and the effective influence of the themes on the variance of the total index scores is unsurprising since the theme weights were chosen based on a review of literature and on the opinions of experts who we interviewed, rather than on statistical analysis.

It is interesting to note that there are several variables (and even themes) that do not appear to have a strong effect on the overall index scores of cities (i.e. they appear to be cosmetic). Although it could be argued that these should be removed from the Index, they do appear to have some (if only small) effect on the index score and they are factors which experts reported to be important, for this reason they were kept in the Index.

As well, the negative correlations observed between certain variables and the final index score are a result of these variables being negatively correlated with several other variables in the Index. We do not believe that this is a problem and as discussed earlier, we believe that this correctly reflects important real world trade-offs.

7. Robustness and Sensitivity Analysis

To understand the impact of the methodology decisions made, we tested the effect of the following:

1. **Variable Selection** - The effect of discarding a variable
2. **Normalisation method** - The effect of using distance to a reference point rather than Min-Max normalisation
3. **Imputation method** - The effect of using multiple imputation rather than theme mean imputation to account for missing data
4. **Aggregation selection** - The effect of using geometric (variable) / geometric (theme) rather than arithmetic (variable) / geometric (theme) aggregation.
5. **Weight Selection** - The effect of varying weightings of variables

7.1 Variable Selection

The aim of this analysis was to determine whether a single variable had an unduly large impact on the overall ranking. To test this, we ran a Monte Carlo simulation that tested the effect of sequentially and randomly excluding variables/themes from the Index.

In general, the top ranking and bottom ranking cities were the least sensitive to changes in the Index composition with middle ranking cities being more sensitive. Tallinn, Aarhus, Bratislava, Stuttgart and Vilnius were particularly sensitive to which variables were included in the Index. Nevertheless, this analysis shows that the ranking is relatively stable, even to major changes in variable composition.

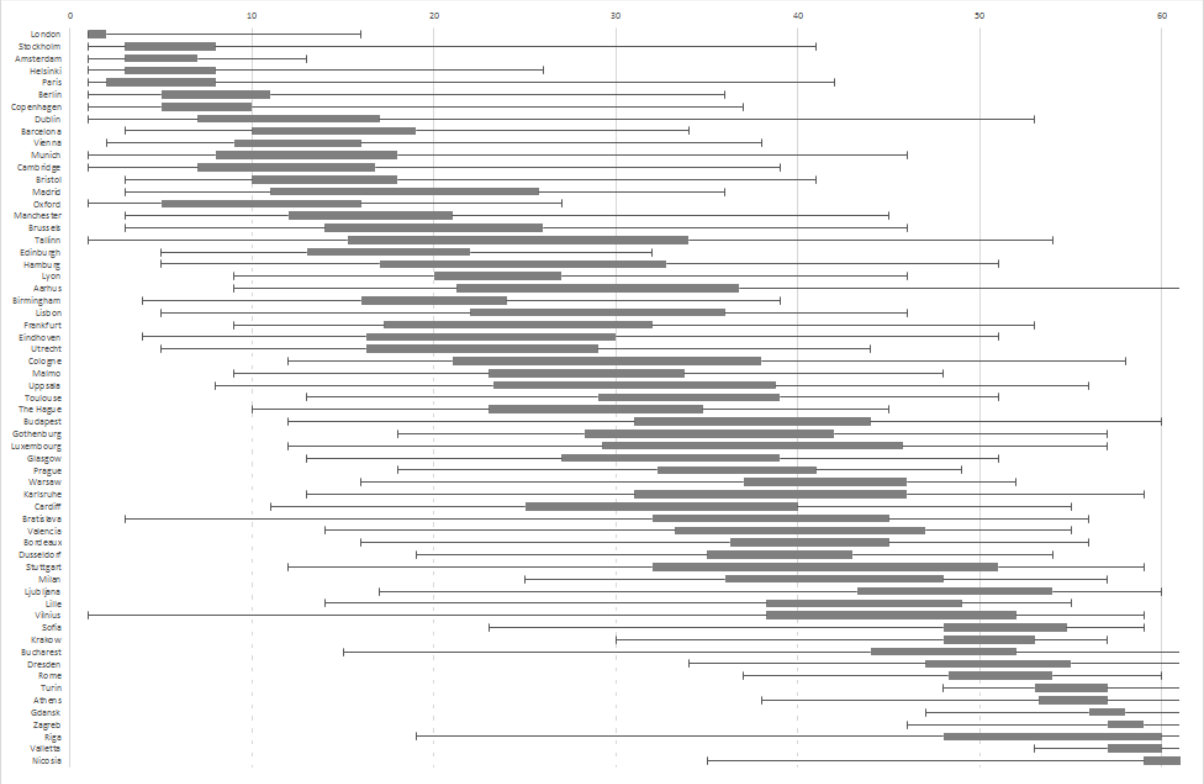


Figure 7 Box and whisker diagram showing the impact of removing each variable on the rank. Box = interquartile range; whiskers = range

7.2 Normalisation method

We tested how using the distance to a reference point normalisation method, rather than Min-Max normalisation, effects the overall ranking of cities in the Index. As described in section 5.2, the reference level chosen for reference point normalisation was the maximum value recorded for that variable across all the cities. After distance to reference normalisation, all values were in the range [-1,1] and all but two values were positive; these being Malmo and Gothenburg's values for the variable 'Growth in local online transactions' (Figure 8).

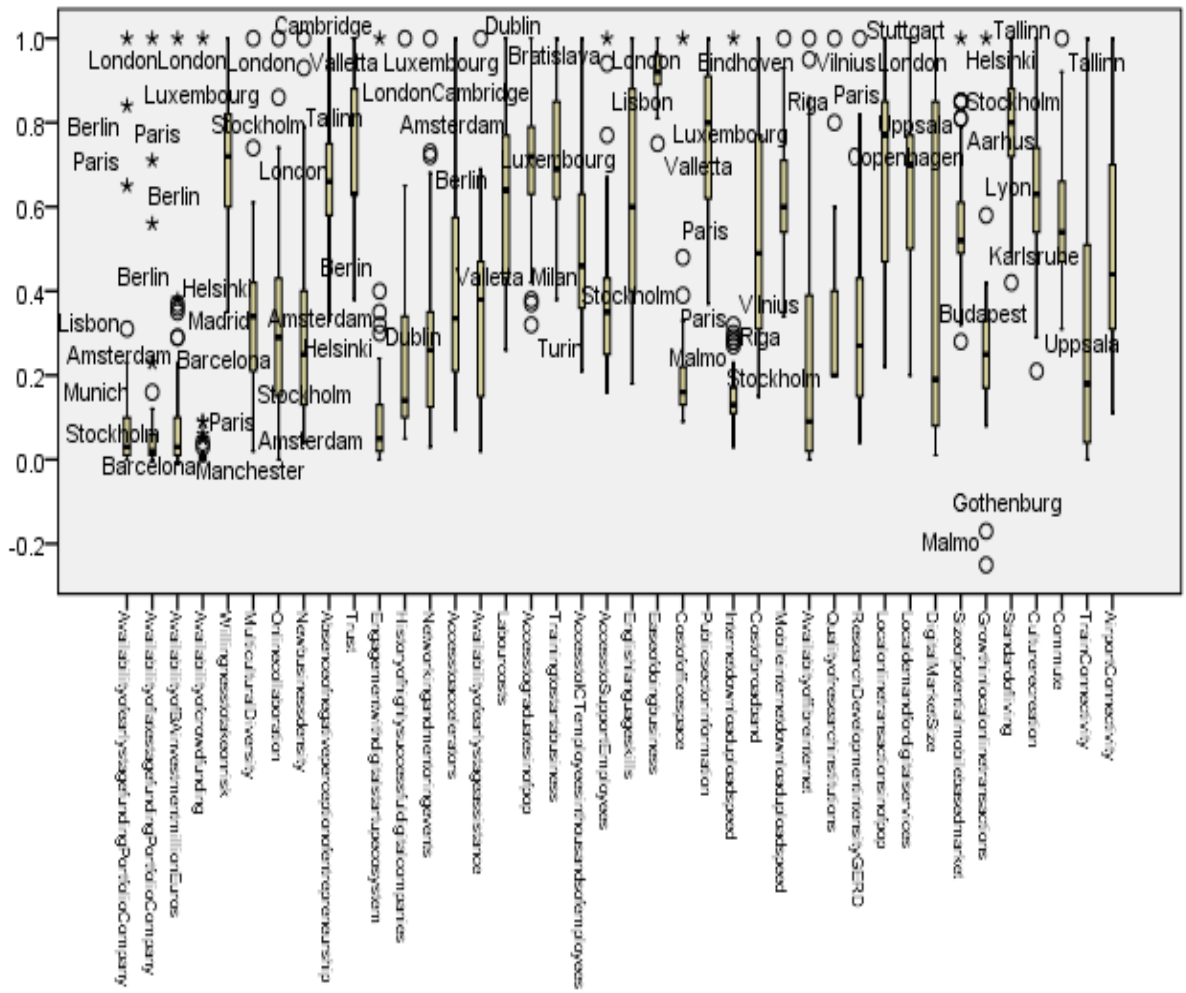


Figure 8 Box and whisker diagram showing data after distance to reference normalisation.
Box = interquartile range (IQR); bar = median; whiskers = 1.5 x IQR; small circles = outliers (below Q1 – 1.5 × IQR or above Q3 + 1.5 × IQR); Stars = extreme outliers below Q1 – 3 × IQR or above Q3 + 3 × IQR).

For Startups, London remained in first place when using distance to reference normalisation; however, beyond this point, several cities rankings changed relative to when Min-Max normalisation was used (see downloadable data file for rankings). While many cities changed their absolute rank, nine of the top ten ranking cities remained in the top ten, with Munich replacing Vienna as one of the top ten. While within the top ten, cities changed ranking by a maximum of 3 places, further down in the rankings there were larger changes, Uppsala for example, dropped 13 places from 30th to 43rd position and Prague fell 12 places from 37th to 49th position.

London remained in first position for scale-ups when using distance to reference normalisation, but beyond this point, there was slight ranking changes compared

to when Min-Max was used. Although for several cities exact ranks changed, the top ten cities for scale-ups were the same for both normalisation methods. Like for startups, the top ten cities scale-up ranking changed by a maximum of 3 places. However, while there were some bigger changes further down in the rankings, these changes were not as major as for startups; for example, the biggest scale-up ranking change was for Prague which moved down 8 places when distance to reference normalisation was used.

Together, this analysis shows that although the normalisation method can have fairly large effects on the ranking, the top ten cities were relatively resistant to which method was used.

7.3 Imputation method

The aim of this analysis is to explore how using multiple imputation (as in EDCi 2015), rather than theme mean imputation (as described in section 5.1) to assign values to missing data affected the ranking of cities.

To perform multiple imputation, predicted values were calculated using a multiple linear regression procedure in the SPSS V.23 software package. In following this procedure, we assumed that data was missing at random (MAR), meaning that the probability that data is missing did not depend on the value of Y, after controlling for observed variables. The data imputation procedure in SPSS automatically scans the data for monotonicity in the missing values (missing values are said to be *monotonic* when a variable is missing for a particular case then all subsequent variables are also missing for that case) and if discovered, uses the monotone imputation method and otherwise, defaults to the Markov Chain Monte Carlo (MCMC) method. In this case, SPSS did not find evidence of monotonicity and therefore the MCMC method was used. A visual analysis of the missing values' distribution confirmed that missing values did not follow a monotonic pattern (Figure 9). Where data was missing for a particular variable, predicted values were computed using the other variables in the same theme as explanatory terms. For each missing value, 5 predictions were made and a mean of these 5 values replaced the missing value.

For startups, the top 20 ranking cities were in the same position regardless of which imputation method was used (see downloadable data for rankings). There were some minor differences in rankings between positions 21 and 60 but rankings never differed by more than three places between the two imputation methods tested.

For scale-ups, there were some minor differences in cities rankings in the top five with Stockholm in first position and London in second position when using multiple imputation and these two cities switching positions when using theme

mean imputation. Copenhagen and Amsterdam also swapped positions from fifth and sixth position when using multiple imputation to the reverse when using theme mean imputation. Rankings 7 - 30 were the same for both imputation methods and although there were a few ranking changes between positions 31 and 60, these changes were generally minor.

Several of the differences in rankings between imputation methods (including between London and Stockholm) involved cities that did not have any missing data and thus, should not have been affected by which imputation method was used. These ranking differences can be explained by differences in the number of decimal places held, and therefore how numbers were rounded, by the statistical software used for each imputation method (Excel for theme mean imputation and SPSS for multiple imputation). The effect that such small changes in cities scores (caused by these rounding differences) had on their rankings further highlights how closely matched many cities were in this Index.

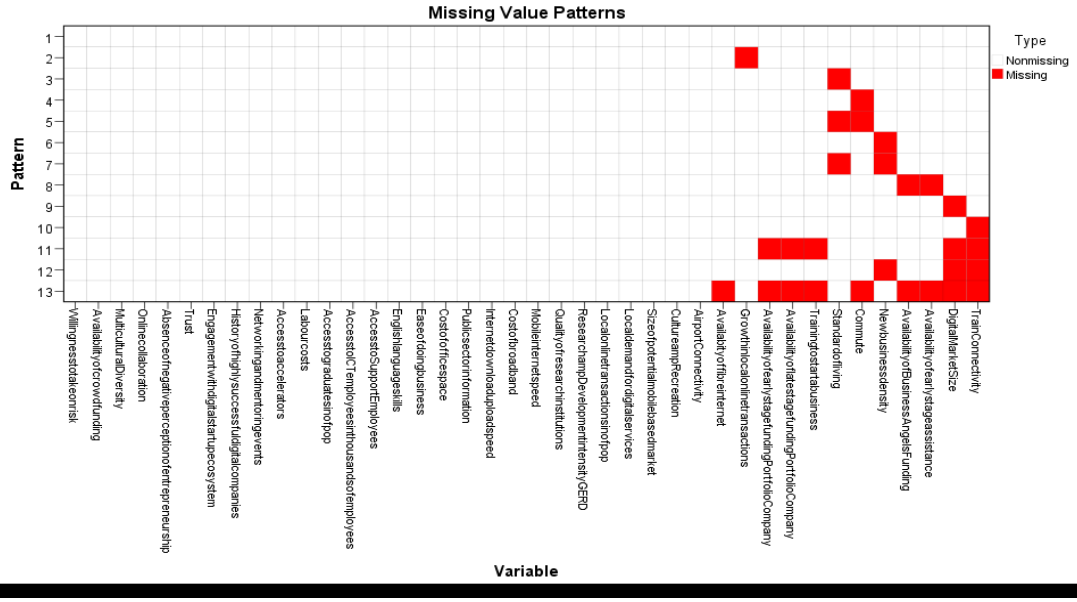


Figure 9 Missing Values Pattern Chart.
Each pattern (row) denotes a group of cases containing missing values for the same variables. Patterns are ordered by how many cases exhibit that pattern of missing values. Since most cases do not contain any missing values (75%), the first pattern denotes cases which contain no missing values. The variables along the x-axis (columns) are ordered by the amount of missing values each contains. In this case, the variables 'Train Connectivity', 'Digital Market Size', 'Availability of Early Stage Assistance', 'Availability of Business Angels Funding', 'New business density' and 'Commute' contain the most missing values (all contain 4 missing values; 6.6%) and are therefore listed last (furthest to the right). The chart allows one to assess the monotonicity of the missing values. If all the missing cells (red) and non-missing (white) cells are touching, then monotonicity is present. If, however, there are clumps of missing and non-missing cells (as is the case here) then the missing values are non-monotonic.

7.4 Aggregation Selection

In section 6, we explained the advantages and disadvantages of linear vs. geometric aggregation at both the variable and theme level. For the reasons discussed in section 6, we decided to use linear aggregation to combine individual variables into the theme scores and geometric aggregation to combine theme scores into an overall index score (hereafter 'lin / geo' aggregation). Here, we explore the effect of instead using geometric aggregation to combine both individual variables and themes scores (hereafter 'geo / geo' aggregation) as in the 2015 version of the Index.

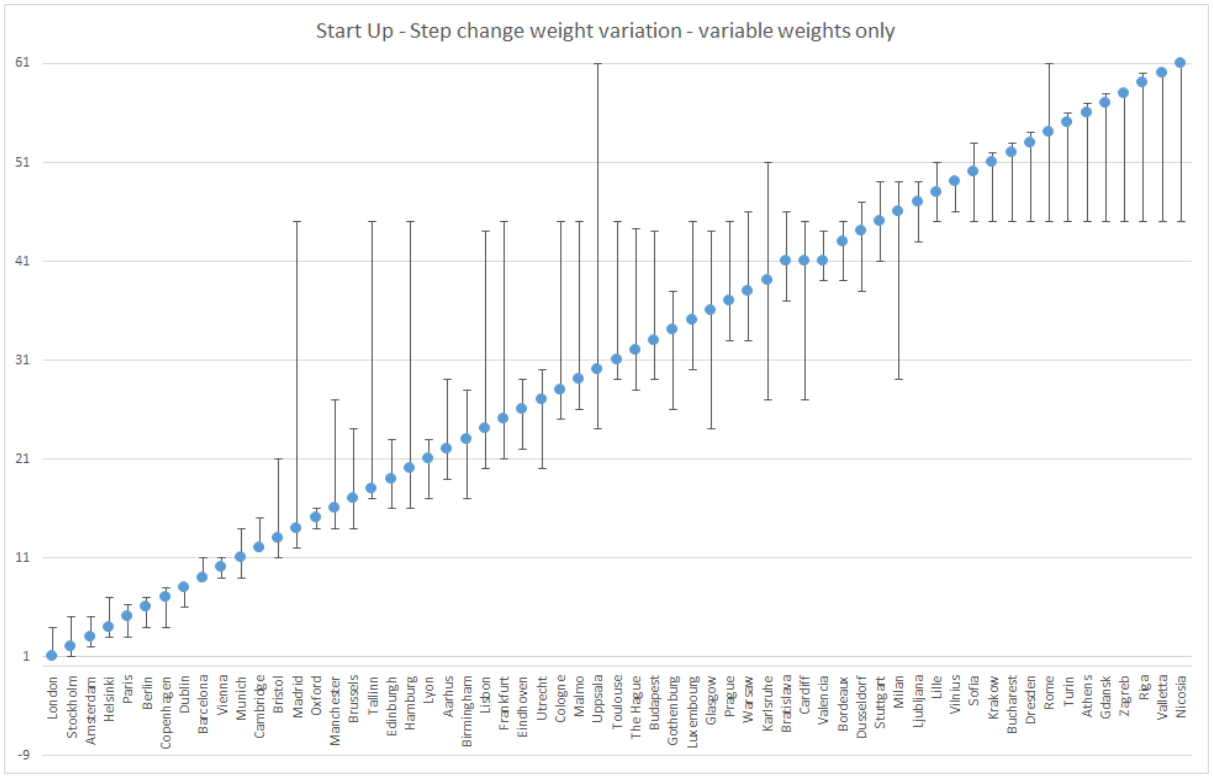
The aggregation method chosen makes quite a large difference on the ranking of cities. For startups, nine out of the top ten ranking cities were the same for both aggregation methods. Barcelona was in the top ten ranking cities instead of Vienna when geo / geo was used rather than lin / geo aggregation (see downloadable data for ranking). However, depending on which method was used there were substantial differences in cities rankings both in the top ten and beyond. For example, London dropped from first place in lin / geo to eighth position when geo / geo was used, with Berlin replacing London first, from eighth, place, and further down in the rankings, Milan moving up from 45th to 28th position.

Similarly, for scale-ups, nine out of the top ten ranking cities were the same for both aggregation methods, with Barcelona replacing Dublin in the top ten when geo / geo was used rather than lin / geo aggregation (see downloadable data for ranking). Again, there were considerable differences between rankings obtained using geo / geo and those obtained using lin /geo aggregation. For example, London moved down from first with lin / geo to ninth with geo / geo aggregation, replaced by Stockholm which moved up from second place.

7.5 Weight Selection

To measure how sensitive the rank is to the weighting selection we tested the impact of step changes in weightings (e.g. from not-applicable, to Low, to Medium, to High etc.) for both variables and themes on rankings. This analysis was run separately for startups and scale-ups (Figure 10).

A visual analysis show that for both startups and scale-ups, the top ten cities in the Index remained relatively stable when the weight were level changed. The most sensitive cities to step changes were: Aarhus, Bratislava, Stuttgart, Tallinn and Vilnius. These cities are particularly sensitive to weight changes because they exhibit a lot of variation in their theme scores – scoring very highly for some themes but much lower for others.



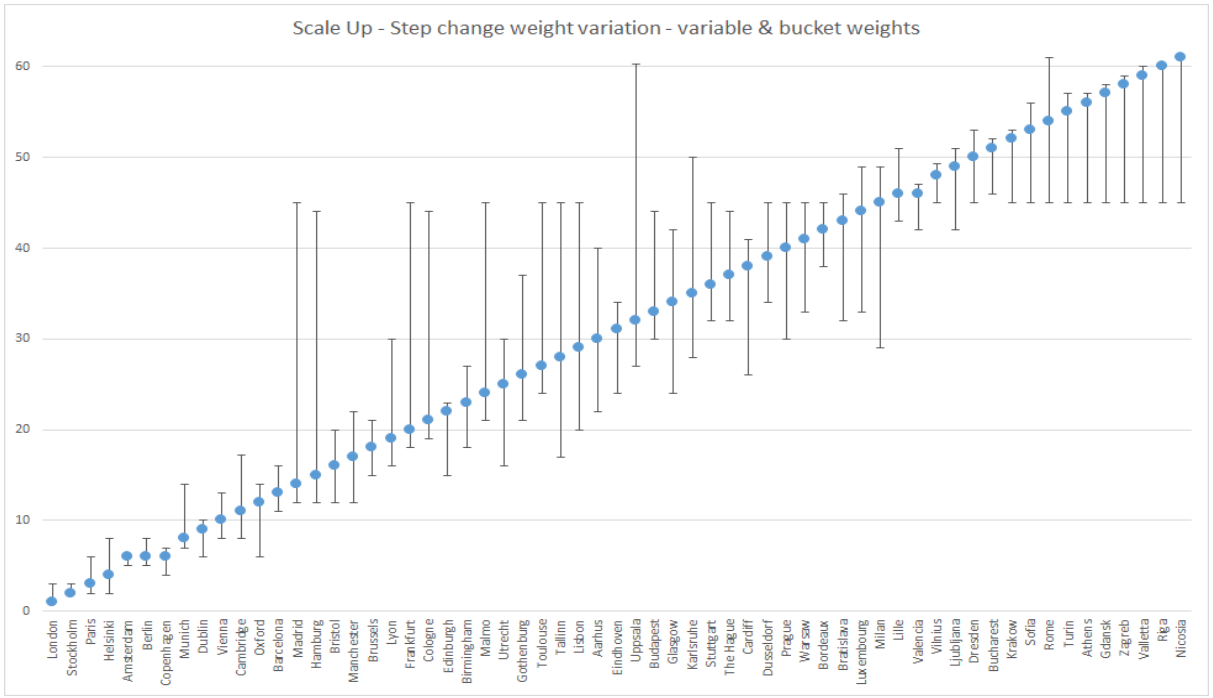


Figure 10 Effect of step weight changes on startup and scaleup rankings.
Blue circles = median rank; bars = minimum and maximum ranking.

8. Conclusions and Next Steps

We launched the European Digital City Index (EDCi) in October 2015 as a ranking intended to measure how well different cities across Europe support startups and scale-ups in digital industries.

In November 2016, as part of Global Entrepreneurship Week, we launched the 2016 version of the EDCi, which again describes the 'fertility' or attractiveness of different European cities for digital entrepreneurs. As before, this is not a simple count of the number of new firms or capital flows, but a composite measure of the varied factors which matter to founders and young firms.

What's new?

One major change is that we have expanded the number of cities in the Index from 35 to 60. Less obvious are the methodological improvements. Over the past year we have worked closely with the Joint Research Centre's Composite Indicator Research Group to make the EDCi as robust as possible. Thus, we made a few changes to the standardisation and weighting of some variables, as well as the way we aggregate these. We also had to find new data sources to replace a handful which became unavailable or were deemed statistically unfit. These changes have been elaborated on in the Executive Summary section of this document.

What are the results for 2016?

As with last year, we find that London leads for both startups and scale-ups –not a huge surprise, given the city's number of 'Unicorns' and globally renowned access to financial resources. However, the rankings are very close, especially towards the top, with a fraction of a percentage point separating London from close contender Stockholm. Therefore, we parsed all possible results with extreme care, as we detail in the Robustness and Sensitivity Analysis section.

The highest new entrant is Bristol, which joins the list in 13th place, and scores particularly well due to its receptive entrepreneurial culture and local business environment. It was also, incidentally, part of a cluster highlighted in the 2016 TechCity/Nesta TechNation report.

As before, we find a significant divide between North-West and South-East Europe, which is particularly visible when it comes to different cultural attitudes towards entrepreneurship, the availability of capital, and mentoring or managerial assistance.

We have also included new visualizations which more readily show how cities group. From these, we see that clusters have formed: the top 5, which are very competitive; a middle group, including cities such as Barcelona, Vienna and Cambridge; and those where substantial progress needs to be made.

One thing that has *not* affected the EDCi is Brexit. Almost all the data which makes up the Index relates to the pre-vote period, so one should not make any inference about its effect on the position of UK cities. We will need to wait to see what, if any, Brexit has on British startups and scale-ups.

What have we learned in the past year?

One thing that was clear from our 2015 EDCi is that indices are provocative, for better and for worse. The positive feature of rankings is that they can attract attention and harness competitive spirits. This was the original intention: to direct energy to the hugely important role that local conditions can play in encouraging the entrepreneurship and scaling that Europe desperately needs.

Their negative side is that some people obsess over rank, leading to ultimately insoluble arguments whether City A is really better than City B. Which brings us to our second learning:

> *"Essentially, all models are wrong, but some are useful"*
>
> - *George Box*

All composite indices are, in some sense, wrong. All necessarily conceal multiple subjective assessments under a cloak of objectivity. However, this does not mean that indices are not useful – on the contrary, like many models, they can be a very helpful way of summarising a set of complex factors into a more manageable form. However, they are necessarily a simplification, multiple dimensions compressed into one.

As such, there is no single 'right' answer – just as there is no single formula for a startup. Therefore, we included the 'customizer tool' and have tried to be transparent about the methodology and weighting of variables. Users can thus re-weight factors according to what matters to them (as well as downloading the source data, if desired, to play with this directly).

What next?

Because of the above, the argument of whether, say, Paris deserves to be above Berlin, will always be contentious. A more productive conversation is to ask what cities can learn from each other, and what each can do to improve the local conditions for startups and scale-ups in their vicinity.

For that reason, we are also launching today an 'Idea Bank' to accompany the 2016 Index. This is a guide which draws together examples from all over the world of policies and initiatives that support startups, especially digital startups, to provide inspiration and options to European policymakers.

The guide is intended to complement the EDCi, following the same ten themes (together with an eleventh, cross-cutting theme relating to the process of policymaking). It concludes with some tools to assist in choosing, developing and implementing these policies. We commend both the guide and the EDCi to policymakers, and hope that they will help in creating better conditions for digital entrepreneurs across Europe, to everyone's benefit.

We welcome feedback on any aspect of the Index at EDFx@nesta.org.uk

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10. Appendices

Appendix 10.1 Comparison with Other Indices

Index	Similarities with EDFx DECI	Differences with EDFx DECI
Atlas of ICT poles of excellence (EIPE)	Broadly, the indices overlap conceptually in the folLowing areas: · Quantity/quality education · Finance for SMEs Specifically, indicators used that are similar are: · Some notion of university quality (ranking) in locality · Financing to ICT firms/SMEs (though EDFx looks at Digital Startups) Both cover aspects of network and engagement but the area is approached in a methodologically different manner Geography - Both attempt a sub-national analysis of hubs of activity with EIPE using NUTS3 and EDFx looking at cities.	Aims - EIPE looks at poles of excellence as defined above. EDFx really looks at how ready a city's environment is to support digital startups; the two do not necessarily correlate. Audience - Both intend to target policy makers, albeit for different reasons. EDFx aims to Highlight areas that could be affected by policy at the city level. Geography - EDFx focus is upon a number of EU cities specifically, including all capitals. EIPE's use of NUTS3 regions has permitted non-metropolitan areas to be included (e.g. UKJ11 - Berkshire) Unit of analysis - EDFx specifically looks at the ability of cities to cater for digital startups. EIPE targets ICT activity in a very broad sense of the word and as such will consider units outside of EDFx's remit e.g. large ICT firms.
Digital Entrepreneurship Monitor (DEM)	The aims of both DEM and EDFx are in alignment to some extent; both intend to measure aspects of digital entrepreneurship across the EU. Broadly there is some overlap in the folLowing major themes: · Digital business environment (Digital infrastructure) · Access to Finance (Access to Capital) · Entrepreneurial culture (Entrepreneurial culture) Specifically, indicators used	Aims/Audience - DEM has a much wider remit, targeting all interested in incorporating digital technology within business; SMEs of all varieties are targeted for support. EDFx caters for digital startups and relevant policy-makers. Geography - The granularity of EDFx is more specific. DEM looks at countries and not cities. EDFx will uncover differences across cities within, or in neighbouring, countries. Unit of analysis - DEM aims to provide a framework of support for all SMEs and specifically the uptake of digital technology within those. EDFx explicitly considers digital startups. Coverage of themes/dimensions - Areas that EDFx will cover beyond the scope of DEM include mentoring and managerial assistance, physical infrastructure, lifestyle and data protection and

	that are similar are ones attempting to measure some notion of: · Ease of doing business · Internet bandwidth	policy. Access to finance - Although this is covered in both, DEM takes a more qualitative stance and looks at the ease of access through surveys. Tax rate and cost of tax compliance also measured. EDFx takes a more quantitative view and looks at amounts raised and number of angel investors/VCs present in cities. Weighting - A weighting system is incorporated into EDFx to Highlight priorities for digital startups, as defined by primary research in the form of expert interviews Output - EDFx will provide a composite index ranking of cities for digital readiness startups. DEM provides a scorecard of factors associated with promoting digital technology
Digital Economy & Society Index (DESI)	There is conceptual and measurable (i.e. similar variables are measured) overlap in some dimensions, particularly across Human Capital and Connectivity, which correspond to a medium extent with EDFx's 'Digital Infrastructure' and 'Education and Skills, Access to Talent'. There is also conceptual overlap between the EDFx theme called 'Business Environment' and the sub-dimension 'e-Government'. Both DESI and EDFx are focused on digital technology.	Aim - EDFx is very specific in comparing the quality of digital startup ecosystems. DESI is different because it only looks at digital ecosystems; it does not attempt to rank only those aspects of digital economy and society that are relevant for digital startups. This means that it both measures different factors and weights those factors differently to EDFx Audience - Both indices target policy-makers but EDFx will be relevant to both local and national policy-makers, whilst DESI is only relevant to national policy-makers. Geography - EDFx will analyse the quality of city-level rather than country-level ecosystems. Coverage of themes/dimensions - EDFx will measure how well cities perform across a much broader range of indicators than DESI. Many 'themes' are included as part of EDFx that are not included in DESI, such as Access to Finance, Coverage of themes/dimensions - EDFx will measure how well cities perform across a much broader range of indicators than DESI. Many 'themes' are included as part of EDFx that are not included in DESI, such as Access to Finance, Knowledge Spillovers, Lifestyle. Likewise, the DESI 'dimensions' called 'Use of Internet' and 'Integration of Digital Technology' are, for various reasons, not measured at all in EDFx.
Global Entrepreneurship Monitor (GEM)	There is some overlap between the major theme 'Attitudes and Perceptions' included in ADDI and 'Entrepreneurial Culture' which is included in EDFx.	Aims - EDFx will specifically compare the quality of digital startup ecosystems, but GEM compares entrepreneurship ecosystems more generally. Output - GEM does not attempt to create a general

	There are also some indicators used that are similar; for example, those attempting to measure some notion of: · Availability of funding · Ease of doing business · Current Entrepreneurial activity · Attitudes towards risk · Perceptions of entrepreneurship · Market dynamics · Both digital and non-digital infrastructure	index or to rank the quality of ecosystems. Coverage of themes/dimensions - EDFx will measure how well cities perform across a broader range of indicators than GEM and will compare the infrastructure, facilities and environment conducive to digital entrepreneurship in more detail than GEM. Geography – Unlike GEM, EDFx will analyse the quality of startup ecosystems at the city-level rather than the country-level.
Accenture Digital Density Index (ADDI)	ADDI compares the extent to which digital technologies are adopted. The adoption of digital technology is one of many factors that are considered to affect the quality of digital startup ecosystems. It is therefore unsurprising that there is some overlap with the folLowing major themes: Making Markets (Market) & Fostering Enablers (Entrepreneurial Culture).	Aims/Audience - EDFx will compare the quality of digital startup ecosystems; whereas, ADDI compares the adoption of digital technology skills, ways of working and regulatory frameworks. Geography – Unlike ADDI, EDFx will analyse the quality of startup ecosystems at the city-level rather than the country-level. Weighting - While ADDI weights the importance of all major themes equally, EDFx will incorporate a weighting system to Highlight priorities for digital startups, as defined by primary research in the form of expert interviews.
City Initiatives for Technology, Innovation and Entrepreneurship (CITIE)	Geography – Both attempt a city-level analysis of entrepreneurship support. There is a broad overlap in the folLowing major themes: · City as an advocate (Entrepreneurial culture) · City as a connector (Digital Infrastructure, Non-Digital Infrastructure) There are also some indicators used that are similar; for example, those attempting to measure some notion of: · Availability of High speed fibre optic broadband	Aims – CITIE compares the quality of startup ecosystems in the widest sense. EDFx is different because it compares factors which are particularly important to digital startups. Output - Unlike EDFx, CITIE does not attempt to create a general index for the quality of each city's startup ecosystem. Geography – CITIE analyses cities globally. EDFx, on the other hand, focusses on selected European cities. Coverage of themes/dimensions – CITIE is focussed on a top-down government level policy levers. However, EDFx will analyse the digital startup ecosystem as a whole including political, economic, social / cultural, and technological factors affecting a city. Data collected - Whilst CITIE's data is largely

	· Availability of free public broadband · The speed of broadband · Availability of co-working spaces · Cost of office space	qualitative, EDFx will take a more quantitative view of the factors affecting the quality of a cities digital startup ecosystem.

Appendix 10.2 Selected Literature Review

No.	Title	Authors	Year	Key Factors Discussed
1	New Business Start-Ups and Economic Activity: An Empirical Investigation	R Highfield R Smiley	1987	• Real GNP growth • Access to finance • Unemployment rate • Real interest rates and inflation
2	Network evolution, entrepreneurial success, and regional development	John E. Butler Gary S. Hansen	1991	• Networking • Collaborations with HEIs
3	Local and Regional Characteristics Affecting Small Business Formation: A Cross-National Comparison	R.D Reynolds D. J Storey	1993	• Demand growth (growth in size of population and economy) • Urbanization (population density) • Unemployment • Personal/household wealth • Small firms specialization (industry level differentiation) • Government spending on infrastructure, education and health
4	Links between Higher education institutions and High technology firms	Paul Westhead David Storey	1995	• Collaborations with HEIs • Proximity to HEIs • Incubators and Science parks
5	The Determinants of Regional Variation in New Firm Formation	Catherine Armington Zoltan J. Acs	2000	• Population growth • Industry density • Size of current establishments • Unemployment rate • Education level of population
6	Fostering entrepreneurship through university education and training: Lessons from Massachusetts Institute of Technology	Christian Lüthje	2002	• Entrepreneurship education • Collaboration with HEIs
7	What Success Factors are Important to Small Business Owners?	Elizabeth Walker Alan Brown	2004	• Lifestyle • Access to skilled labour • Access to finance
8	University spillovers and new firm location	D.B Audretsch	2004	• Proximity to HEIs • Collaboration with HEIs

9	Regional transformation through technological entrepreneurship	S.Venkataraman	2004	• HEIs, Incubators and R&D hubs • Role models • Informal forums of entrepreneurship • Safety nets ○ Tolerance of risk ○ Tax breaks ○ Bankruptcy laws ○ Social welfare system • Access to large national or international markets • Skilled workforce
10	Entrepreneurship, Wealth, Liquidity Constraints and Start-up Costs	Raquel Fonseca Pierre-Carl Michaud Thepthida Sopraseuth	2007	• Startup costs
11	Social sources of information in opportunity recognition: Effects of mentors, industry networks, and professional forums	Eren Ozgen Robert A. Baron	2007	• Mentoring
12	Entrepreneurship and Regional Economic Growth	Thomas Gries Wim Naudé	2008	• Education level of population • Startup costs • Low competition • Urbanization (population density) • Financial development • Access to finance
13	New small firm survival in England	George Saridakis Kevin Mole David J. Storey	2008	• Access to finance • Education level in a population
14	Nations of entrepreneurs: A social capital perspective	Seok-Woo Kwon Pia Arenius	2010	• Generalised trust
15	Networks as institutional support: Law firm and venture capitalist relations and regional diversity in High-technology IPOs	Helena Buhr Jason Owen-Smith	2010	• Access to financial and law services
16	Impact of Media on Entrepreneurial Intentions and Actions	Jonathan Levie Mark Hart	2010	• Absence of negative media perception of entrepreneurs

		Mohammed Shamsul Karim		
17	Patterns and Trends in Entrepreneurship Policy and Practice in Ten Economies	Lois Stevenson Anders Lundström	2011	• Absence of tax and regulatory burden • Access to finance • Ease of starting a business • Easy exit from business • Public infrastructure • Education level of population • Investment in digital infrastructure (e.g. Fibre optic broadband)
18	National culture and modes of entry into entrepreneurship	Joern H. Block Sascha G. Walter	2012	• Culture ○ Power distance Individualism ○ Uncertainty avoidance ○ Long-term orientation
19	Fostering Innovative Entrepreneurship – Challenges and Policy Options	United Nations	2012	• Collaborations with HEIs • Entrepreneurship • Education • Incubators and Science parks • Access to finance ○ Business angels ○ Venture capitals ○ Public funding
20	What Drives the Dynamics of Business Growth?	Albert Bravo-Biosca Chiara Criscuolo Carlo Menon	2013	• Flexibility of labour market regulations • Financial development • Bankruptcy regimes that do not severely penalise "failed" entrepreneurs
21	Entrepreneurial Ecosystems and Growth oriented Entrepreneurship	Colin Mason Ross Brown	2013	• A core of large established businesses, including some that have been entrepreneur-led • Business angels • Venture capitals • Mentoring • Collaboration with HEIs • Fear of failure • Access to financial, law, business and recruitment services
22	Growth and growth intentions	Jonathan Levie Erkko Autio	2013	• Education level of population • Risk taking propensity • Absence of burdensome regulations affecting entry, growth and exit of businesses
23	Silicon Valley's New Immigrant High-Growth Entrepreneurs	Anna Lee Saxenian	2013	• Multiculturalism

24	GEM Global Report	Slavic Singer Jose Ernosto Amoros Daniel Moska	2014	• Access to finance • Government policy that support entrepreneurship • The presence of government entrepreneurship programs • Entrepreneurship education • R&D transfer • Commercial and legal Infrastructure • Entry Regulation • Market Dynamics • Market Openness
25	Entrepreneurial innovation: The importance of context	Erkko Autioa Martin Kenney Philippe Mustar Don Siegel, Mike Wright	2014	• Networking opportunities • Collaboration with HEIs • Access to business and financial services
26	The Global Entrepreneurship Monitor (GEM)	Zoltán J. Ács László Szerb Erkko Autio	2014	• Perception of opportunity • Entrepreneurship education • Fear of failure • Networking opportunities • Cultural Support • Diffusion and absorption of new Technology • Prevalence of Highly educated workforce • Low competition • Potential to generate new products and to adopt or imitate existing products • Potential to apply or create new technology • Market growth expectation Potential for internationalization • Availability of risk finance
27	Enhancing Europe's Competitiveness Fostering Innovation-driven Entrepreneurship in Europe	World Economic Forum	2014	• Fear of failure • Entrepreneurship education • Perception of entrepreneurial career options • Access to finance ○ Business angels ○ Venture capital ○ Bank loans • Collaboration potential
28	Growing and sustaining entrepreneurial ecosystems: What they are and the role of government policy	SEAANZ	2014	• Mentoring • Incubators • Co-working spaces • Networking opportunities • Accelerators • Business angels • Venture capitals • Availability of bank finance

				• Links to Large firms • Collaborations with HEIs • Professional associations • Entrepreneurship clubs / startup communities • Business enterprise centres • Business brokers • Social status of entrepreneurs • Presence of role models • Entrepreneurship education • Business migration programs • Failure tolerance / Innovation embracing
29	The scale-up report	Sherry Coutu	2014	• Access to skilled labour • Availability of employees experienced in scaling up • Collaboration with schools and HEIs • Collaboration with R&D centres • Access to R&D facilities • Access to finance • Digital Infrastructure • Access to affordable work spaces
30	The Promise of digital entrepreneurs	Accenture	2014	• Simple regulations • Tax breaks • Public procurement • Access to finance at all stages • Labour market flexibility • Entrepreneurial culture

Appendix 10.3 List of Experts that were Interviewed

Name	Organisation	Role	Country	Type of Entity
Mike Reiner	Amazon	Business Development Venture Capital EMEA	USA	Corporate
Andrei Pitis	ANIS (National Association of the Software and Services Industry)	President	Romania	Association
Dmitri Sarle	ArcticStartup	CEO & Co-founder	Finland	Startup / Tech Blog
Neil Lee	London School of Economics	Assistant Professor of Economic Geography	UK	Academic
Can Ertugrul	Austrian Startups	Board Member	Austria	Association
Ricardo Marvao	Beta - I	Co-Founder	Portugal	Association
Julie Foulon	Betagroup	Managing Director	Belgium	Association
Lucie Volquartz	Bitkom	Project Manager	Germany	Scale-up
Veronika Pistyur	Bridge Budapest	CEO	Hungary	Association
Niko Porkka	Building Ventures	Co-Founder	Finland	Accelerator
John Spindler	Capital Enterprise	CEO	UK	Investor
Serge Rollinger	Chameleon invest	Managing Director	Luxembourg	Investor
David Cohen	TechStars	Co-Founder & Managing Partner	USA	Accelerator
Kristofs Blaus	Creative Mobile	CEO	Latvia	Scale-up
Ivor Bihar	Degordian	Product Manager	Croatia	Scale-up
Gabor Viche	Digital Europe	Project Manager	Brussels & Hungary	Association
Giusy Canella	Digital Europe	Project Manager and Director respectively	Belgium	Association
Jonathan Murray	Digital Europe	Director of Operations		Association
Chris Waclawek	Estimote	Contextual Computing Evangelist	Poland	Startup
Siim Sikkut	ICT Policy Adviser to the Prime Minister of Estonia	Estonian Government	Estonia	Government
Marc Van Gastel	Flanders Investment & Trade	Head of Department Invest	Belgium	Government
Dilyan Dimitrov	Eleven Accelerator	Founder	Bulgaria	Accelerator
Rob Fitzpatrick	Founder Centric	Co-founder	UK/Spain	Startup
Virginie Lambert	France Digitale	Campaigns Director	France	Association

Ferry				
Chris Foreman	Georgia Tech	Brady Family Term Professor	USA	Academic
Risto Rautakorpi	Gorilla Ventures	Co-Founder	Finland	Accelerator / Investor
Giuseppe Folonari	H-ART	Strategic Advisor	Italy	Scaleup
Timo Felin	Helsinki Ventures	Partner	Finland	Accelerator / Investor
Laszlo Koranyi	Hungarian National Innovation Office (Government)	Vice President for International and Domestic Affairs	Hungary	Government
Jan Adriaenssens	iMinds	Director	Belgium	Incubator
Sven De Cleyn	iMinds	Incubation & Entrepreneurship Manager	Belgium	Incubator
Uldis Leiterts	infogr.am	CEO	Latvia	Startup
Michał Kalina	Innovation Nest	Community Evangelist	Poland	Accelerator
Didier Tranchier	Institut Mines-Telecom	Professor	France	Academic
Rafał Brzoska	Integer Group	CEO	Poland	Corporate
Wolfgang Hubschle	Invest in Bavaria	Executive Director	Germany	Government
Doris Pold	ITL, Tallinn	Project Manager	Estonia	Association
Jacek Adamski	Lewiatan Business Angels	Project Coordinator	Poland	Association
Miklos Peter Mader	Magyar Telecom	Business Development	Hungary	Corporate
Raphael Halberthal	Maily	Co-founder	Brussels	Startup
Johnny Warstrom	Mentimeter	CEO	Sweden	Startup
Zuzanna Stańska	Moiseum	Project Manager	Poland	Startup
Barnabas Malnay	Multimedia Cluster Budapest	Managing Director	Hungary	Association
Ivan Stefunko	Neulogy Ventures	Managing Director	Slovakia	Investor
Michaela Jacova	Neulogy Ventures	Investment Manager	Slovakia	Investor
Kostas Baubinas	NFQ	Communication Manager	Lithuania	Accelerator
Alexander Pflaum	Otto-Friedrich University Bamberg & the Fraunhofer Institute for Integrated Circuits	Head of Centre for Intelligent Objects & Chair for Supply-Chain Management	Germany	Academic

Ondrej Bartos	Credo Ventures	Partner	Czech Republic	Investor
Antonio Murta	Pathena	Co-Founder	Portugal	Investor
Nuno Coelho Martins	Pioneers	VP Corporate Development	Austria	Association
Guy MukLow	Triggar	CEO & Co-founder	UK	Startup
Remco Janssen	Proudly Represents	Founder	Netherlands	Startup
Rune Theill	Rockstart Accelerator	Co-founder & Programme Director	Netherlands	Accelerator
Gianmarco Carnovale	Rome Startup	President	Italy	Association
Liam Booger	Rude Baguette	Editor	France	Startup / Tech Blog
Kenneth Hellem	Seed Nordic	Co-Founder	Sweden	Accelerator / Investor
Bindi Karia	Silicon Valley Bank	Vice President	UK	Investor
Karen Boers	Startup Belgium	Co-Founder & Managing Director	Belgium	Association
Emil Abirascid	Startup Business	Founder & CEO	Italy	Association
Rokas Tamošiūnas	Startup Highway	Managing Director	Lithuania	Accelerator
Rafael Pires	Startup Pirates	Founder	Portugal	Accelerator
Rob Aalders	Startup Spirit	Founder	Netherlands	Startup / Mentoring
Calum Cameron	Startup Wise Guys	Managing Director	Estonia	Accelerator
Johanna Palmberg	Swedish Entrepreneurs Forum	Research Director	Sweden	Association
Simon Azzopardi	Tain and Able	Managing Director	Malta	Startup / Mentoring
Carmen Bermejo	Tetuan Valley	CEO	Spain	Accelerator
Andrew Humphries	The Bakery	Founder	UK	Accelerator
Edmundas Balcikonis	Trackduck	CEO	Lithuania	Startup
Mikko Pohjola	Turku School of Economics	Head of R&D	Finland	Academic
Sean Carr	University of Virginia, Darden School of Business	Executive Director and Assistant Professor	USA	Academic
Gyula Feher	Ustream	CTO	Hungary	Scale-up
Nils-Erik Jansson	Young Entrepreneurs Sweden	President	Sweden	Association