RIERC Regional Innovation and Entrepeneurship Research Center

WORKING PAPER SERIES

2021-004

Measuring the digital platform economy

Zoltan J. Acs
George Mason University

László Szerb
University of Pécs, Faculty of Business and Economic

Abraham K. Song
George Mason University

Éva Komlósi
MTA-PTE Innovation and Economic Growth Research Group
University of Pécs, Faculty of Business and Economics

Esteban Lafuente
Department of Management, UPC Barcelona Tech

Measuring the digital platform economy

Zoltan J. Acs, George Mason University

László Szerb, University of Pécs, Faculty of Business and Economics

Abraham K. Song, George Mason University

Éva Komlósi, MTA-PTE Innovation and Economic Growth Research Group, University of
Pécs

Esteban Lafuente, Department of Management, UPC Barcelona Tech

Abstract: The application of big data, new algorithms and cloud computing is creating a global
digital platform economy built around platform companies. If a country builds out its *digital
ecosystem* there is no guarantee it will be exploited by existing firms, whereas the adoption of new
technologies by startups as a result of a consolidated *entrepreneurial ecosystem* is also uncertain. For
technology to be successfully introduced both the *digital ecosystem* and the *entrepreneurial ecosystem*
need to be developed simultaneously. The *Digital Platform Economy Index* (DPE Index) framework
includes 12 variables to integrate these two ecosystems, and this study measures the DPE Index for
116 countries. Developed Anglo-Saxon and Nordic countries lead the DPE index ranking followed by
other European, Asian as well as two Oceania prosperous nations (New Zealand and Australia). Many
middle-developed European, Asian and Latin American countries, together with a group of oil rich
countries (i.e., Bahrain, Oman, Qatar, Saudi Arabia, and United Arab Emirates) report below average
DPE index scores, while developing economies from Africa, Asia, Europe and Latin America are
included in the group of poor performing countries. Among EU member states, the DPE results reveal
that most countries (22 out of 27) are on or above the trend-line; however, they are far from the top
DPE performers (i.e., US and UK), except the Netherlands. The paper offers plain policy
recommendations on how to enhance both the digital and entrepreneurial ecosystem.

Introduction

In one of the most interesting articles on the Information-technology Revolution (ITR),
Hobijn and Jovanovic (2001) argued that the arrival of the ITR in the 1970s created the need
for new firms to emerge.[1] Technology breakthroughs favor new firm formation for three

---

[1] Also see Greenwood and Jovanovic (1999)

reasons: awareness and skills; vintage capital; and vested interests. The stock market incumbents of the day were not ready to implement the new digital technologies and it took new firms to bring the technology to market after the mid-1980s. Stock prices of incumbents fell immediately. New capital flowed via venture capital to startups in the United States that built the new industries but not in Europe (Gompers and Lerner, 2001). Between 1980 and 2020 the U.S. stock market raised thirty fold. The five most valuable public companies in the United States in 2020—i.e., Apple, Amazon, Microsoft, Facebook and Google—are valued at or near $1 trillion each.[2] Many of them are *Matchmaker* businesses whose core competency is the ability to match one group of users with another by reducing transaction costs.

The ITR is about digital technology and the representation of information in bits (Shannon, 1948). Information in bits reduces the cost of storage, computation and transmission of data. *Digital economics* examines whether and how digital technology changes economic activity (Goldfarb and Tucker, 2019). Digital technologies reduce five types of distinct costs that affect economic activities; search, replication, transportation, tracking and verification. The reduction of search costs leads to more matching and peer to peer platforms that increase the efficiency of trade. Most of the major technology firms can be seen as platform-based businesses. There are two main reasons why digital markets give rise to platforms (Jullien, 2012). First, platforms facilitate matching because they provide a structure that can take advantage of low search costs to create efficient matches. Second, platforms increase the efficiency of trade. They do this through lower search costs, lower reproduction costs and lower verification costs (Goldfarb and Tucker, 2019, p. 13). While the literature on digital economics has examined how digital technology changes economic activity less has been written about how it affects the platform economy.

The purpose of this paper is to create a framework to better understand the platform economy, multisided platforms and the platform-based ecosystems. The term 'Digital Platform Economy' was coined by Kenney and Zysman (2016, p.62) as, "…a more neutral term that encompasses a growing number of digitally enabled activities in business, politics, and social interaction.[3] If the industrial revolution was organized around the factory, today's changes are organized around these digital platforms, loosely defined." The advancements in information and communication technologies (ICT) opened a pathway for these businesses. More specifically, platforms are enabled by technological openness (architectural interface

specification) and organizational openness (governance) both of which are mediated by the platform owner. This rise of digital *multi-sided platforms* as avenues for value creation, appropriation, and innovation is commonly known as *platformization*.

While Kenny and Zysman (2016) focused on the nature of work this study focuses on the changing structure of the economy. In the platform economy costs are reduced not by management but via digital platforms—technology. Therefore, one of the hallmarks of the platform economy is the creation of markets where they did not exist through increased matching and the spread of platform-based businesses (Cusumano, Gawer and Yoffie, 2019). A question that has received less attention is how the ITR has affected the organization of the firm. In other words, "How do lower search costs affect firm organization? The reduction in search costs and verification costs has also led to a new form of organization—*the platform-based ecosystem.*

This chapter makes two contributions to the literature. First, we provide a concept-based measure of the Digital Platform Economy consisting of twelve pillars and four quadrants: Digital Multisided Platforms, Digital User Citizenship, Digital Technology Entrepreneurship and Digital Technology Infrastructure. These four quadrants include the key economic, business, social and policy issues: competition, privacy, innovation and security, respectively (Sussan and Acs 2017, Song 2019). Building on the National Systems of Entrepreneurship methodology (Acs, Autio and Szerb, 2014) we calculate the DPE index for 116 countries. A major advantage of our index is that it allows us to make international comparisons about digital efficiency across countries and over time.

Second, we examine the European Union's platform economy dilemma using the new measure of the DPE index. The EU platformization lag stems from the fact that incumbent firms in Europe have not introduced new technologies in sufficient volume and startups have remained small and not scalable (Naude, 2016).

The concept of platform-based ecosystem: The digital platform economy

The transition from the managed economy in the 20th century to the platform economy in the 21st century is perhaps best summed up by the Historian Niall Ferguson in his book *The Square and the Tower: Networks and Power from the Freemasons to Facebook.* Ferguson starts his story in Italian city states where a tower sits in the middle of the town square. The tower

represents hierarchy and the crucial incentive that favored hierarchical order was that it made the exercise of power more efficient. Moreover, absolutism could be a source of social cohesion. Yet the defect of autocracy is obvious, too. No individual, no matter how talented, has the capacity to contend with all the challenges of imperial governance, and almost none is able to resist the corrupting temptations of absolute power. Networks are changing the power balance of firms, governments and countries (Root, 2020).

One of the main institutional differences, if not the most significant, between the managed economy and the platform economy is the role of the *platform-based ecosystem*. While a large literature has now developed on entrepreneurial ecosystems this literature can be misleading in some ways. Entrepreneurial ecosystems appear to be a regional or local phenomenon as many have argued (Stam 2015).[4] However, when one compares entrepreneurial ecosystems with *platform-based ecosystems* and includes the role of digital technology the *platform-based ecosystem* is immediately global in nature with billions of users and millions of agents (Sussan and Acs, 2017). The *platform-based ecosystems* are developed and nurtured not by regions or governments but by platform organizations. Ecosystem governance, the rules for who gets on a platform and what the rules of good behavior are determined by the owners of the platform firms.

Among the first to recognize this shortcoming in the ecosystem literature was Sussan and Acs (2017). They observed that *a significant gap exists in the conceptualization of entrepreneurship in the digital age precisely because it ignored the fundamental role of knowledge as a resource in the economy*. To address this gap Sussan and Acs proposed a novel framework for the *platform-based ecosystem* also known as the Digital Entrepreneurial Ecosystem (DEE) integrating two separate but related literatures on ecosystems, namely, the digital ecosystem and the entrepreneurial ecosystem literature. This new framework situates the platform-based ecosystem in the broader context of users, agents, infrastructure and institutions, such that two biotic entities (users and agents) actuate individual agency, whereas two abiotic components (digital technology and digital institutions) form the external environment. Song (2019) further refined the DEE framework and expanded it to multi-sided platforms.

The DPE framework consists of four concepts: (1) Digital User Citizenship (DUC) includes users on the demand-side and the supply-side; (2) Digital Technology Entrepreneurship

---

[4] Malecki (2018) emphasized the regional aspect of entrepreneurial ecosystems and Cavallo, Balocco and Ghezzi (2018) focused on the present debates and future directions.

(DTE) includes app developers and various agents that contribute to entrepreneurial innovation, experimentation and value creation on platforms; (3) Digital Multi-sided Platforms (DMP) that orchestrate social and economic activities between users and agents; (4) Digital Technology Infrastructure (DTI) pertains to all regulations that govern technical, social and economic activities of the digital technology

Figure 1: The platform-based ecosystem
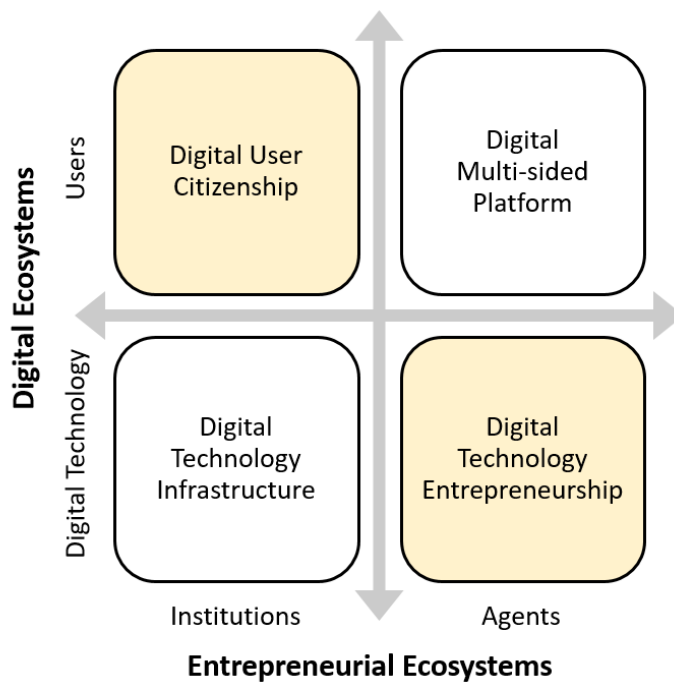
Source: Song, 2019 p. 576

First, users' privacy protection is critical for a healthy and active *Digital User Citizenship*. If the public trust becomes eroded, the sustainability of the DEE suffers. Erosion of trust in platforms can lead to a decline in user activities or membership. For example, Facebook's scandal involving Cambridge Analytica exposed millions of users and served as a watershed moment that prompted more government regulation of the internet to protect consumer privacy. Since then, Facebook has experienced a steady decline of daily active users in Europe.

Second, *Digital Technology Entrepreneurship* brings forth entrepreneurial innovation and thereby increases platform efficiency. The larger the user base, the larger the market segments and niches. A good platform sponsor provides boundary resources ease the entrepreneurial innovation process and offers a fair profit-share plan. Over the years, some critics have complained that Apple's high developer commissions and fierce control over its App store can limit experimentation, entrepreneurial innovation, and value creation.

Third, *Digital Multi-sided platforms* are the key organizational innovation of the ITR (Rochet and Tirole, 2003, 2006; Gawer 2009; Evans and Schmalensee, 2007, 2016). Saadatmand, Lindgren and Shultze (2019) describe, "digital platforms as an emergent organizational form characterized by technology and social processes. The monopolistic behavior of *Digital Multi-*

sided Platform will stifle competition, innovation, and entrepreneurial activities, which results in a welfare loss for consumers and the society as a whole. For example, European regulators have penalized Google for antitrust violations three times: for unfairly pushing its apps on smartphone users and blocking rivals; for using its search engine to steer consumers to its own shopping platforms; and for blocking its rivals from placing advertisements on third party websites.

Fourth, *digital technology infrastructure* enables the platform economy to operate. Digital infrastructure represents the technology of the digital age along with the rules and regulations that govern its use. This technological infrastructure is crucial to the smooth working of the DPE that is also responsible for keeping the digital economy open and secure. Huawei has been accused of being controlled by the Chinese government, and its equipment spying on companies and countries. These allegations on the issues of control, ownership, and fraud have raised questions whether the Chinese smartphone and telecommunication giant should be allowed to build the world's 5G mobile infrastructure. While Huawei has defended itself as an open, transparent and trustworthy company, it remains to be seen how global users and governments will respond.

In addition to the aforementioned conditions, one cannot leave out the role of digital finance to building a sustainable DPE. Secure and reliable digital technologies are necessary preconditions for the flourishing of the online financial transactions. A migration to a cashless society is a necessary first step, which users will be inclined to take only if there are tangible benefits. One such benefit is the reduction of transaction costs—the seamless payment experience between users and agents. In the digital age, digital finance has transformed capital markets too. One rather remarkable trend is the emergence of crowdfunding as an alternative method to raising capital. Similar to the way knowledge commons is a concerted effort of sourcing knowledge online, crowdfunding is a concerted effort of sourcing funding online. Another important trend is the rise of digital platforms many of which are unicorns. Startups are reaching $1 billion or even $10 valuation (e.g. decacorns) at faster pace. The average time for a US technology company to go public has gone down from eleven years in 1999 to four years in 2011. The formation of mega funds, such as the Softbank's $100 billion Vision Fund, and the availability of venture capital funds increasingly leave little incentive for platform startups to go public. Part of this decision-making is that demand-side driven businesses tend to take long to develop a sustainable revenue model and going public would subject it to

scrutiny and pressure that tends to drive down the value. In short, finding a sustained long-term growth remains elusive.

Table 1: Keys to Building a Sustainable Digital Platform Economy

Digital User Citizenship	Digital Multi-sided Platform
For a sustainable DPE, terms to user privacy should be clearly laid out and upheld by a social contract since public trust is a prerequisite to user participation in the digital economy. - Key word: "Privacy" - Example: Facebook	For a sustainable DPE, digital platforms should be kept in check from partaking in monopolistic behavior that stifles market competition, innovation, and entrepreneurial activities. - Key word: "Competition" - Example: Google
Digital Technology Infrastructure	Digital Technology Entrepreneurship
For a sustainable DPE, governments are responsible for enacting and enforcing rules and regulations that discourage destructive activities that undermine data security and encourage productive activities. - Key word: "Security" - Example: Huawei	For a sustainable DPE, third-party agents engage in entrepreneurial innovation and knowledge exchange that close the gap between supply opportunity and demand need within platforms that increase platform efficiency. - Key word: "Efficiency" - Example: Apple

From concept to measurement - The twelve pillars and their measurement

While ecosystem theories and concepts have a relatively long history for both entrepreneurial ecosystems (Acs, Stam, Audretsch and O'Connor, 2017) and digital ecosystems (Li, Badr and Biennier 2012, Weill and Woerner 2015), the concepts of digital entrepreneurship ecosystem and platform-based economy has been emerging only recently (Elia, Margherita, and Passiante, 2020, Nambisan 2017, Sahut, Iandoli, and Teulon 2019). However, measurements have been lagging behind conceptual developments. Some argue that all ecosystems are unique and have their own component structure, strengths and weaknesses. Consequently, case studies rather than simple or composite indicators are more appropriate to describe the ecosystem phenomenon (Isenberg 2010, Spigel 2017). While we can agree that the specifics of each ecosystem can be viewed under a microscope, a birds-eye view can identify some common structures and features (Szerb et al 2019). Accurate measurement is vital because of three reasons. First, one can recognize the relative development of a particular unit by comparing to other units based on rankings and index scores. Second, ecosystem strengths and weaknesses can be identified from a benchmarking perspective. Third, solid policy recommendations should ideally be based on appropriate measures.

While digital ecosystem and entrepreneurship ecosystem measures have been available for a longer time there is only one country level digital entrepreneurship ecosystem index, known as the European Index of Digital Entrepreneurship Systems (EIDES), that we are aware of (Autio et al 2018, 2019). EIDES has its theoretical roots in the entrepreneurship ecosystem concept, where entrepreneurship ecosystem pillars are contextualized by their digital counterpart. This notion reflects the general-purpose use of digitalization, in particular of digital technologies. Our suggested DPE index is different from this because EIDES conceptualizes entrepreneurship ecosystem based on the three business development stages (stand-up, start-up, and scale-up), while DPE index is designed to focus on the context of users, agents, digital technology, and institutions to capture fully the systemic developments as identified by Jovanovic (1982, 2001). Second, our DPE Index is centered around platformization and not solely on the use or the application of digital technologies. Moreover, EIDES is only for the EU member countries while DPE makes possible to compare EU countries to other nations.[5]

The new DPE index proposed in this study attempts to measure the Digital Platform Economy at the country-level. Figure 1 pictures the structure of DPE index showing the four frameworks, called sub-indices. All four frameworks include three constituents reflecting the most important aspects of Digital Technology Infrastructure, Digital User Citizenship, Digital Multi-sided Platforms, and Digital Technology Entrepreneurship. All pillars have two types of components, called variables (Figure 2). For example, Digital rights pillar have an Institutions and a User's component; and Digital adoption pillar consists of a Digital technology and an Agent variable.

---

[5] For other entrepreneurship ecosystem measures see the Global Entrepreneurship Index, its regional counterpart the regional Entrepreneurship and Development index, Kauffmann's entrepreneurship ecosystem and the Startup Genome's Global Startup Ecosystem model. Digital measures can be divided into maturity/readiness, transformation, and complex indices. The most well-known composite digital index is the European Union's Digital Economy and Transformation Index (DESI). Beside it, there are the Mastercard and the Fletcher School at Tufts University's Digital Evolution Index, and the Economic Intelligence Unit' Inclusive Internet Index.

Figure 2 The structure of DPE index

Sub-indexes	Pillars	Variables (entrepreneurship/digital)
Digital Technology Infrastructure	Digital access	*Digital access Institutions*
		Digital access Digital technology
	Digital freedom	*Digital Freedom Institutions*
		Digital Freedom Digital technology
	Digital protection	*Digital protection Institutions*
		Digital protection Digital technology
Digital User Citizenship	Digital literacy	*Digital literacy Institutions*
		Digital literacy Users
	Digital openness	*Digital Opennesss Institutions*
		Digital openness Digital technology
	Digital rights	*Digital rights Institutions*
		Digital rights Digital technology
Digital Multi-sided Platform	Networking	*Networking Agents*
		Networking Users
	Matchmaking	*Matchmaking Agents*
		Matchmaking Users
	Financial facilitation	*Financial facilitation Agents*
		Financial facilitation Users
Digital Technology Entrepreneurship	Digital adaptation	*Digital adoption Agents*
		Digital adoption Digital technology
	Technology absorption	*Technology absorption Agents*
		Technology absorption Digital technology
	Technology transfer	*Technology transfer Agents*
		Technology transfer Digital technology

DIGITAL PLATFORM ECONOMY

Digital Technology Infrastructure (DTI) "...addresses the coordination and governance needed to establish a set of institutional standards…" (Sussan and Acs 217, p. 64) that are related to digital technology.

- *Digital openness* reflects to how well a country's institutions support the reach and the use of digital technology. The digital technology part is proxied by the percentage of individuals and household having access to the internet. The institutions side is measured by an indicator reflecting to the laws relating to ICT and a more complex indicator, the Global Cyberlaw Tracker.

- *Digital freedom* reflects to how the government and their institutions are able to give enough freedom to digital technology development. The infrastructure part is measured by three indicators. The Freedom House two indices, the Freedom of the press, the Freedom of the world reflects to the overall freedom of a country. The Internet and telephone competition from the WEF Network Readiness Index measure the potential monopolization of the digital technology. The associated counterpart from the digital technology is measured by the number of internet domains from Global Innovation Index, and Webhosting, standardized by the size of population

- *Digital protection* captures the degree how law and regulation protect from piracy and cybercrime. The infrastructure part is measured by the Legal sub index of the Global Security Index and the Corruption Perception Index from Transparency International. The digital part is proxied by the WEF Network Readiness Index software piracy rate.

Digital User Citizenship "…addresses the explicit legitimization and implicit social norms that enable users to participate in digital society" (Sussan and Acs 217, p. 64).

- *Digital literacy* refers to the abilities of the citizens necessary to use computers, the digital technology and digital platforms. From the user side we use two indicators one is the level of digital skills amongst the population from WEF and the other is the number of search users in a country as reported by Bloom Consulting. From the institutional part, we use two educational indicators, as the quality of education and the internet access to schools, both are from WEF.

- *Digital access* refers to level citizens have access to the digital technology including computers and the internet. The institutional part of Digital access is captured by two proxy indicators, the technical and organizational sub-index from the Global Cybersecurity Index. The user part includes three indicators as fixed broadband internet subscriptions, International Internet bandwidth, and the percentage of individuals using a computer.

- *Digital rights* reflect to those human and legal rights that make possible citizens to use the digital technology and protect their privacy at the same time. The institutional part of Digital Rights is captured by personal rights – from the Global Talent Competitiveness Index - by fundamental rights – from the Rule of Law index and by property rights - from the Property Rights Alliance. The digital part is proxied by a Kaspersky based variable that is the Net infection rate and the Internet censorship and surveillance data from Wikipedia.

Digital Multi-sided Platforms where users of the digital technology and agent of the entrepreneurship ecosystem meet. DMSP serves as an "…intermediary for transaction of goods and services, and also a medium for knowledge exchanges that enables and facilitates experimentation, entrepreneurial innovation, and value creation" (Song 2019, p. 4).

- The *Networking* pillar aims to grasp the network and other externality effect of MSP. We apply three, partially overlapping, indicators from the users' side: the use of virtual social networks (ITU), social media penetration (Hootsuite), and the use of virtual professional networks (WEF). From the agent side, we apply two WEF related indicators that are the ICT use of Business-to-business transactions and the business-to-costumer internet use.

- *Matchmaking* component aims to capture the multisided platform model effect. From the user side the active participation effect captured by two indicators from INSEAD that are the Wikipedia yearly edits, and the Video uploads on YouTube. From the agent side we use the number of professional developers as a percentage of population and as a logarithmic of the country share. This later indicator is supposed to grasp the size effect.

- *Financial facilitation* reflects to various aspect of finance that fuels matchmaking startups, makes possible financial transactions via the internet as well as providing platforms for financial source providers and users. From the user side, we apply four World Bank related indicators as Debit/credit card average, Used the internet to pay bills or to buy something online, used a mobile phone or the internet to access a financial institution account, Made or received digital payments. For the agent side we rely on three indicators, the Depth of Capital Market Sub-Index Score from The Venture Capital and Private Equity Country Attractiveness Index, the standardized number of Fintech companies based on Deal room data, and Venture capital availability from WEF.

Digital Technology Entrepreneurship "…is comprised of various third-party agents that partake in experimentation, entrepreneurial innovation, and value creation using hardware/software to build products that connect to platforms" (Song 2019, p.9).

- *Digital adaptation* aims to detect the basic capabilities of entrepreneurial agents to use digital technologies. From the agent side, we use two proxies, one for measuring the level of digitalization by computer software spending and another for the quantifying the basic talents in the country (skills of the workforce)

- The *Digital Absorption* pillar involves the advanced capabilities of the agents to be able to build new business models and/or digital products/services based on the opportunities provided by the digital technology. The digital technology component is captured by two indicators: The number of data centers from Data Centers catalog and the Availability of latest technology from WEF. The agent component is measured by a complex variable that is the knowledge absorption capacity sub-index and by two indicators reflecting to the effect of ICT on new business and organizational models. All data are from the Global Innovation Index.

- The *Technology transfer* pillar includes the knowledge spillover effect when agents are working on the discovery, evaluation, and exploitation of new opportunities brought about by evolving technologies. From the agent side, the tech transfer capability is proxied by a Startupranking based indicator that is the number of startups. The skill component is measured by the High-level skills which is a complex sub-index from the Global Talent Competitiveness Report. From the digital

technology part, we use two components one is from the Global Innovation index that is the Knowledge and technology output and a similar component from the Global Competitiveness Index that is the Innovation capacity.

The full description of the applied 61 indicators and their sources can be found in the Appendix.

Measurement - Calculating the DPE index and its component scores

According to the model pictured in Figure 1, and detailed out in Figure 2, we suggest a five-level composite indicator building following as (1) indicators (2) variables, (3) pillars, (4) sub-indices, and (5) the super-index. The super index is called the Digital Platform Economy index and its sub-indices are the four frameworks. The twelve components are called pillars. Pillars are the most important constituents of the model. Pillars are comprised from 24 variables, representing digital ecosystem (12) and entrepreneurship ecosystem (12). Variables are built from 61 indicators that are the elementary building blocks of DPE index.

Indicator selection was based on four criteria:

    1. Relevance of the indicator for the phenomenon we aim to measure

    2. Specificity of the variable to the phenomenon it represents

    3. Potentially flawless and clear interpretation of the indicator

We also aimed to have the indicator available for at least 90% of the countries, but in five cases, we could not reach this goal. For 85 countries more than 95.1%, for 23 countries 90.1-95.0%, and for 8 countries 80.1-90.0% of the indicators are available. The results for these eight countries – Benin, Burundi, Hong Kong, Jamaica, Macedonia, Madagascar, Namibia, Taiwan – should be viewed with precaution. Variables were calculated from normalized indicator scores. Following the Global Entrepreneurship Index building methodology we provide the most important steps of calculation (Acs et al 2014).

All pillars contain two types of variables: One is representing the Digital Ecosystem (Digital technology and Users) and the other representing the Entrepreneurship Ecosystem

(Institutions and Agents). The overall influence of these two types of variables is captured by multiplying the two components:

$$DPE\_pillar_{i,j} = DE\_variable_{i,j} * EE\_variable_{i,j} \qquad (1)$$

where

> i=1……n, the number of countries
>
> DPE_pillar$_{i,j}$ represents the digital entrepreneurship ecosystem pillars, j= 1,…..12
>
> DE_pillar$_{i,j}$ represents the digital ecosystem pillars, j= 1,…..12
>
> EE_pillar$_{i,j}$ represents the entrepreneurship ecosystem pillars, j= 1,…..12

After the calculation of the raw pillar scores we normalized them using the distance methodology:

$$DPE\_pillar(norm)_{i,j} = \frac{DPE\_pillar_{i,j}}{\max DPE\_pillar_{i,j}} \qquad (2)$$

> for all j= 1 ... 12, the number of pillars
>
> where $DPE\_pillar(norm)_{i,k}$ is the normalized score value for country i and pillar j
>
> max DPE_pillar $p_{i,j}$ is the maximum value for pillar j

When we calculate the normalized averages of the twelve pillars for the 116 countries, it ranges from 0.153 (Matchmaking) to 0.525 (Digital rights) with 0.361 overall average value. The different averages of the normalized values of the pillars imply that reaching the same pillar values requires different efforts and resources. Consequently, the effect of additional resources to achieve the same marginal improvement of the pillar values is different and it is problematic for using the pillar values to public policy purposes. The Average pillar adjustment methodology developed by Acs, Autio and Szerb (2014) reduces but not fully eliminates this problem.

The following equations (3a-3c) show the calculation steps.

First, we calculate the average value of the j=12 pillar:

$$\overline{DPE\_pillar(norm)}_j = \frac{\sum_{i=1}^{n} DPE\_pillar(norm)_{i,j}}{n} \qquad \text{for all j} \qquad (3a)$$

> where $\overline{DPE\_pillar(norm)}_j$ is the average value of all j=12 normalized pillars

We want to transform the DPE_pillar(norm)$_{i,j}$ values such that the potential values to be in the [0,1] range.

$$DPE\_pillar(equal)_{i,j} = DPE\_pillar(norm)_{i,j}^{t} \qquad (3b)$$

where t is the "strength of adjustment", the t-th moment of DEE_pillar(norm)$_j$ is exactly the needed average, $\overline{DPE\_pillar(equal)}_j$

We have to find the root of the following equation for t:

$$\sum_{i=1}^{n} DPE\_pillar(norm)_{i,j}^{t} - n\overline{DPE\_pillar(equal)}_j = 0 \qquad (3c)$$

For solution, the Newton-Raphson method is used with an initial guess of 0. After obtaining t, the computations are straightforward.

After these transformations, the penalty for bottleneck methodology was used to create pillar-adjusted PFB values. A bottleneck is defined as the worst performing pillar or a limiting constraint in a particular country's digital entrepreneurship system. Here, bottleneck is defined as the lowest level of a particular pillar, relative to other pillars in a particular country. This notion of a bottleneck is important for policy purposes considering the systemic nature of DEE. The system perspective means that that pillars have an effect to one another. This interaction should be included in the calculation of the pillar, the sub-index and the DPE index scores. We consider the system being optimal if all the average adjusted pillar scores are the same for the particular country. Differences imply non-optimal use of the resources. Practically it means that after equalizing the pillar averages, the value of each pillar of a country is penalized by linking it to the score of the pillar with the weakest scores in that country. This simulates the notion of a bottleneck; if the weakest pillar were improved, the whole DPE Index would show a significant improvement.

We define our penalty function following as:

$$DPE\_penalized_{(i),j} = 100 * \min DPE\_pillar(equal)_{(i),j} + (1 - e^{-(y_{(i)j} - \min DPE\_pillar(equal)_{(i),j})}) \quad (4)$$

where DPE_penalized$_{i,j}$ is the modified, post-penalty value of pillar j in country i

DPE_pillar(equal)$_{i,j}$ is the normalized value of index component j in country i

DPE_pillar(equal)$_{min}$ is the lowest value of y$_{i,j}$ for country i.

i = 1, 2,……116 = the number of countries

j= 1, 2,…….12= the number of pillars

Note, that the multiplication by 100 is purely practical to get a 0-100 point scale instead of the 0-1 range.

Sub-index calculation is simple, just taking the arithmetic average of its PFB-adjusted pillars for that sub-index.

$$DIG_i = \sum_{j=1}^{3} \frac{DPE\_penalized_j}{3} \qquad (5a)$$

$$DUC_i = \sum_{j=4}^{6} \frac{DPE\_penalized_j}{3} \qquad (5b)$$

$$DMSP_i = \sum_{j=7}^{9} \frac{DPE\_penalized_j}{3} \qquad (5c)$$

$$DTE_i = \sum_{j=10}^{12} \frac{DPE\_penalized_j}{3} \qquad (5d)$$

where

DIG_i = Digital Technology Infrastructure score for country i
DUC_i = Digital User Citizenship score for country i
$DMSP_i$= Digital Multi-sided Platform score for country i, and
DTE_i =Digital Technology Entrepreneurship score for country i

Finally, the Digital Platform Economy index (DPE) score is calculated as the simple arithmetic average of the four sub-indices.

$$DPE_i = \frac{1}{4}(DIG_i + \ DUC_i + DMSP_i + DTE_i) \qquad (6)$$

Where DPE_i is the Digital Platform Economy index score for country i.

We have done the basic tests for consistency of the composite indicator components. The Cronbach alpha values for the four sub-indices are in an acceptable range; for DUC=0.93, for DIG=0.84 for DMSP=0.92 for DTE=0.93.

Basic analysis – Country rankings and clustering

In this section, we provide a basic analysis of the DPE index for 116 countries from all continents and all development stages. First, we present the DPE Index scores ranking of the 116 country in Table 2.

According to Table 2, the United States leads the DPE Index 2020 ranking with a score of 85.0 followed by the United Kingdom (82.7), and the Netherlands (82.4). In the first ten countries there are two from North America (US and Canada), seven from Europe (UK, Netherland, Sweden, Switzerland, Norway, Denmark and Finland) and there is only one Asian country, the ninth ranked Australia. The second ten countries, ranked in the 11-20 spots, show a similar regional distribution: Besides eight European countries – Ireland, Luxemburg, Germany, France, Iceland, Belgium, Estonia, and Austria there are New Zealand and Hong Kong. All of these countries are highly developed, innovation driven economies. In contrast, the last ten places (107-116) there are low developed, resource driven countries mainly from the African continent with the exception of Cambodia.

Table 2: The DPE index ranking of the countries, 2020

| Rank	Country	DPE 2020	GDP 2017	Rank	Country	DPE 2020	GDP 2017	Rank	Country	DPE 2020	GDP 2017
1	United States	85,0	54225	40	Slovakia	40,5	30155	79	Ecuador	21,3	10582
2	United Kingdom	82,7	39753	41	Hungary	38,4	26778	80	Tunisia	21,1	10849
3	Netherlands	82,4	48473	42	Uruguay	36,3	20551	81	Albania	20,5	11803
4	Canada	78,2	44018	43	Greece	35,9	24574	82	Vietnam	20,3	6172
5	Sweden	76,8	46949	44	Bulgaria	35,0	18563	83	Dominican Republic	19,8	14601
6	Switzerland	76,3	57410	45	Croatia	34,8	22670	84	Jamaica	19,7	8194
7	Norway	74,4	64800	46	Costa Rica	34,1	15525	85	Egypt	19,5	10550
8	Denmark	71,1	46683	47	Romania	33,0	23313	86	Iran	19,5	19083
9	Australia	69,3	44649	48	Russia	32,7	24766	87	Botswana	19,5	15807
10	Finland	68,9	40586	49	Turkey	32,3	25129	88	Namibia	18,3	9542
11	Ireland	66,0	67335	50	Mauritius	32,0	20293	89	Sri Lanka	18,3	11669
12	Luxembourg	65,6	94278	51	Brazil	31,2	14103	90	Lebanon	17,6	13368
13	New Zealand	65,3	36086	52	Argentina	30,4	18934	91	Kenya	17,5	2993
14	Germany	64,4	45229	53	Mexico	29,4	17336	92	Mongolia	17,3	11841
15	France	63,6	38606	54	Ukraine	29,3	7894	93	El Salvador	16,7	7292
16	Iceland	62,6	46483	55	Saudi Arabia	29,3	49045	94	Paraguay	15,6	8827
17	Belgium	62,5	42659	56	Oman	28,8	37961	95	Guatemala	15,0	7424
18	Estonia	60,0	29481	57	Montenegro	28,5	16409	96	Senegal	14,5	2471
19	Hong Kong	58,5	56055	58	China	28,1	15309	97	Pakistan	14,0	5035
20	Austria	57,0	45437	59	Colombia	28,0	13255	98	Honduras	13,9	4542
21	Japan	56,8	39002	60	Panama	28,0	22267	99	Nigeria	13,7	5338
22	South Korea	56,4	35938	61	Bahrain	27,6	43291	100	Zambia	13,4	3689
23	Israel	56,2	33132	62	Serbia	27,5	14049	101	Algeria	12,5	13914
24	Singapore	55,8	85535	63	Thailand	27,2	16278	102	Rwanda	11,9	1854
25	Spain	53,5	34272	64	Georgia	26,5	9745	103	Nepal	11,6	2443
26	Malta	53,4	36513	65	South Africa	26,4	12295	104	Kyrgyzstan	11,5	3393
27	Portugal	50,8	27937	66	Macedonia	25,3	13111	105	Bangladesh	11,2	3524
28	Czech Republic	48,9	32606	67	Jordan	25,0	8337	106	Uganda	11,0	1698
29	Taiwan	47,1	50294	68	Armenia	25,0	8788	107	Cameroon	10,8	3365
30	Italy	46,1	35220	69	Moldova	24,4	5190	108	Mali	10,4	2014
31	Slovenia	45,1	31401	70	Morocco	24,4	7485	109	Zimbabwe	10,0	1900
32	Lithuania	44,3	29524	71	Philippines	24,3	7599	110	Cambodia	9,8	3645
33	Cyprus	44,3	32415	72	Azerbaijan	23,9	15847	111	Tanzania	9,8	2683
34	United Arab Emirates	43,1	67293	73	India	23,8	6427	112	Malawi	9,8	1095
35	Latvia	42,8	25064	74	Peru	23,6	12237	113	Benin	9,6	2064
36	Malaysia	42,1	26808	75	Kazakhstan	23,5	24056	114	Madagascar	7,3	1416
37	Qatar	40,7	116936	76	Indonesia	23,1	11189	115	Burundi	6,9	702
38	Chile	40,6	22767	77	Kuwait	22,8	65531	116	Ethiopia	6,0	1730
39	Poland	40,6	27216	78	Bosnia and Herzegovina	21,4	11714				

Legend: DPE INDEX: Digital Platform Economy index score; Light blue: European Union countries
The per capita GDP of the country in purchasing power parity, 2017 from the World Bank,
(https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD)

Table 2 provides us a look at the global position of the EU verses the rest of the world. Scandinavian countries (Sweden, Norway, Denmark and Finland) as well as the Switzerland are stronger than the large European countries; however, they are small in terms of population and output. While there are four EU member countries are in the first ten

countries, Europe's large countries, Germany, France, Italy and Spain are clearly in second cohort of ranking. The difference between the first three leading countries is marginal. However, the US DPE Index score is higher than that of the 14th ranked Germany by more than 20 DPE Index score, by almost 25%.

There is a close connection between development and DPE Index scores: The Pearson correlation coefficient is 0.66, without the oils-rich countries, and countries with higher than 65 000 Int. $ per capita GDP. The third-degree trend line shows even closer connection as pictured in Figure 3.

Figure 3: The connection between development and the DPE Index scores (third-degree polynomial adjustment)
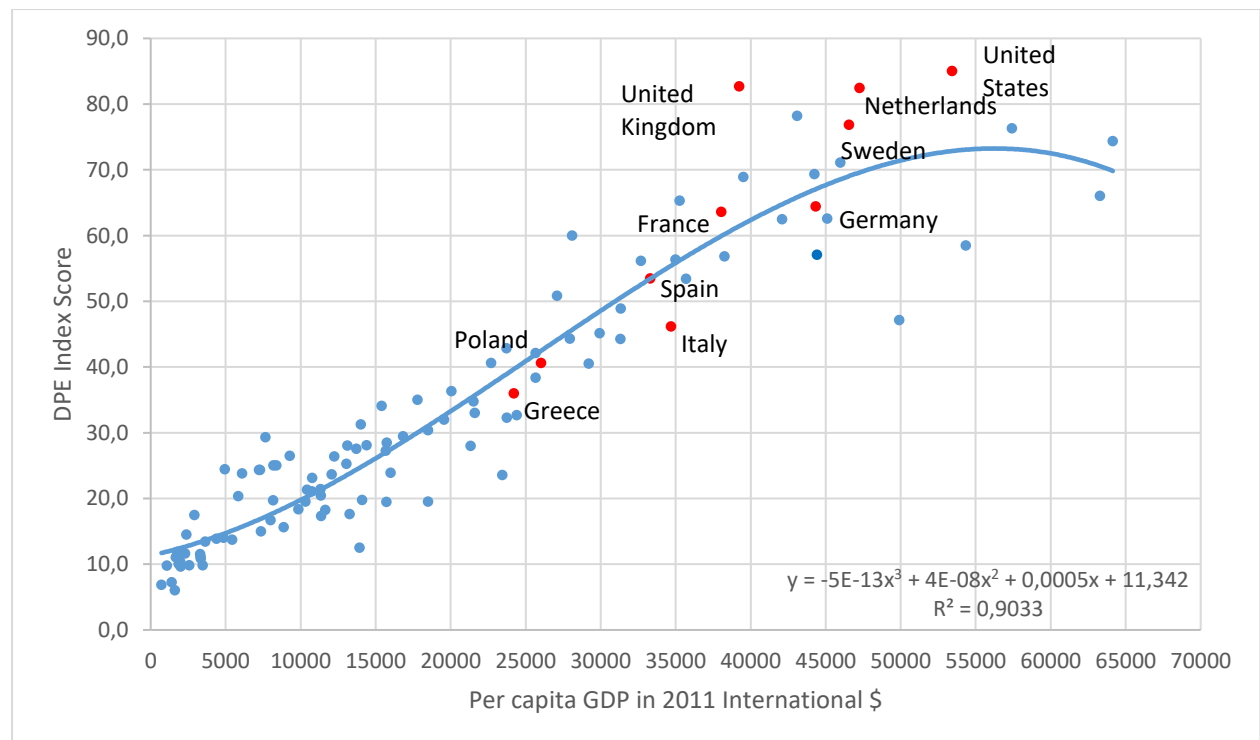
Note: Trend line is calculated without countries over 65 000 inter. $ per capital GDP and without oil-based economies of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates.

The third-degree adjusted curve explains around 90% of the variation between development (measured by the per capita GDP) and digital platform-based ecosystem (DPE Index). Note that it is not implying a causal relationship; we simply refer to the strong connection between development and digital entrepreneurship ecosystem. Examining a particular country's position being below or above the development implied trend line is more appropriate than

simply comparing differently developed nations. For example, the United States has the highest DPE Index score, 85.0, and is above the trend line as is the United Kingdom, the Netherlands, and Sweden. Out of the large EU countries, only France and Spain are on or above the trend line. Germany and Italy both have lower DPE Index scores than implied by the trend line. Poorer EU countries like Poland or Greece have much lower DPE Index scores and they are below the trend-line.

While DPE Index score is useful to evaluate the digital platform-based ecosystem performance of a country as compared to other nations, it does not tell us anything about the strengths and weaknesses of this country. For viewing it, we need to decompose the DPE Index into its components. Table 3 presents the four sub-index score and ranking of the first 25 countries.

Table 3: The four sub-index scores and ranking of the first 25 countries

DPEIndex Ranking	Country	DIGITAL INFRASTUCTURE GOVERNANCE score	DIGITAL INFRASTUCTURE GOVERNANCE ranking	DIGITAL USER CITIZENSHIP score	DIGITAL USER CITIZENSHIP ranking	DIGITAL MULTI-SIDED PLATFORM score	DIGITAL MULTI-SIDED PLATFORM ranking	DIGITAL TECHNOLOGY ENTREPRENEURSHIP score	DIGITAL TECHNOLOGY ENTREPRENEURSHIP ranking
1	United States	86,9	2	73,3	6	87,5	1	92,3	1
2	United Kingdom	83,1	4	81,4	1	84,8	3	81,3	3
3	Netherlands	90,5	1	74,1	4	86,3	2	78,7	4
4	Canada	78,5	6	78,1	2	78,9	5	77,2	5
5	Sweden	79,4	5	73,9	5	79,5	4	74,4	6
6	Switzerland	77,9	8	72,9	7	69,4	9	84,9	2
7	Norway	83,6	3	76,6	3	73,5	6	63,8	12
8	Denmark	75,2	9	71,3	10	73,4	7	64,4	11
9	Australia	78,2	7	72,9	8	69,3	10	57,0	18
10	Finland	70,7	11	71,6	9	67,2	11	66,1	8
11	Ireland	64,8	17	64,3	15	65,4	14	69,6	7
12	Luxembourg	73,7	10	65,6	14	60,3	17	63,0	14
13	New Zealand	67,3	14	68,5	11	70,4	8	55,0	23
14	Germany	69,6	12	68,3	12	56,4	23	63,2	13
15	France	67,2	15	61,3	18	60,4	16	65,4	9
16	Iceland	65,4	16	53,8	22	65,6	13	65,4	10
17	Belgium	64,0	18	61,4	17	64,9	15	59,6	17
18	Estonia	63,7	19	63,5	16	57,5	22	55,2	21
19	Hong Kong	69,4	13	48,8	26	58,8	20	57,0	19
20	Austria	62,7	21	58,6	19	50,1	28	56,7	20
21	Japan	62,7	20	66,4	13	44,3	34	53,8	24
22	Korea	56,0	23	56,5	20	59,6	18	53,3	26
23	Israel	49,1	29	47,6	28	67,0	12	61,0	16
24	Singapore	56,6	22	46,7	30	58,6	21	61,2	15
25	Spain	52,3	27	55,1	21	52,6	25	53,8	25

Legend: Light blue color: EU member countries

The leading United States is the first in the DMSP and the DTE sub-indices but the sixths in DUC and second in DIG. The US best sub-index score is 92.3 (DTE) and the worst is 73.3 (DUC) a 20.6% difference. The United Kingdom's performance is even more balanced ranging from the first (DUC=84.8) to the fourth (DIG=81.3). Some other countries show higher variations. For example, the 9th ranked Australia is the sevenths in DIG=78.2 score but only the 18th in DTE=57.0, a 27,1% difference. Looking at the EU member countries, various

unbalanced can be seen. While Netherlands is the first in DTI(DIG=90.5) it is only the fourth in DUC (DUC=74.1) with significantly lower score (18% difference). Germany has its major weaknesses in DMSP, while France and Spain are more balanced.

Further analysis – pillar based investigations

To see common features, similarities and differences we have conducted a K-Means cluster analysis with respect to the twelve pillars. For our purposes the four cluster group solution proved to the most useful.

Table 4 shows a relative unbalance in cluster memberships: The Leaders consists of only seven countries, the Followers are 20, the Gainers are 35 and the Laggards are 54 countries. The differences amongst the groups in terms of DPE INDEX mean score varies, the Leaders (DPE INDEX=77.7) are ahead of the Followers (DPE INDEX= 61.3) by around 16 point, the Gainers (DPE INDEX = 35.9) are behind the Followers by around 25 points, and the Laggards (DPE INDEX=17.4) are the last by roughly 19 points. The first six countries in the DPE INDEX ranking belong to the Leaders group, mainly North American and European (Nordic and Anglo-Saxon) nations. The Followers group contains only developed European and Asian countries with two developed Oceania countries, New Zealand and Australia. Gainers are geographically mixed, dominated by middle-developed European, Asian and Latin American countries. Most oil rich countries (i.e., Bahrain, Oman, Qatar, Saudi Arabia, and United Arab Emirates) belong to this cluster. Laggards are formed from low developed African and Asian countries together with some relatively poor European and Latin American nations.

Table 4: The four groups of the countries and average pillar scores based on the twelve pillars

Categories/groups	Leaders	Followers	Gainers	Laggards
Digital Access	82.3	74.9	43.7	11.1
Digital Freedom	80.2	60.3	35.3	22.2
Digital Protection	88.3	74.2	37.5	14.6
Digital Literacy	77.4	59.2	33.6	24.1
Digital Openness	76.6	71.7	43.2	13.4
Digital Rights	68.5	62.8	36.3	22.2
Networking	84.1	64.2	37.2	19.1
Matchmaking	82.7	61.3	40.6	18.1
Financial Facilitation	79.3	70.1	38.3	16.8
Digital Adoption	81.8	63.0	39.0	18.6
Technology Absorption	83.3	59.1	34.4	22.9
Technology Transfer	82.0	63.2	35.8	20.6
Digital Platform Economy Index score mean	**77.7**	**61.3**	**35.9**	**17.4**
Number of cases	7	20	35	54

Legend:

Leaders: Canada, Iceland, Netherlands, Sweden, Switzerland, United Kingdom, United States;
Followers: Australia, Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Hong Kong, Ireland, Israel, Japan, South Korea, Luxembourg, Malta, New Zealand, Norway, Singapore, Spain, Taiwan,
Gainers: Argentina, Bahrain, Brazil, Bulgaria, Chile, China, Costa Rica, Croatia, Cyprus, Czech Republic, Georgia, Greece, Hungary, Italy, Latvia, Lithuania, Macedonia, Malaysia, Mauritius, Mexico, Montenegro, Oman, Poland, Portugal, Qatar, Romania, Russia, Saudi Arabia, Slovakia, Slovenia, Turkey, Ukraine, United Arab Emirates; Uruguay;
Laggards: Albania, Algeria, Armenia, Azerbaijan, Bangladesh, Benin, Bosnia and Herzegovina, Botswana, Burundi, Cambodia, Cameroon, Colombia, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Guatemala, Honduras, India, Indonesia, Iran, Jamaica, Jordan, Kazakhstan, Kenya, Kuwait, Kyrgyzstan, Lebanon, Madagascar, Malawi, Mali, Moldova, Mongolia, Morocco, Namibia, Nepal, Nigeria, Pakistan, Panama, Paraguay, Peru, Philippines, Rwanda, Senegal, Serbia, Sri Lanka, South Africa, Tanzania, Thailand, Tunisia, Uganda, Vietnam, Zambia, Zimbabwe

The Leaders are the best in all twelve pillar score averages. These countries are mainly rich Anglo-Saxon and Nordic countries with well-balanced digital entrepreneurship ecosystems. While they spend the most for digital protection, digital rights is their lowest valued pillar. There are only two small EU member countries (Netherlands and Sweden) are here. Followers are also rich, developed nations. Although some aspects of the digital entrepreneurship ecosystem are well developed (Digital Access, Digital Protection), some pillars have relative low score (Digital Literacy, Technology absorption). Gainers enjoys good digital technologies

and that citizens are active users, however many aspects of the digital entrepreneurship ecosystem requires considerable development. Laggards are the worst in terms of every pillar score average. These countries lack good digital technologies and an active stock of users. The last two group members are very homogenous, differences inside the groups are minimal. This is particularly true for the most numerously populated Laggards cluster.

Figure 4 shows five European countries, Austria, Greece, Netherlands, Spain and the United Kingdom at the pillar level. We already have seen the United Kingdom and the Netherlands are leaders and that other countries lag significantly behind. In digital technology the difference between the leaders and the followers is clear from all three pillars: openness, freedom and production. Those differences are similar with respect to digital users: literacy, access and rights. However, the differences are greater in literacy than in rights as the EU has moved ahead on rights without regard to literacy. When we look at digital platforms we see that the real differences between leaders and followers are even greater. The United Kingdom and the Netherlands are almost thirty points above Spain and more than thirty-five points above Italy. In digital entrepreneurship the differences are the smallest in digital adoption and the greatest in technology absorption. The differences across Europe are the greatest in Technology Entrepreneurship and Multisided platforms.

Figure 4: Selected European countries by pillar
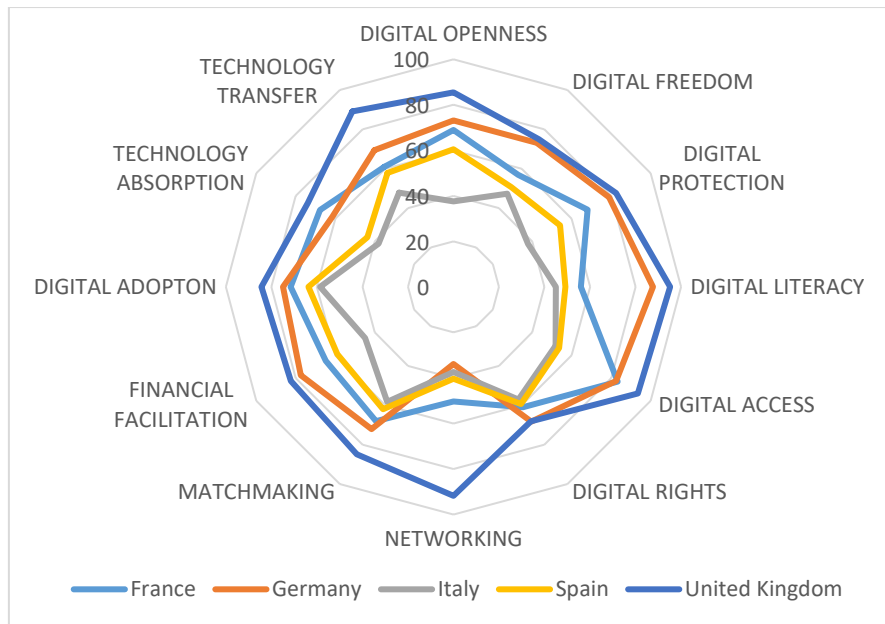
Basic DPE Index policy suggestions - DPE Index trend line and Digital Ecosystem-Entrepreneurship Ecosystem difference analysis

Figure 5 shows the grouping of the 116 countries into four quadrants. On the horizontal axis is the difference between the DPE Index trend-line and the actual DPE Index score in percentages. The DPE INDEX trend-line calculation is based on the per capita GDP. The DPE Index trend-line represent the best fit power function according to the following equation:

$$GDP\ per\ capita = -5E\ (-13)*DPE\ Index^3 + 4E\ (-08)DPE\ Index^2 + 0.0005*DPE\ Index + 11.34 \quad (7)$$

Countries above zero have higher digital entrepreneurship ecosystem development then implied by its per capita GDP (I and IV. quadrants). Countries below zero have lower digital entrepreneurship ecosystem development then implied by the trend-line (II. and III. quadrants). For countries, significantly below the trend-line (by rule of thumbs the 10% threshold is selected) is suggested to increase more on the development of the digital entrepreneurship ecosystem. Caution is advised if the DE is somewhere between 5%-10% range.

Figure 5: The four groups of countries based on the difference between DE and EE scores and the deviation from development implied trend-line.
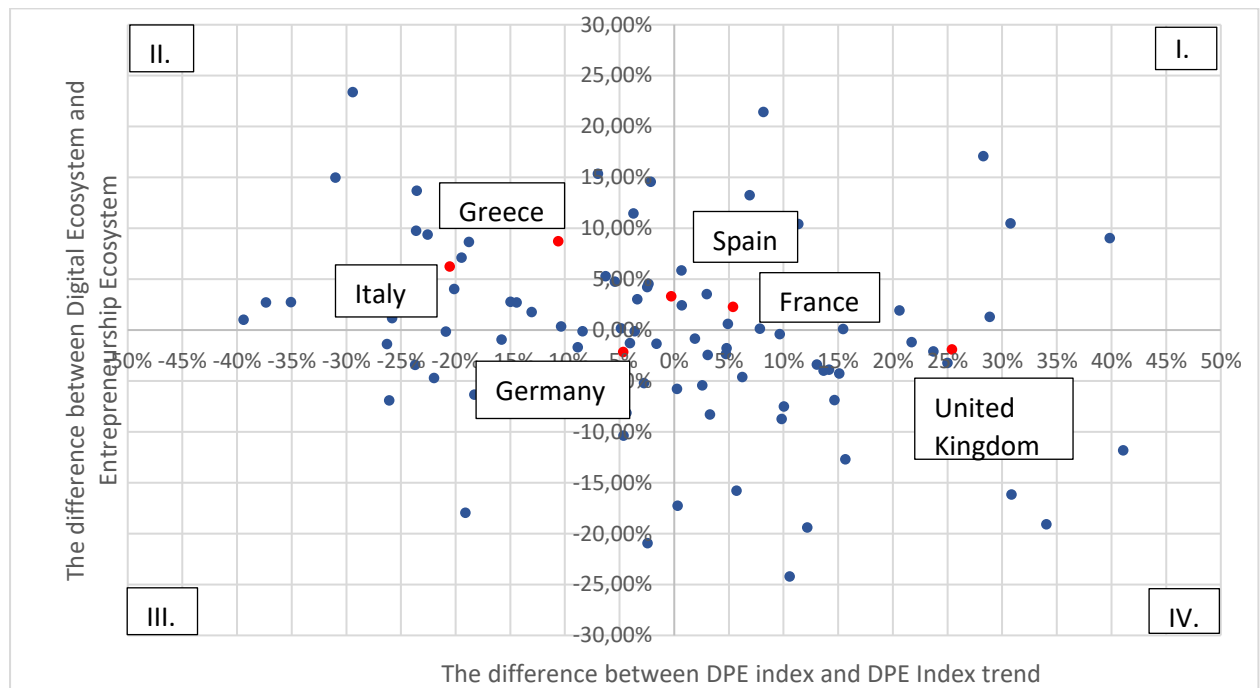
On the vertical axis, there is the difference between the digital ecosystem (DE) and the Entrepreneurship Ecosystem (EE) scores. Countries in Quadrant I and II have higher DE then EE score. In quadrants III and IV, countries have higher EE then DE scores. For a balanced development, DE and EE scores should be about the same. If the difference is higher than 10%, resources should be redirected to harmonize the digital and the entrepreneurship ecosystems. If the difference is between 5% and 10%, some resource allocation seems to be reasonable to balance the two ecosystems. So, for countries in quadrants I and II entrepreneurship ecosystem development is suggested. For countries in quadrants III and IV digital ecosystem development is more fruitful. Countries where the DPE Index-DPE Index trend difference is positive and there are within the ten percent DE-EE difference range are suggested to maintain DPE Index spending to keep space with development and to keep the balance between DE and EE.

According to Figure 5 the countries in the [-10%; 10%] range of DE and EE difference and have lower than -10% value in the DPE Index-DPE Index trend difference are considered to be optimal implying that no extra spending for DPE Index development is necessary and their DE-EE balance is roughly fine. Germany, France and Spain all belong to this group together with many innovation-driven, developed countriesand with some efficiency driven, developing countries. For the second cohort, Chile is an example.

Another group of mainly lower developed countries that have positive deviation from the development implied trend line and significantly higher DE score (quadrant I). For example, Morocco has low DPE Index score but it is higher than implied by its development. At the same time, the country's digital ecosystem is much higher than the entrepreneurship ecosystem. None of our examined countries belong to this group.

Quadrant IV countries' overall DPE Index level is sufficient; however, their digital component is relatively underdeveloped as compared to the entrepreneurship components. For example, China can be found here. China's DPE Index score is higher than implied by the trend line but its EE score is higher than its DE score (by 11.3%). Consequently, further effort is suggested to improve China's digital ecosystem. The United Kingdom, being second in the DPE Index ranking is also here, but its digital and entrepreneurship components are in balance. In fact, the positive 25% deviation from the development implied trend-line implies that UK's digital entrepreneurship ecosystem is an important factor of its growth.

There are many countries that have lower DPE Index score than implied by the trend line and have imbalances in the DE-EE context in favor of digital ecosystem development (quadrant II.). Note that we maximized the deviation up to -55% in Figure 5. Our highlighted examples are Italy and Greece. Their overall DPE Index development is well below what we could expect from these developed countries. Moreover, their digital ecosystem is more advanced than their entrepreneurship component. Though, this imbalance is below the critical 10% threshold.

In Quadrant III there are nations that spend too little to DPE Index development and their digital ecosystem is also lacking as compared to their entrepreneurship ecosystem. For example, some poorer African countries belong to this quadrant.

Table 5 provides further details about policy suggestions in terms of DEE and the DE/EE mix based on Table 4 data. The recommendations are based on the deviation from the DPE Index trend-line and the difference between DE and EE scores. As it clearly seen most countries (41) and most EU member countries (15) belong to the balanced category where DEE development should follow the development of the country with keeping the balance between DE and EE. The second largest group (19) with two EU member countries, where the DE and EE are balanced but the country is well below the development implied trend-line. Eleven countries belong to the cohort where DEE level fits to development, but the digital ecosystem requires

significant improvement. Eight countries have proper DEE level but their entrepreneurship ecosystems are at a low level. Seven countries DPE Index scores are somewhat below the trend-line and the DE and the EE are in balance. Four EU member countries can be found here. All the other groups contain less than seven countries. Note that only five EU member countries – Austria, Cyprus, Greece, Italy, and Slovakia require substantial DEE development. It is also important to add, that the trend-line is about the average performance. So if EU wants to step ahead in the digital entrepreneurship ecosystem then the proper benchmarks are the United States, the United Kingdom, and the Netherlands.

Table 5: Suggested policy recommendation with respect to DPE Index trend-line deviation, and Digital Ecosystem/Entrepreneurship Ecosystem mix

	Strong DE development (DE-EE difference is below -10%)	Some DE development (DE-EE difference is between (-5%, -10%)	Keep balance between DE and EE (DE-EE difference is between (-5%, 5%)	Some EE development (DE-EE difference is between(5%, 10%)	Strong EE development (DE-EE difference is above 10%)
Keep DEE development with GDP	Albania, Bosnia and Herzegovina, Colombia, Honduras, India, Indonesia, Peru, Philippines, Senegal, Ukraine, Vietnam	China, **Finland**, Jordan Pakistan, South Africa, Switzerland,	Argentina, Armenia, Australia, Bahrain, **Belgium**, Brazil, **Bulgaria**, Canada, Chile, Costa Rica, **Croatia, Czech Republic, Denmark**, Ecuador, Egypt, **Estonia, France, Germany**, Israel, Jamaica, Kenya, Korea, **Lithuania, Luxembourg**, Malaysia, Mexico, Montenegro, **Netherlands,** New Zealand, Norway, **Poland, Portugal**, Qatar, Singapore, **Spain**, **Sweden,** Tunisia, United Arab Emirates, United Kingdom, United States, Zambia	Kuwait, **Latvia**, Moldova, Saudi Arabia, Thailand	Georgia, Macedonia, Mauritius, Morocco, Oman, Rwanda, Serbia, Uruguay
Some DEE development (deviation from trend-line is 5%-10%)	-	**Malta**	El Salvador, **Hungary,** Iceland, **Ireland**, Nepal, **Romania, Slovenia**	Japan, Namibia	-
Overall DEE development (deviation from trend-line is over 10%)	Madagascar, Sri Lanka	**Austria,** Dominican Republic	Azerbaijan, Botswana, Burundi, Cambodia, Cameroon, **Cyprus**, Ethiopia, Guatemala, Hong Kong, Kazakhstan, Kyrgyzstan, Lebanon, Malawi, Mali, Nigeria, Panama, **Slovakia**, Taiwan, Turkey	Bangladesh, **Greece**, **Italy,** Mongolia, Paraguay, Russia	Algeria, Benin, Iran, Tanzania, Uganda, Zimbabwe

Legend: Bold letters are the EU member countries

While the DPE Index measures the digital platform-based ecosystem on a country level it is important to see where the most important platform companies reside. Figure 6 shows the top 100 platform company market values.

Figure 6: The top 100 platform companies all around the world (June 2020)
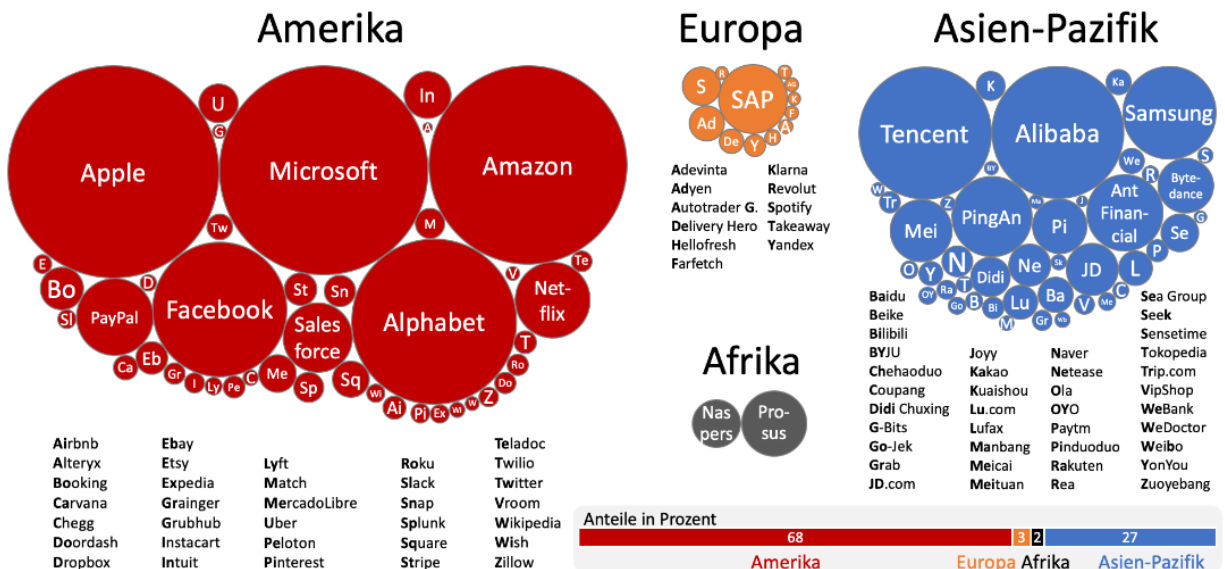
Source: https://www.netzoekonom.de/plattform-oekonomie/

It is immediately clear from Figure 6 that two countries the US and China dominate the landscape. The US alone takes more than two-third (68%) of the world platform economy based on the market value of the companies. Second, European platform based companies play a marginal role having only 3% of the market value. Third, the distribution of the top 100 platform-based companies is uneven; the first fifteen companies take around 75% of the whole market value.

Examining further the twelve European platform-based companies, there are one Norwegian, one Russian, two Netherlands, two Swedish, three German and three UK based businesses. Just comparing it to the DPE Index ranking the UK, Netherlands, Sweden and Norway are in the top ten, while Germany is 14th and Russia is 48th. It is immediately clear that strong digital-platform based ecosystem alone is not enough to nurture multi-billion dollar platform-based companies. Country size also seems to matter. Now UK is leaving the EU and the number of top platform-based EU companies narrows down to seven, and out of them only SAP is among the top 15.

Perhaps, a more unified EU could provide a more favorable environment for platform-based development.

Summary and conclusion

Recent digital and information technology revolution has a major impact on entrepreneurship. In particular, platform based developments contribute to drastically decreasing transaction costs and the appearance of new business models. This Schumpeterian type of organizational innovations has given rise to trillion dollar businesses like Apple, Alphabet, Amazon, Microsoft, or Facebook. Together with others, these platforms provide a fertile field for Kirznerian type of digital entrepreneurs. However, digital entrepreneurs require a different environmental context as compared to non-digital ones. If a country builds out its *digital ecosystem* there is no guarantee it will be implemented by existing firms. In the same vain if a country builds out its *entrepreneurial ecosystem* there is no guarantee startups will introduce new technologies. For technology to be successfully introduced, both the *digital ecosystem* and the *entrepreneurial ecosystem* need to be developed simultaneously. The digital entrepreneurship ecosystem theory developed by Sussan and Acs (2017) and amended by Song (2019), integrates the entrepreneurship ecosystem and the digital ecosystem concepts.

This paper builds on the DEE concept and provides a measurement of it. The Digital Platform Economy Index consist of four sub-indices (i.e., *Digital User Citizenship, Digital Technology Infrastructure, Digital Multi-sided Platform* and *Digital technology Entrepreneurship*), twelve pillars (i.e., *Digital Access, Digital Freedom, Digital Protection, Digital Literacy, Digital Openness, Digital Rights, Networking, Matchmaking, Financial Facilitation, Digital Adoption, Technology Absorption,* and *Technology Transfer*), and 61 indices.

At the global scale, developed Anglo-Saxon and Nordic nations lead the DPE ranking followed by other European, Asian as well as Oceania (i.e., Australia and New Zealand) prosperous countries. Many mid-developed countries from Europe, Asia and Latin America together with some oil rich countries (i.e., Bahrain, Oman, Qatar, Saudi Arabia, and United Arab Emirates) report below average DPE index scores. The group of poor performing countries, in terms of the DPE index, includes underdeveloped African and Asian countries as well as some developing European and

Latin American nations. The specific analysis for the EU reveals that for most countries (22 out of 27), they are on or above the development implied trend-line; however, they are far from the DPE top performing countries (US and UK), with the exception of the Netherlands. The gap between the US and the large EU member countries like Germany and France is significant, around 25%. Spain, Italy and Poland lag behind the US by more than 35%. It seems that EU's institutional setup supports more the self-employment type of small business than fast growing billion dollar businesses, that is, the unicorns. Recent regulations, like the General Data Protection Regulation or GDPR, focusing on ensuring that users know, understand, and consent to the data collected about them, are not really helpful and limit not only the existing non-EU businesses but also weaken EU based startups. Other EU investigations against Microsoft, Alphabet/Google or Facebook and other digital giants could only provide temporal protection for EU based platform businesses.

Another example is the German auto industry that dominates the world in many respects from the mass market to the luxury market and even the racing world. However, they have lagged in the adoption and implementation of many new technologies. Hobijn and Jovanovic (2001) suggested that new technologies will not be effectively implemented by existing firms in the absence of: awareness and skills; vintage capital; and vested interests. The German auto industry fits this analysis like a glove. The move of Tesla to Berlin, the digital capital of Europe is an indication that the future of the European auto industry may be with the startup and not the incumbent.

If the EU is to survive and prosper, the EU needs to rebalance it digital entrepreneurial ecosystem policy to promote technology innovation, platform companies and create a sustainable platform economy.

Literature

Acs, Z. J., Autio, E., & Szerb, L. (2014). National Systems of Entrepreneurship: Measurement issues and policy implications. *Research Policy*, *43*(3), 476–494. https://doi.org/10.1016/j.respol.2013.08.016

Acs, Zoltan J., Stam, E., Audretsch, D. B., & O'Connor, A. (2017). The lineages of the entrepreneurial ecosystem approach. *Small Business Economics*, *49*(1), 1–10. https://doi.org/10.1007/s11187-017-9864-8

Autio, E., Szerb, L., Komlosi, E., & Tiszberger, M. (2019). *EIDES 2019-The European Index of Digital Entrepreneurship Systems* (No. JRC117495). Joint Research Centre (Seville site).

Autio, E., Szerb, L., Komlosi, E., & Tiszberger, M. (2018). The European index of digital entrepreneurship systems. *Publications Office of the European Union (Ed.), JRC Technical Reports*, *153*.

Cavallo, A., Ghezzi, A., & Balocco, R. (2018). Entrepreneurial ecosystem research: Present debates and future directions. *International Entrepreneurship and Management Journal*. https://doi.org/10.1007/s11365-018-0526-3

Cusumano, M. A., Gawer, A., & Yoffie, D. B. (2019). *The business of platforms: Strategy in the age of digital competition, innovation, and power*. New York, NY: HarperCollins.

Elia, G., Margherita, A., & Passiante, G. (2020). Digital entrepreneurship ecosystem: How digital technologies and collective intelligence are reshaping the entrepreneurial process. *Technological Forecasting and Social Change*, *150*, 119791.

Evans, D. S., & Schmalensee, R. (2016). *Matchmakers: The new economics of multi-sided platforms*. Boston, Massachusetts: Harvard Business Review Press.

Ferguson, N. (2019). *The square and the tower: Networks and power, from the Freemasons to Facebook*. Penguin Books.

Gawer, A. (Ed.). (2009). *Platforms, Markets, and Innovation*. Cheltenham, UK ; Northampton, MA: Edward Elgar.

Goldfarb, A., &Tucker, C. (2019). Digital Economics. *Journal of Economic Literature*, 57(1), 3-43.

Gompers, P., & Lerner, J. (2001). The venture capital revolution. *Journal of Economic Perspectives*, *15*(2), 145-168.

Hobijn, B., & Jovanovic, B. (2001). The Information-Technology Revolution and the Stock Market: Evidence. *American Economic Review*, *91*(5), 1203–1220. https://doi.org/10.1257/aer.91.5.1203

Isenberg, D. J. (2010). How to start an entrepreneurial revolution. *Harvard business review*, *88*(6), 40-50.

Jovanovic, B. (1982). Selection and the Evolution of Industry. *Econometrica*, *50*(3), 649–670. https://doi.org/10.2307/1912606

Jovanovic, B. (2001). New Technology and The Small Firm. *Small Business Economics*, *16*(1), 53–56. https://doi.org/10.1023/A:1011132809150

Jullien, B. 2012. "Two-Sided B to B Platforms." In *The Oxford Handbook of the Digital Economy*, edited by Martin Peitz and Joel Waldfogel, 161–85. Oxford and New York: Oxford University Press.

Kenney, M., & Zysman, J. (2016). The rise of the platform economy. *Issues in science and technology*, *32*(3), 61.

Li, W., Badr, Y., & Biennier, F. (2012). Digital ecosystems: challenges and prospects. In *proceedings of the international conference on management of Emergent Digital EcoSystems* (pp. 117-122).

Malecki, E. J. (2018). Entrepreneurship and entrepreneurial ecosystems. *Geography Compass*, *12*(3). https://doi.org/10.1111/gec3.12359

Nambisan, S. (2017). Digital Entrepreneurship: Toward a Digital Technology Perspective of Entrepreneurship. *Entrepreneurship Theory and Practice*, *41*(6), 1029–1055. https://doi.org/10.1111/etap.12254

Naudé, W. (2016). "Is European Entrepreneurship in Crisis?" *IZA Working Paper, DP* 9817.

Peitz, M., & Waldfogel, J. (Eds.). (2012). *The Oxford handbook of the digital economy*. Oxford University Press.

Rochet, J.-C., & Tirole, J. (2006). Two-sided markets: A progress report. *The RAND Journal of Economics*, *37*(3), 645–667. https://doi.org/10.1111/j.1756-2171.2006.tb00036.x

Root, H.L. (2020) *Network Origins of the Global Economy*, Cambridge University Press.

Saadatmand, F., Lindgren, R., & Schultze, U. (2019). Configurations of platform organizations: Implications for complementor engagement. *Research Policy*, *48*(8), 103770. https://doi.org/10.1016/j.respol.2019.03.015

Sahut, J.-M., Iandoli, L., & Teulon, F. (2019). The age of digital entrepreneurship. *Small Business Economics*. https://doi.org/10.1007/s11187-019-00260-8

Shannon, C. (1948). A Mathemataical Theory of Communication, *Bell Systems Technical Journal,* 27(3), 379-423.

Song, A. K. (2019). The Digital Entrepreneurial Ecosystem—A critique and reconfiguration. *Small Business Economics*, *53*(3), 569–590. https://doi.org/10.1007/s11187-019-00232-y

Spigel, B. (2017). The relational organization of entrepreneurial ecosystems. *Entrepreneurship Theory and Practice*, *41*(1), 49-72.

Stam, E. (2015). Entrepreneurial Ecosystems and Regional Policy: A Sympathetic Critique. *European Planning Studies*, *23*(9), 1759–1769. https://doi.org/10.1080/09654313.2015.1061484

Szerb, L., Lafuente, E., Horváth, K., & Páger, B. (2019). The relevance of quantity and quality entrepreneurship for regional performance: the moderating role of the entrepreneurial ecosystem. *Regional Studies*, *53*(9), 1308-1320.

Sussan, F., & Acs, Z. J. (2017). The digital entrepreneurial ecosystem. *Small Business Economics*, *49*(1), 55–73. https://doi.org/10.1007/s11187-017-9867-5

Weill, P., & Woerner, S. L. (2015). Thriving in an increasingly digital ecosystem. *MIT Sloan Management Review*, *56*(4), 27.

1. Appendix: The applied indicators in the Digital Entrepreneurship Index

Table A.1 The applied indicators of DTIsub-index

DIG_P1_I1	*Laws relating to ICTs, 1-7 (best)* World Economic Forum, Executive Opinion Survey, 2014 and 2015 editions Digital Openness - Institutions	How developed are your country's laws relating to the use of ICTs (e.g., e-commerce, digital signatures, consumer protection)? [1 = not developed at all; 7 = extremely well developed]
DIG_P1_I2	*Global Cyberlaw Tracker* UNCTAD, 19/12/2017 Digital Openness - Institutions	It tracks the state of e-commerce legislation in the field of e-transactions, consumer protection, data protection/privacy and cybercrime adoption in the 194 UNCTAD member states. It indicates whether or not a given country has adopted legislation, or has a draft law pending adoption. In some instances where information about a country's legislation adoption was not readily available, 'no data' is indicated.
DIG_P1_I3	*Percentage of Individuals using the Internet* World Telecommunication/ICT Indicators Database, 2018 (2016 data) Digital Openness - Digital technology	Percentage of Individuals using the Internet
DIG_P1_I4	*Percentage of households with Internet access at home* World Telecommunication/ICT Indicators Database, 2018 (2017 data) Digital Openness - Digital technology	Percentage of households with Internet access at home
DIG_P2_I1	*Business freedom* Index of Economic Freedom, 2018 (data 2016, 2017) Digital Freedom - Institutions	Business freedom is an overall indicator of the efficiency of government regulation of business. The quantitative score is derived from an array of measurements of the difficulty of starting, operating, and closing a business.
DIG_P2_I2	*Freedom of the Press* Freedom House, 2017 (data 2016) Digital Freedom - Institutions	Annual report on media independence around the world, assesses the degree of print, broadcast, and digital media freedom in 199 countries and territories
	Freedom in the World Freedom House, 2018 (data 2017) Digital Freedom - Institutions	Freedom in the World is an annual global report on political rights and civil liberties, composed of numerical ratings and descriptive texts for each country and a select group of territories. The 2018 edition covers developments in 195 countries and 14 territories from January 1, 2017, through December 31, 2017. It uses a three-tiered system consisting of scores, ratings, and status. The complete list of the questions used in the scoring process, and the tables for converting scores to ratings and ratings to status, appear at the end of this essay.
DIG_P2_I3	*Internet & telephony competition/Global Cyberlaw Tracker* ICT Regualtory Tracker, ITU, 2017 Digital Freedom - Digital technology	Competition framework for the ICT sector (level of competition in the main market segments).
DIG_P2_I4	*Generic top-level domains (gTLDs)* Global Innovation Index, 2017 (data 2016) Digital Freedom- Digital technology	Generic top-level domains (gTLDs) (per thousand population 15–69 years old)
	Internet domains / 1000 population Webhosting, 2015 Digital Freedom- Digital technology	Number of active Internet domain registrations per 1000 number of population.

DIG_P3_I1	**Software piracy rate, % software installed** WEF Network Readiness Index, 2013 data Digital Protection - Digital technology	Unlicensed software units as a percentage of total software units installed. This measure covers piracy of all packaged software that runs on personal computers (PCs), including desktops, laptops, and ultra-portables, including netbooks. This includes operating systems; systems software such as databases and security packages; business applications; and consumer applications such as games, personal finance, and reference software. The study does not include software that runs on servers or mainframes, or software loaded onto tablets or smart phones.
DIG_P3_I2	**Secure Internet servers/million pop.** WEF Network Readiness Index 2016 report (2014 data) Digital Protection - Digital technology	Secure Internet servers per million population.
DIG_P3_I3	**Corruption Perception Index** Corruption Perception Index (CPI), 2017 (data 2016-2018) Digital Protection - Institutions	The index, which ranks 180 countries and territories by their perceived levels of public sector corruption according to experts and businesspeople, uses a scale of 0 to 100, where 0 is highly corrupt and 100 is very clean.
DIG_P3_I4	**Globa Cybersecurity Index legal subisndex (GCI), 2017** Digital Protection - Institutions	The GCI revolves around the ITU Global Cybersecurity Agenda (GCA) and its five pillars (legal, technical, organizational, capacity building and cooperation). For each of these pillars, questions were developed to assess commitment. Legal component is based on the existence of legal institutions and frameworks dealing with cybersecurity and cybercrime.

Table A.2 The applied indicators of the DUC sub-index

DUC_P1_I1	**Digital skills among population** Global Competitiveness Index, 2017 , WEF Digital literacy – Users	Executive Opinion Survey: "In your country, to what extent does the active population possess sufficient digital skills (e.g. computer skills, basic coding, digital reading)? (1= not at all, 7= to a great extent)"
DUC_P1_I2	**Number of search by users in a country** The Digital Country Index, 2017 Digital literacy – Users	First presented in 2015, the Digital Country Index tracks the number of searches performed by all worldwide citizens toward any given country, in connection with six topic areas: tourism, investment, exports, talent and national prominence.
DUC_P1_I3	**Quality of the education system, 1-7 (best)** Global Competitiveness Index, 2017-2018 (data 2015-2016 average) Digital Literacy- Institutions	In your country, how well does the education system meet the needs of a competitive economy? [1 = not well at all; 7 = extremely well]
DUC_P1_I4	**Internet access in schools, 1-7 (best)** Global Competitiveness Index, 2017-2018 (data 2015-2016 average) Digital Literacy- Institutions	In your country, to what extent is the Internet used in schools for learning purposes? [1 = not at all; 7 = to a great extent]
DUC_P2_I1	**Fixed broadband Internet subscriptions/100 pop.** Global Competitiveness Index, 2017-2018 (2016 or most recent data) Digital access – Users	Fixed-broadband Internet subscriptions per 100 population
	Int'l Internet bandwidth, kb/s per user Global Competitiveness Index, 2017-2018 (2016 data) Digital access – Users	International Internet bandwidth (kb/s) per Internet user
DUC_P2_I2	**Percentage of households equipped with a personal computer** World Telecommunication/ICT Indicators Database, 4 January 2018 (2017 data) Digital access – Users	Percentage of households equipped with a personal computer

	Percentage of individuals using a computer World Telecommunication/ICT Indicators Database, 4 January 2018 (2017 data) Digital access – Users	Percentage of individuals using a computer
DUC_P2_I3	*Global Cybersecurity Index technical subindex* ITU, 2017 Digital access – Institution	Technical: Measured based on the existence of technical institutions and frameworks dealing with cybersecurity.
DUC_P2_I4	*Global Cybersecurity Index technical subindex* ITU, 2017 Digital access – Institution	Organizational: Measured based on the existence of policy coordination institutions and strategies for cybersecurity development at the national level.
DUC_P3_I1	*Net infection ratio* Securelist statistics, Kaspersky, Download: 17/03/2018 (monthly data) Digital Rights- Users	The map shows the percentages of users on whose devices Kaspersky Lab products intercepted Local infections in the Last 24 hours. KL products' users are always protected from all – even the very latest – threats.
DUC_P3_I2	*Internet censorship and surveillance* Wikipedia, 2018 Digital Rights- Users	Detailed country by country information on Internet censorship and surveillance is provided in the Freedom on the Net reports from Freedom House, by the OpenNet Initiative, by Reporters Without Borders, and in the Country Reports on Human Rights Practices from the U.S. State Department Bureau of Democracy, Human Rights, and Labor. The ratings produced by several of these organizations are summarized below as well as in the Censorship by country article. Four category rating: 1: pervasive; 2: selective; 3: substantial; 4: little or none
DUC_P3_I3	*Personal rights* The Global Talent Competitiveness Report, 2018 (2016 data) Digital Rights -Institution	Personal Rights are a component in the Opportunity Dimension of the Social Progress Index. This component is based on five variables: Political rights, Freedom of speech, Freedom of assembly/association, Freedom of movement, and Private property rights.
	Fundamental rights Rule of Law Index, World Justice Project, 2017-2018 Digital Rights -Institution	Equal treatment and absence of discrimination 4.2 The right to life and security of the person is effectively guaranteed 4.3 Due process of law and rights of the accused 4.4 Freedom of opinion and expression is effectively guaranteed 4.5 Freedom of belief and religion is effectively guaranteed 4.6 Freedom from arbitrary interference with privacy is effectively guaranteed 4.7 Freedom of assembly and association is effectively guaranteed 4.8 Fundamental labor rights are effectively guaranteed
	Property rights International Property Rights Index, Property Rights Alliance, 2013 Digital Rights -Institution	The average of the two subindexes as Physical property rights and Intellectual property rights from International Property Rights Index

Table A.3 The applied indicators of the DMSP sub-index

DMSP_P1_I1	*Use of virtual social networks, 1-7 (best)* WEF Network Readiness Index, 2016 (2014-2015 average data) Networking - Users	In your country, how widely are virtual social networks used (e.g., Facebook, Twitter, LinkedIn)? [1 = not at all used; 7 = used extensively]
DMSP_P1_I2	*Social media penetration* 2017 DIGITAL YEARBOOK INTERNET, SOCIAL MEDIA, AND MOBILE DATA FOR Networking - Users	Active social media users, penetration (%)
DMSP_P1_I3	*Use of virtual professional networks* The Global Talent Competitiveness Report, 2018 (2015 data)	LinkedIn users refers to the number of registered LinkedIn accounts per 1,000 labour force (15–64 years old).

	Networking - Users	
DMSP_P1_I4	**ICT use for business-to-business transactions, 1-7 (best)** WEF Network Readiness Index, 2016 (2014-2015 average data) Networking - Agent	In your country, to what extent do businesses use ICTs for transactions with other businesses? [1 = not at all; 7 = to a great extent]
DMSP_P1_I5	**Business-to-consumer Internet use, 1-7 (best)** WEF Network Readiness Index, 2016 (2014-2015 average data) Networking - Agent	In your country, to what extent do businesses use the Internet for selling their goods and services to consumers? [1 = not at all; 7 = to a great extent]
DMSP_P2_I1	**Wikipedia yearly edits** Global Innovation Index, 2017 (2016 data) Matchmaking - Users	Wikipedia yearly edits by country (per million population 15–69 years old) | 2014 Data extracted from Wikimedia Foundation's internal data sources. For every country with more than 100,000 edit counts in 2016, the data from 2016 are used. For all other countries, the data from 2014 are utilized. The data excludes bot contributions to the extent that is identifiable in the data sources. Data are reported per million population 15–69 years old.
DMSP_P2_I2	**Video uploads on YouTube** Global Innovation Index, 2017, (2016 data) Matchmaking - Users	Number of video uploads on YouTube (scaled by population 15–69 years old) | 2015 Total number of video uploads on YouTube, per country, scaled by population 15–69 years old. The raw data are survey based: the country of affiliation is chosen by each user on the basis of a multi-choice selection. This metric counts all video upload events by users. For confidentiality reasons, only normalized values are reported; while relative positions are preserved, magnitudes are not
DMSP_P2_I3	**Number of professional developers / population** **Developer Survey Results, 2017 (2016 data)** Matchmaking - Agent	Ratio of professional developers
DMSP_P3_I1	**Credit card (% age 15+)** World Bank Global Financial Inclusion, 2017 Financial facilitation - Users	Denotes the percentage of respondents who report having a credit card (% age 15+). [ts: data are available for multiple waves].
	Debit card (% age 15+) World Bank Global Financial Inclusion, 2017 Financial facilitation - Users	Denotes the percentage of respondents who report having a debit card (% age 15+). [ts: data are available for multiple waves].
DMSP_P3_I2	**Used the internet to pay bills or to buy something online in the past year (% age 15+)** World Bank Global Financial Inclusion, 2017 Financial facilitation - Users	Denotes the percentage of respondents who report paying bills or making purchases online using the Internet in the past 12 months (% age 15+). [w2: data are available for wave 2].
DMSP_P3_I3	**Used a mobile phone or the internet to access a financial institution account in the past year (% age 15+)** World Bank Global Financial Inclusion, 2017 Financial facilitation - Users	Denotes the percentage of respondents who used a mobile phone or the internet to access a financial institution account in the past year (% with an account, age 15+). [w2: data are available for wave 2].
DMSP_P3_I4	**Made or received digital payments in the past year (% age 15+)** Financial facilitation - Users	Denotes the percentage of respondents who report making or receiving digital payments in the past 12 months (% age 15+).

DMSP_P3_I5	**Depth of Capital Market Sub-Index Score (US 2016=100)** World Bank Global Financial Inclusion, 2017 (data 2016) Financial facilitation - Agent	The Depth of Capital Market is one of the six sub-indices of the Venture Capital and Private Equity index. This variable is a complex measure of the size and liquidity of the stock market, level of IPO, M&A and debt and credit market activity.
DMSP_P3_I6	**Fintech business** dealroom, 26/03/2018 Financial facilitation - Agent	The number of financial technology businesses standardized by the number of population 2018, own calculation
DMSP_P3_I7	**Venture capital availability** Global Competitiveness Index, 2017-2018 (2016-2017 average data) Financial facilitation - Agent	Answers to the quation: In your country, how easy is it for entrepreneurs with innovative but risky projects to find venture capital? [1 = extremely difficlut; 7 = extremely easy], (World Economic Forum dataset)

Table A.4 The applied indicators of DTE sub-index

DTE_P1_I1	**Quality of electricity supply, 1-7 (best)** Global Competitiveness Index, 2017.2018 (2016-2017 average data) Digital adoption - Digital technology	In your country, how reliable is the electricity supply (lack of interruptions and lack of voltage fluctuations)? [1 = extremely unreliable; 7 = extremely reliable]
	Electricity production, kWh/capita WEF Network Readiness Index, 2016 (2013 data) Digital adoption - Digital technology	Electricity production (kWh) per capita
DTE_P1_I2	**Fixed telephone lines/100 pop.** Global Competitiveness Index, 2017.2018 (2016-2017 average data) Digital adoption - Digital technology	Number of fixed-telephone lines per 100 population
DTE_P1_I3	**Mobile telephone subscriptions/100 pop.*** Global Competitiveness Index, 2017.2018 (2016-2017 average data) Digital adoption - Digital technology	Number of mobile-cellular telephone subscriptions per 100 population
DTE_P1_I4	**Mobile network coverage, % pop.** WEF Network Readiness Index, 2016 (2014 data) Digital adoption - Digital technology	Percentage of total population covered by a mobile network signal
DTE_P1_I5	**Computer software spending** Global Innovation Index, 2018(2016 data) Digital adoption - Agent	Total computer software spending (% of GDP)
DTE_P1_I6	**Skills of workforce** Global Innovation Index, 2018 Digital adoption - Agent	Skills, a pilar of GCI, consist of two parts, skills of current workforca and skills of future workforce
DTE_P2_I1	**Data centers** Data Centers Catalog, 2019 Technology absorption – Digital technology	Combined data centers number and density based on population
DTE_P2_I2	**Availability of latest technologies, 1-7 (best)** Global Competitiveness Index, 2017-2018 (2016-2017 average data) Digital technology absorption – Technology absorption – Digital technology	In your country, to what extent are the latest technologies available? [1 = not at all; 7 = to a great extent]

DTE_P2_I3	**Knowledge absorption (sub-index in GII)** Global Innovation Index, 2017 (data 2016) Digital technology absorption – Technology absorption - Agent	It reveals how good economies are at absorbing knowledge. A complex variable from GII consisting of five indicators as: Intellectual property payments, High-tech
DTE_P2_I4	**Impact of ICTs on business models, 1-7 (best)** Global Innovation Index, 2017 (2016 data) Technology absorption - Agent	Average answer to the question: In your country, to what extent do ICTs enable new business models? [1=not at all; 7=to a great extent]
	Impact of ICTs on new organizational models, 1-7 (best) Global Innovation Index, 2017 (2016 data) Technology absorption - Agent	Average answer to the question: In your country, to what extent do ICTs enable new organizational models?
DTE_P3_I1	**Knowledge and technology outputs (GII)** The Global Innovation Index, 2017 (2016 data) Technology transfer – Digital technology	A subindex of GII conssiting of three part, knowledge creation, knowledge impact and knowledge diffusion
DTE_P1_I2	**Capacity for innovation** Global Competitiveness Index, 2007-2017 Technology transfer – Digital technology	In your country, to what extent do companies have the capacity to innovate? [1 = not at all; 7 = to a great extent]
DTE_P2_I3	**High level skills (GTCI)** The Global Talent Competitiveness Report, 2018 (data 2015) Technology transfer - Agent	The average of six indicators as Workforce with tertiary education, Population with tertiary education, Professionals, Researchers, Senior officials and managers, Availability of scientists and engineers
DTE_P2_I4	**Statups** Startup ranking, 2018 Technology transfer - Agent	Number of Startups, a normalized average of the population standardized startups and the log of startups in the country.