The Digital Entrepreneurship Ecosystem Index 2021

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About The Global Entrepreneurship and Development Institute

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The Global Entrepreneurship and Development Institute (The GEDI Institute) is the leading research organization in advancing knowledge on the relationship between entrepreneurship, economic development, and prosperity. The Institute, headquartered in Washington, DC, was founded by leading entrepreneurship scholars from George Mason University, the University of Pécs, Imperial College London, and the London School of Economics. For a long time, the Institute's flagship project was the Global Entrepreneurship Index (GEI), a breakthrough advance in measuring the quality and dynamics of entrepreneurship ecosystems at a national and regional level. The GEI project was completed in 2019 and a new index developed. Incorporating changes caused by the information technology revolution and globalization, the Institute has turned its focus to the connection between digitalization and entrepreneurship. This newly developed measure, called the Digital Entrepreneurship Ecosystem Index, is a country-level composite indicator of the global digital ecosystem. We hope it will be as helpful as the GEI.

Preface

In April 2020, The GEDI launched a preliminary report about measuring the digital entrepreneurship ecosystem. Over time, the concept has gone through several iterations and is now ready to be published. Like the Global Entrepreneurship Index products, we are planning to continue this research and to publish yearly reports. However, digital entrepreneurship ecosystems are fastly evolving, now technologies and now data are coming. The conceptual model behind the DEE Index should reflect to these changes, so this version could also go through some alteration in the future.

The application of big data, new algorithms, and cloud computing is creating a global digital platform economy built around platform companies. The Digital Entrepreneurship Ecosystem Index (DEE Index) integrates two separate but related literatures on ecosystems, namely, the digital ecosystem and the entrepreneurial ecosystem. This new framework situates digital entrepreneurship within the broader context of users, platforms, and institutions, such that two biotic entities (users and agents) actuate individual agency, and two abiotic components (digital infrastructure and digital platforms) form the external environment. If a country builds out its digital ecosystem, there is no guarantee it will be exploited by existing firms. Startups' adoption of new technologies because of an entrepreneurial ecosystem is also uncertain. For technology to be introduced successfully, the digital ecosystem and the entrepreneurial ecosystem must be developed simultaneously.

To measure the size of the digital platform economy, we have developed the DEE Index, a multi-dimensional, composite indicator. The DEE Index framework includes 12 pillars that integrate the digital and the entrepreneurship ecosystems. Here, we report on the DEE Index, the four sub-indices, and the 12 pillar values for 115 countries; we also provide a cluster analysis based on the 12 pillars. The developed Anglo-Saxon and Nordic countries lead the DEE Index ranking, followed by other European and Asian nations, New Zealand, and Australia. Many mid-developed European, Asian, and Latin American countries and a group of oil-rich countries (i.e., Bahrain, Oman, Qatar, Saudi Arabia, and United Arab Emirates) report below-average DEE Index scores, while developing economies in Africa, Asia, Europe, and Latin America are in the group of poorly performing countries. The DEE Index results reveal that most European Union (EU) member states (22 out of 27) are on or above the trend line; however, except for The Netherlands, they are below the two top DEE performers (the US and UK).

While it is useful to identify the common components of the digital platform economy ecosystem, policy recommendations should be individual and tailor-made. This report offers policy recommendations on three levels and are based on the harmonization of digital and entrepreneurship ecosystem components, and the 12 pillars. First, we identify the countries that are below the development-implied trend line, and which should spend more on improving their digital platform economy ecosystem. Next, we examine the balance of the digital and the entrepreneurship ecosystems. Imbalances could result in asynchronous operation; thus a healthy digital platform economy requires both digital and entrepreneurial ecosystem components. Finding the weak components of the digital platform economy ecosystem constitutes the third-level policy propositions. Weak components, called bottlenecks, could prevent a country from fully exploiting the possibilities provided by the stronger elements of the ecosystem. We center our focus on the European countries.

1. 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 a need for new firms.[1] Technology breakthroughs favor the formation of new firms for three reasons: They provide awareness and skills, vintage capital, and vested interests. The stock market incumbents of the day were not ready to implement new digital technologies, thus it took new firms to bring the technology to market after the mid-1980s.The stock prices of incumbents fell immediately. New venture capital flowed to startups that built the new industries in the United States, but this did not occur in Europe (Gompers & Lerner, 2001). Between 1980 and 2020, the U.S. stock market increased thirty-fold. The five most valuable public companies in the United States in 2020—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), which reduces the cost of data storage, computation, and transmission. Digital economics examines whether and how digital technology changes economic activity (Goldfarb & Tucker, 2019). Digital technologies reduce five distinct types of costs that affect economic activities: search, replication, transportation, tracking, and verification. Reducing 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 through lower search costs, lower reproduction costs, and lower verification costs (Goldfarb & Tucker, 2019, p. 13). The literature on digital economics has examined how digital technology changes economic activity; less has been written about how it affects the platform economy.

In this report, we provide a framework to promote better understanding of the platform economy, multi-sided 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

[1] Also see Greenwood and Jovanovic (1999)
[2] See https://www.androidcentral.com/alphabet-becomes-fourth-trillion-dollar-company; accessed 2/14/2020.

interaction.[3] If the industrial revolution was organized around the factory, today's changes are organized around these digital platforms, loosely defined." 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 multi-sided digital 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 by digital platforms—that is, technology. Therefore, one hallmark of the platform economy is the creation of markets where they did not exist by increased matching and the spread of platform-based businesses (Cusumano, Gawer, & Yoffie, 2019). A question that has received little attention is how the ITR has affected the organization of the firm. In other words, how do lower search costs affect firm organization? Lower search and verification costs have led to a new form of organization—the platform-based ecosystem.

The newly created Digital Entrepreneurship Ecosystem Index (DEE Index) provides a country-level measure of the digital entrepreneurship ecosystem centering on the digital platform economy. The DEE Index consists of twelve pillars and four sub-indices: Digital Multisided Platforms, Digital User Citizenship, Digital Technology Entrepreneurship, and Digital Technology Infrastructure. These sub-indices include the key economic, business, social, and policy issues: competition, privacy, innovation, and security, respectively (Sussan & Acs, 2017; Song, 2019). Building on the National Systems of Entrepreneurship methodology (Acs, Autio, & Szerb, 2014), we calculate the DEE Index scores for 115 countries. A major advantage of this index is that it allows us to make international comparisons about digital efficiency across countries and over time.

Following the conceptual description of the digital platform economy, in Chapter 3 we provide a detailed description of the structure of the DEE Index, focusing on the 12 pillars. In Chapter 4, we report the DEE Index scores and ranking for 115 countries, which represent all regions of the world. We use cluster analysis to classify the countries into four groups, as well as a regional-level analysis based on the World Bank classification. Our index-building methodology makes it possible to

[3] Also see Peitz and Waldfogel (2012).

identify the critical weak points in the efficient operations of the digital entrepreneurship ecosystem. In Chapter 5, we offer policy recommendations that are individual, country sensitive, and include the overall ecosystem development, the balance of the digital and entrepreneurship components, and the identification of bottlenecks across the 12 pillars. Finally, using the new measure of the DEE Index, we examine the EU's platform economy dilemma.

2. The concept of the platform-based digital entrepreneurship ecosystem

The transition from a managed economy in the 20th century to a digital platform economy in the 21st century is perhaps best summed up by Historian Niall Ferguson (2019) 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 the hierarchy, and the crucial incentive that favored the 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 no one 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 there is an extensive literature on entrepreneurial ecosystems, this literature is misleading. As many have argued (Stam, 2015), entrepreneurial ecosystems appear to be a regional or local phenomenon.[4] However, when one compares entrepreneurial ecosystems with platform-based ecosystems, including the role of digital technology, the platform-based ecosystem becomes global in nature with billions of users and millions of agents (Sussan & Acs, 2017). Moreover, these ecosystems are developed and nurtured not by regions or governments but by platform organizations. Ecosystem governance—that is, the rules for who gets on a platform and what constitutes good behavior—is determined by the platform firm owners.

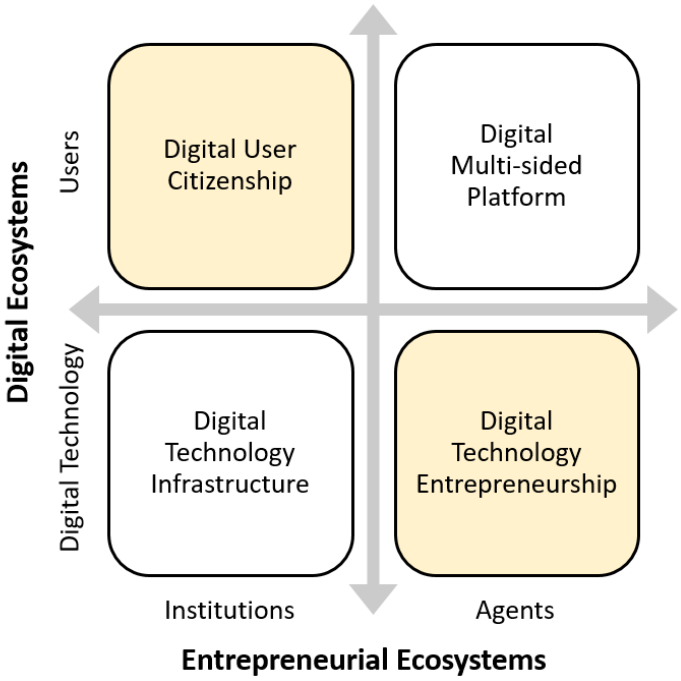
Sussan and Acs (2017) were among the first to recognize this shortcoming in the ecosystem literature. They observed that a significant gap exists in the conceptualization of entrepreneurship in the digital age precisely because it ignored the fundamental role of knowledge as a resource in the economy. To address this gap, Sussan and Acs (2017) proposed the platform-based ecosystem, a novel framework also known as the Digital Entrepreneurial Ecosystem (DEE), which integrates two separate but related ecosystem literatures, 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

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

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 include multi-sided platforms.

The DEE framework consists of four concepts: (1) Digital User Citizenship (DUC), which includes users on the demand side, agents on the supply side, and influential institutions; (2) Digital Technology Entrepreneurship (DTE), which includes app developers and various agents that contribute to entrepreneurial innovation, experimentation, and value creation; (3) Digital Multi-sided Platforms (DMSP), which orchestrate social and economic activities between users and agents; and (4) Digital Technology Infrastructure (DTI), which pertains to all regulations that govern technical, social, and economic activities of the digital technology.

1. Figure The platform-based digital entrepreneurship ecosystem



Source: Song (2019, p. 576)

First, protecting users' privacy is critical for a healthy and active DUC. If the public trust is eroded, the sustainability of the DEE suffers. Erosion of trust in platforms can lead to a decline in user activity or membership. For example, Facebook's scandal involving Cambridge Analytica exposed millions of users and became 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, DTE 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 that ease the entrepreneurial innovation process and offers a fair profit-share plan. Some critics have complained over the years that Apple's high developer commissions and fierce control over its app store can limit experimentation, entrepreneurial innovation, and value creation.

Third, DMSP are the key organizational innovation of the ITR (Rochet & Tirole, 2003 , 2006; Gawer 2009; Evans & 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 DMSP will stifle competition, innovation, and entrepreneurial activities, resulting in a welfare loss for consumers and society as a whole. For example, European regulators have penalized Google for three anti-trust violations: 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, DTI 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 DEE, which is responsible for keeping the digital economy open and secure. Chinese smartphone and telecommunication giant Huawei have been accused of being controlled by the Chinese government and of using its equipment to spy on companies and countries. These allegations about control, ownership, and fraud have raised questions as to whether Huawei 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.

1. Table Keys to building a sustainable Digital Platform Economy

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

In addition to the aforementioned conditions, one must point out the role digital finance plays in building a sustainable DEE. Secure and reliable digital technologies are a necessary precondition for online financial transactions to flourish. Migration to a cashless society is a necessary first step that users will be inclined to take only if there are tangible benefits. One such benefit is lower transaction costs—the seamless payment experience between users and agents. Digital finance has also transformed capital markets. One rather remarkable trend is the emergence of crowdfunding as an alternative method to raising capital. Crowdfunding is a concerted effort to source funding online, much like knowledge commons efforts to source knowledge online. Another important trend is the rise of digital platforms, many of which are unicorns. Startups are reaching a $1 billion or even $10 billion valuation (e.g., decacorns) at a faster pace: the average time for a US technology company to go public has gone from eleven years in 1999 to four years in 2011. The formation of megafunds, such as the Softbank's $100 billion Vision Fund, and the availability of venture capital increasingly leave little incentive for platform startups to go public. Behind this is the fact that demand-side driven businesses tend to take a long time to develop a sustainable revenue model; going public would subject them to scrutiny and pressure could drive down the value. In short, finding sustained long-term growth remains elusive.

3. From concept to measurement: The 12 pillars and their measurement

While ecosystem theories and concepts have a relatively long history with both entrepreneurial ecosystems (Acs et al., 2017) and digital ecosystems (Li, Badr, & Biennier, 2012; Weill & Woerner, 2015), the digital entrepreneurship ecosystem and a platform-based economy research have emerged only recently (Elia, Margherita, & Passiante, 2020; Nambisan 2017; Sahut, Iandoli, & Teulon, 2019). The 2010s were about the conceptualization and the identification of the DEE components. However, the measurement of DEE is still in the infantry phase lagging behind conceptual developments. Some argue that all ecosystems are exclusive, as each has its unique component structure, strengths, and weaknesses. Consequently, case studies are more appropriate than simple or composite indicators to describe the ecosystem phenomenon (Isenberg, 2010; Spigel, 2017). While we agree that the specifics of each ecosystem can be viewed up close, when looking from a certain distance, one can recognize the common structures and features (Szerb et al., 2019). Accurate measurements are vital for three reasons. First, solid policy recommendations should be based on appropriate measures. Second, one can recognize the relative development of a particular unit by comparing it to other units' rankings and index scores. And third, an ecosystem's strengths and weaknesses can be identified from a benchmarking perspective.

While measures of digital and entrepreneurship ecosystems have been available for some time, there are only two country-level measure, the European Index of Digital Entrepreneurship Systems (EIDES) (Autio et al., 2018, 2019) and its Asian version, the Asian index of Digital Entrepreneurship Systems (AIDES) (Autio et al 2021). EIDES and AIDES have their theoretical roots in the entrepreneurship ecosystem concept, where the entrepreneurship ecosystem pillars are contextualized by their digital counterparts. This notion reflects the general use of digitalization, of digital technologies, in particular. The DEE Index differs from EIDES, in that the latter conceptualizes entrepreneurship ecosystems based on three business-development stages (stand up, start up, and scale up), whereas the former focuses on the context of users, agents, digital technologies, and institutions to fully capture the systemic developments, as identified by Jovanovic (1982, 2001). Furthermore, the DEE Index is centered around platformization, rather than solely on the use or application of digital technologies. Finally, EIDES is used only for

EU member countries AIDES for Asian countries, while the DEE Index includes 115 nations from all over the world. The former version of the DEE index is the Digital Platform Economy (DEE) Index (Szerb et al 2020). DEE is a more advanced measure of digital entrepreneurship ecosystem. The changes are both conceptual and methodological ones. First, we have improved the Digital Technology Entrepreneurship (DTE) component to incorporate a larger part of the digital entrepreneurship ecosystem. We detail out the changes later in this chapter. Therefore, DTE is capturing not only the platform-based digital entrepreneurship and innovation. Second, as compared to the DEE Index, we also incorporate new indicators and variables reflecting to the newly available and disappearing data.

The structure of the DEE Index

The DEE Index proposed in this study measures the DEE at the country level. Figure 1 pictures the DEE Index structure, including the four frameworks, called sub-indices. All four frameworks include three components that reflect the most important aspects of DTI, DUC, DMSP, and DTE. Each pillar has two types of components, called variables (Figure 2). For example, the digital rights pillar variables include institutions and digital technology; and the digital adoption pillar variables are digital technology and an agent.

2. Figure The structure of the DEE Index

	Sub-indices	Pillars	Variables (entrepreneurship/digital)	Variable content
DIGITAL PLATFORM ECONOMY	Digital Technology Infrastructure	Digital openness	*Digital openness institutions*	capturing ICT and e-commerce regulation
			Digital openness Digital technology	population use of G2-G5 networks and radio frequency coverage
		Digital freedom	*Digital freedom institutions*	Business, world press, and general freedom
			Digital freedom Digital technology	ICT competition, mobile tariffs and handset prices
		Digital protection	*Digital protection institutions*	Measuring laws and regulations on cybercrime and cybersecurity
			Digital protection Digital technology	Secure Internet servers per million population, net infection ratio
	Digital User Citizenship	Digital literacy	*Digital literacy institutions*	Human capital, the promotion of e-participation,
			Digital literacy Users	Digital skills among population
		Digital access	*Digital access institutions*	the existence of technical institutions, frameworks, policy coordination institutions, and strategies dealing with cybersecurity
			Digital access Users	Percentage of households with computer and internet access
		Digital rights	*Digital rights institutions*	Regulatory quality, personal rights, fundamental rights and property rights
			Digital rights Users	Percentage of individuals using the internet,
	Digital Multi-sided Platform	Networking	*Networking agents*	number of professional developers
			Networking users	Social media use
		Matchmaking	*Matchmaking agents*	Mobile apps developed per person, number of apps in national language
			Matchmaking users	Accessibility of the top ranked apps
		Financial facilitation	*Financial facilitation agents*	Risk attitudes, the number of financial technology businesses
			Financial facilitation users	the usage of digital financial solution
	Digital Technology Entrepreneurship	Digital Tech Usage	*Digital tech usage agents*	Technicians and associate professionals, intermediate education, firms with website
			Digital tech usage Digital technology	Availability of electricity, internet bandwidth,
		Digital Technology Adaptation	*Digital tech adaptation agents*	professionals and advanced education, adoption of emerging technology
			Digital tech adaptation Digital technology	Generic top level domains
		Digital Technology Absorption	*Digital tech absorption agents*	managers and research talent at business, innovative startups
			Digital tech absorption Digital technology	Computer software spending, data centers

The pillar variables include 2-5 indicators that represent the lowest level of our composite indicator. Our indicator selection criteria are based on the following:

1. Potential to link theoretically or at least logically to the particular digital or entrepreneurship variable
2. The selected indicator's clear interpretation and explanatory power
3. To avoid the potential duplication of the indicators

In building our composite indicator, we applied a total of 56 indicators. We believe this number is sufficient to describe the complex phenomenon of the digital entrepreneurship ecosystem while also avoiding including too many indicators, which could lead to interpretation problems.

The description of the pillars and their components

In this section, we provide a short view of each of the four sub-indices and the twelve pillars, as well as their measurement. The full description of the 56 indicators applied and their sources can be found in Appendix A.

Digital Technology Infrastructure "addresses the coordination and governance needed to establish a set of institutional standards" (Sussan & Acs, 2017, p. 64) that are related to digital technology.

Digital openness

Digital openness reflects to how well a country's institutions support the reach and the use of digital technology infrastructure. Access to and the free use of information are vital for any society (Peters & Roberts, 2015). The creator of the World Wide Web, Berners-Lee (2009) was one of the first to urge governments to provide open-access data on the internet so users could exploit the full potential of digitization. The general development of the digital infrastructure, ability to connect to the Internet, and the use of ICT, including various digital devices, enable users and agents to freely access digital information, which requires the support of government institutions and regulations. Legislation also should support interaction between the users and agents of e-commerce and e-transactions via the various platforms available.

In the DTE, the digital infrastructure is proxied by population use of G2-G5 networks and radio frequency coverage. The institution side of the pillar is measured by an indicator reflecting to the laws relating to the use of ICT and by the more complex Global Cyberlaw Tracker.

Digital freedom

Digital freedom reflects how much freedom a government and its institutions provide in developing digital infrastructure. A typical example of hampering such development is restricting the use of the internet or internet services for security or political reasons (Weidman et al., 2016). ICT-enabled services helped to organize both civil society and revolutionary movements in several countries, including Iran, Indonesia, Kyrgyzstan, Kuwait, Malaysia, and Turkey (Howard, 2010). Milner (2006) argued that democratic institutions facilitate the spread of the internet, whereas autocratic ones restrict it.

Another aspect of digital freedom is the potential monopolization of the digital infrastructure players (Nuechterlein & Weiser, 2007). Economies of scale are important drivers of digital infrastructure development, and network effects are vital in the digital platforms (Hindman, 2018). The limited number of service providers could be a sign of attempts to monopolize control and/or to restrain particular users (Moore & Tambini, 2018; Wentrup & Ström, 2017). Bock et al. (2014) claim that the EU has been lagging behind Asian and North American countries in providing advanced digital networks, mainly due to regulatory deficiencies. Maintaining sustainable infrastructure competition should be an important focus for EU regulatory bodies.

In the Digital freedom, the digital infrastructure is measured by three indicators, the price of mobile tariffs, the price of handset prices, and the internet and telephone competition indicator. The institution part includes the Freedom of the press, Freedom in the World, and Business freedom indicators. This Freedom of the world includes a measure of political rights and civil liberties.

Digital security

Digital security captures the degree to which laws and regulations protect users from piracy and cybercrime. While openness and freedom are important aspects of the digital infrastructure, exposure to cyberattacks and violation of digital property rights could undermine its development. Herhalt (2011) categorized cyberattacks as financial scams, computer hacking, downloading pornographic images from the internet, virus attacks, e-mail stalking, and creating websites that promote racial hatred. The widening use of digital technology and online services has provided new opportunities—e-business, e-commerce, e-learning, e-banking, e-government—while also creating new challenges to security (Kundi & Akhtar, 2014; Lampson, 2004). Moreover, the growing reliance on the digital infrastructure increases its vulnerability and could do serious damage in almost every aspect of life, from basic services like electricity and water to transportation, education, and health-care systems (Johnson, 2016). Security imposes increasingly high costs on private users, businesses, and other organizations (Whitman & Mattord, 2012), including governments, which also are the target of attacks. As the cost of defending the digital

infrastructure has been rising, internet or online piracy and the violation of copyrights have forced governments to create new law enforcement methods, such as the US Digital Millennium Copyright Act (Chaudhry et al., 2011).

The borderless cyberspace makes it difficult to track the source of crimes and identify culprits (Herhalt, 2011). The lack of access to computer experts also makes it difficult to fight against cybercrime, primarily but not exclusively in the less developed countries (Kundi & Akhtar, 2014). Recently, the Trump administration was urged to engage in a more aggressive and active cyber defense (Rosenzweig, Bucci, & Inserra, 2017).

In the DTE, the infrastructure component is measured by the legal subindex of the Global Cybersecurity Index from Transparency International and the National Cyber Security Index. The digital part of the digital protection pillar is proxied by the WEF Network Readiness Index software piracy rate and by Kaspersky's net infection rate.

Digital User Citizenship "addresses the explicit legitimization and implicit social norms that enable users to participate in digital society" (Sussan & Acs, 2017, p. 64). While DTI components aim to capture the role of institutions in terms of the digital infrastructure, the focus here is the effect institutions have on users, governments in particular, as they are a key influence on digital literacy. Although maintaining privacy is a key component of effective DUC and privacy is a widely investigated issue, it is difficult to quantify. Hence, we can use only partially appropriate proxy indicators.

Digital literacy

Digital literacy refers to citizens' ability to use computers, the digital infrastructure, and digital platforms. Without such skills, people cannot take full advantage of the digital infrastructure. Literacy in a broad sense refers to skills or competences (Williams, 2003), but a narrower interpretation is having operational capabilities, such as "understanding ICT terminology, the ability to use basic features of software tools such as word-processors and spreadsheets; and the ability to save data, copy and paste, manage files, and standardize formats within documents." Advanced literacy "includes the use of search engines and databases, and the ability to make more advanced use of software tools" (Buckingham, 2006, p. 266).

An extended definition includes literacy in various areas: ICT and other technologies, information and media, visual and communications (Goodfellow, 2011, p. 133). Literacy is also used in a broader context that reflects the ability to understand, evaluate, and interpret information provided by the digital infrastructure, most importantly by the internet (Baron, 2019;

Njenga, 2018). As more and more young children use and rely on the internet, protection from harmful online content has become an important issue in education (Poore, 2015). Internet users are increasingly exposed to fake news, dis- and -misinformation, and manipulation (Morgan, 2018; Weeks & de Zúñiga, 2019). The 2016 US presidential campaign and the UK Brexit vote induced new research into the spread of fake news and false information (Persily, 2017; Rose, 2017).

From the user side in the DUC, we use one indicators: the Global Competitiveness Index, WEF measure of digital skills among the population. From the institutional side we use the Human capital index and the tertiary school enrollment provided by the World Bank, and the UN related e-participation index.

Digital access

Digital access refers to the level of access citizens have to the digital infrastructure, including computers, the internet, and various digital tools (tablets, laptops, mobile phones, etc.). Without proper access, individuals cannot participate in the digital world. The digital divide refers to the cultural groups or counties that do not have proper or equal access to digital tools (Van Dijk, 2017). The first level of the digital divide was initially observed in terms of gender, age, race, and disability (Friemel, 2016), but it now also includes the gap between developed and developing countries. A large proportion of developing country populations still have no access to the internet, which makes it impossible for them to enjoy the benefits of digital revolution (West, 2015)

However, digital inequality can occur even for those with access to digital content when they cannot access particular information. This second level of the digital divide is associated with the lack of "ability to efficiently and effectively find information on the Web" (Hargittai, 2002). This can create material, immaterial, and educational types inequality (Ghobadi & Ghobadi, 2015), and can reinforce or even exacerbate social inequalities (Robinson et al., 2015). A third degree of the digital divide was identified recently as inequality in the tangible outcomes of internet use (Scheerder, van Deursen, & van Dijk, 2017).

In the DEE, the institutional aspect of digital access is captured by two proxy indicators, the technical and the organizational sub-indices from the Global Cybersecurity Index. While these indicators do not really measure government efforts to increase digital access and reduce the digital divide, we assume that government security efforts could be positively associated with these two issues, including developing technical institutions and institutions that coordinate cybersecurity policy and

strategy. The digital infrastructure aspect of digital access is more straightforward, including two indicators of the percentage of households having internet access and the percentage of households equipped with a personal computer.

Digital rights

Digital rights reflect the human and legal rights that make it possible for citizens to use the digital infrastructure, while at the same time protecting their privacy. Human rights include the right of free opinion and expression, as reinforced by the Vienna Declaration and Programme of Action in 1993. According to Klang and Murray (2005), human rights also include the free communication that is the central element of the information society. Limitless and borderless participation are important factors in having access to the information society offers and in respecting human rights. At the same time, all actors should take appropriate action to prevent the use of digital sources and technologies for illegal, abusive, criminal, or terrorist purposes. Since the beginning of the information age and the internet, privacy and the ability to control one's personal information have been of central interest (Smith, Dinev, & Xu, 2011; Bélanger & Crossler, 2011). Several researchers have observed contradicting behavior among internet users: while there is increasing concern about privacy, individuals are ready to share or sell their personal information for little or no compensation (Kokolakis, 2017; Kummer & Schulte, 2019)

The appearance of new digital communication tools and technologies opens up new fronts in the effort to balance and maintain easy access, privacy, and security, all at the same time. The millions of users of social networks are at the forefront of the privacy issue (Hajli & Lin, 2016). Users were alarmed when it came to light that Facebook passed the personal information of more than 87 million users to Cambridge Analytica (Isaak & Hanna, 2018), and the company's current practice of canceling users and censoring harmful content has raised a whole new set of concerns about the violation of privacy (Alkire, Pohlmann, & Barnett, 2019). The increasing use of mobile applications (Christin et al., 2011), online finance and banking (Roca, García, & de la Vega, 2009), and the internet of things (Pasquier et al., 2018) challenges the access and the privacy of users, governments, and digital infrastructure developers.

In the DUC, the institutional aspect of digital rights is captured by personal rights measure via the Global Talent Competitiveness Index, fundamental rights via the Rule of Law index, and property rights via the Property Rights Alliance. The digital aspect is proxied by the percentage of individuals using the internet from the users side.

Digital Multi-sided Platforms are where digital technology users and agents of the entrepreneurship ecosystem meet. DMSP serves as an "intermediary for [the] transaction of goods and services, and also [as] a medium for knowledge exchange that enables and facilitates experimentation, entrepreneurial innovation, and value creation" (Song, 2019, p. 4). In the DMSP sub-index, we capture only a few characteristics of multi-sided platforms (MSP). From a country perspective, the two most important features of MSP are networking and competition. The effect of virtual networks is the main part of the networking pillar. The matchmaking pillar focuses on catching the user's contribution and the competitive push of startups. The third pillar emphasizes the digital financial facilitation potential of MSP that is vital to the digital entrepreneurship ecosystem.

Networking

The networking pillar aims to grasp the network effects and other external effects of MSP. Network effect is a kind of externality that occurs when the value of the product or service depends on the number of users (Shapiro & Varian, 1999). In the case of MSP, the value of the service to each member increases as the number of users rises. In the early phase of a platform launch, the attraction of both sides is vital. If there is a shortage of sellers, buyers may not find the platform attractive, and a lack of buyers discourages sellers from joining—a "chicken-and-egg problem" (Hagiu, 2014; Evans & Schmalensee, 2016).

Researchers have identified two kinds of effects: the same-side or direct effect, when users value the presence of similar users, and the cross-side or indirect effect, when users value the increased number of the agent side on the platform (Evans, 2013; McIntyre & Srinivasan, 2017). Social media platforms like Facebook are good examples of the direct effect, Uber of the indirect effect. Network effects can be further strengthened by high multi-homing and switching costs (Farrell & Klemperer, 2007; Hyrynsalmi, Suominen, & Mäntymäki, 2016). Both scale effect and scope effect are present in MSP, and platform providers can serve many different user groups with the same product (Lee, 2001). A supply side for scale effect could also emerge. According to Gawer (2014), modular design and the use of platforms makes it possible for firms to gain economies of scope in innovation.

In the DMSP, networking pertains to the application of various virtual networks and social media from the user side, and to business capabilities to provide goods and services via the internet from the agent side. We apply two partially overlapping indicators from the users side: the use of virtual social networks (WEF), and social media penetration (Hootsuite). Professional developers from Stockoverflow dataset represent the agent side of entrepreneurship ecosystem. professional developers are assumed to provide apps to the platforms.

Matchmaking

In the matchmaking components, we aim to capture MSP business models that are different from earlier models. Traditional business models are based on a chain of vertically integrated firms. In MSP, both sides (supply and demand or buyers and sellers) become customers that interact with each other through the platform (Parker & Van Alstyne, 2014).

Matchmaking, or pairing the two sides of the platform, is not an easy task (Evans & Schmalensee, 2016). The key to matchmaking is the platform design, which includes the platform architecture, value creation logic, governance, and platform competition (Tura, Kutvonen, & Ritala, 2018). Platform architecture refers to the core interaction of users and agents, including the openness of the platform and the potential restrictions on participation. For effective value creation and to maximize the network effect, the different shareholders' value positions should be understood. Pricing and revenue models are the key to value capture (Weyl, 2010). Platform designers also should deal with the potential effects of competition. In a turbulent environment, it is difficult to balance and maintain the ability to capture the market early, reach a critical mass, and prevent competitors from entering the market. Small changes in the platform design could produce significantly different results. MSP do not just connect supply and demand; they require the active participation of users who contribute to platform efficiency by commenting, evaluating, or correcting the content, goods, or services (Sussan & Acs, 2017).

In the DMSP, this effect from the agent side is captured by an indicator from GSMA Mobile Connectivity Index: the accessibility of the top ranked apps. From the user side, we use the mobile apps per person and the number of mobile apps available in national language, all are from GSMA.

Financial facilitation

Financial facilitation refers to various aspects of finance that rely on the digital technologies that fuel matchmaking-related startups, make financial transactions via the internet possible, and provide platforms for financial service providers and users. New technology trends such as artificial intelligence and machine learning, automation, big data, cloud computing, distributed ledger technology such as blockchain; new entrants such as mobile network operators, payment service providers, merchant aggregators, retailers, FinTech companies, neo-banks, and super platforms; and new business models have been reshaping the whole finance sector by providing cheaper, faster solutions and new financial services (Gomber et al., 2018; Alt, Beck, & Smits; 2018). Gomber, Koch, and Siering (2017) put digital finance business functions into six broad categories: digital financing, digital investments, digital money, digital payments, digital insurance, and digital financial advice.

In the DMSP, we have only a few indicators available to measure the components of the financial facilitation pillar. From the user side, we apply four World Bank-related indicators, such as debit/credit cards used the internet to pay bills or buy something, used a mobile phone or the internet to access a financial institution account, and made or received digital payments. For the agent side we rely on two indicators:, the standardized number of Fintech companies based on Dealroom data, and the risk attitudes of the population. That later represent the bear of entrepreneurial risk amongst agents.

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). Baierl, Behrens, and Brem (2019) describe digital entrepreneurship "as creating new ventures and transforming existing businesses by developing novel digital technologies or novel usage of such technologies . . . Additionally, digital technologies have become a new economic and social force for reshaping traditional business models, strategies, structures, and processes" (p. V). The first part of the definition refers to digital entrepreneurship as an output, the second part as a context (Elia et al., 2020). From another perspective, this differentiates two types of entrepreneurship: Schumpeterian and Kirznerian. Schumpeterian (1934) entrepreneurship is referred to as "creative destruction." From the DTE side, Schumpeterian entrepreneurship is assumed to be an exogenous given, whereas DTE captures entrepreneurial efforts that contribute to a more efficient or novel use, adaptation and absorption of digital technologies. This kind of entrepreneurship is usually labeled Kirznerian, or opportunity motivated entrepreneurship (Kirzner, 2015; Lafuente et al., 2020).

Digital tech usage

The Digital tech usage pillar components reflect entrepreneurial agents' basic ability to use digital technologies. By using digital technologies, startups and existing businesses can increase their efficiency by reducing production, communication, and coordination costs (Goldfarb & Tucker, 2019; Sahut et al., 2019). This is particularly important for businesses in less developed countries, where advanced technology can reduce the physical distances between markets. Differences in digital and ICT capabilities could create a digital divide that would be a serious barrier to use digital technologies (Fong, 2009; Cruz-Jesus et al., 2017). Several phases of digital use lead to digital maturity (Becker, Knackstedt, & Pöppelbuß, 2009). Moreover, the degree and the content of digitization change over time, therefore, striving for maturity is a never-ending process rather

than a static state (Kane et al., 2017). From 1990 to 2000, having a web presence, digital marketing, and digital selling were at the center of the digital transformation (Hull et al., 2007). Later, offering integrated solutions that included the strategy, the workforce, the culture, the technology, and the structure to meet the expectations of various stakeholders became the core of digital transformation and digital maturity (Kane et al., 2017).

The digital tech usage pillar components capture the basic development of the digital infrastructure as measured by the electricity production, Fixed-broadband Internet subscriptions, and International Internet bandwidth. From the agent side of the pillar, we use two proxies, one to measure intermediate level of education (the ability to use the technology) and the percentage of firms having website.

Digital tech adoption

Technology adoption measures the extent to which entrepreneurial agents can adopt existing digital technologies. It requires recognizing useful, newly developed digital technologies and building them into the business model. Digital technologies and the widely interpreted digital infrastructure provide new opportunities for entrepreneurs. Digital technologies enable the entrepreneur to experiment and to implement new business models (Von Briel, Davidsson, & Recker, 2018). Autio et al. (2018) identified three digitalization promoted affordances "that shape both the locus of entrepreneurial opportunities in the economy, as well as the effective practices to pursue such opportunities" (p. 74). These affordances are decoupling form and function; disintermediation, or shrinking the role of the intermediary in the value chain; and generativity, the ability to connect dispersed participants. According to Amit and Zott (2012), business model innovation occurs in three ways: introducing new business activity, altering the structure of the activities, and changing the governance of the activities. The role of entrepreneurs is not only to recognize evolving opportunities provided by new technology but to exploit their value creation and build it into the business model (Elia et al., 2020; Steininger, 2019).

In the digital adoption pillar, the digital infrastructure component is captured by the Generic top-level domains (gTLDs) indicator. The agent component is measured by the professionals as a share of the total workforce, the advanced education level and the adoption capacity of the latest technology.

Digital tech absorption

Technology absorption identifies another aspect of technology entrepreneurship, the ability to deeply absorb, integrate digital technologies. The speed at which a country can absorb new technologies is an important factor in improving efficiency and development (Kiiski & Pohjola, 2002). Technological absorption is a highly uneven process, and the success of laggard countries depends on how quickly their leaders can integrate new technology to a country-specific context (Andrews, Criscuolo, & Gal, 2015).

The speed and depth of a country's technology absorption depends on its overall innovation capabilities. Innovation-based digital technology is different from classic innovation in several respects. Unlike traditional supply and demand models, the concept of open innovation describe digital innovation better (Chesbrough, 2006). Traditional innovation usually occurs in-house, while digital innovation relies increasingly on external actors and knowledge (Lund & Ebbesson, 2019). Moreover, digital innovation is a non-linear process wherein networks orchestrate ideas, technologies, tools, actors, and know-how (Lyytinen, Yoo, & Boland, 2016). Digital technologies enable connections between various heterogeneous actors with transaction costs close to zero.

Technology absorption is not a mechanical process; it requires tacit knowledge that is difficult to transmit. Incomplete knowledge spillover in digital technologies can slow regional growth (Batabyal & Nijkamp, 2016). Moving from adopting simple digital technology to more complex absorption and absorption demands advanced digital skills from both the entrepreneurs and their employees (Dede, 2010). Developing new skills and capabilities are key factors in successful knowledge spillover. It has been well-known for more than two decades that routine types of jobs and the associated skills are disappearing, and that digital technology increasingly demands new competencies (Murawski & Bick, 2017; Prensky, 2009). Voogt and Roblin (2012) identified the new competencies as transversal (can be applied in many fields), multidimensional (involving knowledge, skills, and attitudes), and higher order (reflecting the ability to solve complex problems in unpredictable environments). Communication and teamworking ability, as well as a solid understanding of the information exchanged, are also key to successful technology absorption (Elia et al., 2020).

An increasing number of tech startups and well-functioning innovation capacities are the key for a successful technology absorption. From the agent side of the Technology absorption pillar, this influence is proxied by a Startupranking -based indicator of the number of startups. The skill component is measured by the research talent at business and the number of managers. From the digital infrastructure part of this pillar, we use two components: the number of data centers from the Data Centers catalog, and the percentage of computer software spending.

4. The Digital Entrepreneurship Ecosystem Index: Country rankings and clustering

In this section, we provide a basic analysis of digital entrepreneurship ecosystem by relying on the DEE Index, that is a composite indicator for 115 countries from all continents and in all development stages. The calculation steps of the DEE Index are found in Appendix B. Note that data collection reflect pre-Covid, 2017-2019 years, and the DEE Index 2021 analysis is based on 2019 or most recently available data up to 2019.

Country ranking: DEE Index and sub-index analysis

According to Table 2, the United States leads the DEE Index 2021 ranking with a score of 83.8, followed by the United Kingdom (83.5), and The Netherlands (83.0). Of the top 10 countries, two are in North America (US and Canada) and six in Europe (UK, Netherlands, Denmark, Finland, Switzerland, and Norway. Singapore is ranking sevenths and Australia ranks tenth. The next 10 countries, ranked 11-20, have a similar regional distribution: eight European countries (Sweden, Ireland, Germany, Austria, Iceland, Luxembourg, France, and Belgium), and New Zealand and Hong Kong. All of these countries are highly developed, innovation-driven economies. In contrast, the countries in the last 10 places (106-115) are less developed, resource-driven countries on the African continent.

2. Table The Digital Platform Economy Index ranking of the countries, 2021

Rank	Country	DEE_2021	Rank	Country	DEE_2021	Rank	Country	DEE_2021
1	United States	**83.8**	40	Chile	**48.6**	78	Bosnia and Herzegovina	**27.7**
2	United Kingdom	**83.5**	41	Malaysia	**46.7**	79	Iran	**27.3**
3	Netherlands	**83.0**	42	Russia	**45.8**	80	Vietnam	**27.0**
4	Denmark	**82.9**	43	Costa Rica	**44.6**	81	Ecuador	**26.8**
5	Finland	**81.9**	44	Romania	**44.4**	82	Paraguay	**26.3**
6	Canada	**81.4**	45	Turkey	**44.0**	83	India	**25.9**
7	Singapore	**81.3**	46	Bulgaria	**43.9**	84	Armenia	**25.8**
8	Switzerland	**80.9**	47	Uruguay	**43.4**	85	Lebanon	**25.0**
9	Norway	**80.1**	48	Serbia	**42.8**	86	Jordan	**23.8**
10	Australia	**79.7**	49	Argentina	**41.8**	87	Azerbaijan	**23.6**
11	Sweden	**79.2**	50	Brazil	**40.6**	88	Mongolia	**22.0**
12	Ireland	**79.2**	51	Qatar	**40.4**	89	Sri Lanka	**21.6**
13	Germany	**79.1**	52	Saudi Arabia	**40.3**	90	Kenya	**20.0**
14	Austria	**75.1**	53	Ukraine	**39.5**	91	Botswana	**19.3**
15	Iceland	**74.3**	54	Mauritius	**38.3**	92	El Salvador	**18.8**
16	New Zealand	**73.2**	55	China	**37.6**	93	Kyrgyzstan	**18.3**
17	Hong Kong	**72.6**	56	Bahrain	**37.6**	94	Guatemala	**18.3**
18	Luxembourg	**71.6**	57	Oman	**37.5**	95	Nigeria	**17.1**
19	France	**70.4**	58	Montenegro	**37.0**	96	Honduras	**16.2**
20	Belgium	**67.5**	59	Mexico	**36.6**	97	Algeria	**16.1**
21	Estonia	**66.9**	60	Kuwait	**35.8**	98	Bangladesh	**15.3**
22	Spain	**66.7**	61	Thailand	**35.5**	99	Pakistan	**14.7**
23	Malta	**66.4**	62	Colombia	**34.4**	100	Namibia	**14.4**
24	Japan	**63.1**	63	Panama	**33.1**	101	Senegal	**14.3**
25	Italy	**61.6**	64	Albania	**32.7**	102	Rwanda	**13.8**
26	Cyprus	**61.1**	65	Peru	**32.6**	103	Nepal	**12.8**
27	Slovenia	**61.0**	66	Kazakhstan	**31.9**	104	Cambodia	**12.0**
28	Korea	**60.8**	67	Moldova	**31.6**	105	Cameroon	**11.6**
29	Czech Republic	**60.6**	68	Tunisia	**30.4**	106	Uganda	**11.6**
30	Portugal	**60.6**	69	Jamaica	**30.1**	107	Zimbabwe	**11.5**
31	Israel	**59.6**	70	South Africa	**30.1**	108	Zambia	**11.0**
32	Latvia	**58.3**	71	Dominican Republic	**30.1**	109	Benin	**10.8**
33	Poland	**56.7**	72	Philippines	**30.0**	110	Tanzania	**10.2**
34	Greece	**53.8**	73	Georgia	**30.0**	111	Malawi	**7.2**
35	Lithuania	**53.5**	74	North Macedonia	**29.2**	112	Mali	**6.8**
36	Croatia	**52.6**	75	Morocco	**28.8**	113	Madagascar	**6.6**
37	United Arab Emirates	**52.1**	76	Indonesia	**28.5**	114	Ethiopia	**5.4**
38	Slovakia	**50.8**	77	Egypt	**28.4**	115	Burundi	**3.3**
39	Hungary	**49.6**						

Note: DEE=Digital Platform Economy index score; GDP=the per capita GDP of the country in purchasing power parity (World Bank, 2017) (https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD)

While the DEE Index score is useful in comparing a country's digital platform-based ecosystem performance to that of other nations, it does not reveal any of a country's strengths and weaknesses. For further details, we need to break down the components of the DEE Index. Table 3 presents the four sub-index scores and ranking of the top 25 countries.

3. Table The four sub-index scores and ranking of the top 25 countries (based on 2021 data)

Country	Digital Technology Infrastructure	Digital Technology Infrastructure rank	Digital User Citizenship	Digital User Citizenship rank	Digital Multi-sided Platform	Digital Multi-sided Platform rank	Digital technology Entrepreneurship	Digital technology Entrepreneurship rank	Digital Entrepreneurship Ecosystem Index	Digital Platform Economy Index rank
United States	73,6	11	81,7	9	91,6	1	88,2	1	**83,8**	1
United Kingdom	81,2	2	81,1	10	89,5	3	82,3	5	**83,5**	2
Netherlands	71,6	14	89,3	1	86,7	5	84,5	3	**83,0**	3
Denmark	77,7	8	86,2	5	88,4	4	79,2	8	**82,9**	4
Finland	86,9	1	87,5	3	78,2	15	75,0	16	**81,9**	5
Canada	68,3	18	82,5	7	90,3	2	84,6	2	**81,4**	6
Singapore	74,2	9	88,1	2	80,7	10	82,3	6	**81,3**	7
Switzerland	78,5	4	81,1	11	80,1	12	83,8	4	**80,9**	8
Norway	79,1	3	87,0	4	79,0	13	75,2	14	**80,1**	9
Australia	77,8	7	81,9	8	85,8	7	73,3	17	**79,7**	10
Sweden	66,6	20	85,3	6	86,0	6	79,0	9	**79,2**	11
Ireland	77,9	6	78,3	13	85,3	8	75,4	13	**79,2**	12
Germany	78,4	5	78,8	12	78,9	14	80,1	7	**79,1**	13
Austria	73,9	10	77,3	15	77,9	16	71,4	19	**75,1**	14
Iceland	62,9	27	77,8	14	80,7	11	75,9	12	**74,3**	15
New Zealand	71,6	13	75,8	17	84,1	9	61,3	22	**73,2**	16
Hong Kong	66,4	21	75,7	18	70,8	19	77,4	11	**72,6**	17
Luxembourg	64,2	24	70,4	23	74,5	18	77,4	10	**71,6**	18
France	70,0	16	68,6	24	67,8	21	75,1	15	**70,4**	19
Belgium	65,5	23	71,6	21	64,0	23	69,0	20	**67,5**	20
Estonia	70,4	15	74,9	19	63,8	24	58,5	28	**66,9**	21
Spain	67,7	19	71,8	20	66,7	22	60,5	23	**66,7**	22
Malta	53,9	37	60,8	30	77,8	17	73,0	18	**66,4**	23
Japan	62,2	28	70,9	22	59,8	26	59,6	25	**63,1**	24
Italy	71,7	12	57,6	36	58,0	28	59,0	27	**61,6**	25

The United States is first in the DMSP and DTE sub-indices, ninth in the DUC, and eleventh in the DTI. The best sub-index score for the US is 91.6 (DMSP), the worst is 73.6 (DTI), a 19.7% difference. The UK's scores are even more balanced, ranging from its best of 89.5 (DMSP) to its lowest of 81.1 (DUC). Some countries have greater variation. For example, sixth-ranked Canada is the second in the DMSP (90.3) but 18th in the DTI (68.3), a 24.4% difference. The balance for EU member countries is varied. While The Netherlands is first in the DUC (89.3), it is only 14th in the DTI (71.6), with a significantly lower score and 19,8% difference. Australia's major weakness is in the DTE, while Germany, France and Spain are more balanced.

Country grouping: Pillar-level analysis

We have conducted a cluster analysis that shows common features and differences in the 12 pillars. The four-cluster group solution proved the most useful for our purposes. Table 4 shows a relative balance in the number of cluster members: Leaders consist of 25 countries, Followers of 27, Gainers of 35, and Laggards number 28 countries. The differences among the groups

in terms of the DEE Index mean score varies. The Leaders (DEE Index=75.3) are ahead of the Followers (DEE Index= 49.9) by around 25 points, the Gainers (DEE Index = 31.5) are behind the Followers by around 18 points, and the Laggards (DEE Index=13.6) are last, by roughly 18 points. The first six countries in the DEE Index ranking belong to the Leaders group, are all developed nations mainly from Europe and North America. Developed Asian countries Israel and Japan and two Asian city-countries Singapore and Hong Kong together with Australia and New Zealand also part of the Leader cluster. The Followers group include the medium-high income South and Central European and Asian countries, and two South American nations, Chile and Uruguay. Most oil-rich countries (i.e., Bahrain, Oman, Qatar, Saudi Arabia, and United Arab Emirates) also belong to this cluster. Gainers constitute the most numerous cluster. They are geographically mixed, dominated by mid-developed European, Asian, and Latin American countries together with a few African nations (Egypt, Morocco, South Africa, Tunisia). Laggards are formed from less-developed African and Asian countries, together with relatively poor Latin American nations. There are no European countries here.

Standard deviation serves to examine the differences amongst the four clusters with respect to the pillars, subindices, and ecosystem components. The differences are the smallest in Digital Access (20.1), Technology Absorption (23.5), and Digital Protection (24.2) pillars, while the largest in Digital Openness (35.6), Digital Rights (31.6), and Financial Facilitation (31.1). Viewing the four sub-indices of DEE, it seems that the four clusters are the most equal in terms of Digital Technology Infrastructure (23.2) and the least equal in Digital Usage Citizenship (29.1). Viewing from another perspective, the differences of the four clusters are the least in the Digital Infrastructure (18.4) and the most in Users (22.8). This finding implies that even poor countries focus on establishing a good digital infrastructure while the population capabilities to be able to use digital technologies are lagging digital infrastructure development.

4. Table The four groups of countries, average pillar scores based on the twelve pillars, the sub-index, ecosystem scores and standard deviations (based on 2021 data)

Pillars/sub-indices/ecosystems	Leaders	Followers	Gainers	Laggards	Standard deviation
Digital Access	66,6	55,8	36,4	21,4	20,1
Digital Freedom	80,6	46,6	33,1	16,7	27,1
Digital Protection	71,6	59,2	34,9	17,6	24,2
Digital Literacy	72,4	53,1	32,4	14,9	24,9
Digital Openness	85,9	74,4	39,9	7,1	35,6
Digital Rights	85,5	53,7	33,2	11,2	31,6
Networking	81,1	53,4	36,2	15,6	27,7
Matchmaking	80,8	43,5	36,3	12,2	28,4
Financial Facilitation	84,7	52,6	25,2	15,4	31,1
Digital Usage	78,9	53,2	32,9	10,3	29,2
Digital Adoption	78,5	44,7	31,7	16,5	26,4
Technology Absorption	73,5	45,5	34,8	17,4	23,5
Digital Technology Infrastructure	70,8	50,7	32,3	17,0	23,2
Digital User Citizenship	77,8	55,5	32,3	10,5	29,1
Digital Multi-sided Platform	78,4	47,5	30,3	13,2	27,8
Digital Technology Entrepreneurship	74,4	45,8	30,9	13,8	25,7
Digital Entrepreneurship Ecoystem Index	75,3	49,9	31,5	13,6	26,4
Institutions	87,5	76,1	61,5	44,5	18,6
Agents	85,9	69,0	58,9	41,3	18,7
Digital Infrastructure	84,3	71,0	58,7	41,1	18,4
Users	88,2	75,9	60,6	35,2	22,8
Digital Ecosytem	86,3	73,4	59,7	38,1	20,6
Entrepreneurship Ecosystem	86,7	72,5	60,2	42,9	18,6
Number of cases	25	27	35	28	

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

The Leaders are best in all 12 pillar score averages. These are mainly rich Anglo-Saxon, Nordic and developed Asian countries with well-balanced digital entrepreneurship ecosystems. While they spend the most for digital protection, Digital Access is

their lowest value pillar. The Followers are medium-rich developed nations. Although some aspects of their digital entrepreneurship ecosystems are well developed (Digital Access, Digital Protection), they have relatively low scores on some pillars (Digital Literacy, Technology Absorption). The Gainers enjoy good digital technologies and citizens who are active users, but many aspects of their digital entrepreneurship ecosystems require considerable development. The Laggards are the lowest in every pillar score average. These countries lack digital infrastructure, good digital technologies, and active users. The last two group members are relatively homogenous, with minimal in-group differences. This is particularly true for the most populated Laggards cluster.

Regional Performance

For many countries, a regional benchmark is more relevant to identify best practices for fostering digital platform economy development. We follow the World Bank categorization in terms of regional membership. The map in Figure 3 reveals significant differences in the digital platform economy development across regions and within regions. It is clear that developed countries in North America, Europe, and the Asia-Pacific region have more developed digital entrepreneurship ecosystem than nations in Latin America, South Asia, and Africa. Alterations within regions are associated with the countries' development: poorer countries typically have lower DEE Index scores, while richer countries have the highest scores in the DEE Index ranking.

3. Figure Digital Platform Economy Index, 2021 map

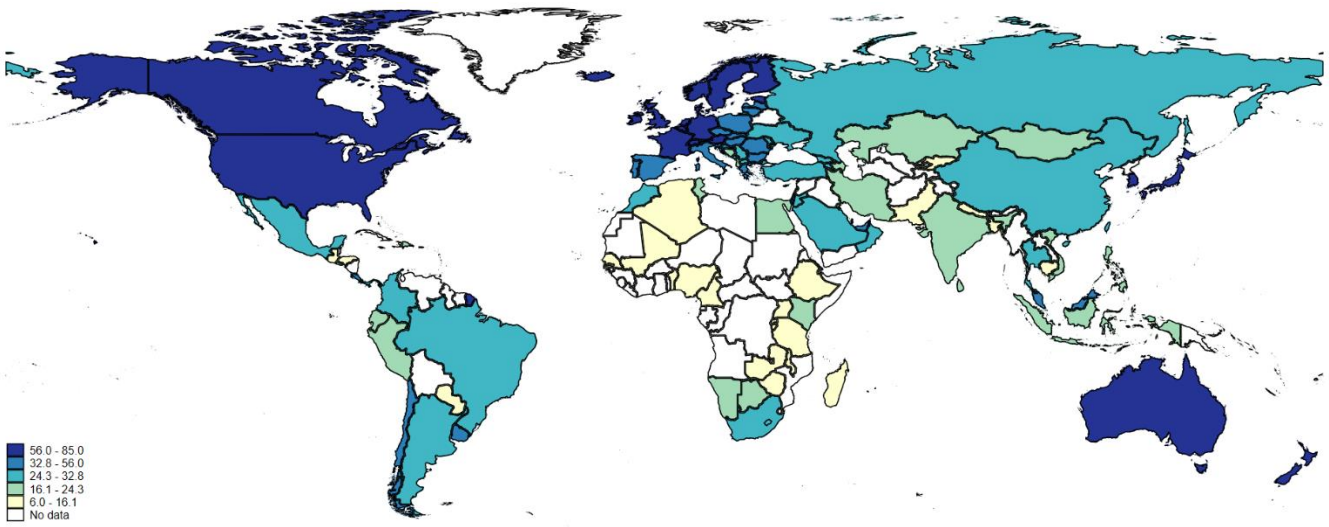


Table 5 lists the regional leaders and regional average values. In addition to the DEE Index scores and ranking, we provide the four sub-index scores.

5. Table Top DEE and sub-index scores by region and regional averages (based on 2021 data)

Region	Country/ Regional average	World Rank	GDP per Capita PPP 2019	DTI score	DUC score	DMSP score	DTE score	DEE Index score
North America	United States	1.	62555	73.6	81.7	91.6	88.2	83.8
	Regional average		55786	71.0	82.1	91.0	86.4	82.6
Europe / Central Asia	United Kingdom	2.	46406	81.2	81.1	89.5	82.3	83.5
	Regional average		37545	56.4	58.7	53.0	54.7	55.7
East Asia / Pacific	Singapore	7.	97989	74.2	88.1	80.7	82.3	81.3
	Regional average		31606	45.7	51.8	48.4	45.6	47.9
Middle East / North Africa	Malta	23.	43703	53.9	60.8	77.8	73.0	66.4
	Regional average		32580	32.2	42.2	37.8	34.2	36.6
Latin America / Caribbean	Chile	40.	24969	51.0	53.3	48.5	41.6	48.6
	Regional average		16074	33.7	29.9	37.1	30.0	32.6
Sub-Saharan Africa	Mauritius	54.	22870	37.8	42.4	37.5	35.5	38.3
	Regional average		5472	18.7	11.0	12.4	13.5	13.9
South Asia	India	83.	6717	31.9	19.8	23.5	28.3	25.9
	Regional average		6533	21.4	15.0	16.2	19.6	18.1

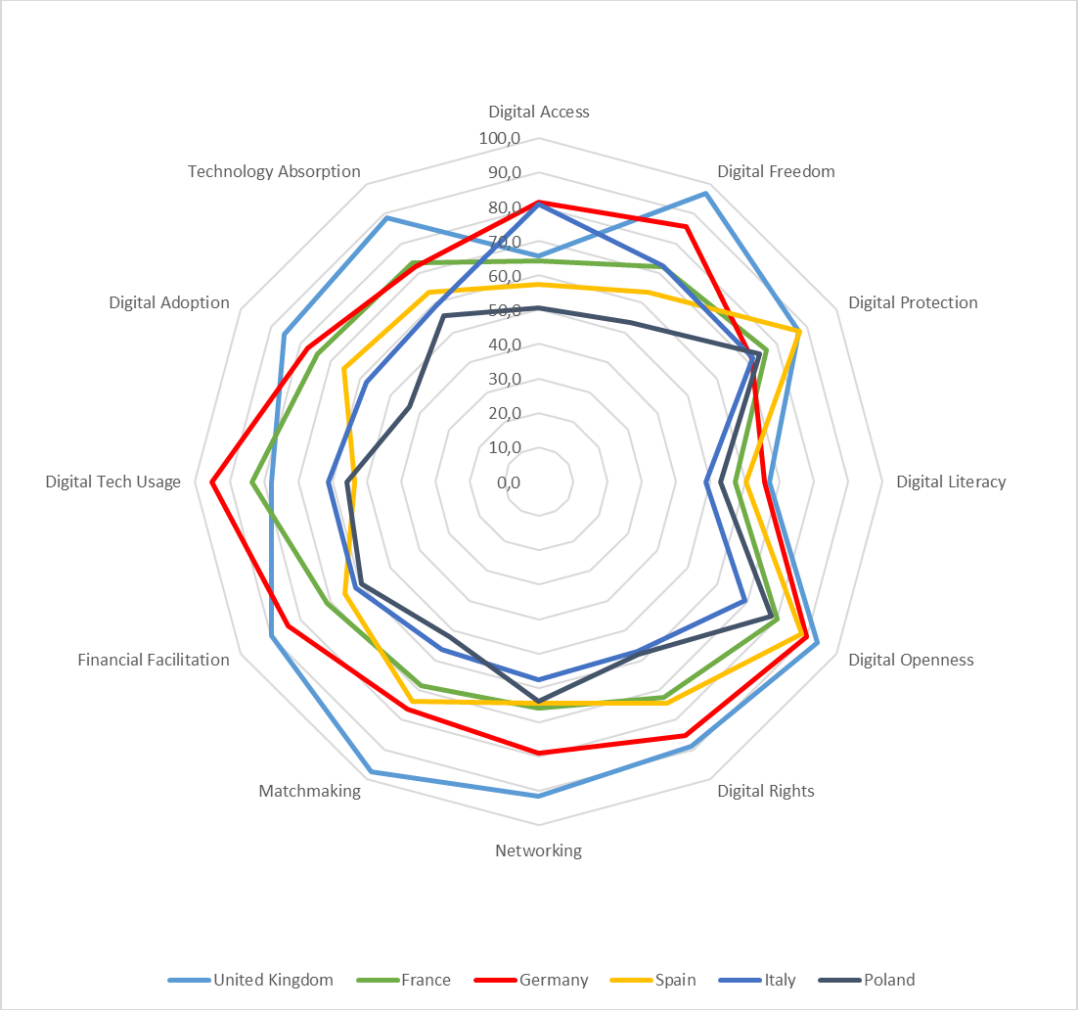
Legend: DTI= Digital Technology Infrastructure; DUC= Digital user Citizenship ; DMSP= Digital Multi-sided Platform; DTE= Digital Technology Entrepreneurship
Source: Based on own calculation

The US leads the world in entrepreneurship and is first in the North American region. Canada ranks sixth, making North America the world's most powerful region. The UK, second in the overall ranking, is first in the Europe-Central Asia region. Brexit cost the EU a dominant player in the digital platform economy game. Nordic countries and Switzerland have strong digital platform economies, while other large EU nations such as Germany and France lag behind the leading nations. Singapore ranks first in the Asia-Pacific region, ahead of Australia, New Zealand and economic powerhouses Hong Kong, Japan, and Korea. Malta, an EU member country ranks 23rd , tops in the MENA region ahead of Israel, the UAE, Qatar, and Saudi Arabia. Chile ranks first in South and Central America and the Caribbean (40th overall), ahead of Costa Rica and Uruguay. In Sub-Saharan Africa, Mauritius is the leader at 54th, ahead of South Africa. Other sub-Saharan countries are at the bottom of the DEE Index ranking having less than 20.0 DEE index score. There are only five countries in the South Asian region; India, ranking 83rd, is the leader here with a 25.9 DEE Index score, followed by Sri Lanka and Pakistan. These low-middle income countries should increase their efforts to develop their digital entrepreneurship ecosystem.

A healthy digital entrepreneurship economy requires balancing the sub-indices. In Table 5 we can see that most of the regional leaders have relatively well-balanced digital and entrepreneurship ecosystems. In the US and Malta, the differences are relatively high, while Mauritius and the United Kingdom have well-well-adjusted digital entrepreneurship ecosystems. The other regional leaders posit between these United Kingdom and the United States.

We selected the largest European countries – except Russia - to represent within-region differences: France, Germany, Italy, Poland, Spain, and the UK. The differences in the DEE Index scores as compared to the leaders is clear: Germany is behind the UK by 5.3%, France is by 15.7%, Spain is by 20.1%, Italy is by 26.2 and Poland, a relatively newly assessed EU country is by 32.1%. While the UK, Germany, France, and Spain belong to the Leader group, Italy and Poland are in the Followers cluster. Figure 4 shows differences at the pillar level. We already have seen that the UK lead the region and that other countries lag significantly behind. This particularly true for Digital Freedom, Networking, Matchmaking, Technology Adoption and Technology Adsorption. UK seems to be disadvantageous position only in Digital Access and Digital Usage, wo out of the twelve pillars. All the six European countries have problems in Digital Literacy while Digital Openness is their relatively strong pillar.

4. Figure Selected European countries by pillar (based on 2021 data)

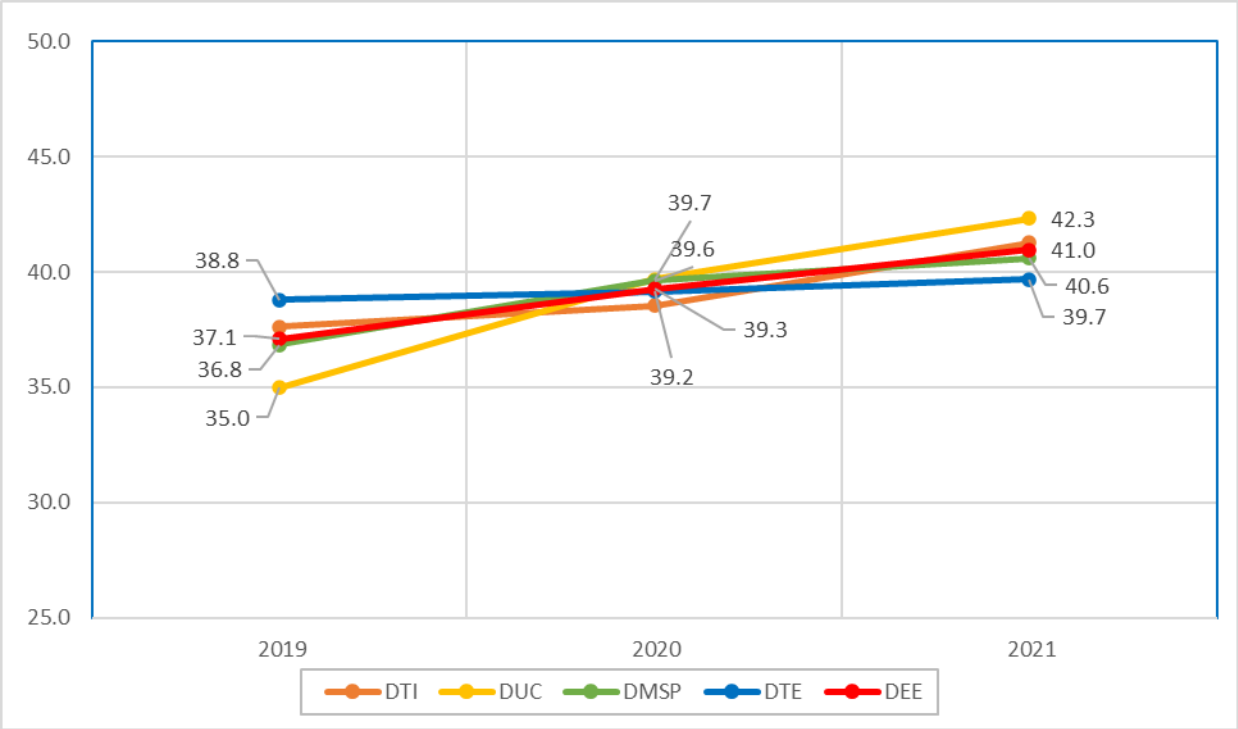


Change of digital entrepreneurship ecosystem over the 2019-2021 time period

Digital entrepreneurship ecosystems are quickly evolving, the differences are clearly visible even from one year to another.

Figure 5 presents the DEE Index and its four sub-indices change over the 2019-2021 time period.

5. Figure The change of the DEE and the four sub-indices over 2019-2021 (115 countries)



Legend: DEE=Digital Entrepreneurship Ecosystem; DTI= Digital Technology Infrastructure; DUC= Digital user Citizenship ; DMSP= Digital Multi-sided Platform; DTE= Digital Technology Entrepreneurship;

Looking at the average DEE score of the 115 countries, it increased from 37.1 to 39.3 by 5.8% from 2018 to 2019 and to 41.0 another 4.4% increase from 2019 to 2021. Over the 2019-2021 period the DEE Index score increased by 10.4%, a huge development. Looking at the four sub-indices of DEE, the development is positive but uneven in all cases. DUC that was the last out of the four sub-indices, increased by 21% and become the strongest sub-index by 2021. DMSP and DTI both increased by 10.2% and 9.7%, respectively. DTE produced the smallest rise by 2.3% and has become the last out of the four sub-indices.

Table 6 present the regional pattern of the change of DEE score over the 2019-2021 time period. South Asian and Sub-Saharan African regions with the lowest DEE score improved their digital entrepreneurship ecosystem the most by 19.3% and 14.3%, respectively. On the other extreme, the two North American nation, Canada and the US increased their DEE score by only 5.7%. It is typical that leading countries with high scores could grow at a lower speed than low score, lagging countries. In absolute terms, North America has improved by 4.5 its DEE Index points, that is the second highest after Europe/Central Asia. At the same time, Sub-Saharan Africa DEE score grew by 1.7 points only. In relative terms, the Middle East/North Africa

region has improved upon by 11.8%, followed by Europe/Central Asia (10.6%) and East Asia/Pacific with a mix of developed, medium and lower developed countries by 8.7%. Altogether, the DEE differences between the more and less developed regions decreased in relative but increased in absolute terms.

6. Table DEE Index scores and changes over the 2019-2021 period by regions

Region	DEE Score 2019	DEE Score 2020	DEE Score 2021	DEE score change (%) 2019-2021	DEE score change (point) 2019-2021
South Asia	15.1	17.3	18.0	19.3%	2.9
Sub-Saharan Africa	12.1	13.2	13.9	14.3%	1.7
Middle-East/North Africa	32.8	35.2	36.6	11.8%	3.9
Europe/Central Asia	50.4	53.2	55.7	10.6%	5.3
Latin America/Caribbean	29.7	31.6	32.7	10.0%	3.0
East Asia/Pacific	44.0	46.2	47.9	8.7%	3.8
North America	78.1	78.5	82.6	5.7%	4.5

Finally, Table 7 and 8 shows the ten largest and lowest gainers.

7. Table The ten largest gainer countries in the DEE Index scores over the 2019-2021 period

Country	Region	DEE Score 2019	DEE Score 2020	DEE Score 2021	DEE score change (%) 2019-2021	DEE score change score 2019-2021
Benin	Sub-Saharan Africa	7.1	8.6	10.8	53.1%	3.7
Malawi	Sub-Saharan Africa	4.9	7.4	7.2	46.5%	2.3
Kuwait	Middle-East/North Africa	24.8	31.7	35.8	44.3%	11.0
Mali	Sub-Saharan Africa	4.8	5.9	6.8	42.4%	2.0
Madagascar	Sub-Saharan Africa	5.0	6.4	6.6	32.0%	1.6
Vietnam	East Asia/Pacific	20.8	25.1	27.0	29.7%	6.2
Sri Lanka	South Asia	17.0	20.3	21.6	27.3%	4.6
Dominican Republic	Latin America/Caribbean	23.7	27.5	30.1	26.7%	6.4
Mongolia	East Asia/Pacific	17.6	20.0	22.0	25.2%	4.4
Tanzania	Sub-Saharan Africa	8.2	12.8	10.2	23.7%	2.0

Out of the ten largest gainers, five are from the Sub-Saharan Africa. While their relative growth is impressive, they remain at the bottom of DEE ranking. Two Asian countries, Vietnam and Sri Lanka were in better position than the Sub-Saharan countries, and their advances are higher in absolute terms similar to the Dominican Republic. The oil rich Kuwait has done an

impressive advance both in absolute and relative terms by increasing its DEE score from 24.8 to 35.8. Note that all of these countries but Kuwait belong to the low income country group.

8. Table The ten lowest gainer countries in the DEE Index scores over the 2019-2021 period

Country	Region	DEE Score 2019	DEE Score 2020	DEE Score 2021	DEE score change (%) 2019-2021	DEE score change (point) 2019-2021
Georgia	Europe/Central Asia	28.9	30.2	30.0	4.0%	1.1
United States	North America	80.7	81.4	83.8	3.8%	3.1
Moldova	Europe/Central Asia	30.8	29.4	31.6	2.7%	0.8
Korea	East Asia/Pacific	59.2	60.0	60.8	2.7%	1.6
Qatar	Middle-East/North Africa	39.5	40.5	40.4	2.5%	1.0
Panama	Latin America/Caribbean	33.0	33.8	33.1	0.5%	0.2
Algeria	Middle-East/North Africa	16.1	16.1	16.1	0.0%	0.0
Jordan	Middle-East/North Africa	25.2	24.0	23.8	-5.3%	-1.3
Ethiopia	Sub-Saharan Africa	9.5	5.8	5.4	-42.7%	-4.1
Burundi	Sub-Saharan Africa	5.9	2.4	3.3	-44.6%	-2.6

Now looking at the lowest gainers in Table 8 we can see that there were only three countries where the DEE decreased over the 2019-2021 time period: Two belligerent Sub-Saharan African countries, Ethiopia and Burundi and the Middle East Jordan. The North African Algeria has not done any progress. The Latin American Panama seems also to have problems, since its DEE score decreased from 2019 to 2021, similar to the rich Middle East Qatar. The developed Korea from East Asia produced continuous but moderate development similar to the European Moldova and Georgia. The US is also in this group, and due its relatively low 3.8%, and 3.1-point development, other countries have reduced the difference between the leader and their position. In fact, the difference between the first US and the second UK is only marginal, 0.5 point.

5. Improving the digital entrepreneurship ecosystem: Policy suggestions

Facilitating digital and entrepreneurship ecosystems is high on many government policy agendas. Many nations focus on developing the digital infrastructure, maintaining digital freedom and privacy, protecting users from cybercrime and piracy, improving the population's digital literacy, and supporting technology-related startups. However, enhancement of digital platform economies at the country level has been fragmented. Unfortunately,

there is little understanding of how policies can foster this new type of economy most effectively. Some policies, such as the European Union Global Data Protection Regulation, have in fact had negative effects on some information-sensitive business models (Hoofnagle, van der Sloot, & Borgesius, 2019). Those who want to regulate the digital entrepreneurship ecosystem should acknowledge that the most important digital technology companies are global and therefore call for global rather than local action.

Recent regulations, like the General Data Protection Regulation and the Global Data Protection Regulation, focus on ensuring that users know, understand, and consent to the data collected about them, which is not really helpful and not only limits the existing non-EU businesses but weakens EU-based startups. EU investigations of Microsoft, Alphabet/Google, Facebook, and other digital giants has only provided temporary protection for EU-based platform businesses. Therefore, national or EU-level regulators face dominant platform-based market players, most of which reside in the US. No dominant European player appears to be emerging in the platform business arena. Therefore, it is vitally important that the EU create an ecosystem that will enable local platform companies to become global actors.

The DEE Index is particularly helpful in identifying weaknesses in the ecosystem and providing solid policy suggestions. This index-building methodology relies on the Global Entrepreneurship Index techniques (Acs et al., 2014). Our policy propositions are based on two important postulates:

1. Classic economic policy focuses on easing market failures. Ecosystem policies thus should center on alleviating system failures, such as weaknesses in the digital entrepreneurship ecosystem.
2. Since the digital entrepreneurship ecosystem is different in each country, policy recommendations should be country specific. There is no one-size-fits-all policy.

Two important index-building techniques make it possible to sharpen policy suggestions. Equalization of the pillar averages balances out the marginal effects of improvements, and the Penalty for Bottleneck (PFB) penalizes for bottlenecks in the 12 pillars in the digital platform economy.[5]

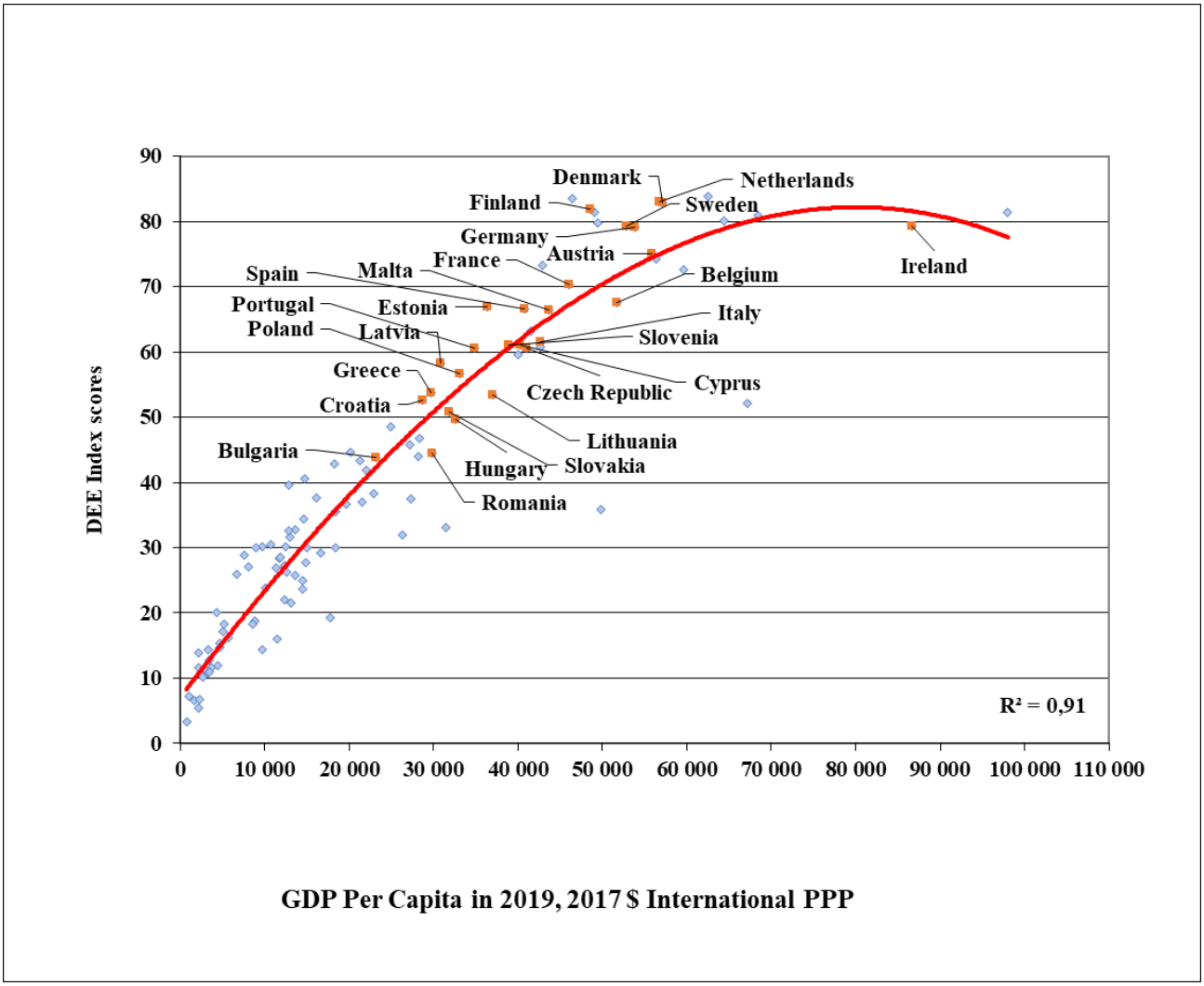
[5] For further details see Acs, Autio, and Szerb (2014).

We provide policy recommendations in three ways. First, we study how advanced a country's digital entrepreneurship ecosystem is. To do so, we calculate the development implied trend line and determine whether that country is above or below the line. This method takes into account the fact that countries have different levels of development. Therefore, we compare countries with similarly developed digital entrepreneurship ecosystem. We apply the third-degree polynomial adjustment because of two reasons: It provides a better fit in terms of explanatory power than the linear, logarithmic or the exponential functions and it properly reflect to the S shape of the learning curve. Second, we examine the balance of the digital ecosystem and entrepreneurship ecosystem components. We believe that a healthy digital platform economy requires both ecosystem components to be at around the same level. If a country's digital component is more advanced, it should work to strengthen its entrepreneurship ecosystem, and vice versa. Third, we identify the weak pillars in the digital platform economy ecosystem. We provide country-specific policy suggestions for distributing additional resources over the 12 pillars. We apply a 10% increase in the DEE Index scores. Our examples include the US, the UK, and select EU member countries.

The progress of the digital platform economy in the European Union

There is a close connection between development and DEE Index scores: The Pearson correlation coefficient is 0.92 without the oil-rich countries or countries with a per-capita GDP higher than 65,000 International $. The third-degree trend line shows an even closer connection, as pictured in Figure 6.

6. Figure The position of the EU countries in terms of the development implied trendline (third-degree polynomial adjustment)



Note: The trend line is calculated without countries over 65 000 international $ per-capita GDP and without the oil-based economies of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates.

The third-degree adjusted curve explains around 91% of the variation between development (measured by the per-capita GDP) and digital entrepreneurship ecosystem (DEE Index). Note that it does not imply a causal relationship; we simply refer to the strong connection between development and the digital entrepreneurship ecosystem. Examining a particular country's position below or above the implied development trend line is more appropriate than simply comparing differently developed nations. For example, the United Kingdom has the second highest DEE Index score (83.5) and is above the trend line. Of the large EU countries, Germany, France, Spain, and Poland are on or above the trend line. Italy has lower DEE Index scores than a similarly developed average country. This implies that Italy should focus to improve its digital entrepreneurship

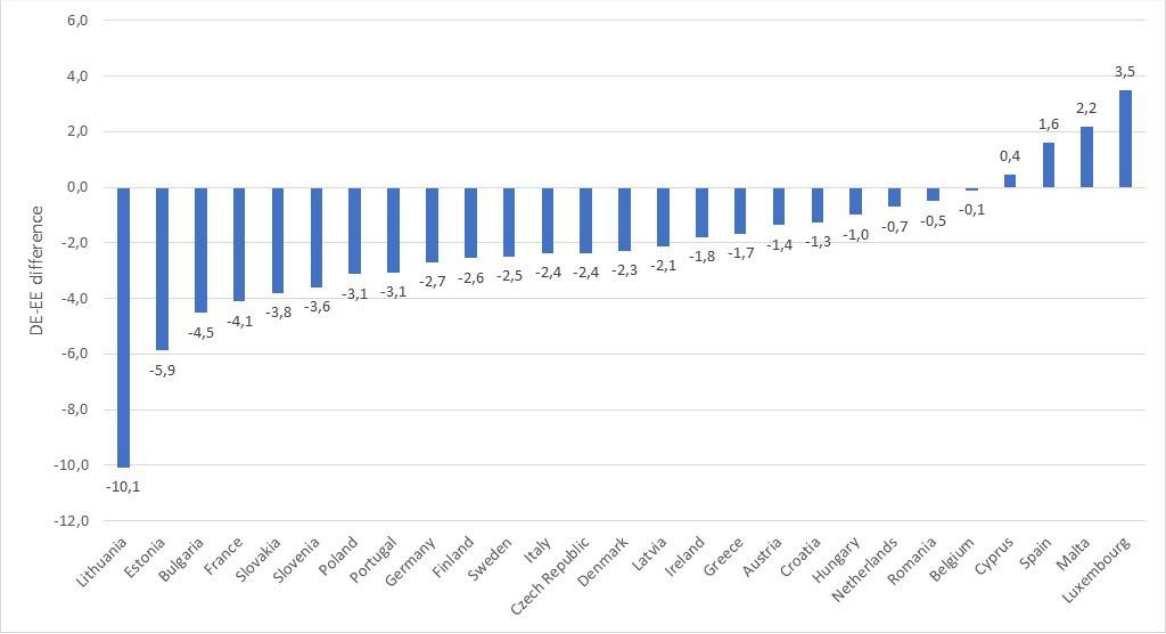
ecosystem since its DEE score is relatively low. The other examined countries that are better than an average similarly developed country are not urged to disproportionally spend more on improving their DEE score. However, if the EU targets to step ahead in the digital entrepreneurship ecosystem, the proper benchmarks are the United States, the United Kingdom, and The Netherlands.

Digital and entrepreneurship ecosystem investigations and policy recommendations

We believe that policy makers should focus on the balanced working of the digital entrepreneurship ecosystem. Fist, balance means that the digital and the entrepreneurship ecosystem component values are equal or close to be same. In order to investigate it, we calculate the digital and the entrepreneurship ecosystem scores from the average and withdraw it from the actual country scores. Then we withdraw the digital ecosystem score from the entrepreneurship ecosystem score for each country one by one. Positive values imply that a particular country has a better digital than entrepreneurship ecosystem. Negative values mean the opposite: A country has better entrepreneurship than digital ecosystem. The magnitude of the difference reflects to the size of deviations: the farther we are from zero the larger the difference between these two ecosystems. Figure 7 shows that DE and EE differences for our selected countries.

Based on Figure 7, Luxembourg, Malta, Spain and Cyprus have a stronger digital entrepreneurship than entrepreneurship ecosystems, while all the other EU countries' entrepreneurship ecosystems are more developed. This implies that Luxembourg, Malta, Spain and Cyprus should focus on improving their entrepreneurship ecosystem, and all the others should spend more on enhancing the digital ecosystem components. The size of the imbalances varies – Lithuania, Estonia, France, Slovakia, and Slovenia have larger imbalances while Belgium, Croatia, the Netherlands, and Hungary seem to be more balanced.

7. Figure Digital Ecosystem (DE) and Entrepreneurship Ecosystem (EE) score differences for selected European countries (based on 2021 data)



Source: based on own calculation

The increase of the DEE Index scores: Optimizing additional resources

The distinctive methodological features of the DEE Index are designed to capture the unique characteristics of digital entrepreneurship ecosystems, and thus to facilitate effective policymaking for these ecosystems. It captures the digital entrepreneurship ecosystem dynamic by interacting with the digital and the entrepreneurship ecosystem components. It uses 12 interacted pillars that are organized into four sub-indices. Importantly, it uses a PFB algorithm to facilitate the identification of bottleneck factors that hold back digital entrepreneurship economy performance. See Appendix B for a detailed description of the DEE Index method.

The DEE Index methodology captures two important aspects that define the digital entrepreneurship economy. First, it recognizes that the different pillars need to work together to create a high-quality ecosystem dynamic. Traditional indices fail to capture this aspect. In traditional indexing methods, the different components (pillars) are allowed to substitute for one another. In other words, a traditional index would allow, say, digital access to compensate for digital literacy. The DEE Index methodology requires that a high-quality digital entrepreneurship economy dynamic have both high digital access and high-quality digital literacy, in addition to the system's 10

other pillars. If one or more pillars perform poorly, it is likely to hold back the performance of the entire system. Although one can compensate to some degree for, say, digital access with digital literacy, the digital platform economy ecosystem is likely to grind to a halt if either element is completely absent.

The notion of bottlenecks derives directly from the notion that ecosystem elements interact to co-produce ecosystem performance. Because one cannot fully substitute individual pillars for others, poorly performing pillars can create bottlenecks that prevent the ecosystem from fully leveraging its strengths. To simulate this effect, the DEE Index methodology applies the PFB algorithm. This algorithm systematically penalizes ecosystem pillars according to its poorly performing pillars. By highlighting potential constraining factors in the entrepreneurial ecosystem, the PFB algorithm guides policy attention to the aspects of the ecosystem that may benefit most from coordinated policy action. These methodological innovations of the DEE Index provide important insights into the workings of digital entrepreneurship ecosystems. Essential to the bottlenecks notion is that some factors may unduly constrain system performance beyond their objective importance. With the PFB methodology, it is possible to identify both where bottlenecks might lurk in any given system and how much the system performance will suffer as a result.

Table 9 presents the 12 pillar scores of our selected European countries. It is clear that countries differ in the pillar configuration. While three countries—France, Germany, and Italy—have the same weakest pillar, Digital Literacy, the size of the bottleneck is different in each case. The balance of the configuration also varies considerably. The difference between the lowest and the highest pillar values is around 36.5-38.9% in the relatively well-balanced Germany, France, and the United Kingdom; in Italy and Spain it is close to 50%, and 57.1% in Poland.

9. Table The DEE Index pillar scores of the EU countries (based on 2021 data)

Country	Digital Access	Digital Freedom	Digital Protection	Digital Literacy	Digital Openness	Digital Rights	Networking	Matchmaking	Financial Facilitation	Technology Usage	Digital Adoption	Technology Absorption
Austria	76.7	75.9	69.8	**67.6**	85.8	80.8	78.9	85.7	71.3	74.4	70.1	69.8
Belgium	**48.6**	83.2	72.8	59.2	85.1	81.8	69.4	52.2	76.1	77.8	62.3	74.6
Denmark	72.2	87.0	75.4	82.9	83.7	97.0	90.7	86.6	93.5	89.9	79.9	**70.0**
Finland	100.0	95.3	75.3	99.9	80.2	91.9	82.2	**65.4**	91.3	87.7	71.1	68.7
France	64.3	72.2	76.6	**57.0**	80.0	72.4	65.9	68.5	71.1	83.5	74.5	73.3
Germany	81.1	85.6	71.6	**65.8**	90.0	85.2	79.0	76.5	84.1	95.2	77.8	72.1
Ireland	71.9	98.4	69.2	69.3	89.3	80.9	82.1	100.0	82.9	**63.7**	83.7	82.3
Luxembourg	56.3	77.0	67.4	**44.0**	92.8	96.4	67.0	83.4	92.7	91.9	99.8	65.5
Netherlands	**64.7**	85.7	66.6	91.6	93.1	94.2	94.6	81.7	92.7	86.5	92.8	81.3
Sweden	**57.2**	87.9	59.1	83.4	92.3	95.1	100.0	79.4	95.3	87.7	79.5	78.3
Western Europe	69.3	84.8	70.4	72.1	87.2	87.6	81.0	77.9	85.1	83.8	79.1	73.6
Cyprus	**58.6**	52.8	57.3	69.3	82.3	67.0	58.5	62.8	55.9	75.3	83.6	**42.3**
Greece	61.1	55.9	69.9	54.0	68.2	48.2	60.0	45.9	**41.1**	57.4	49.8	49.1
Italy	80.7	72.3	71.8	**48.5**	69.4	57.1	57.7	56.4	61.5	61.3	57.9	59.5
Portugal	58.6	71.4	73.3	**55.6**	78.9	58.5	63.9	53.9	54.8	**50.9**	57.9	59.6
Spain	57.4	63.7	87.6	60.4	88.3	74.3	64.4	73.6	65.2	**53.5**	65.5	63.6
Malta	60.2	52.2	**49.7**	54.7	65.3	64.8	94.7	77.4	77.0	77.0	88.5	64.7
South Europe	62.8	61.4	68.3	57.1	75.4	61.7	66.5	61.7	59.2	62.6	67.2	56.5
Bulgaria	40.4	45.6	58.7	55.3	39.9	40.8	70.1	**20.3**	40.4	55.8	58.3	50.3
Croatia	60.8	51.9	84.7	39.4	72.2	49.7	56.7	47.7	49.7	68.7	51.4	**33.7**
Czech Republic	68.0	59.7	97.3	51.9	69.2	67.0	66.5	**40.6**	60.5	80.8	54.3	51.6
Estonia	62.0	73.2	100.0	79.2	91.7	81.6	90.2	**38.0**	83.7	73.9	50.4	59.8
Hungary	63.9	49.9	66.6	35.1	79.2	52.7	61.2	**27.4**	43.2	65.4	45.9	51.8
Latvia	66.9	58.7	80.1	59.4	82.8	66.9	57.7	**36.6**	66.3	64.9	48.0	53.5
Lithuania	62.7	69.6	73.9	57.2	79.4	63.9	70.4	**22.1**	59.2	69.5	55.4	47.7
Poland	50.6	53.5	74.1	53.0	78.2	57.9	63.9	51.9	59.5	55.8	**43.5**	55.6
Romania	57.8	51.6	66.8	40.0	51.4	47.3	54.0	31.7	**29.8**	48.0	36.3	39.3
Slovakia	49.4	54.0	72.1	42.6	82.6	63.6	53.8	**30.4**	56.1	72.0	33.2	42.9
Slovenia	57.7	68.1	74.3	64.0	55.3	63.6	85.3	**42.8**	65.6	73.9	60.8	50.5
Central and Eastern Europe	58.2	57.8	77.2	52.5	71.1	59.5	66.3	**35.4**	55.8	66.2	48.9	48.8
Average	**63.3**	**68.6**	**72.7**	**60.7**	**78.0**	**70.4**	**71.8**	**57.0**	**67.4**	**71.9**	**64.2**	**59.7**

Source: Own calculation

Note: Bold letters are the weakest pillar values

This basic analysis can be taken further. Because the DEE Index methodology allows the ecosystem pillars to interact, it is possible to conduct sensitivity analyses and simulate different policy scenarios. We present a case where additional policy efforts were taken to achieve a 10% increase in the overall DEE Index score. This analysis, presented in Table 10, shows how the additional policy efforts should be allocated across the 12 pillars, assuming equal cost to increase pillar performance. These figures were calculated by focusing policy efforts on the most pressing bottleneck until it was alleviated, then moving to the next most pressing bottleneck, and so on. The colors in Table 10 represent the severity of the bottleneck pillar: darker colors mean an effect that is more pervasive, while lighter colors mean less bottleneck influence.

The optimal policy mix—the targeted pillars and the assigned resources—is different in every case underlying the validity of the tailor-made, country-specific policy recommendations. France has a relatively well-balanced ecosystem where nine out of the twelve pillars need to improve to reach the desired 10% increase in the DEE Index score. France should spend 28% of the additional resources for the Digital Literacy pillar, 17% for Digital Access, 15% for Networking, 11%. Less than 10% is necessary to increase for Matchmaking, 8% on Financial Facilitations, 7% Digital freedom, 6% on Digital rights, 4% on Technology Absorption and 3% on Technology Adoption. Similarly, Germany should improve nine pillars, but its pillar composition differs from France. While Germany and Italy both have the same bottleneck as France, the share of the additional resources to ease the bottleneck effect is different in each case. Poland also should spend the most to improve its technology Adoption pillar, but its policymakers should also strongly target Digital Access and Matchmaking. Spain's main focus is Digital Usage with 24% of the additional resources but Digital Access (20%) and Digital Literacy (15%) are also strong bottlenecks. The United Kingdom, second in the DEE Index ranking, has three serious bottlenecks as Digital Access (34%), Digital Literacy (31%) and Digital Usage (18%) all the other pillars seem to require significantly les improvement. It seems that Digital Literacy is the most problematic pillar in the European Union that might require a central program to improve.

10. Table Digital platform economy optimization analysis for the EU countries: The distribution of additional resources for a 10% increase of the DEE Index scores (based on 2021 data)

Country	Digital Access	Digital Freedom	Digital Protection	Digital Literacy	Digital Openness	Digital Rights	Networking	Matchmaking	Financial Facilitation	Technology Usage	Digital Adoption	Technology Absorption
Austria	6%	7%	14%	18%	0%	1%	4%	0%	13%	9%	14%	14%
Belgium	38%	0%	0%	19%	0%	0%	0%	32%	0%	0%	11%	0%
Bulgaria	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
Croatia	0%	0%	0%	32%	0%	5%	0%	11%	5%	0%	0%	47%
Cyprus	6%	19%	11%	0%	0%	0%	9%	0%	13%	0%	0%	43%
Czech Republic	0%	0%	0%	19%	0%	0%	0%	47%	0%	0%	14%	21%
Denmark	21%	4%	18%	9%	8%	0%	0%	5%	0%	0%	12%	24%
Estonia	0%	0%	0%	0%	0%	0%	0%	71%	0%	0%	29%	0%
Finland	0%	0%	15%	0%	8%	0%	5%	28%	0%	0%	20%	24%
France	17%	7%	0%	28%	0%	6%	15%	11%	8%	0%	3%	4%
Germany	6%	0%	17%	25%	0%	1%	9%	12%	2%	0%	10%	17%
Greece	0%	2%	0%	6%	0%	15%	0%	21%	29%	0%	13%	13%
Hungary	0%	0%	0%	33%	0%	0%	0%	63%	4%	0%	0%	0%
Ireland	17%	0%	20%	20%	0%	5%	3%	0%	3%	28%	1%	3%
Italy	0%	0%	0%	26%	0%	13%	11%	15%	7%	7%	11%	10%
Latvia	0%	0%	0%	0%	0%	0%	0%	60%	0%	0%	29%	11%
Lithuania	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
Luxembourg	30%	0%	0%	67%	0%	0%	0%	0%	0%	0%	0%	3%
Malta	12%	26%	31%	21%	3%	3%	0%	0%	0%	0%	0%	3%
Netherlands	35%	6%	32%	0%	0%	0%	0%	11%	0%	4%	0%	11%
Poland	16%	11%	0%	11%	0%	4%	0%	15%	0%	7%	29%	7%
Portugal	9%	0%	0%	14%	0%	9%	0%	15%	15%	20%	9%	8%
Romania	0%	0%	0%	8%	0%	0%	0%	29%	34%	0%	18%	11%
Slovakia	0%	0%	0%	9%	0%	0%	0%	44%	0%	0%	38%	9%
Slovenia	10%	0%	0%	0%	17%	0%	0%	42%	0%	0%	4%	27%
Spain	20%	9%	0%	15%	0%	0%	9%	0%	8%	24%	6%	9%
Sweden	45%	0%	42%	0%	0%	0%	0%	4%	0%	0%	4%	5%

Source: Own calculation

While this simulation exercise obviously includes a number of simplifying assumptions (notably, equal cost to address each pillar; an equally applied bottleneck penalty for all pillars; pillars' equal ability to be changed by policy action), it nevertheless demonstrates the DEE Index methodology's ability to assess different policy

scenarios. Although the scenarios should not be taken as prescriptive, the exercise nevertheless highlights priority areas that could be explored further. Another important benefit is that even this simplifying analysis suggests that there may be important differences among European countries in terms of policy priorities in facilitating the digital entrepreneurship ecosystems.

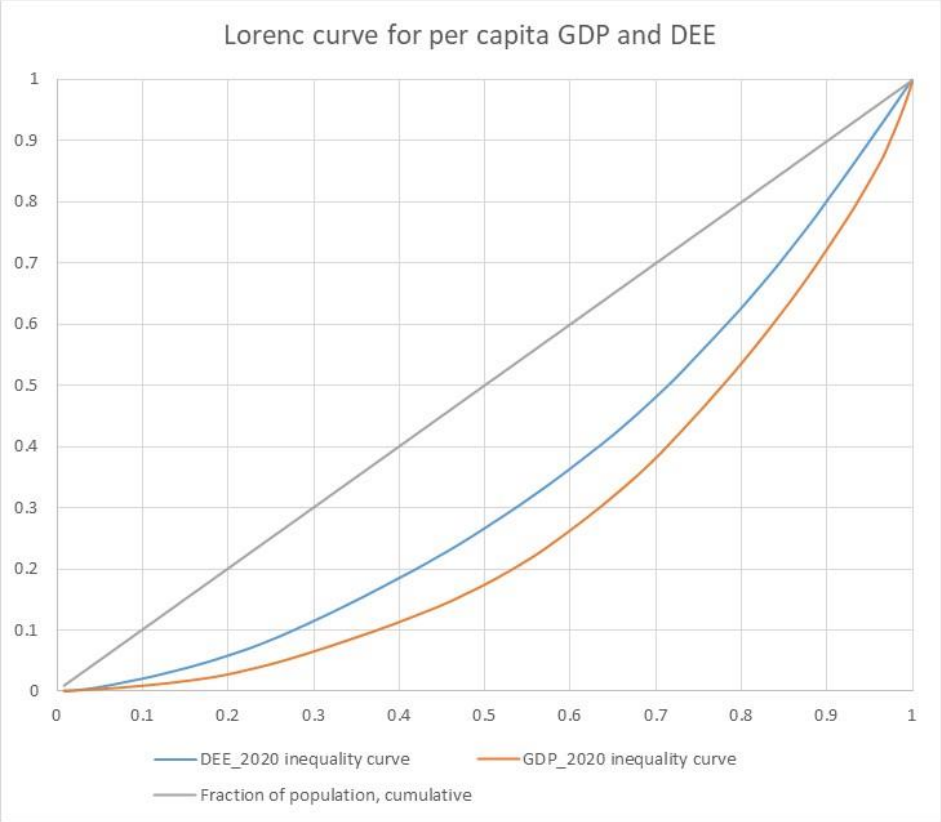
6. The Digital Entrepreneurship Ecosystem and inequality

The world has become a more digitally dependent place, mostly as a result of the rapid penetration of Internet and information and communications technologies (ICTs) in the day-to-day routines of governments, organizations and the people (Acs et al., 2021; Lafuente et al., 2022). But, digital integration is not occurring evenly (United Nations, 2020). The increased digitization of societies has given rise to a new form of inequality—namely, digital inequality—that is rapidly spreading across the globe affecting millions of people, being the poorest the most negatively affected. For the 115 countries included in the DEE, a simple inspection of the data made available by the World Bank (https://data.worldbank.org) reveals that 89% of the population living in OECD countries have access to the Internet in 2021 (84% in 2019), whereas this figure stands at 67% among non-OECD countries (58% in 2019).

Various factors contribute to the reported digital inequality. Besides the obvious economic differences between countries, geopolitics also spurs the digital divide. The rivalry between China—whose recently developed tech industry is propelling the country's digital prosperity—and the USA is fueling a digital polarization that has opened the gate to impose various restrictions on access to 'hard tech' components and the mutual banning of digital platforms (The Economist, 2021).

Besides altering the functioning of societies in various dimensions, the Covid-19 pandemic also left a legacy of increased digital inequality (Nguyen et al., 2021; O'Sullivan, 2021). Finally, from Figure 8 it can be seen that the trajectory of digital inequality figures moves in parallel to economic inequality estimations, which suggests that structural deficiencies exist in the design and development of policies supporting the digital entrepreneurial ecosystem.

8. Figure Lorenz inequality curves for DEE and GDP (based on 2021 data)



All these problems threaten digital integration. For people living on the wrong side of the digital divide the weak Digital Technology Infrastructures have negatively affected the rest of DEE pillars (i.e., Digital User Citizenship, Digital Multi-sided Platform, and Digital Technology Entrepreneurship). The inability to connect to the Internet have materialized in severe limitations in terms of access to information online, e-commerce, remote education, remote work, as well as digital health care and banking services.

Recently, many voices invoke the digital ecosystem supporting the networks of the digital ecosystem's actors as an essential medicine to combat digital inequality and, subsequently, trigger the societal benefits of digitalization (Acs et al., 2021; O'Sullivan, 2021; Lafuente et al., 2022). As in Acs et al. (2023, chapter 8), it should be noted that we interpret Internet access—in terms of total population and proportion of the population with access to the Internet—as an accurate quantitative proxy variable of the degree of digital inclusion.

The components of the digital entrepreneurial ecosystem, especially those linked to digital infrastructures and technologies, are essential to warrant digital inclusion by supporting the access to the Internet to the population and, subsequently, to help

citizens, entrepreneurs and local incumbent businesses to carry out different social and economic activities, for example, electronic trade (e-commerce), work from home, as well as accessing information and essential services such as education and health care.

Throughout this report it has become evident that countries still need to do a lot of work if the development of a solid digital entrepreneurial ecosystem is the desired goal. The results of the DEE are highly influenced by countries' context, and at this point a relevant question raising is whether DEE-enhancing efforts are contributing more to support digital inclusion in developed countries or; on contrary, the positive effect of improvements in DEE pillars, in terms of reduced digital inequality, are more prevalent among developing countries.

We propose a two-stage analysis to answer this question empirically. In the first stage we employ OLS regressions to test if variations in Internet access figures between 2019 and 2021 follow a canonical convergence trajectory where the initial level of Internet access (i.e.in 2019) plays a prominent role, or if such variations in the population with access to the Internet are explained by improvements in the DEE.

In a second analytical stage we take the digital inequality discussion to a more qualitative level, and add to this brief debate potentially valuable insights on how the DEE and its pillars are helping to reduce digital inequality among the 115 countries included in this edition of the DEE.

Regression results are presented in Table 13, while the qualitative inspection of the Internet access data and the DEE results is summarized in Figure 9.

When digital inclusion is measured through the percentage increase in countries' population with access to the Internet, regression results are clear (Table 13). Digital inequality is not necessarily connected to a convergence process in which countries gradually catch-up the leading peers. To the contrary, regardless of the initial level of population with access to the Internet, significant reductions in digital inequality figures can be realized if countries invest in their digital ecosystem. Specifically, it was found that countries that directed their efforts toward improving the DEE pillars linked to Digital Technology Infrastructures and Digital Multi-sided Platforms significantly reduced digital inequality, in terms of increased Internet access figures (Table 13).

Digital infrastructures embody digital technologies as well as the regulation that governs their use. Countries that worked for improving technological infrastructures directly enhanced the quality of their DEE by amplifying Internet accessibility among

the population and keeping the digital economy secure. Developments in digital multi-sided platforms imply improvements in digital networking as well as in the access and use of digital financial solutions, which increases both digital communication (e.g., use of social media) and digital economic transactions (e.g., access to digital financial services, e-commerce).

11. Table Regression results: Digital inequality and the digital entrepreneurial ecosystem

Dependent variable: % variation in Internet access (2019-2021)	Model 1	Model 2
Internet access in 2019 (ln population with access to the Internet)	–0.0074 (0.75)	–0.0060 (0.74)
Variation in DEE score (2019-2021)	0.0378 (1.12)	
Variation in Digital Technology Infrastructures (2019-2021)		0.1045 (1.86)*
Variation in Digital User Citizenship (2019-2021)		–0.0186 (0.21)
Variation in Digital Multi-sided Platforms (2019-2021)		0.4610 (2.02)**
Variation in Digital Technology Entrepreneurship (2019-2021)		–0.2224 (0.61)
Controls	Yes	Yes
Constant	1.2678 (6.30)***	1.1174 (9.36)***
F-test (Adjusted R2)	20.01*** (0.5803)	21.27*** (0.6167)
Countries	115	115

Dependent variable = percentage variation in countries' population with access to the Internet. All models include the logged GDP per capita in 2019 (constant 2015 prices) and a set of continent dummy variables. Absolute *t*-statistics based on robust standard errors clustered by country are presented in parenthesis. * = *p*-value < 0.10, ** = *p*-value < 0.05, and *** = *p*-value < 0.01 (two-tailed).

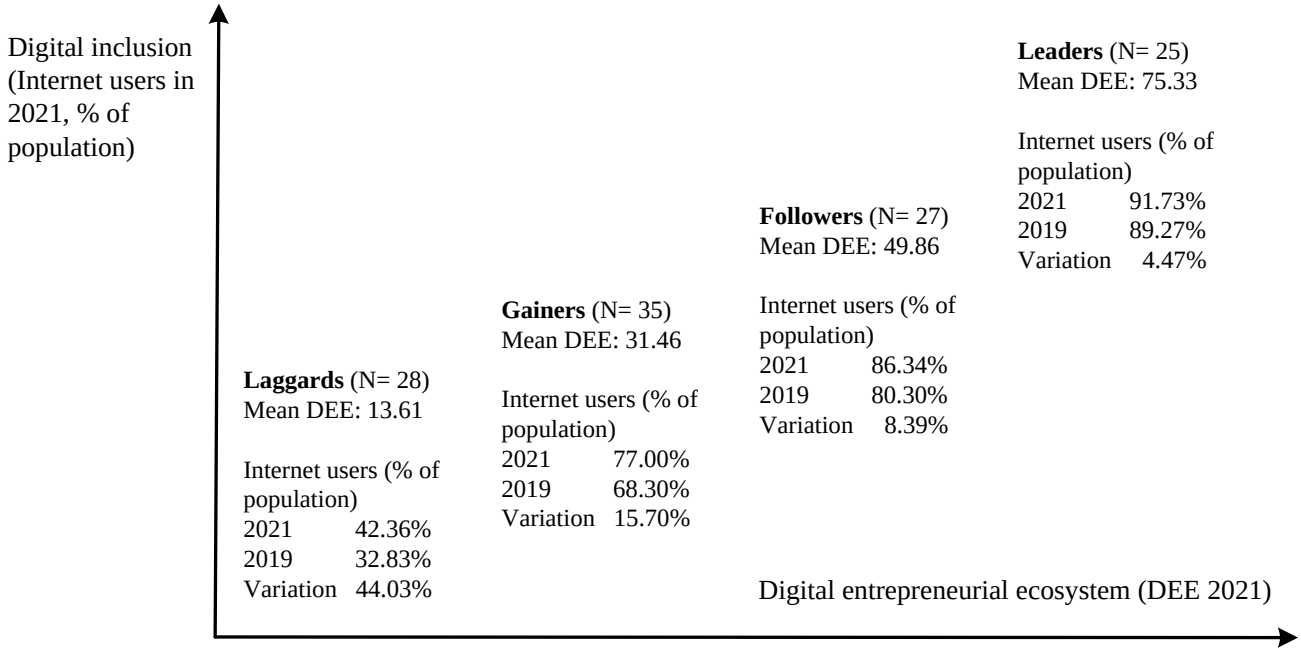
At this point, a further inspection of the results was needed to qualitatively verify what countries are improving their DEE in the right direction. Results are presented in Figure 9. The good news is that at the global scale poor countries are catching up, and the reported 'digital catch-up' between 2019 and 2021 can be linked to improvements in the DEE sub-indexes.

With the exception of the digital technology entrepreneurship sub-index which decreased on average 1.97%, laggard countries report the greatest improvement in the DEE sub-indexes between 2019 and 2021, especially in user citizenship (40.88%) and technology infrastructures (27.94%). In this group of countries, Mali and Benin are atop in terms of improvements in the digital technology infrastructure sub-index, whereas Pakistan, Burundi, Ethiopia and Algeria worsen their digital technology infrastructures between 2019 and 2021. Results in Figure 12 indicate that the average improvement in the multi-sided platform sub-index was less pronounced (16.03%).

A similar path was found for the group of gainers. Among these countries, the user citizenship and the technology infrastructure sub-indexes improved on average 32% and 13.94%, respectively. Kuwait, Vietnam and Dominican Republic are notable cases of countries with large improvements in these sub-indexes. On contrary, Panama, Ecuador and Jordan are example of countries that marginally improved or even deteriorated these relevant sub-indexes.

A different picture emerges when we look at the results for the groups of followers and leaders. For these two groups of countries DEE improvements are primarily dominated by variations in the sub-indexes linked to user citizenship and multi-sided platforms. Compared to the leading countries, the group of followers reports a greater improvement in the user citizenship sub-index (26.40%) (China, Cyprus, and Serbia show the largest variation). In the case of the multi-sided platforms, the leading countries present a slightly higher improvement (12.32%) than that observed for the group of followers (11.38%). Among leading countries, Estonia, Finland, Malta, and Norway show the most notable improvement in the multi-sided platform sub-index, while the poorest variation in this sub-index was reported by Belgium, France and Israel.

9. Figure Digital inequality and the DEE (2019-2021)



DEE sub-indexes in 2021: Scores (variation rate between 2019 and 2021 in parenthesis)

	Laggards	Gainers	Followers	Leaders
DTI	17.03 (27.94%)	32.32 (13.94%)	50.73 (6.98%)	70.76 (8.88%)
DUC	10.50 (40.88%)	32.31 (32.00%)	55.45 (26.40%)	77.81 (12.32%)
DMP	13.17 (16.03%)	30.30 (8.94%)	47.46 (9.55%)	78.36 (11.38%)
DTE	13.76 (-1.97%)	30.92 (4.04%)	45.80 (2.30%)	74.40 (2.51%)

Note: DTI = Digital Technology Infrastructures, DUC = Digital User Citizenship, DMP = Digital Multi-sided Platforms, DTE = Digital Technology Entrepreneurship

7. Summary and conclusion

The recent digital and information technology revolution has had a major impact on entrepreneurship. Platform-based developments have helped to drastically reduce transaction costs and increase the appearance of new business models. This Schumpeterian type of organizational innovation has given birth to trillion-dollar businesses like Apple, Alphabet, Amazon, Microsoft, and Facebook. These platforms and others provide a fertile field for Kirznerian-style digital entrepreneurs. However, digital entrepreneurs require a different environmental context than non-digital ones. Even if a country builds out its digital ecosystem, there is no guarantee it will be implemented by existing firms. In the same vein, if a country builds out its entrepreneurial ecosystem, there is no guarantee that startups will introduce new technologies. For technology to be introduced successfully, the digital ecosystem and the entrepreneurial ecosystem must 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 DEE Index consist of four sub-indices (i.e., Digital User Citizenship, Digital Technology Infrastructure, Digital Multi-sided Platforms, 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 Adoption, and Technology Absorption), and 61 indices.

On a global scale, developed Anglo-Saxon and Nordic nations lead the DEE Index ranking, followed by other prosperous countries in Europe, Asia, and Oceania (i.e., Australia and New Zealand). Many mid-developed countries in 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 DEE Index scores. In terms of the DEE Index, the poorly performing countries include underdeveloped African and Asian countries, as well as some developing European and Latin American nations. The specific analysis for the EU reveals that most countries (22 out of 27) are on or above the implied development trend line; however, they are far from the DEE Index's two top-performing countries (the US and UK), except for 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%. 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 (Naudé, 2016). It seems that the EU's institutional setup is better suited to the self-employment type of small business than to fast growing billion-dollar businesses, the unicorns. If the EU is to survive and prosper, it must rebalance its digital entrepreneurial ecosystem policies to promote technology innovation and platform companies and create a sustainable platform economy.

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Appendix A: The applied indicators in the Digital Entrepreneurship Index

In the following tables—A.1-A.4—we describe all the applied indicators in the DEE Index. The four tables represent the four sub-indices of the DEE Index.

The first column of the tables represents the abbreviated name of the particular indicator. It consists of three parts. The first part is always the name of the sub-index, the second is the number of the pillar, and the third is the number of the indicator. The indicators belonging to a particular pillar are denoted by different colors.

The second column contains the full name of the indicator, the source of the data, and the year of the survey. The bottom part of the second column cell incudes the full name of the pillar and the type of indicator. There are four types of indicators: Institutions and Agent are part of the entrepreneurship ecosystem, and Digital Technology and Users are part of the digital ecosystem.

The third column contains the full description of the particular indicator.

Table A.1 The applied indicators of DTI sub-index

Digital Openness	**DIG_P1_I1**	***ICT regulation,*** ICT Regulatory Tracker, ITU Digital Openness – Institutions	The Tracker pinpoints the changes taking place in the ICT regulatory environment.
	DIG_P1_I2	***Global Cyberlaw Tracker*** UNCTAD, 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. 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	***Network coverage*** GSMA Mobile Connectivity Index Digital Openness – Digital technology	combined measure of the percentage of the population's G2, G3, G4, G5 network coverage
	DIG_P1_I4	***Spectrum*** GSMA Mobile Connectivity Index Digital Openness – Digital technology	Spectrum relates to the radio frequencies allocated to the mobile industry and other sectors for communication over the airwaves. Additional frequencies including both coverage and capacity bands means mobile operators can connect more people and offer faster speeds.
Digital Freedom	**DIG_P2_I1**	***Business freedom*** Index of Economic Freedom, 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, 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, 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 chapter.
	DIG_P2_I3	***Internet & telephony competition/Global Cyberlaw Tracker*** ICT Regulatory Tracker, ITU, Digital Freedom – Digital technology	Competition framework for the ICT sector (level of competition in the main market segments).

	DIG_P2_I4	***Mobile tariff*** ICT Regulatory Tracker, ITU, Digital Freedom – Digital technology	The combined cost of 0,1 GB, 0,5GB, 1GB, and 5GB (% of monthly GDP per capita)
		Handset prices ICT Regulatory Tracker, ITU, Digital Freedom – Digital technology	Cost of cheapest internet-enabled device (% of monthly GDP per capita)
Internet Security	**DIG_P3_I1**	***National Cyber Security Index (NCSI)*** Internet security – Institutions	The National Cyber Security Index is a global index, which measures the preparedness of countries to prevent cyber threats and manage cyber incidents. The NCSI is also a database with publicly available evidence materials and a tool for national cyber security capacity building.
	DIG_P3_I2	***Global Cybersecurity Index legal subindex (ITU)*** Internet security – Institutions	Measuring the laws and regulations on cybercrime and cybersecurity
	DIG_P3_I3	***Secure Internet servers/million pop.*** WEF Network Readiness Index data) Internet security – Digital technology	Secure internet servers per million population.
	DIG_P3_I4	***Net infection ratio*** Kaspersky Internet security – Digital technology	The sum of percentages of users on whose devices Kaspersky Lab products intercepted web threats and network attacks in the last month.

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

Digital Literacy	**DUC_P1_I1**	***Digital skills among population*** Global Competitiveness Index, 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	***Human Capital Index*** World Bank Digital literacy –institutions	The Index measures which countries are best in mobilizing the economic and professional potential of its citizens. The index measures how much capital each country loses through lack of education and health.
	DUC_P1_I3	***E-participation index*** UN E-Government knowledgebase Digital Literacy – Institutions	Promoting participation of the citizenry is the cornerstone of socially inclusive governance. The goal of e-participation initiatives should be to improve the citizen's access to information and public services; and promote participation in public decision-making which impacts the well-being of society, in general, and the individual, in particular
	DUC_P1_I4	***School enrollment, tertiary (% gross)*** World Bank Digital Literacy – Institutions	Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education
Digital Access	**DUC_P2_I1**	***Percentage of households with Internet access at home*** World Telecommunication/ICT Indicators Database, Digital access – Users	Percentage of households with Internet access at home
	DUC_P2_I2	**Percentage of households equipped with a personal computer** World Telecommunication/ICT Indicators Database Digital access – Users	Percentage of households equipped with a personal computer
	DUC_P2_I3	***Global Cybersecurity Index technical subindex*** ITU, Digital access – Institution	Technical: Measured based on the existence of technical institutions and frameworks dealing with cybersecurity.
	DUC_P2_I4	***Global Cybersecurity Index organizational subindex*** ITU,	Organizational: Measured based on the existence of policy coordination institutions and strategies for cybersecurity development at the national level.

		Digital access – Institution	
Digital Rights	DUC_P3_I1	***Percentage of Individuals using the Internet*** World Telecommunication/ICT Indicators Database, Digital Rights – Users	Percentage of Individuals using the Internet
	DUC_P3_I2	***Regulatory quality*** World Bank, Worldwide Governance Indicators Digital Rights – Institutions	The regulatory quality indicator captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.
	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.
		Intellectual property rights International Property Rights Index, Property Rights Alliance, 2013 Digital Rights – Institution	The average of the two sub-indexes as Physical property rights and Intellectual property rights from International Property Rights Index.

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

Social networking	DMSP_P1_I1	***Use of virtual social networks, 1–7 (best)*** WEF Network Readiness Index, 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*** We are social, Hootsuite Networking – Users	Active social media users, penetration (%).
	DMSP_P1_I3	***E-Government*** UN E-Government knowledgebase Networking – Users	The E-Government Development Index presents the state of E-Government Development of the United Nations Member States. The EGDI is a composite measure of three important dimensions of e-government, namely: provision of online services, telecommunication connectivity and human capacity.
	DMSP_P1_I4	**Professional developers** Stockoverflow dataset Networking – Agent	A combined measure of professional developers based on the percentage of professional developers per 100 000 population and the log of the number
Matchmaking	DMSP_P2_I1	***Top ranked apps accessibility*** GSMA Mobile Connectivity Index Matchmaking – Users	Accessibility of the top ranked apps
	DMSP_P2_I2	***Apps developed per person*** GSMA Mobile Connectivity Index Matchmaking – Agent	Mobile apps developed per person
	DMSP_P2_I3	***Number of apps in national language*** GSMA Mobile Connectivity Index	Number of mobile apps available in national language, standardized

		Matchmaking – Agent	
Digital Finance	DMSP_P3_I1	***Credit card (% age 15+)*** World Bank Global Financial Inclusion, 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, 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, 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, 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	***Risk attitude*** Global Competitiveness Index, Financial facilitation – Agent	Answers to the question: In your country, to what extent do people have an appetite for entrepreneurial risk? [1 = not at all; 7 = to a great extent)
	DMSP_P3_I6	***Fintech business*** Dealroom, Financial facilitation – Agent	The number of financial technology businesses standardized by the number of population, own calculation

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

Digital Tech Usage	DTE_P1_I1	***Fixed broadband Internet subscriptions*** World Bank Digital tech usage – Digital technology	Fixed-broadband Internet subscriptions per 100 population
		Internet bandwidth ICT Digital tech usage – Digital technology	International Internet bandwidth (kb/s) per Internet user
	DTE_P1_I2	***Electricity availability*** EIA + World Bank Digital tech usage – Digital technology	Combination of electricity net consumption (billion kWh)/ million population with electricity access of the percentage of population
	DTE_P1_I3	***Technicians and associate professional*** International Labor Organisation Digital tech usage – Agents	The number of technicians and associate professionals as a percentage of the total workforce. Employment by occupation data follows the International Standard Classification of Occupation (ISCO) Revision 2008
	DTE_P1_I4	***Intermediate education level*** International Labor Organisation Digital tech usage – Agents	Labor force with at least intermediate education (% of total working-age population with intermediate and advanced education)
	DTE_P1_I5	***Firms with website*** Network readiness Index Digital tech usage – Agents	Firms with website (% of total)

Digital tech adaptation	**DTE_P2_I1**	***Generic top-level domains (gTLDs)*** Global Innovation Index Digital tech adaptation – Digital technology	Generic top-level domains (gTLDs) (per thousand population 15–69 years old).
	DTE_P2_I2	***Professional*** International Labor Organisation Digital tech adaptation – Agent	Professionals are the number of professionals as a share of the total workforce. The employment by occupation is based on the International Standard Classification of Occupation (ISCO)
	DTE_P2_I3	***Advanced education level*** International Labor Organisation Digital tech adaptation – Agent	Labor force with advanced education (% of total working-age population with advanced education)
	DTE_P2_I4	***Adoption of emerging technology*** Network Readiness Index Digital tech adaptation – Agent	Average answer to survey questions concerning the extent to which companies adopt five types of emerging technology
Digital tech absorption	**DTE_P3_I1**	***Computer software spending*** The Global Innovation Index, Technology transfer – Digital technology	Computer software spending includes the total value of purchased or leased packaged software, such as operating systems, database systems, programming tools, utilities and applications. It excludes expenditures for internal software development and outsourced custom software development.
	DTE_P1_I2	***Data centers*** Data Centers Catalog, 2019 Technology absorption – Digital technology	Combined data centers number and density based on population.
	DTE_P2_I3	***Managers*** Researcher talent at business Technology transfer – Agent	This variable measures the percentage of legislators, senior officials, and managers within total employment. The employment by occupation is based on the International Standard Classification of Occupation (ISCO
	DTE_P2_I4	***Researcher talent at business*** Global Innovation Index Technology transfer – Agent	Percentage of businesses. The full-time equivalence (FTE) of researchers in the business enterprise sector engaged in the conception or creation of new knowledge, products, processes, methods, and systems, as well as in the management of these projects, broken down by the sectors in which they are employed
	DTE_P2_I5	***Innovative startups*** Startup ranking Technology transfer – Agent	The combination of absolute startup number and startup number per population

Appendix B: The calculation of the DEE Index and the components scores

According to the model pictured in Figure 1 and detailed in Figure 2, we suggest a five-level composite indicator 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 of 24 variables representing digital ecosystem (12) and entrepreneurship ecosystem (12). Variables are built from 61 indicators that are the elementary building blocks of the DEE Index.

Indicator selection was based on three 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. The indicators are available as follows: for 85 countries more than 95.1%, for 23 countries 90.1-95.0%, and for 8 countries 80.1-90.0%. The results for these eight countries—Benin, Burundi, Hong Kong, Jamaica, Macedonia, Madagascar, Namibia, Taiwan—should be viewed with caution. 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:

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

where

i=1……n, the number of countries
$DEE\_pillar_{i,j}$ 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:

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

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

When we calculate the normalized averages of the twelve pillars for the 115 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 in using the pillar values for public policy purposes. The average pillar adjustment methodology developed by Acs, Autio, and Szerb (2014) reduces but does not fully eliminate this problem.

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

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

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

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

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

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

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

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

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

For the 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 on one another. This interaction should be included in the calculation of the pillar, the sub-index, and the DEE 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 DEE Index would show a significant improvement.

We define our penalty function following as:

$$\text{DEE\_penalized}_{(i),j} = 100 * \min \text{DEE\_pillar(equal)}_{(i),j} + (1 - e^{-(y_{(i)j} - \min \text{DEE\_pillar(equal)}_{(i),j})}) \qquad (4)$$

where $\text{DEE\_penalized}_{i,j}$ is the modified, post-penalty value of pillar j in country i
$\text{DEE\_pillar(equal)}_{i,j}$ is the normalized value of index component j in country i
$\text{DEE\_pillar(equal)}_{\min}$ is the lowest value of $y_{i,j}$ for country i.
i = 1, 2,……115 = 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:

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

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

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

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

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 DEE Index score is calculated as the simple arithmetic average of the four sub-indices:

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

Where DEE_i is the Digital Entrepreneurship Ecosystem 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 DTE=0.84, for DMSP=0.92, and for DTE=0.93.