



# Measuring digital entrepreneurship ecosystems: The Digital Entrepreneurship Index

## Preliminary report

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**Abstract:** The application of big data, new algorithms and cloud computing is creating a global digital platform economy built around platform companies. If a country builds out its *digital ecosystem* there is no guarantee it will be implemented by existing firms. In the same vein if a country builds out its *entrepreneurial ecosystem* there is no guarantee startups will introduce new technologies. For technology to be successfully introduced both the *digital ecosystem* and the *entrepreneurial ecosystem* need to be developed simultaneously. The *digital entrepreneurial ecosystem* (DEE) framework integrated these two ecosystems and the current report measures it for 116 countries in twelve aspects of DEE. Rich Anglo-Saxon and Nordic countries lead the Digital Entrepreneurship Index (DEI) ranking followed by other European and Asian developed nations with two developed Oceanian countries, New Zealand and Australia. Many middle-developed European, Asian and Latin American countries have below average DEI scores together with some oil rich countries, Bahrain, Oman, Qatar, Saudi Arabia, United Arab Emirates. Countries at the bottom are low developed African and Asian countries together with some relatively poor European and Latin American nations.

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## 1. Introduction – The concept of digital entrepreneurship ecosystem

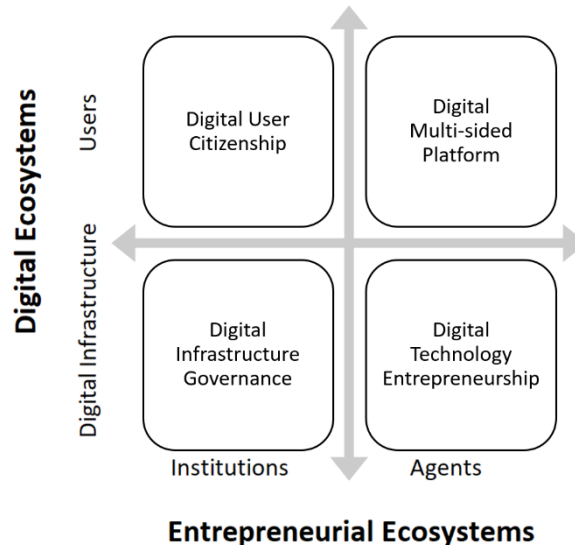
Over the last few decades, a new breed of businesses equipped with digital technologies has disrupted industries, including finance, communication, advertising, operating system as well as various internet-based industries ranging from real estate to transportation. Some are startups that have become new market leaders. Consider the likes of Uber and Airbnb or Facebook, Amazon, Apple, Netflix and Google (FAANG). Many of them are *Matchmaker* businesses whose core competency is the ability to match one group of users with another by reducing the transaction cost. The advancements in information communication technologies (ICT) opened a pathway for these businesses. More specifically, platforms are enabled by technological openness (architectural interface specification) and organizational openness (governance) both of which are mediated by the platform owner. This rise of digital *multi-sided platforms* as avenues for value creation, appropriation, and innovation is commonly known as *platformization*.

Digital platforms are an emergent organizational form characterized by (1) technology: a modular core, standardized interfaces, and complementary extensions, and (2) social processes: a set of governance mechanisms managing the ecosystem of independent complementors. The ICT has elevated role of *users* and *agents*, and also the creation of platform ecosystems that facilitate their social and economic activities. In 2011, Stephen Elop, the Chief Executive Officer at Nokia, stated in a company memo, “Our competitors aren’t taking our market share with devices; they are taking our market share with an entire ecosystem.” Apple and Google opened up their platforms providing application programming interfaces (APIs), software development kits (SDKs) and other boundary resources that enabled complementors to access, customize, and exploit market opportunities within their digital platforms. These platforms offer important benefits to agents – such as, access to established market, reliability in transactions, reputation of platforms, and guaranteed operability. In effect, platforms have dramatically lowered the costs of development and distribution of mobile applications and other complementary products connecting to platforms that now worldwide app developers and other agents can exploit using heterogeneity of knowledge resources. *Entrepreneurial innovation closes the gap between supply opportunity and demand need within platforms*. The effective use of technology and mobilizing factors of production by third-party complementors increases platform efficiency.

The “Digital Entrepreneurial Ecosystem” (DEE) integrates two separate but related literatures on ecosystems, namely, digital ecosystem and entrepreneurial ecosystem. The framework consists of four components (See Figure 1): (1) Digital User Citizenship (DUC) concept includes users on the demand-side and the supply-side; (2) Digital Technology Entrepreneurship (DTE) includes app developers and various agents that contribute to entrepreneurial innovation, experimentation and value creation on platforms; (3) Demand-side driven intermediaries enabled by digital technologies that orchestrate social and economic activities between users and agents; (4) Digital Infrastructure Governance (DIG) pertains to all government policies and regulations that govern social and economic activities of users, agents, and platforms at the local, national, and

international levels in the digital age. *This new framework situates digital entrepreneurship in 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.*

**Figure 1: The Digital Entrepreneurship Ecosystem**



A sustainable biological ecosystem is one which can thrive and support itself without external assistance or interference. A number of conditions need to be satisfied for an ecosystem to be self-sustaining. A sustainable “Digital Entrepreneurial Ecosystem” is one in which (1) user privacy is protected; (2) platform efficiency enhanced by third-party agents; (3) market competition is not stifled by platforms; (4) security of digital infrastructure ensured. Creating and maintaining these conditions present its own unique set of challenges (See Table 3).

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

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

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

Fourth, *Digital Infrastructure Governance* is responsible for keeping the digital economy open and secure. Huawei has been accused of being controlled by the Chinese government, and its equipment spying on companies and countries. These allegations on the issues of control, ownership, and fraud have raised questions whether the Chinese smartphone and telecommunication giant should be allowed to build the world's 5G mobile infrastructure. While Huawei has defended itself as an open, transparent and trustworthy company, it remains to be seen how global users and governments will respond.

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

**Table 1: Keys to Building a Sustainable Digital Entrepreneurial Ecosystem**

| Digital User Citizenship  | Digital Multi-sided Platform  |
|---|---|
| <p>For a sustainable DEE, terms to user privacy should be clearly laid out and upheld by a social contract since public trust is a prerequisite to user participation in the digital economy.</p> <ul style="list-style-type: none"> <li>• Key word: “Privacy”</li> <li>• Example: Facebook</li> </ul>                  | <p>For a sustainable DEE, digital platforms should be kept in check from partaking in monopolistic behavior that stifles market competition, innovation, and entrepreneurial activities.</p> <ul style="list-style-type: none"> <li>• Key word: “Competition”</li> <li>• Example: Google</li> </ul>                                 |
| Digital Infrastructure Governance   | Digital Technology Entrepreneurship   |
| <p>For a sustainable DEE, governments are responsible for enacting and enforcing rules and regulations that discourage destructive activities that undermine data security and encourage productive activities.</p> <ul style="list-style-type: none"> <li>• Key word: “Security”</li> <li>• Example: Huawei</li> </ul> | <p>For a sustainable DEE, third-party agents engage in entrepreneurial innovation and knowledge exchange that close the gap between supply opportunity and demand need within platforms that increase platform efficiency.</p> <ul style="list-style-type: none"> <li>• Key word: “Efficiency”</li> <li>• Example: Apple</li> </ul> |

## 2. The concept refined - The twelve pillars and their measurement

We have spent the last three years assembling data and constructing the Digital Entrepreneurship Index (DEI) with which we attempt to measure the Digital Entrepreneurial Ecosystem at the country-level. Figure 1 (see above) pictures the structure of DEE showing the four frameworks, called sub-indices. All four framework include three constituents reflecting to most important aspects of Digital User Citizenship, Digital Multi-sided Platforms, Digital Technology Entrepreneurship, and Digital Infrastructure Governance. All pillars have two types of components, called variables according to Figure 2. For example, Digital rights pillar have an Institutions and a User’s component; and Digital adoption pillar consists of a Digital infrastructure and an Agent variable.

**Figure 2 The structure of DEI**

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

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

- The *Networking* pillar aims to grasp the network and other externality effect of MSP. We apply three, partially overlapping, indicators from the users' side: the use of virtual social networks (ITU), social media penetration (Hootsuite), and the use of virtual professional networks (WEF). From the agent side, we apply two WEF related indicators that are the ICT use of Business-to-business transactions and the business-to-costumer internet use.
- *Matchmaking* component aims to capture the multisided platform model effect. From the user side the active participation effect captured by two indicators from INSEAD that are the Wikipedia yearly edits, and the Video uploads on YouTube. From the agent side we use the number of professional developers as a percentage of population and as a logarithmic of the country share. This later indicator is supposed to grasp the size effect.
- *Financial facilitation* reflects to various aspect of finance that fuels matchmaking startups, makes possible financial transactions via the internet as well as providing platforms for financial source providers and users. From the user side, we apply four World Bank related indicators as Debit/credit card average, Used the internet to pay bills or to buy something online, used a mobile phone or the internet to access a financial institution account, Made or received digital payments. For the agent side we rely on three indicators, the Depth of Capital Market Sub-Index Score from The Venture Capital and Private Equity Country Attractiveness Index, the standardized number of Fintech companies based on Deal room data, and Venture capital availability from WEF.

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

- *Digital literacy* refers to the abilities of the citizens necessary to use computers, the digital infrastructure and digital platforms. From the user side we use two indicators one is the level of digital skills amongst the population from WEF and the other is the number of search users in a country as reported by Bloom Consulting. From the institutional part, we use two educational indicators, as the quality of education and the internet access to schools, both are from WEF.
- *Digital access* refers to level citizens have access to the digital infrastructure including computers and the internet. The institutional part of Digital access is captured by two proxy indicators, the technical and organizational sub-index from the Global Cybersecurity Index. The user part includes three indicators as fixed broadband internet



subscriptions, International Internet bandwidth, and the percentage of individuals using a computer.

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

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

- *Digital adaptation* aims to detect the basic capabilities of entrepreneurial agents to use digital technologies. From the agent side, we use two proxies, one for measuring the level of digitalization by computer software spending and another for the quantifying the basic talents in the country (skills of the workforce)
- The *Digital Absorption* pillar involves the advanced capabilities of the agents to be able to build new business models and/or digital products/services based on the opportunities provided by the digital infrastructure. The digital infrastructure component is captured by two indicators: The number of data centers from Data Centers catalog and the Availability of latest technology from WEF. The agent component is measured by a complex variable that is the knowledge absorption capacity sub-index and by two indicators reflecting to the effect of ICT on new business and organizational models. All data are from the Global Innovation Index.
- The *Technology transfer* pillar includes the knowledge spillover effect when agents are working on the discovery, evaluation, and exploitation of new opportunities brought about by evolving technologies. From the agent side, the tech transfer capability is proxied by a Startupranking based indicator that is the number of startups. The skill component is measured by the High-level skills that is a complex sub-index from the Global Talent Competitiveness Report. From the digital infrastructure part, we use two components one is from the Global Innovation index that is the Knowledge and technology output and a similar component from the Global Competitiveness Index that is the Innovation capacity.

*Digital Infrastructure Governance (DIG)* “...addresses the coordination and governance needed to establish a set of institutional standards...” (Sussan and Acs 217, p. 64) that are related to digital infrastructure.

- *Digital openness* reflects to how well a country’s institutions support the reach and the use of digital infrastructure. The digital infrastructure part is proxied by the percentage of individuals and household having access to the internet. The institutions side is measured by an indicator reflecting to the laws relating to ICT and a more complex indicator, the Global Cyberlaw Tracker.
- *Digital freedom* reflects to how the government and their institutions are able to give enough freedom to digital infrastructure development. The infrastructure part is measured by three indicators. The Freedom House two indices, the Freedom of the press, the Freedom of the world reflects to the overall freedom of a country. The Internet and telephone competition from the WEF Network Readiness Index measure the potential monopolization of the digital infrastructure. The associated counterpart from the digital infrastructure is measured by the number of internet domains from Global Innovation Index, and Webhosting, standardized by the size of population
- *Digital protection* captures the degree how law and regulation protect from piracy and cybercrime. The infrastructure part is measured by the Legal sub index of the Global Security Index and the Corruption Perception Index from Transparency International. The digital part is proxied by the WEF Network Readiness Index software piracy rate.

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

### **3. Measurement - Calculating of the DEI and the components scores**

Digital entrepreneurship is defined as the overlapping constituent of the digital and entrepreneurship ecosystems such that two biotic entities (users and agents) actuate individual agency, and two abiotic components (digital infrastructure and institutions) form the external environment. DEI framework includes Digital Infrastructure Governance, Digital User Citizenship, Digital Multi-sided Platform, and Digital Technology Entrepreneurship. According to this model pictured in Figure 2, we suggest a five-level composite indicator building following as (1) indicators (2) variables, (3) pillars, (4) sub-indices, and (5) the super-index. The super index is called the Digital Entrepreneurship Ecosystem index and its sub-indices are the four frameworks. The twelve components are called pillars. Pillars are the most important constituents of the model. Pillars are comprised from 24 variables, representing digital ecosystem (12) and entrepreneurship ecosystem (12). Variables are built from 61 indicators that are the elementary building blocks of DEI 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.<sup>1</sup> Table 2 contains the percentage of the indicators available for all the countries. For 85 countries more than 95.1%, for 23 countries 90.1-95.0%, and for 8 countries 80.1-90.0% of the indicators are available. The results for these eight countries – Benin, Burundi, Hong Kong, Jamaica, Macedonia, Madagascar, Namibia, Taiwan – should be viewed with precaution.

**Table 2: The availability of the indicators, in percentages, for the 116 countries**

| Country                | Indicator* | Country      | Indicator* | Country      | Indicator* |
|------------------------|------------|--------------|------------|--------------|------------|
| Albania                | 93.4%      | Honduras     | 95.1%      | Norway       | 98.4%      |
| Algeria                | 96.7%      | Hong Kong    | 88.5%      | Oman         | 95.1%      |
| Argentina              | 98.4%      | Hungary      | 98.4%      | Pakistan     | 96.7%      |
| Armenia                | 91.8%      | Iceland      | 93.4%      | Panama       | 96.7%      |
| Australia              | 98.4%      | India        | 98.4%      | Paraguay     | 95.1%      |
| Austria                | 98.4%      | Indonesia    | 98.4%      | Peru         | 98.4%      |
| Azerbaijan             | 93.4%      | Iran         | 90.2%      | Philippines  | 98.4%      |
| Bahrain                | 93.4%      | Ireland      | 96.7%      | Poland       | 98.4%      |
| Bangladesh             | 96.7%      | Israel       | 96.7%      | Portugal     | 98.4%      |
| Belgium                | 98.4%      | Italy        | 98.4%      | Qatar        | 95.1%      |
| Benin                  | 83.6%      | Jamaica      | 85.2%      | Romania      | 98.4%      |
| Bosnia and Herzegovina | 93.4%      | Japan        | 98.4%      | Russia       | 96.7%      |
| Botswana               | 95.1%      | Jordan       | 98.4%      | Rwanda       | 91.8%      |
| Brazil                 | 98.4%      | Kazakhstan   | 96.7%      | Saudi Arabia | 96.7%      |
| Bulgaria               | 98.4%      | Kenya        | 98.4%      | Senegal      | 96.7%      |
| Burundi                | 83.6%      | Korea. South | 95.1%      | Serbia       | 98.4%      |
| Cambodia               | 93.4%      | Kuwait       | 96.7%      | Singapore    | 96.7%      |
| Cameroon               | 90.2%      | Kyrgyzstan   | 91.8%      | Slovakia     | 96.7%      |
| Canada                 | 98.4%      | Latvia       | 96.7%      | Slovenia     | 98.4%      |
| Chile                  | 98.4%      | Lebanon      | 98.4%      | South Africa | 98.4%      |
| China                  | 96.7%      | Lithuania    | 96.7%      | Spain        | 98.4%      |
| Colombia               | 98.4%      | Luxembourg   | 95.1%      | Sri Lanka    | 95.1%      |
| Costa Rica             | 95.1%      | Macedonia    | 82.0%      | Sweden       | 98.4%      |
| Croatia                | 96.7%      | Madagascar   | 86.9%      | Switzerland  | 96.7%      |
| Cyprus                 | 93.4%      | Malawi       | 93.4%      | Taiwan       | 80.3%      |

<sup>1</sup> Indicator availability as a percentage of the 116 countries below 90%: Software piracy rate: 86.2%; Fundamental rights: 76.7%; Use of virtual networks: 85.3%; Video uploads in YouTube: 62.0%; Fintech businesses: 81.0%.

|                    |       |             |       |                      |       |
|--------------------|-------|-------------|-------|----------------------|-------|
| Czech Republic     | 98.4% | Malaysia    | 98.4% | Tanzania             | 93.4% |
| Denmark            | 98.4% | Mali        | 91.8% | Thailand             | 98.4% |
| Dominican Republic | 90.2% | Malta       | 93.4% | Tunisia              | 96.7% |
| Ecuador            | 95.1% | Mauritius   | 93.4% | Turkey               | 98.4% |
| Egypt              | 98.4% | Mexico      | 98.4% | Uganda               | 95.1% |
| El Salvador        | 93.4% | Moldova     | 93.4% | Ukraine              | 98.4% |
| Estonia            | 98.4% | Mongolia    | 93.4% | United Arab Emirates | 98.4% |
| Ethiopia           | 90.2% | Montenegro  | 95.1% | United Kingdom       | 98.4% |
| Finland            | 98.4% | Morocco     | 98.4% | United States        | 98.4% |
| France             | 98.4% | Namibia     | 88.5% | Uruguay              | 95.1% |
| Georgia            | 95.1% | Nepal       | 91.8% | Vietnam              | 96.7% |
| Germany            | 98.4% | Netherlands | 96.7% | Zambia               | 91.8% |
| Greece             | 98.4% | New Zealand | 98.4% | Zimbabwe             | 96.7% |
| Guatemala          | 96.7% | Nigeria     | 95.1% |                      |       |

\*Indicator: the percentage of the 61 indicators available for a particular country

Variables were calculated from normalized indicator scores. Below, we provide the most important steps of calculation. We follow the Global Entrepreneurship Index building methodology (Acs et al 2014).

All pillars contain two types of variables: One is representing the Digital Ecosystem (Digital infrastructure 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:

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

where

$i=1, \dots, n$ , the number of countries

$DEI\_pillar_{i,j}$  represents the Digital Entrepreneurship Index pillars,  $j= 1, \dots, 12$

$DE\_pillar_{i,j}$  represents the digital ecosystem pillars,  $j= 1, \dots, 12$

$EE\_pillar_{i,j}$  represents the entrepreneurship ecosystem pillars,  $j= 1, \dots, 12$

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

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

for all  $j= 1 \dots 12$ , the number of pillars

where  $DEI\_pillar(norm)_{i,k}$  is the normalized score value for country  $i$  and pillar  $j$

$\max DEI\_pillar p_{i,j}$  is the maximum value for pillar  $j$

When we calculate the normalized averages of the twelve pillars for the 116 countries, it ranges from 0.153 (Matchmaking) to 0.525 (Digital rights) with 0.361 overall average value. The

different averages of the normalized values of the pillars imply that reaching the same pillar values requires different efforts and resources. Consequently, the effect of additional resources to achieve the same marginal improvement of the pillar values are different and it is problematic for using the pillar values to public policy purposes. The Average pillar adjustment methodology developed by Acs et al (2014) reduces but not fully eliminates this problem.

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

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

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

where

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

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

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

where

$t$  is the “strength of adjustment”, the  $t$ -th moment of  $DEI\_pillar(norm)_{i,j}$  is exactly the needed average,  $\overline{DEI\_pillar(equal)}_j$

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

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

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

After these transformations, the penalty for bottleneck methodology was used to create pillar-adjusted PFB values. A bottleneck is defined as the worst performing pillar or a limiting constraint in a particular country’s digital entrepreneurship system. Here, bottleneck is defined as the lowest level of a particular pillar, relative to other pillars in a particular country. This notion of a bottleneck is important for policy purposes considering the systemic nature of DEI. The system perspective means that that pillars have an effect to one another. This interaction should be included in the calculation of the pillar, the sub-index and the DEI 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 DEI would show a significant improvement. We define our penalty function following as:

$$DEI_{penalized(i),j} = 100 * \min DEI_{pillar(equal)}_{(i),j} + (1 - e^{-(y_{(i)j} - \min DEI_{pillar(equal)}_{(i),j})}) \quad (4)$$

where

$DEI_{penalized_{i,j}}$  is the modified, post-penalty value of pillar  $j$  in country  $i$

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

$DEI_{pillar(equal)}_{min}$  is the lowest value of  $y_{i,j}$  for country  $i$ .

$i = 1, 2, \dots, 116$  = the number of countries

$j = 1, 2, \dots, 12$  = 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.

$$DIG_i = \sum_{j=1}^3 \frac{DEI_{penalized_j}}{3} \quad (5a)$$

$$DUC_i = \sum_{j=4}^6 \frac{DEI_{penalized_j}}{3} \quad (5b)$$

$$DMSP_i = \sum_{j=7}^9 \frac{DEI_{penalized_j}}{3} \quad (5c)$$

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

where

$DIG_i$  = Digital Infrastructure Governance score for country  $i$

$DUC_i$  = Digital User Citizenship score for country  $i$

$DMSP_i$  = Digital Multi-sided Platform score for country  $i$ , and

$DTE_i$  = Digital Technology Entrepreneurship score for country  $i$

Finally, the Digital Entrepreneurship Index (DEI) score is calculated as the simple arithmetic average of the four sub-indices.

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

Where

DEI<sub>i</sub> is the Digital Entrepreneurship Index score for country i.

We have done the basic tests for consistency of the composite indicator components. The overall Kaiser-Meyer-Olkin (KMO) test for sampling adequacy is 0.95, well over the critical 0.7 level. The KMO tests for the four sub-indices are also acceptable; for DUC=0.71, for DIG=0.81 for DMSP=0.76 for DTE=0.74.

#### **4. Analysis – Country rankings and clustering**

In this section, we provide a basic analysis of digital entrepreneurship called index for 116 countries all around the world including all continents and all development stages. First, we present the DEI scores ranking of the 116 country in Table 3.

According to Table 3, the United States leads the DEI 2019 ranking with 84.8 score followed by the United Kingdom (82.4), and the Netherlands (82.2). In the first ten countries there are two from North America (US and Canada), seven from Europe (UK, Netherland, Sweden, Switzerland, Norway, Denmark and Finland) and there is only one Asian country, the ninths ranked Australia. The second ten countries, ranked at the 11-20 places, show a similar regional distribution: Besides eight European countries – Ireland, Luxemburg, Germany, France, Iceland, Belgium, Estonia, and Austria there are New Zealand and Hong Kong. All of these countries are highly developed, innovation driven economies. In contrast, the last ten places (107-116) there are low developed, resource driven countries mainly from the African continent with the exception of Cambodia.

**Table 3: The DEI ranking of the countries, 2019**

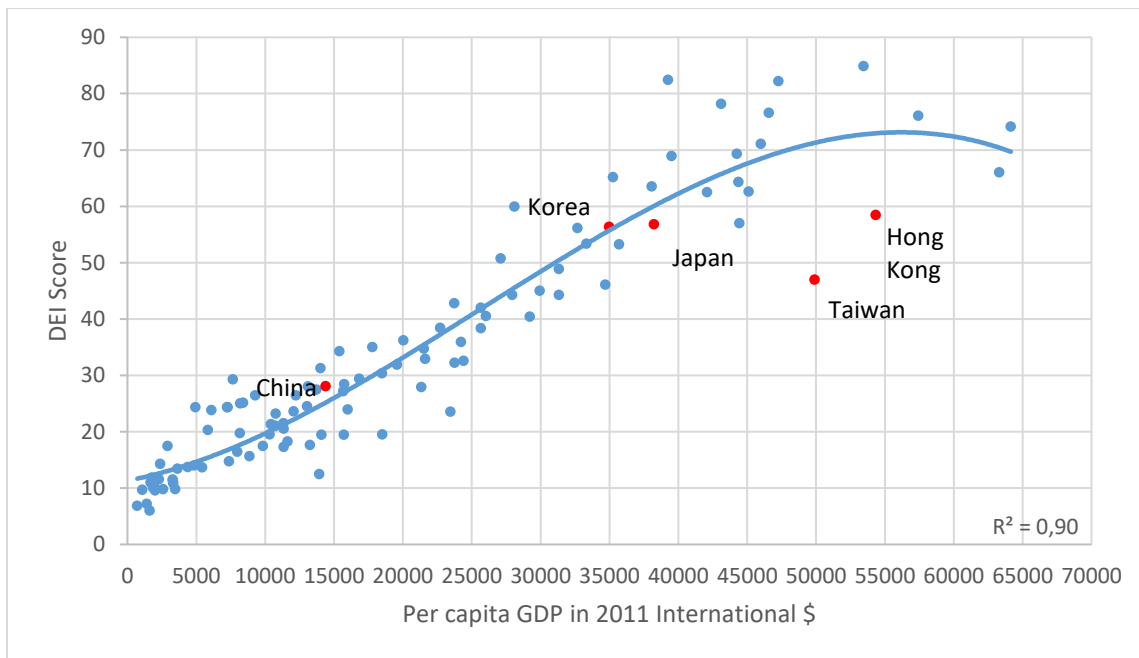
| Rank | Country          | DEE 2019 | GDP 2017 | Rank | Country      | DEE 2019 | GDP 2017 | Rank | Country     | DEE 2019 | GDP 2017 |
|------|------------------|----------|----------|------|--------------|----------|----------|------|-------------|----------|----------|
| 1    | United States    | 84.8     | 53445    | 40   | Chile        | 38.4     | 22707    | 79   | Ecuador     | 21.3     | 10424    |
| 2    | United Kingdom   | 82.4     | 39255    | 41   | Hungary      | 38.3     | 25664    | 80   | Tunisia     | 21.0     | 10752    |
| 3    | Netherlands      | 82.2     | 47270    | 42   | Uruguay      | 36.2     | 20047    | 81   | Albania     | 20.5     | 11359    |
| 4    | Canada           | 78.2     | 43114    | 43   | Greece       | 35.9     | 24224    | 82   | Vietnam     | 20.3     | 5838     |
| 5    | Sweden           | 76.6     | 46568    | 44   | Bulgaria     | 35.0     | 17795    | 83   | Jamaica     | 19.7     | 8180     |
| 6    | Switzerland      | 76.1     | 57428    | 45   | Croatia      | 34.7     | 21528    | 84   | Iran        | 19.5     | 18498    |
| 7    | Norway           | 74.1     | 64140    | 46   | Costa Rica   | 34.3     | 15401    | 85   | Egypt       | 19.5     | 10319    |
| 8    | Denmark          | 71.1     | 45991    | 47   | Romania      | 32.9     | 21615    | 86   | Botswana    | 19.4     | 15723    |
| 9    | Australia        | 69.3     | 44261    | 48   | Russia       | 32.6     | 24417    |      | Dominican   |          |          |
| 10   | Finland          | 68.9     | 39522    | 49   | Turkey       | 32.2     | 23756    | 87   | Republic    | 19.4     | 14099    |
| 11   | Ireland          | 66.0     | 63301    | 50   | Mauritius    | 31.9     | 19567    | 88   | Sri Lanka   | 18.2     | 11639    |
| 12   | Luxembourg       | 65.5     | 94921    | 51   | Brazil       | 31.2     | 14024    | 89   | Lebanon     | 17.6     | 13268    |
| 13   | New Zealand      | 65.1     | 35268    | 52   | Argentina    | 30.3     | 18489    | 90   | Namibia     | 17.5     | 9852     |
| 14   | Germany          | 64.3     | 44357    | 53   | Mexico       | 29.4     | 16832    | 91   | Kenya       | 17.4     | 2926     |
| 15   | France           | 63.5     | 38061    | 54   | Ukraine      | 29.2     | 7668     | 92   | Mongolia    | 17.3     | 11361    |
| 16   | Iceland          | 62.6     | 45116    | 55   | Saudi Arabia | 29.2     | 50458    | 93   | El Salvador | 16.4     | 7990     |
| 17   | Belgium          | 62.5     | 42095    | 56   | Oman         | 28.7     | 40139    | 94   | Paraguay    | 15.6     | 8871     |
| 18   | Estonia          | 59.9     | 28110    | 57   | Montenegro   | 28.4     | 15737    | 95   | Guatemala   | 14.7     | 7367     |
| 19   | Hong Kong        | 58.4     | 54354    | 58   | China        | 28.1     | 14399    | 96   | Senegal     | 14.3     | 2379     |
| 20   | Austria          | 57.0     | 44439    | 59   | Colombia     | 28.0     | 13124    | 97   | Pakistan    | 14.0     | 4855     |
| 21   | Japan            | 56.8     | 38252    | 60   | Panama       | 27.9     | 21335    | 98   | Honduras    | 13.7     | 4392     |
| 22   | Korea            | 56.3     | 34986    | 61   | Bahrain      | 27.6     | 43926    | 99   | Nigeria     | 13.7     | 5435     |
| 23   | Israel           | 56.1     | 32688    | 62   | Serbia       | 27.5     | 13721    | 100  | Zambia      | 13.4     | 3647     |
| 24   | Singapore        | 55.6     | 81443    | 63   | Thailand     | 27.2     | 15683    | 101  | Algeria     | 12.5     | 13921    |
| 25   | Spain            | 53.3     | 33320    | 64   | Georgia      | 26.4     | 9277     | 102  | Rwanda      | 11.9     | 1774     |
| 26   | Malta            | 53.2     | 35705    | 65   | South Africa | 26.4     | 12237    | 103  | Nepal       | 11.6     | 2298     |
| 27   | Portugal         | 50.7     | 27103    | 66   | Jordan       | 25.1     | 8390     | 104  | Kyrgyzstan  | 11.5     | 3294     |
| 28   | Czech Republic   | 48.9     | 31339    | 67   | Armenia      | 25.0     | 8190     | 105  | Bangladesh  | 11.2     | 3319     |
| 29   | Taiwan           | 47.0     | 49901    | 68   | Macedonia    | 24.5     | 13055    | 106  | Uganda      | 11.0     | 1687     |
| 30   | Italy            | 46.1     | 34700    | 69   | Philippines  | 24.4     | 7236     | 107  | Cameroon    | 10.8     | 3347     |
| 31   | Slovenia         | 45.0     | 29930    | 70   | Moldova      | 24.3     | 4944     | 108  | Mali        | 10.2     | 1971     |
| 32   | Lithuania        | 44.3     | 27944    | 71   | Morocco      | 24.3     | 7286     | 109  | Zimbabwe    | 10.0     | 1880     |
| 33   | Cyprus           | 44.3     | 31331    | 72   | Azerbaijan   | 23.9     | 16001    | 110  | Cambodia    | 9.8      | 3465     |
| 34   | United Arab Emir | 43.0     | 67133    | 73   | India        | 23.8     | 6093     | 111  | Tanzania    | 9.8      | 2584     |
| 35   | Latvia           | 42.8     | 23729    | 74   | Peru         | 23.6     | 12072    | 112  | Malawi      | 9.6      | 1084     |
| 36   | Malaysia         | 42.0     | 25669    | 75   | Kazakhstan   | 23.5     | 23447    | 113  | Benin       | 9.5      | 2010     |
| 37   | Qatar            | 40.6     | 118207   | 76   | Indonesia    | 23.2     | 10765    | 114  | Madagascar  | 7.2      | 1397     |
| 38   | Poland           | 40.5     | 26036    | 77   | Kuwait       | 21.7     | 68862    | 115  | Burundi     | 6.8      | 721      |
| 39   | Slovakia         | 40.4     | 29212    |      | Bosnia and   |          |          | 116  | Ethiopia    | 6.0      | 1608     |
|      |                  |          |          | 78   | Herzegovina  | 21.5     | 11327    |      |             |          |          |

Legend: DEI: Digital Entrepreneurship Ecosystem index score  
The per capita GDP of the country in purchasing power parity, 2017 from the World Bank,  
(<https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD>)

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



**Figure 3: The connection between development and the DEI scores (third-degree polynomial adjustment)**



Note: Trend line is calculated without countries over 65 000 inter. \$ per capital GDP and without oil-based economies of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates.

The third-degree adjusted curve explains around 90% of the variation between development (measured by the per capita GDP) and digital entrepreneurship ecosystem (DEI). Note that it is not implying causal relationship, we simply refer to the strong connection between development and digital entrepreneurship ecosystem. Examining a particular country's position being below or above the development implied trend line is more appropriate than simply comparing differently developed nations. For example, China is only 58<sup>th</sup> in the DEI ranking that seems to be surprising. However, one should not forget that China is a big and diverse country where regional differences are high and besides the highly developed Beijing and Shanghai there are many poor regions. DEI is a country and not a regional level measure. Looking at China's position in Figure 3, China can be found somewhat above the trend-line implying that the country's overall digital entrepreneurship ecosystem progress fits to its level of development. At the same time, Taiwan with DEI=47.0 is below the trend line, implying that the country should have higher level of DEI scores as compared to other similarly developed countries. Looking at another developed Asian country, Korea with DEI=56.3 score has higher digital entrepreneurship ecosystem development then implied by its per capita GDP and Hong Kong is similar to Taiwan, has lower DE score than implied by its development.

While DEI score is useful to evaluate the digital entrepreneurship ecosystem performance of a country as compared to other nations, it does not tell us anything about the strengths and

weaknesses of this country. For viewing it, we need to decompose the DEI index into its components. Table 4. is presenting the four sub-index score and ranking of the first 25 countries.

**Table 4: The four sub-index scores and ranking of the first 25 countries**

| DEE Ranking | Country        | DIGITAL INFRASTRUCTURE GOVERNANCE score | DIGITAL INFRASTRUCTURE GOVERNANCE ranking | DIGITAL USER CITIZENSHIP score | DIGITAL USER CITIZENSHIP ranking | DIGITAL MULTI-SIDED PLATFORM score | DIGITAL MULTI-SIDED PLATFORM ranking | DIGITAL TECHNOLOGY ENTREPRENEURSHIP score | DIGITAL TECHNOLOGY ENTREPRENEURSHIP ranking |
|-------------|----------------|---|---|--------------------------------|----------------------------------|------------------------------------|--------------------------------------|---|---|
| 1           | United States  | 80.7                                    | 3   | 79.0                           | 3                                | 87.4                               | 1                                    | 92.2                                      | 1   |
| 2           | United Kingdom | 80.1                                    | 4   | 83.5                           | 1                                | 84.8                               | 3                                    | 81.3                                      | 3   |
| 3           | Netherlands    | 89.5                                    | 1   | 74.3                           | 7                                | 86.3                               | 2                                    | 78.6                                      | 4   |
| 4           | Canada         | 75.4                                    | 8   | 81.3                           | 2                                | 78.8                               | 5                                    | 77.1                                      | 5   |
| 5           | Sweden         | 78.3                                    | 5   | 74.2                           | 8                                | 79.5                               | 4                                    | 74.3                                      | 6   |
| 6           | Switzerland    | 75.5                                    | 7   | 74.6                           | 6                                | 69.3                               | 9                                    | 84.8                                      | 2   |
| 7           | Norway         | 84.4                                    | 2   | 75.0                           | 5                                | 73.5                               | 6                                    | 63.7                                      | 12  |
| 8           | Denmark        | 78.2                                    | 6   | 68.4                           | 11                               | 73.3                               | 7                                    | 64.3                                      | 11  |
| 9           | Australia      | 73.7                                    | 9   | 77.3                           | 4                                | 69.2                               | 10                                   | 56.9                                      | 18  |
| 10          | Finland        | 71.5                                    | 11  | 70.9                           | 9                                | 67.1                               | 11                                   | 66.0                                      | 8   |
| 11          | Ireland        | 66.0                                    | 15  | 63.2                           | 17                               | 65.3                               | 14                                   | 69.5                                      | 7   |
| 12          | Luxembourg     | 73.6                                    | 10  | 65.5                           | 14                               | 60.3                               | 17                                   | 62.9                                      | 14  |
| 13          | New Zealand    | 69.4                                    | 13  | 66.0                           | 13                               | 70.3                               | 8                                    | 54.9                                      | 23  |
| 14          | Germany        | 67.6                                    | 14  | 70.3                           | 10                               | 56.3                               | 23                                   | 63.1                                      | 13  |
| 15          | France         | 63.5                                    | 18  | 64.9                           | 15                               | 60.3                               | 16                                   | 65.3                                      | 9   |
| 16          | Iceland        | 70.7                                    | 12  | 48.7                           | 28                               | 65.6                               | 13                                   | 65.3                                      | 10  |
| 17          | Belgium        | 65.8                                    | 16  | 59.8                           | 18                               | 64.9                               | 15                                   | 59.5                                      | 17  |
| 18          | Estonia        | 63.1                                    | 19  | 64.0                           | 16                               | 57.4                               | 22                                   | 55.1                                      | 21  |
| 19          | Hong Kong      | 62.0                                    | 20  | 56.1                           | 20                               | 58.7                               | 20                                   | 56.9                                      | 19  |
| 20          | Austria        | 63.7                                    | 17  | 57.6                           | 19                               | 50.0                               | 28                                   | 56.6                                      | 20  |
| 21          | Japan          | 61.0                                    | 21  | 68.2                           | 12                               | 44.2                               | 34                                   | 53.7                                      | 24  |
| 22          | Korea          | 57.9                                    | 22  | 54.6                           | 22                               | 59.5                               | 18                                   | 53.2                                      | 26  |
| 23          | Israel         | 48.2                                    | 31  | 48.5                           | 29                               | 66.9                               | 12                                   | 60.9                                      | 16  |
| 24          | Singapore      | 55.1                                    | 24  | 47.7                           | 30                               | 58.5                               | 21                                   | 61.2                                      | 15  |
| 25          | Spain          | 54.0                                    | 25  | 53.1                           | 23                               | 52.5                               | 25                                   | 53.7                                      | 25  |

The leading United States is the first in the DMSP and the DTE sub-indices but the third in DUC and in DIG. The US best sub-index score is 92.2 (DTE) and the worst is 79.0 (DUC) a 16.7% difference. The United Kingdom’s performance is also well balanced ranging from the first (DUC=83.5) to the fourth (DIG=80.1). Some other countries show even higher variations. For example, the 9<sup>th</sup> ranked Australia is the fourth in DUC=77.3 score but only the 18<sup>th</sup> in DTE=56.9, a 35,8% difference.

To see common features, similarities and differences we have conducted a K-Mean cluster analysis with respect to the twelve pillars. For our purposes the four cluster group solution proved to be the most useful (Table 5).

**Table 5: The four groups of the countries and average pillar scores based on the twelve pillars**

| <b>Categories/groups</b>        | <b>Leaders</b> | <b>Followers</b> | <b>Gainers</b> | <b>Laggards</b> |
|---------------------------------|----------------|------------------|----------------|-----------------|
| Digital Openness                | 76.6           | 71.7             | 44.5           | 14.0            |
| Digital Freedom                 | 80.2           | 60.2             | 35.3           | 22.8            |
| Digital Protection              | 88.3           | 74.2             | 38.8           | 14.9            |
| Digital Literacy                | 77.3           | 59.1             | 34.5           | 23.9            |
| Digital Access                  | 80.9           | 74.9             | 43.6           | 12.9            |
| Digital Rights                  | 68.4           | 62.7             | 37.1           | 22.3            |
| Networking                      | 84.0           | 64.1             | 37.7           | 19.6            |
| Matchmaking                     | 82.6           | 61.2             | 40.9           | 19.0            |
| Financial Facilitation          | 79.2           | 70.0             | 39.5           | 17.1            |
| Digital Adoption                | 81.7           | 62.9             | 40.0           | 19.0            |
| Technology Absorption           | 83.2           | 59.0             | 36.3           | 22.2            |
| Technology Transfer             | 82.0           | 63.1             | 36.6           | 20.8            |
| <b>Digital Entrepreneurship</b> | <b>77.6</b>    | <b>61.2</b>      | <b>36.7</b>    | <b>17.8</b>     |
| <b>Ecosystem score mean</b>     |                |                  |                |                 |
| <i>Number of cases</i>          | 7              | 20               | 32             | 57              |

Legend:

**Leaders:** Canada, Iceland, Netherlands, Sweden, Switzerland, United Kingdom, United States;

**Followers:** Australia, Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Hong Kong, Ireland, Israel, Japan, South Korea, Luxembourg, Malta, New Zealand, Norway, Singapore, Spain, Taiwan,

**Gainers:** Argentina, Bahrain, Brazil, Bulgaria, Chile, China, Costa Rica, Croatia, Cyprus, Czech Republic, Greece, Hungary, Italy, Latvia, Lithuania, Malaysia, Mauritius, Mexico, Montenegro, Oman, Poland, Portugal, Qatar, Romania, Russia, Saudi Arabia, Slovakia, Slovenia, Turkey, Ukraine, United Arab Emirates; Uruguay;

**Laggards:** Albania, Algeria, Armenia, Azerbaijan, Bangladesh, Benin, Bosnia and Herzegovina, Botswana, Burundi, Cambodia, Cameroon, Colombia, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Georgia, Guatemala, Honduras, India, Indonesia, Iran, Jamaica, Jordan, Kazakhstan, Kenya, Kuwait, Kyrgyzstan, Lebanon, Macedonia, Madagascar, Malawi, Mali, Moldova, Mongolia, Morocco, Namibia, Nepal, Nigeria, Pakistan, Panama, Paraguay, Peru, Philippines, Rwanda, Senegal, Serbia, Sri Lanka, South Africa, Tanzania, Thailand, Tunisia, Uganda, Vietnam, Zambia, Zimbabwe

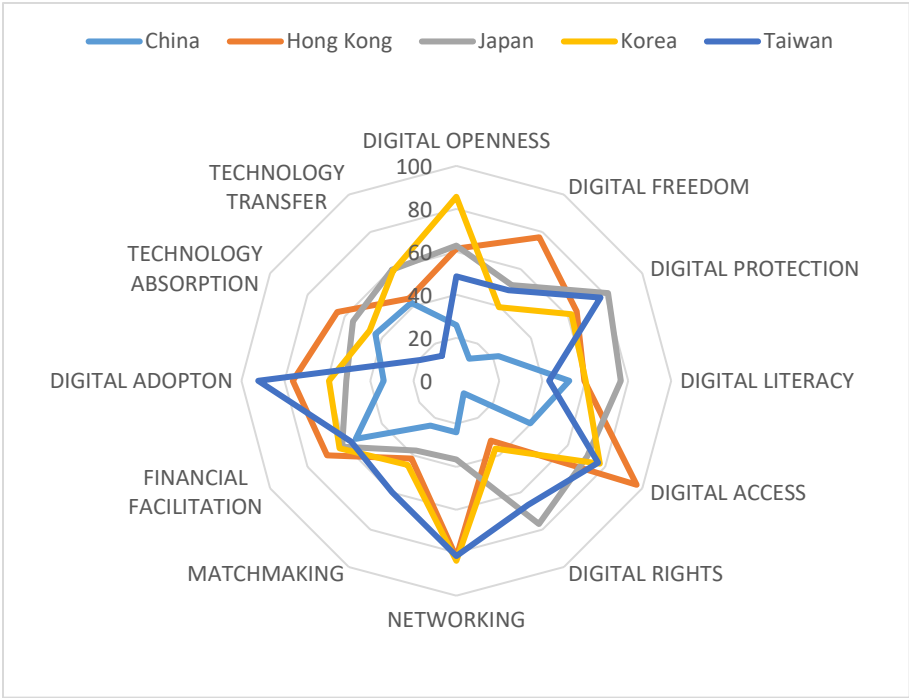
Table 5. shows a relative unbalance number of cluster membership: The Leaders consists of only seven countries, the Followers are of 20, the Gainers are of 32 and the Laggards are of 57 countries. The differences amongst the groups in terms of DEI mean score varies, the Leaders (DEI=77.6) are ahead of the Followers (DEI= 61.2) by around 16 point, the Gainers (DEI = 36.7) are behind the Followers by around 25 points, and the Laggards (DEI=17.8) are the last by roughly 19 points. The first six countries in the DEI ranking belong to the Leaders group, mainly North American and European (Nordic and Anglo-Saxon) nations. The Followers group contains only developed European and Asian countries with two developed Oceanian countries, New Zealand and Australia. Gainers are geographically mixed, dominated by middle-developed European, Asian and Latin American countries. Most oil rich countries, Bahrain, Oman, Qatar,

Saudi Arabia, United Arab Emirates belong to this cluster. Laggards are formed from low developed African and Asian countries together with some relatively poor European and Latin American nations.

The Leaders are the best in all twelve pillar score averages. These countries are mainly rich Anglo-Saxon and Nordic countries with well-balanced digital entrepreneurship ecosystems. While they spend the most for digital protection, digital rights is their lowest valued pillar. Followers are also rich, developed nations. While some aspects of the digital entrepreneurship ecosystem are well developed (Digital Access, Digital Protection), some pillars have relative low score (Digital Literacy, Technology absorption). Gainers enjoys good digital infrastructures and that citizens are active users, however many aspects of the digital entrepreneurship ecosystem requires considerable development. Laggards are the worst in terms of every pillar score average. Their are precisely the lack of good digital infrastructures and the lack of an active stock of users. The last two group members are very homogenous, differences inside the groups are minimal. This is particularly true for the most numerously populated Laggards cluster.

A careful look at the Asian countries by pillar reveals the strengths and weaknesses of the leading Asian countries. While the United States leads in all areas (not shown) Asian countries show their weaknesses in digital technology entrepreneurship. China is particularly weak in digital infrastructure governance as is well known. However, what is not clear is where China sits in the global ecosystem race as the statistics are for the whole country and might not represent the strengths of Eastern China.

**Figure 4: Selected Asian Countries by pillar**



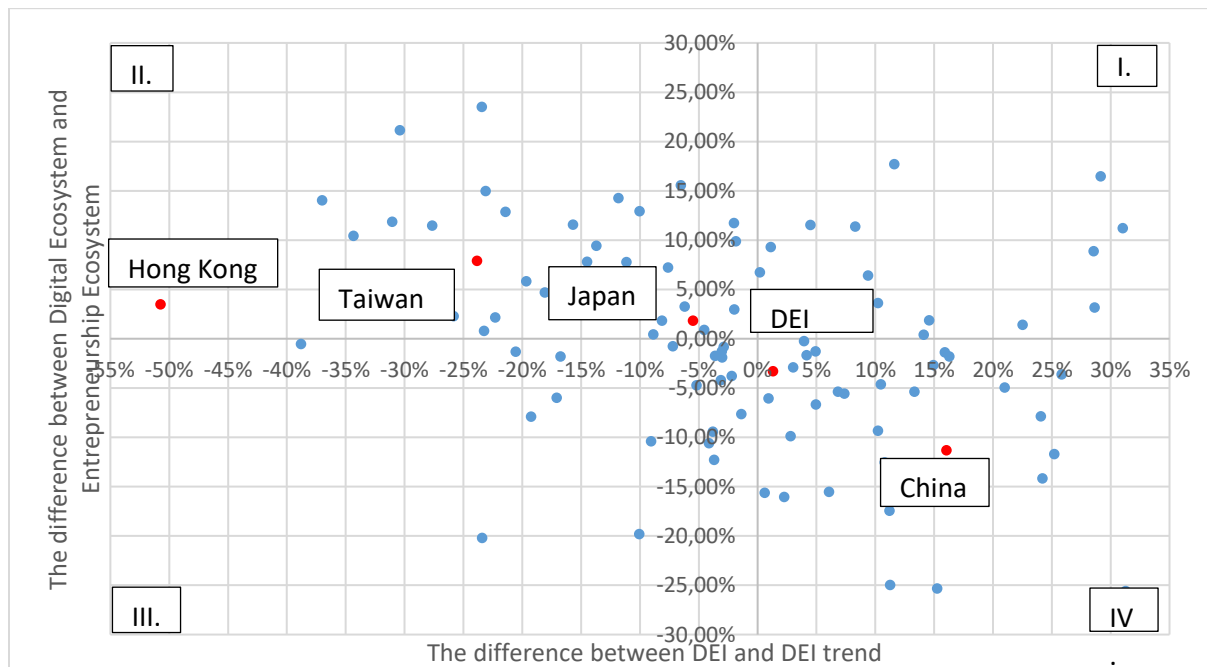
## 5. Basic DEI policy suggestions - DEI trend line and Digital Ecosystem-Entrepreneurship Ecosystem difference analysis

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

$$GDP \text{ per capita} = -5E(-13)*DEI^3 + 4E(-08)DEI^2 + 0.0005*DEI + 11.32 \quad (7)$$

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

**Figure 5: The four group of the countries based on the difference between DE and EE scores and the deviation from development implied trend-line.**



On the vertical axis, there is the difference between the digital ecosystem (DE) and the Entrepreneurship Ecosystem (EE) scores. Countries in Quadrant I and II. have higher DE then EE score. In quadrants III. and IV., countries have higher EE then DE scores. For a balanced development, DE and EE scores should be about the same. If the difference is higher than 10%, resources should be redirected to harmonize the digital and the entrepreneurship ecosystems. So,

for countries in quadrants I and II entrepreneurship ecosystem component development is suggested. For countries in quadrant III. and IV. digital ecosystem development is more fruitful. Countries where the DEI-DEI trend difference is positive and there are within the ten percent DE-EE difference range are suggested to maintain DEI spending to keep space with development and to keep the balance between DE and EE.

According to Figure 5. the countries in the [-10%; 10%] range of DE and EE difference and have lower than -10% value in the DEI-DEI trend difference are considered to be optimal implying that no extra spending for DEI development is necessary and their DE-EE balance is fine. One of the leading countries, Australia and Belgium belong to this group together with many innovation-driven, developed country group together with some efficiency driven, developing countries. For the second cohort, Chile is an example. Two of our examined Asian countries Korea and Japan also belong to this group.

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

Quadrant IV countries' overall DEI level is sufficient; however, their digital component is relatively underdeveloped as compared to the entrepreneurship components. Our example is China, that has also higher DEI score then implied by the trend line but its EE score is higher than its DE score (by 11.3%). Consequently, further effort is suggested to improve China's digital ecosystem.

There are many countries that have lower DEI score then implied by the trend line and have imbalances in the DE-EE context in favor of digital ecosystem development (quadrant II.). We maximized the deviation up to -55% in Figure 4.2. Our highlighted examples are Hong Kong and Taiwan. Their overall DEI development is well below what we could expect from these developed countries. Moreover, their digital ecosystem is more advanced than their entrepreneurship component. However, this imbalance is below 10%.

In Quadrant III there are the nations that spend too little to DEI development and their digital ecosystem is also deprived as compared to entrepreneurship ecosystem. For example, some poor African countries belong to this quadrant.

## 6. Literature

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## 7. Appendix: The applied indicators in the Digital Entrepreneurship Index

**Table A.1** The applied indicators of DIG sub-index

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



|           |  |   |
|-----------|--|---|
|           | <b>Internet domains / 1000 population</b><br>Webhosting, 2015<br><br><b>Digital Freedom- Digital infrastructure</b>  | Number of active Internet domain registrations per 1000 number of population.   |
| DIG_P3_I1 | <b>Software piracy rate, % software installed</b><br>WEF Network Readiness Index, 2013 data<br><br><b>Digital Protection - Digital infrastructure</b>        | Unlicensed software units as a percentage of total software units installed. This measure covers piracy of all packaged software that runs on personal computers (PCs), including desktops, laptops, and ultra-portables, including netbooks. This includes operating systems; systems software such as databases and security packages; business applications; and consumer applications such as games, personal finance, and reference software. The study does not include software that runs on servers or mainframes, or software loaded onto tablets or smart phones. |
| DIG_P3_I2 | <b>Secure Internet servers/million pop.</b><br>WEF Network Readiness Index 2016 report (2014 data)<br><br><b>Digital Protection - Digital infrastructure</b> | Secure Internet servers per million population.   |
| DIG_P3_I3 | <b>Corruption Perception Index</b><br>Corruption Perception Index (CPI), 2017 (data 2016-2018)<br><br><b>Digital Protection - Institutions</b>               | The index, which ranks 180 countries and territories by their perceived levels of public sector corruption according to experts and businesspeople, uses a scale of 0 to 100, where 0 is highly corrupt and 100 is very clean.  |
| DIG_P3_I4 | <b>Globa Cybersecurity Index legal subsindex (GCI), 2017</b><br><br><b>Digital Protection - Institutions</b>   | The GCI revolves around the ITU Global Cybersecurity Agenda (GCA) and its five pillars (legal, technical, organizational, capacity building and cooperation). For each of these pillars, questions were developed to assess commitment. Legal component is based on the existence of legal institutions and frameworks dealing with cybersecurity and cybercrime.   |

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

|           |   |  |
|-----------|---|--|
| DUC_P1_I1 | <b>Digital skills among population</b><br>Global Competitiveness Index, 2017 , WEF<br><br><b>Digital literacy – Users</b>   | 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 | <b>Number of search by users in a country</b><br>The Digital Country Index, 2017<br><br><b>Digital literacy – Users</b>   | First presented in 2015, the Digital Country Index tracks the number of searches performed by all worldwide citizens toward any given country, in connection with six topic areas: tourism, investment, exports, talent and national prominence. |
| DUC_P1_I3 | <b>Quality of the education system, 1-7 (best)</b><br>Global Competitiveness Index, 2017-2018 (data 2015-2016 average)<br><br><b>Digital Literacy- Institutions</b> | In your country, how well does the education system meet the needs of a competitive economy? [1 = not well at all; 7 = extremely well]   |
| DUC_P1_I4 | <b>Internet access in schools, 1-7 (best)</b><br>Global Competitiveness Index, 2017-2018 (data 2015-2016 average)<br><br><b>Digital Literacy- Institutions</b>      | In your country, to what extent is the Internet used in schools for learning purposes? [1 = not at all; 7 = to a great extent]   |
| DUC_P2_I1 | <b>Fixed broadband Internet subscriptions/100 pop.</b><br>Global Competitiveness Index, 2017-2018 (2016 or most recent data)<br><br><b>Digital access – Users</b>   | Fixed-broadband Internet subscriptions per 100 population  |
|           | <b>Int’l Internet bandwidth, kb/s per user</b><br>Global Competitiveness Index, 2017-2018 (2016 data)   | International Internet bandwidth (kb/s) per Internet user  |

|                  |   |   |
|------------------|---|---|
|                  | <b>Digital access – Users</b>   |   |
| <b>DUC_P2_I2</b> | <b>Percentage of households equipped with a personal computer</b><br>World Telecommunication/ICT Indicators Database, 4 January 2018 (2017 data)                  | Percentage of households equipped with a personal computer  |
|                  | <b>Digital access – Users</b><br><b>Percentage of individuals using a computer</b><br>World Telecommunication/ICT Indicators Database, 4 January 2018 (2017 data) | Percentage of individuals using a computer  |
| <b>DUC_P2_I3</b> | <b>Global Cybersecurity Index technical subindex</b><br>ITU, 2017   | Technical: Measured based on the existence of technical institutions and frameworks dealing with cybersecurity.   |
|                  | <b>Digital access – Institution</b>   |   |
| <b>DUC_P2_I4</b> | <b>Global Cybersecurity Index technical subindex</b><br>ITU, 2017   | Organizational: Measured based on the existence of policy coordination institutions and strategies for cybersecurity development at the national level.   |
|                  | <b>Digital access – Institution</b>   |   |
| <b>DUC_P3_I1</b> | <b>Net infection ratio</b><br>Securelist statistics, Kaspersky, Download: 17/03/2018 (monthly data)   | The map shows the percentages of users on whose devices Kaspersky Lab products intercepted Local infections in the Last 24 hours. KL products' users are always protected from all – even the very latest – threats.  |
|                  | <b>Digital Rights- Users</b>  |   |
| <b>DUC_P3_I2</b> | <b>Internet censorship and surveillance</b><br>Wikipedia, 2018  | Detailed country by country information on Internet censorship and surveillance is provided in the Freedom on the Net reports from Freedom House, by the OpenNet Initiative, by Reporters Without Borders, and in the Country Reports on Human Rights Practices from the U.S. State Department Bureau of Democracy, Human Rights, and Labor. The ratings produced by several of these organizations are summarized below as well as in the Censorship by country article. Four category rating: 1: pervasive; 2: selective; 3: substantial; 4: little or none |
|                  | <b>Digital Rights- Users</b>  |   |
| <b>DUC_P3_I3</b> | <b>Personal rights</b><br>The Global Talent Competitiveness Report, 2018 (2016 data)  | 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.   |
|                  | <b>Digital Rights -Institution</b>  |   |
|                  | <b>Fundamental rights</b><br>Rule of Law Index, World Justice Project, 2017-2018  | Equal treatment and absence of discrimination<br>4.2 The right to life and security of the person is effectively guaranteed<br>4.3 Due process of law and rights of the accused<br>4.4 Freedom of opinion and expression is effectively guaranteed<br>4.5 Freedom of belief and religion is effectively guaranteed<br>4.6 Freedom from arbitrary interference with privacy is effectively guaranteed<br>4.7 Freedom of assembly and association is effectively guaranteed<br>4.8 Fundamental labor rights are effectively guaranteed                          |
|                  | <b>Digital Rights -Institution</b>  |   |
|                  | <b>Property rights</b><br>International Property Rights Index, Property Rights Alliance, 2013   | The average of the two subindexes as Physical property rights and Intellectual property rights from International Property Rights Index   |
|                  | <b>Digital Rights -Institution</b>  |   |

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

|                   |   |   |
|-------------------|---|---|
| <b>DMSP_P1_I1</b> | <b>Use of virtual social networks, 1-7 (best)</b><br>WEF Network Readiness Index, 2016 (2014-2015 average data) | In your country, how widely are virtual social networks used (e.g., Facebook, Twitter, LinkedIn)? [1 = not at all used; 7 = used extensively] |
|-------------------|---|---|

|            |   |   |
|------------|---|---|
|            | <b>Networking - Users</b>   |   |
| DMSP_P1_I2 | <b>Social media penetration</b><br>2017 DIGITAL YEARBOOK INTERNET,<br>SOCIAL MEDIA, AND MOBILE DATA FOR<br><br><b>Networking - Users</b>  | Active social media users, penetration (%)  |
| DMSP_P1_I3 | <b>Use of virtual professional networks</b><br>The Global Talent Competitiveness<br>Report, 2018 (2015 data)<br><br><b>Networking - Users</b>   | LinkedIn users refers to the number of registered LinkedIn accounts per 1,000 labour force (15–64 years old).   |
| DMSP_P1_I4 | <b>ICT use for business-to-business transactions, 1-7 (best)</b><br>WEF Network Readiness Index, 2016<br>(2014-2015 average data)<br><b>Networking - Agent</b>                            | In your country, to what extent do businesses use ICTs for transactions with other businesses? [1 = not at all; 7 = to a great extent]  |
| DMSP_P1_I5 | <b>Business-to-consumer Internet use, 1-7 (best)</b><br>WEF Network Readiness Index, 2016<br>(2014-2015 average data)<br><b>Networking - Agent</b>  | In your country, to what extent do businesses use the Internet for selling their goods and services to consumers? [1 = not at all; 7 = to a great extent]   |
| DMSP_P2_I1 | <b>Wikipedia yearly edits</b><br>Global Innovation Index, 2017 (2016 data)<br><br><b>Matchmaking - Users</b>  | Wikipedia yearly edits by country (per million population 15–69 years old)   2014<br>Data extracted from Wikimedia Foundation’s internal data sources. For every country with more than 100,000 edit counts in 2016, the data from 2016 are used. For all other countries, the data from 2014 are utilized. The data excludes bot contributions to the extent that is identifiable in the data sources. Data are reported per million population 15–69 years old.                             |
| DMSP_P2_I2 | <b>Video uploads on YouTube</b><br>Global Innovation Index, 2017, (2016 data)<br><br><b>Matchmaking - Users</b>   | Number of video uploads on YouTube (scaled by population 15–69 years old)   2015<br>Total number of video uploads on YouTube, per country, scaled by population 15–69 years old. The raw data are survey based: the country of affiliation is chosen by each user on the basis of a multi-choice selection. This metric counts all video upload events by users. For confidentiality reasons, only normalized values are reported; while relative positions are preserved, magnitudes are not |
| DMSP_P2_I3 | <b>Number of professional developers / population</b><br><i>Developer Survey Results, 2017 (2016 data)</i><br><br><b>Matchmaking - Agent</b>  | Ratio of professional developers  |
| DMSP_P3_I1 | <b>Credit card (% age 15+)</b><br>World Bank Global Financial Inclusion, 2017<br><br><b>Financial facilitation - Users</b>  | Denotes the percentage of respondents who report having a credit card (% age 15+). [ts: data are available for multiple waves].   |
|            | <b>Debit card (% age 15+)</b><br>World Bank Global Financial Inclusion, 2017<br><br><b>Financial facilitation - Users</b>   |   |
| DMSP_P3_I2 | <b>Used the internet to pay bills or to buy something online in the past year (% age 15+)</b><br>World Bank Global Financial Inclusion, 2017<br><br><b>Financial facilitation - Users</b> | 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].   |

|                   |   |   |
|-------------------|---|---|
| <b>DMSP_P3_I3</b> | <b>Used a mobile phone or the internet to access a financial institution account in the past year (% age 15+)</b><br>World Bank Global Financial Inclusion, 2017<br><b>Financial facilitation - Users</b> | 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].   |
| <b>DMSP_P3_I4</b> | <b>Made or received digital payments in the past year (% age 15+)</b><br><b>Financial facilitation - Users</b>  | Denotes the percentage of respondents who report making or receiving digital payments in the past 12 months (% age 15+).  |
| <b>DMSP_P3_I5</b> | <b>Depth of Capital Market Sub-Index Score (US 2016=100)</b><br>World Bank Global Financial Inclusion, 2017 (data 2016)<br><b>Financial facilitation - Agent</b>  | The Depth of Capital Market is one of the six sub-indices of the Venture Capital and Private Equity index. This variable is a complex measure of the size and liquidity of the stock market, level of IPO, M&A and debt and credit market activity. |
| <b>DMSP_P3_I6</b> | <b>Fintech business</b><br>dealroom, 26/03/2018<br><b>Financial facilitation - Agent</b>  | The number of financial technology businesses standardized by the number of population 2018, own calculation  |
| <b>DMSP_P3_I7</b> | <b>Venture capital availability</b><br>Global Competitiveness Index, 2017-2018 (2016-2017 average data)<br><b>Financial facilitation - Agent</b>  | Answers to the quation: In your country, how easy is it for entrepreneurs with innovative but risky projects to find venture capital? [1 = extremely difficult; 7 = extremely easy], (World Economic Forum dataset)                                 |

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

|                  |  |  |
|------------------|--|--|
| <b>DTE_P1_I1</b> | <b>Quality of electricity supply, 1-7 (best)</b><br>Global Competitiveness Index, 2017.2018 (2016-2017 average data)<br><b>Digital adoption - Digital infrastructure</b> | In your country, how reliable is the electricity supply (lack of interruptions and lack of voltage fluctuations)? [1 = extremely unreliable; 7 = extremely reliable] |
|                  | <b>Electricity production, kWh/capita</b><br>WEF Network Readiness Index, 2016 (2013 data)<br><b>Digital adoption - Digital infrastructure</b>                           | Electricity production (kWh) per capita  |
| <b>DTE_P1_I2</b> | <b>Fixed telephone lines/100 pop.</b><br>Global Competitiveness Index, 2017.2018 (2016-2017 average data)<br><b>Digital adoption - Digital infrastructure</b>            | Number of fixed-telephone lines per 100 population   |
| <b>DTE_P1_I3</b> | <b>Mobile telephone subscriptions/100 pop.*</b><br>Global Competitiveness Index, 2017.2018 (2016-2017 average data)<br><b>Digital adoption - Digital infrastructure</b>  | Number of mobile-cellular telephone subscriptions per 100 population   |
| <b>DTE_P1_I4</b> | <b>Mobile network coverage, % pop.</b><br>WEF Network Readiness Index, 2016 (2014 data)<br><b>Digital adoption - Digital infrastructure</b>                              | Percentage of total population covered by a mobile network signal  |
| <b>DTE_P1_I5</b> | <b>Computer software spending</b><br>Global Innovation Index, 2018(2016 data)<br><b>Digital adoption - Agent</b>   | Total computer software spending (% of GDP)  |
| <b>DTE_P1_I6</b> | <b>Skills of workforce</b><br>Global Innovation Index, 2018<br><b>Digital adoption - Agent</b>   | Skills, a pillar of GCI, consist of two parts, skills of current workforca and skills of future workforce  |

|           |  |   |
|-----------|--|---|
| DTE_P2_I1 | <p><b>Data centers</b><br/>Data Centers Catalog, 2019</p> <p>Technology absorption – Digital infrastructure</p>  | Combined data centers number and density based on population  |
| DTE_P2_I2 | <p><b>Availability of latest technologies, 1-7 (best)</b><br/>Global Competitiveness Index, 2017-2018 (2016-2017 average data)<br/>Digital technology absorption –</p> <p>Technology absorption – Digital infrastructure</p> | In your country, to what extent are the latest technologies available? [1 = not at all; 7 = to a great extent]  |
| DTE_P2_I3 | <p><b>Knowledge absorption (sub-index in GII)</b><br/>Global Innovation Index, 2017 (data 2016)<br/>Digital technology absorption –</p> <p>Technology absorption - Agent</p>   | It reveals how good economies are at absorbing knowledge. A complex variable from GII consisting of five indicators as: Intellectual property payments, High-tech   |
| DTE_P2_I4 | <p><b>Impact of ICTs on business models, 1-7 (best)</b><br/>Global Innovation Index, 2017 (2016 data)</p> <p>Technology absorption - Agent</p>   | Average answer to the question: In your country, to what extent do ICTs enable new business models? [1=not at all; 7=to a great extent]   |
|           | <p><b>Impact of ICTs on new organizational models, 1-7 (best)</b><br/>Global Innovation Index, 2017 (2016 data)</p> <p>Technology absorption - Agent</p>   | Average answer to the question: In your country, to what extent do ICTs enable new organizational models?   |
| DTE_P3_I1 | <p><b>Knowledge and technology outputs (GII)</b><br/>The Global Innovation Index, 2017 (2016 data)</p> <p>Technology transfer – Digital infrastructure</p>   | A subindex of GII consisting of three parts, knowledge creation, knowledge impact and knowledge diffusion   |
| DTE_P1_I2 | <p><b>Capacity for innovation</b><br/>Global Competitiveness Index, 2007-2017</p> <p>Technology transfer – Digital infrastructure</p>  | In your country, to what extent do companies have the capacity to innovate? [1 = not at all; 7 = to a great extent]   |
| DTE_P2_I3 | <p><b>High level skills (GTCL)</b><br/>The Global Talent Competitiveness Report, 2018 (data 2015)</p> <p>Technology transfer - Agent</p>   | The average of six indicators as Workforce with tertiary education, Population with tertiary education, Professionals, Researchers, Senior officials and managers, Availability of scientists and engineers |
| DTE_P2_I4 | <p><b>Startups</b><br/>Startup ranking, 2018</p> <p>Technology transfer - Agent</p>  | Number of Startups, a normalized average of the population standardized startups and the log of startups in the country.  |