

## Conference Paper

# Measuring Innovation of Countries

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**ORCID:**Spyros Roukanas: <http://orcid.org/0000-0001-9706-266X>**Abstract**

The aim of this article was to measure the innovation of countries in order to help improve their productive capabilities under the prism of the global political economy. For this purpose, the following indicators were analysed: 1) the global innovation index; 2) the digital economy and society index; 3) the international digital economy and society index; and 4) the Bloomberg innovation index. The selection of indicators was based on two key characteristics: a) they include a large sample of countries; and b) they are published at regular intervals on the basis of recent data. This research comparatively assessed countries on different aspects of innovation. The aim was to draw conclusions about the strengths and weaknesses of the countries under study, but also to understand the position of these countries in the world economy. The findings highlighted the changes that have occurred since the manifestation of the global economic crisis of 2007-2009, as well as the impacts of the COVID-19 pandemic. The research focused on China, Germany, Greece and the United States, over the last decade (2010-2020), on the basis of the available data.

**Keywords:** global political economy, innovation, indexes, economic globalisation**JEL CLASSIFICATION codes:** F5, O3, O31

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Published: 30 November 2021

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## 1. Introduction

The purpose of this paper is to measure how innovative states are in their effort to improve their productive capabilities. For this purpose, the following indices will be analysed:

1. Global Innovation Index (GII)
2. Digital Economy and Society Index (DESI)
3. The International Digital Economy and Society Index (I-DESI)
4. Bloomberg innovation index

The indices were selected on the basis of two key characteristics: a) they cover a broad sample of countries, and b) are published at regular intervals on the basis of the latest data. Indices that, despite analysing various aspects of innovation have not been updated and, consequently, do not permit the comparative analysis of countries on

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the basis of contemporary data, were not selected. We will try to make a comparative evaluation of countries on various aspects of innovation. The aim is to draw conclusions about the strengths and weaknesses of the countries under review, as well as to understand the position of these countries in the global economy. It is important to clarify that the concept of innovation is broad, and includes the creation of new products, as well as services. Innovation pertains to the application of an idea that carries economic risk, and the coverage of a specific need. There are two broad types of innovation: a) evolutionary innovation, which is about gradual advances in technology or procedures, and b) revolutionary innovation, which is also known as breakthrough innovation, and creates totally new products, services, procedures or methods of organising production. The concept of innovation is also related to the assumption of higher risks as new markets are created [1].

## 2. Global Innovation Index (GII)

According to the Global Innovation Index (GII), which is published by Cornell University in the US; INSEAD (*Institut Européen d'Administration des Affaires*), which is a graduate school of business administration; and the World Intellectual Property Organization (WIPO), the concept of innovation is not restricted to research and innovation laboratories and published scientific papers. The definition of innovation is broader and may include business model innovations, as well as social and technical innovations. The GI places greater emphasis on “measuring the climate and infrastructure for innovation” [2]. The GI was introduced by Professor Dutta at INSEAD, the main goal being to understand the importance of innovation beyond traditional measures of innovation such as research and development (R&D) expenditures and the number of research articles [2]. The 2020 report is the 13th edition of the GI, which aims at creating an “environment that evaluates innovation factors continuously” [3].

The GI tries to analyse the key parameters that define the concept of innovation. The GI comprises two sub-indices, the **Innovation Input** Sub-Index, and the **Innovation Output** Sub-Index, as shown in Table 1. The Innovation Input Sub-Index for each national economy comprises five pillars. The Innovation Output Sub-Index comprises two pillars related to the production of innovation within a national economy. Both sub-indices have the same weight in calculating overall GI scores [2]. In 2020, the total number of pillars stood at 80, and the sample included 131 economies [3, p. vii and 11].

Determining innovation in national economies, in accordance with the GI, includes a series of factors. The number of science and technology clusters is instrumental to the development of innovation.

As shown in Table 2 for 2020, and Figure 1 for 2019, research centres are concentrated in certain geographical areas. In 2020, 25 S&T clusters were located in the US, 17 in China, 10 in Germany, and 5 in Japan. Some of the top 100 clusters are located in middle-income countries: Russia, Turkey, India, Brazil, and Iran [3, p. 46]. Germany, China, and the US, all countries under review, have a very strong presence in science and technology clusters, and this can also explain their key role in the global economy.

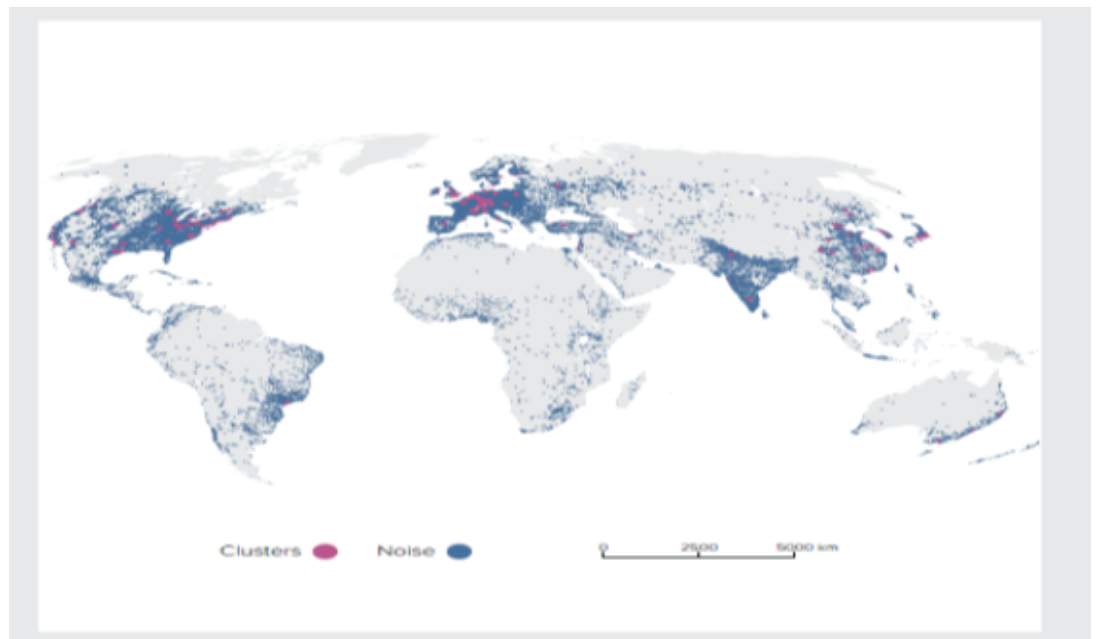
TABLE 1: Global Innovation Index

Innovation Input					Innovation Output	
Pillars					Pillars	
Institutions	Human capital and research	Infrastructure	Market sophistication	Business sophistication	Knowledge and technology outputs	Creative outputs
Political environment	Education	Information and communication technologies (ICTs)	Credit	Knowledge workers	Knowledge creation	Intangible assets
Regulatory environment	Tertiary education	General infrastructure	Investment	Innovation linkages	Knowledge impact	Creative goods and services
Business environment	Research & development	Ecological sustainability	Trade, competition, & market scale	Knowledge absorption	Knowledge diffusion	Online creativity

Source: [2, p. 57]

TABLE 2: Top-100 Science and Technology Clusters for 2020 (Source: [3, p. xxviii])

GII cluster rank	Cluster name	Economy	Rank change from GII 2019 to GII 2020
1	Tokyo-Yokohama	JP	0
2	Shenzhen-Hong Kong-Guangzhou	CN / HK	0
3	Seoul	KR	0
4	Beijing	CN	0
5	San Jose-San Francisco, CA	US	0
10	Paris	FR	-1
15	London	GB	0
18	Amsterdam-Rotterdam	NL	0
19	Cologne	DE	1
24	Tel Aviv-Jerusalem	IL	-1
27	Taipei-Hsinchu	TW	15
28	Singapore	SG	0
32	Moscow	RU	1
33	Stockholm	SE	-1
34	Eindhoven	BE / NL	-3
35	Melbourne	AU	0
39	Toronto, ON	CA	0
41	Brussels	BE	-1
43	Tehran	IR	3
45	Madrid	ES	-3
48	Milan	IT	0
49	Zurich	CH / DE	1
51	Istanbul	TR	3
54	Copenhagen	DK	1
60	Bengaluru	IN	5
61	São Paulo	BR	-2
68	Heilinki	FI	0
70	Vienna	AT	-1
89	Lausanne	CH / FR	-3
95	Basel	CH / DE / FR	-4
99	Warsaw	PL	1



**Figure 1:** Top science and technology clusters worldwide, 2019 (Source: [4, p. xxviii])

It is, indeed, telling that, while in 1997 China accounted for 2% of all patent applications, in 2017 this percentage stood at 44% of the total [4, p. 6].

The GII analysis for Germany in Tables 3 and 4 captures the strong position of the country's economy, which is a top performer in the human capital and research pillar, as it is ranked 5th worldwide with a score of 61.1. Moreover, as far as the aforementioned pillar is concerned, the country is a top performer in tertiary education (6th) and research and development (7th). Germany is also ranked very high in the trade, competition, & market scale sub-pillar (6th).

At the same time, Germany is a top performer in the innovation output sub-index, as it is ranked 10th in knowledge and technology outputs and 9th in creative outputs. The country's high ranking in knowledge and technology outputs is due to knowledge creation (5th), while the high ranking in creative outputs is due to intangible assets (7th).

Greece's performance is not as strong as Germany's, but, according to the GII report, it is in line with the level of development of a high-income economy, as shown in Tables 5 and 6 [3, p. xxv]. As regards the innovation input, Greece performs better in the human capital pillar, as it is ranked 20th with a score of 49.9. Its strongest performance lies in tertiary education, where the country is ranked 3rd with a score of 64.6. Greece's performance in the innovation output sub-index is not so strong, as the country is ranked 47th in knowledge and technology outputs and 56th in creative outputs.

The US is a top performer in many pillars of the innovation input sub-index, as shown in Table 7, the most typical case being the market sophistication pillar, where the country is ranked 2nd worldwide, while it is ranked first in the credit, and trade, competition, & market scale sub-pillars. Moreover, the US is ranked 2nd worldwide in research and development, as well as in the business environment sub-pillar, while it is ranked 5th in knowledge workers. As regards the innovation output sub-index, Table 8 shows that the US is ranked high in knowledge and technology outputs (3rd), and more specifically

TABLE 3: Global Innovation Index 2020 – Innovation Input– Germany

Innovation Input				
Pillars				
Institutions	Human capital and research	Infrastructure	Market sophistication	Business sophistication
Score	Score	Score	Score	Score
Rank	Rank	Rank	Rank	Rank
84.6	61.1	58.0	56.1	53.7
18	5	12	24	12
Political environment	Education	Information and communication technologies (ICTs)	Credit	Knowledge workers
Score	Score	Score	Score	Score
Rank	Rank	Rank	Rank	Rank
86.1	54.6	88.5	51.9	65.0
14	38	15	29	11
Regulatory environment	Tertiary education	General infrastructure	Investment	Innovation linkages
Score	Score	Score	Score	Score
Rank	Rank	Rank	Rank	Rank
80.9	56.1	42.1	35.1	53.7
28	6	19	75	13
Business environment	Research & development	Ecological sustainability	Trade, competition, & market scale	Knowledge absorption
Score	Score	Score	Score	Score
Rank	Rank	Rank	Rank	Rank
86.7	72.7	43.5	81.2	42.5
14	7	31	6	26

Source: [3, p. 256]

TABLE 4: Global Innovation Index 2020 – Innovation Output – Germany

Innovation Output			
Pillars			
Knowledge and technology outputs		Creative outputs	
Score	Rank	Score	Rank
51.7	10	49.1	9
Knowledge creation		Intangible assets	
Score	Rank	Score	Rank
68.0	5	54.8	7
Knowledge impact		Creative goods and services	
Score	Rank	Score	Rank
41.3	15	27.6	33
Knowledge diffusion		Online creativity	
Score	Rank	Score	Rank
45.8	17	59.1	11

Source: [3, p. 256]

in knowledge creation (3rd) and knowledge impact (3rd), as well as in creative outputs, as it holds the 7th place in creative goods and services. The US, as well as Germany, are above expectations as regards the level of development in high-income countries [3, p. xxv].

The case of China is different from that of the aforementioned countries, as shown in Tables 9 and 10. The key distinction is that China is an upper middle-income economy, and not a high-income economy, as the other countries under review. That said, China's innovation performance is much higher than its income level would suggest [3, p. xxv]. The country's performance is strong in the innovation input sub-index, and more specifically in the infrastructure pillar, as it gets a 48.1 and is ranked 6th in general infrastructure. As regards the market sophistication pillar, China is a top performer in trade, competition, & market scale, as it is ranked 3rd with a score of 85.3. Moreover, it is the top performer worldwide in the knowledge workers sub-pillar of the business sophistication pillar, with a score of 77.9. China is also a top performer in many pillars of the innovation output sub-index. It is ranked 7th in knowledge and technology outputs, while it is ranked 4th and 6th in the knowledge creation and knowledge impact sub-pillars respectively. Finally, as far as creative outputs are concerned, China is a top performer in intangible assets, as it is ranked 1st in the world, with a score of 72.1.

TABLE 5: Global Innovation Index 2020 – Innovation Input– Greece

Innovation Input		
Pillars		
Institutions	Score	Rank
	68.0	52
Political environment	Score	Rank
	62.3	53
Regulatory environment	Score	Rank
	67.2	59
Human capital and research	Score	Rank
	49.9	20
Education	Score	Rank
	53.7	42
Infrastructure	Score	Rank
	49.9	41
Information and communication technologies (ICTs)	Score	Rank
	80.6	32
General infrastructure	Score	Rank
	22.0	87
Tertiary education	Score	Rank
	64.6	3
Research & development	Score	Rank
	31.3	37
Market sophistication	Score	Rank
	46.0	75
Credit	Score	Rank
	42.1	63
Investment	Score	Rank
	28.5	101
Trade, competition, & market scale	Score	Rank
	67.6	43
Business sophistication	Score	Rank
	26.4	62
Knowledge workers	Score	Rank
	36.0	56
Innovation linkages	Score	Rank
	18.8	80
Knowledge absorption	Score	Rank
	24.5	80
Ecological sustainability	Score	Rank
	46.9	26

Source: [3, p. 258]

TABLE 6: Global Innovation Index 2020 – Innovation Output– Greece

Innovation Output			
Pillars			
Knowledge and technology outputs		Creative outputs	
Score	Rank	Score	Rank
27.3	47	23.8	59
Knowledge creation		Intangible assets	
Score	Rank	Score	Rank
24.5	42	22.1	87
Knowledge impact		Creative goods and services	
Score	Rank	Score	Rank
35.0	26	23.4	43
Knowledge diffusion		Online creativity	
Score	Rank	Score	Rank
22.3	69	27.4	38

Source: [3, p. 258]



TABLE 7: Global Innovation Index 2020 – Innovation Input– USA

Innovation Input										
Pillars										
Institutions	Human capital and research		Infrastructure		Market sophistication		Business sophistication			
	Score	Rank	Score	Rank	Score	Rank	Score	Rank		
	88.9	9	56.3	12	54.7	24	81.4	2	62.8	5
Political environment	Education		Information and communication technologies (ICTs)		Credit		Knowledge workers			
	Score	Rank	Score	Rank	Score	Rank	Score	Rank		
	83.7	16	52.4	45	90.4	9	89.7	1	69.8	5
Regulatory environment	Tertiary education		General infrastructure		Investment		Innovation linkages			
	Score	Rank	Score	Rank	Score	Rank	Score	Rank		
	92.0	11	39.3	45	43.0	15	63.8	13	60.6	8
Business environment	Research & development		Ecological sustainability		Trade, competition, & market scale		Knowledge absorption			
	Score	Rank	Score	Rank	Score	Rank	Score	Rank		
	91.0	2	77.1	2	30.8	59	90.7	1	58.0	5

Source: [3, p. 339]

TABLE 8: Global Innovation Index 2020 – Innovation Output– USA

Innovation Output			
Pillars			
Knowledge and technology outputs		Creative outputs	
Score	Rank	Score	Rank
56.8	3	47.7	11
Intangible assets			
Knowledge creation		Creative goods and services	
Score	Rank	Score	Rank
72.8	3	48.1	15
Knowledge impact		Online creativity	
Score	Rank	Score	Rank
51.8	3	44.2	7
Knowledge diffusion		Online creativity	
Score	Rank	Score	Rank
45.9	16	50.4	18

Source: [3, p. 339]

TABLE 9: Global Innovation Index 2020 – Innovation Input– China

Innovation Input		
Pillars		
Institutions	Score	Rank
	64.6	62
Political environment	Score	Rank
	64.9	47
Regulatory environment	Score	Rank
	50.7	102
Human capital and research	Score	Rank
	49.4	21
Infrastructure	Score	Rank
	52.1	36
Business sophistication	Score	Rank
	52.9	15
Market sophistication	Score	Rank
	58.5	19
Education	Score	Rank
	64.5	12
Information and communication technologies (ICTs)	Score	Rank
	75.8	45
Credit	Score	Rank
	77.9	1
General infrastructure	Score	Rank
	48.1	6
Tertiary education	Score	Rank
	25.0	83
Investment	Score	Rank
	37.1	66
Ecological sustainability	Score	Rank
	32.5	54
Trade, competition, & market scale	Score	Rank
	85.3	3
Research & development	Score	Rank
	58.8	16
Knowledge absorption	Score	Rank
	56.3	6

Source: [3, p. 239]

TABLE 10: Global Innovation Index 2020 – Innovation Output– China

Innovation Output			
Pillars			
Knowledge and technology outputs		Creative outputs	
Score	Rank	Score	Rank
55.1	7	47.0	12
Knowledge creation		Intangible assets	
Score	Rank	Score	Rank
70.4	4	72.1	1
Knowledge impact		Creative goods and services	
Score	Rank	Score	Rank
50.4	6	39.7	12
Knowledge diffusion		Online creativity	
Score	Rank	Score	Rank
44.5	21	4.1	13

Source: [3, p. 239]

### 3. Digital Economy And Society Index (DESI)

The next index under review is the Digital Economy and Society Index (DESI). *“The Digital Economy and Society Index (DESI) is a composite index published annually by the European Commission since 2014. It measures the progress made by EU Member States towards a digital economy and society... The DESI is composed of five principal policy areas, which group 37 indicators overall”* [5]. As shown in Table 11, the five policy areas include indices related to the following subjects:

Figure 2 shows Greece’s performance in the DESI is very poor, as it is ranked 27th among 28 countries in 2020. In the last year, Greece improved its performance in the human capital policy area, and more specifically, the percentage of individuals with at least basic digital skills exceeded 50% for the first time [6]. Figure 3 presents the country’s performance per policy area for 2020, as well as the historical evolution of the index from 2015 to 2020. It is evident that Greece was below the European Union average in all policy areas in 2020, as well as that Greece’s performance is below the EU average in all years under review.

The first dimension under review in the case of Greece is connectivity, and Table 12 shows that Greece’s performance is below the European Union average in all years under review. Greece is ranked last among EU countries in this dimension, with a score

TABLE 11: Digital Economy and Society Index (DESI)

<b>1. Connectivity</b>	Fixed broadband take-up, fixed broadband coverage, mobile broadband and broadband prices
<b>2. Human Capital</b>	Internet user skills and advanced skills
<b>3. Use of Internet</b>	Citizens' use of internet services and online transactions
<b>4. Integration of digital technology</b>	Business digitisation and e-commerce
<b>5. Digital public services</b>	e-Government

Source: [5, p. 1]

of 33.4. In almost all indicators of this policy area Greece falls behind the European Union in 2020, the only exception being 4G coverage, as Greece outperforms the EU by 1%. In contrast, Greece's performance is much lower than the EU average in the following indicators: a) 1a2 At least 100 Mbps fixed broadband take-up; b) 1b2 Fixed Very High Capacity Network (VHCN) coverage; and c) 1c3 5G readiness.

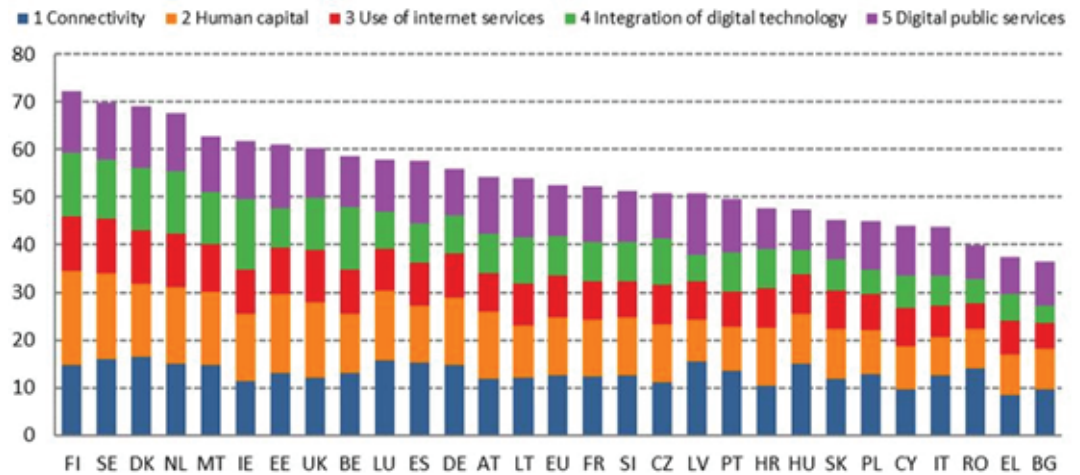


Figure 2: Digital Economy and Society Index (DESI) – European Union (Source: [5, p. 2])

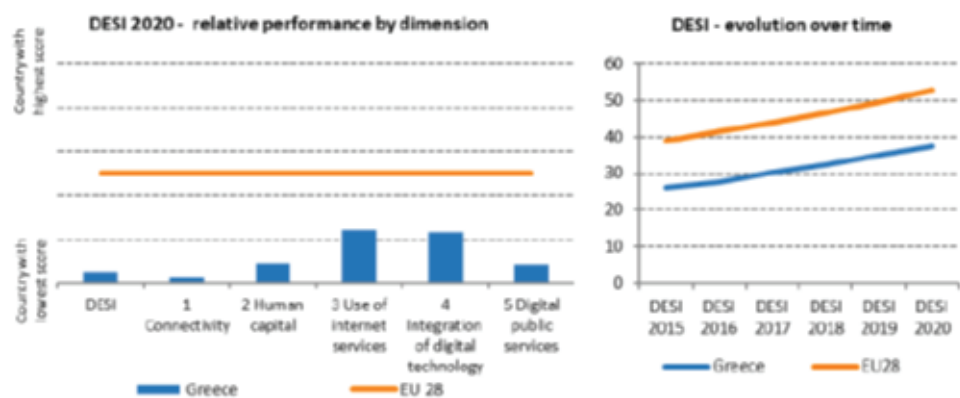


Figure 3: Digital Economy and Society Index (DESI) – Greece (Source: [6, p. 4])

As shown in Table 13, Greece’s performance in the human capital dimension is much lower than the EU average in all years under review, and in 2020 the country is ranked 25th with a score of 34.8. Greece’s best performance in this dimension, according to the 2020 report, is in indicator 2b3. ICT graduates. In contrast, according to the 2020 report, Greece performs poorly in the following indicators: a) 2b1 ICT specialists, with 1.8% of total employment, as compared to 3.9% in the EU-28; and b) 2b2 female ICT specialists, with 0.5% of female employment, as compared to 1.4% in the EU-28.

Greece is well below the EU-28 average in the use of Internet services in all years under review and is ranked 25th, as shown in Table 14. Greece’s outlook in this dimension is better in comparison to the previous two. In certain indicators, Greece is actually outperforming the European Union. More specifically, Greece’s fares better in the following indicators: a) 3b1 News, with 88% of Internet users as compared to 72% in the EU; 2) 3b4 Video calls, with 67%, as compared to 60% in the EU; and c) 3b5 Social networks, with 75%, as compared to 65% in the EU. In contrast, Greece’s performance is very poor in the following indicators: a) 3a1 People who have never used the Internet, with 22% of individuals as compared to 9% in the EU; b) 3a2 Internet users, with 74% as compared to 85% in the EU; c) Video on demand, with 11% of Internet users, as

TABLE 12: Digital Economy and Society Index (DESI) Greece – Connectivity (Source: [6, p. 6])

### 1 Connectivity

1 Connectivity	Greece		EU
	rank	score	score
DESI 2020	28	33.4	50.1
DESI 2019	28	29.5	44.7
DESI 2018	28	26.0	39.9



	Greece			EU
	DESI 2018	DESI 2019	DESI 2020	DESI 2020
<b>1a1 Overall fixed broadband take-up</b>	<b>69%</b>	<b>74%</b>	<b>76%</b>	<b>78%</b>
<small>% households</small>	2017	2018	2019	2019
<b>1a2 At least 100 Mbps fixed broadband take-up</b>	<b>0%</b>	<b>0%</b>	<b>1%</b>	<b>26%</b>
<small>% households</small>	2017	2018	2019	2019
<b>1b1 Fast broadband (NGA) coverage</b>	<b>53%</b>	<b>66%</b>	<b>81%</b>	<b>86%</b>
<small>% households</small>	2017	2018	2019	2019
<b>1b2 Fixed Very High Capacity Network (VHCN) coverage</b>	<b>0%</b>	<b>0%</b>	<b>7%</b>	<b>44%</b>
<small>% households</small>	2017	2018	2019	2019
<b>1c1 4G coverage</b>	<b>86%</b>	<b>92%</b>	<b>97%</b>	<b>96%</b>
<small>% households (average of operators)</small>	2017	2018	2019	2019
<b>1c2 Mobile broadband take-up</b>	<b>66</b>	<b>75</b>	<b>86</b>	<b>100</b>
<small>Subscriptions per 100 people</small>	2017	2018	2019	2019
<b>1c3 5G readiness</b>	<b>NA</b>	<b>0%</b>	<b>0%</b>	<b>21%</b>
<small>Assigned spectrum as a % of total harmonised 5G spectrum</small>	2019	2019	2020	2020
<b>1d1 Broadband price index</b>	<b>NA</b>	<b>NA</b>	<b>49</b>	<b>64</b>
<small>Score (0 to 100)</small>			2019	2019

compared to 31% in the EU; d) 3c1 Banking, with 40% as compared to 66% in the EU; and e) 3c3 Selling online, with 3% as compared to 23%.

In integration of digital technology Greece is ranked 24th, and falls below the European Union average, as shown in Table 15. Greece outperforms the EU average in the following indicators: a) 4a1 Electronic information sharing, with 38% of enterprises, as compared to 34% in the EU, and b) 4a3 Big data, with 13%, as compared to 12% in the EU. At the same time, Greece falls below the European Union average in the following indicators: a) 4a4 Cloud, with 7% of enterprises, as compared to 18% in the EU; b) 4b1 SMEs selling online, with 9% of SMEs, as compared to 18% in the EU; and c) 4b2 e-Commerce turnover, with 4% of SME turnover, as compared to 11% in the EU.

In the last dimension of the index, which concerns digital public services, Greece is ranked 27th among the 28 member states of the European Union. Greece's performance is in line with the EU average in the following indicator: 5a5 Open data, with a score of 66%. Moreover, as regards this dimension, Greece falls behind in the following indicators: a) 5a1 e-Government users, with 39% of Internet users needing to submit forms, as compared to 67% in the EU; b) 5a2 Pre-filled forms, with a score of 25, as compared to 59 in the EU; and c) 5a4 Digital public services for businesses, with a score of 63 as compared to 88 in the EU.

TABLE 13: Digital Economy and Society Index (DESI) Greece – Human capital (Source: [6, p. 9])

## 2 Human capital

2 Human capital	Greece		EU
	rank	score	score
DESI 2020	25	34.8	49.3
DESI 2019	25	32.7	47.9
DESI 2018	25	31.9	47.6



	Greece			EU
	DESI 2018	DESI 2019	DESI 2020	DESI 2020
<b>2a1 At least basic digital skills</b>	<b>46%</b>	<b>46%</b>	<b>51%</b>	<b>58%</b>
% individuals	2017	2017	2019	2019
<b>2a2 Above basic digital skills</b>	<b>22%</b>	<b>22%</b>	<b>23%</b>	<b>33%</b>
% individuals	2017	2017	2019	2019
<b>2a3 At least basic software skills</b>	<b>52%</b>	<b>52%</b>	<b>56%</b>	<b>61%</b>
% individuals	2017	2017	2019	2019
<b>2b1 ICT specialists</b>	<b>1.4%</b>	<b>1.6%</b>	<b>1.8%</b>	<b>3.9%</b>
% total employment	2016	2017	2018	2018
<b>2b2 Female ICT specialists</b>	<b>0.4%</b>	<b>0.4%</b>	<b>0.5%</b>	<b>1.4%</b>
% female employment	2016	2017	2018	2018
<b>2b3 ICT graduates</b>	<b>3.0%</b>	<b>3.2%</b>	<b>2.9%</b>	<b>3.6%</b>
% graduates	2015	2016	2017	2017

Next, we analyse the case of Germany as regards the DESI. As shown in Figure 2, Germany is ranked 12th among the 28 member states of the EU. As demonstrated by the study of the Index and Figure 4, Germany outperforms the European Union average in most dimensions, falling behind only in the integration of digital technology and digital public services. Moreover, we can see that Germany’s performance is marginally above the EU average in all years under review.

In connectivity, Germany is above the European Union average, since it is ranked 8th, with a score of 59.4 in 2020, compared to an average of 50.1 in the EU, as we can see in Table 17. Germany’s strongest performance in this dimension is concentrated in the following indicators: a) 1a1 Overall fixed broadband take-up, with 88% of households covered, as compared to 78% in the EU; and b) 1c3 5G readiness, with 67%, as compared to 21% in the EU. In contrast, Germany is below the EU average in the following indicators: a) 1c1 4G coverage, with 94% of households covered, as compared to 96% in the EU; and b) 1c2 Mobile broadband take-up, with 85 subscriptions per 100 people, as compared to 100 in the EU.

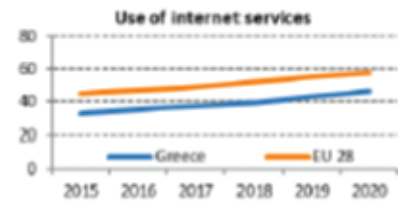
In human capital, Germany is being ranked 10th in the past three years, with a score of 56.4, compared to 49.3 in the EU, as we can see in Table 18. As regards this dimension, Germany’s top performance is concentrated in the following indicators: a) 2a1 At least basic digital skills, with 70% of individuals, as compared to 58% in the EU; b) 2a2 Above basic digital skills, with 39%, as compared to 33%; and c) 2a3 At least basic software skills, with 72%, as compared to 61%. Germany’s poorest performance in this dimension



TABLE 14: Digital Economy and Society Index (DESI) Greece – Use of Internet services (Source: [6, p. 11])

### 3 Use of internet services

3 Use of internet services	Greece		EU
	rank	score	score
DESI 2020	25	46.1	58.0
DESI 2019	25	43.3	55.0
DESI 2018	25	39.3	51.8



	Greece			EU
	DESI 2018	DESI 2019	DESI 2020	DESI 2020
<b>3a1 People who have never used the internet</b>	<b>28%</b>	<b>25%</b>	<b>22%</b>	<b>9%</b>
% individuals	2017	2018	2019	2019
<b>3a2 Internet users</b>	<b>67%</b>	<b>70%</b>	<b>74%</b>	<b>85%</b>
% individuals	2017	2018	2019	2019
<b>3b1 News</b>	<b>87%</b>	<b>87%</b>	<b>88%</b>	<b>72%</b>
% internet users	2017	2017	2019	2019
<b>3b2 Music, videos and games</b>	<b>77%</b>	<b>79%</b>	<b>79%</b>	<b>81%</b>
% internet users	2016	2018	2018	2018
<b>3b3 Video on demand</b>	<b>12%</b>	<b>11%</b>	<b>11%</b>	<b>31%</b>
% internet users	2016	2018	2018	2018
<b>3b4 Video calls</b>	<b>48%</b>	<b>61%</b>	<b>67%</b>	<b>60%</b>
% internet users	2017	2018	2019	2019
<b>3b5 Social networks</b>	<b>72%</b>	<b>73%</b>	<b>75%</b>	<b>65%</b>
% internet users	2017	2018	2019	2019
<b>3b6 Doing an online course</b>	<b>7%</b>	<b>7%</b>	<b>7%</b>	<b>11%</b>
% internet users	2017	2017	2019	2019
<b>3c1 Banking</b>	<b>36%</b>	<b>38%</b>	<b>40%</b>	<b>66%</b>
% internet users	2017	2018	2019	2019
<b>3c2 Shopping</b>	<b>45%</b>	<b>49%</b>	<b>51%</b>	<b>71%</b>
% internet users	2017	2018	2019	2019
<b>3c3 Selling online</b>	<b>3%</b>	<b>5%</b>	<b>3%</b>	<b>23%</b>
% internet users	2017	2018	2019	2019

pertains to indicator 2b2 Female ICT specialists, with 1.4% of female employment, which is equal to the EU average.

Table 19 shows that Germany is ranked 9th in 2020 with a score of 61.6, against 58.0 for the EU, but is outperforming the EU in the other years, as well. The country's strongest performance in this dimension pertains to the following indicators: a) 3a1 People who have never used the Internet, with 5% of individuals, as compared to 9% in the EU; b) 3a2 Internet users, with 91% of individuals, as compared to 85% in the EU; c) 3c2 Shopping, with 84% of individuals, as compared to 71% in the EU; and d) 3c3 Selling online, with 32%, as compared to 23% in the EU. In 2020, Germany's poorest performance in this dimension pertains to the following indicators: a) 3b5 Social networks, with 56% of Internet users as compared to 65%; and b) 3b6 Doing an online course, with 9%, as compared to 11% in the EU.

As regards the integration of digital technology dimension, Germany is ranked 18th with a score of 39.5, compared to a score of 41.4 for the European Union, as shown in Table 20. Germany's strongest performance in this dimension is concentrated in the

TABLE 15: Digital Economy and Society Index (DESI) Integration of digital technology – Greece (Source: [6, p. 12])

### 4 Integration of digital technology

4 Integration of digital technology	Greece		EU
	rank	score	score
DESI 2020	24	28.2	41.4
DESI 2019	22	30.2	39.8
DESI 2018	23	28.6	37.8

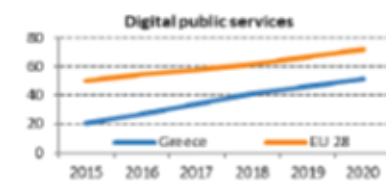


	Greece			EU
	DESI 2018 value	DESI 2019 value	DESI 2020 value	DESI 2020 value
<b>4a1 Electronic information sharing</b> % enterprises	37%	37%	38%	34%
<b>4a2 Social media</b> % enterprises	21%	21%	19%	25%
<b>4a3 Big data</b> % enterprises	11%	13%	13%	12%
<b>4a4 Cloud</b> % enterprises	5%	7%	7%	18%
<b>4b1 SMEs selling online</b> % SMEs	11%	11%	9%	18%
<b>4b2 e-Commerce turnover</b> % SME turnover	3%	4%	4%	11%
<b>4b3 Selling online cross-border</b> % SMEs	7%	7%	4%	8%

TABLE 16: Digital Economy and Society Index (DESI) Greece – Digital public services (Source: [6, p. 14])

### 5 Digital public services

5 Digital public services	Greece		EU
	rank	score	score
DESI 2020	27	51.5	72.0
DESI 2019	27	46.4	67.0
DESI 2018	27	41.2	61.8



	Greece			EU
	DESI 2018 value	DESI 2019 value	DESI 2020 value	DESI 2020 value
<b>5a1 e-Government users</b> % internet users needing to submit forms	38%	36%	39%	67%
<b>5a2 Pre-filled forms</b> Score (0 to 100)	14	23	25	59
<b>5a3 Online service completion</b> Score (0 to 100)	76	82	84	90
<b>5a4 Digital public services for businesses</b> Score (0 to 100) - including domestic and cross-border	60	60	63	88
<b>5a5 Open data</b> % of maximum score	NA	NA	66%	66%

following indicators: a) 4a3 Big data, with 15% of enterprises, as compared to 12% in the EU; and b) 4b3 Selling online cross-border, with 10% of SMEs, as compared to 8% in the

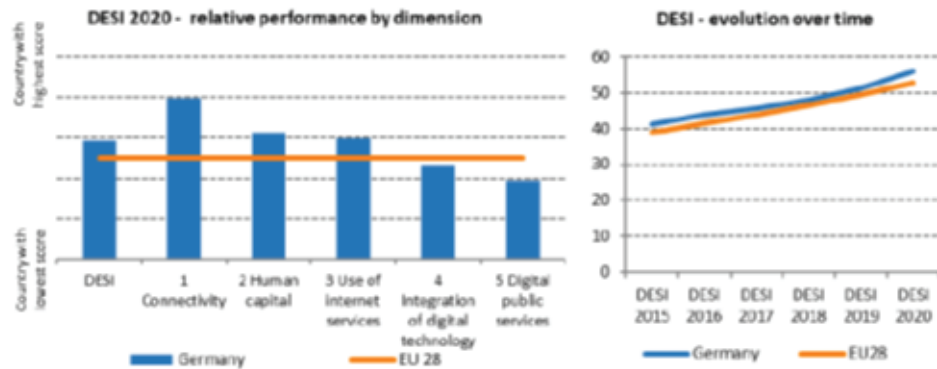
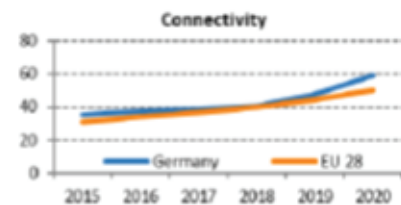


Figure 4: Digital Economy and Society Index (DESI) – Germany (Source: [7, p. 4])

TABLE 17: Digital Economy and Society Index (DESI) Germany – Connectivity (Source: [7, p. 5])

### 1 Connectivity

1 Connectivity	Germany		EU
	rank	score	score
DESI 2020	8	59.4	50.1
DESI 2019	14	47.7	44.7
DESI 2018	16	40.6	39.9



	Germany			EU
	DESI 2018	DESI 2019	DESI 2020	DESI 2020
<b>1a1 Overall fixed broadband take-up</b>	<b>88%</b>	<b>87%</b>	<b>88%</b>	<b>78%</b>
% households	2017	2018	2019	2019
<b>1a2 At least 100 Mbps fixed broadband take-up</b>	<b>11%</b>	<b>15%</b>	<b>21%</b>	<b>26%</b>
% households	2017	2018	2019	2019
<b>1b1 Fast broadband (NGA) coverage</b>	<b>84%</b>	<b>88%</b>	<b>92%</b>	<b>86%</b>
% households	2017	2018	2019	2019
<b>1b2 Fixed Very High Capacity Network (VHCN) coverage</b>	<b>7%</b>	<b>9%</b>	<b>33%</b>	<b>44%</b>
% households	2017	2018	2019	2019
<b>1c1 4G coverage</b>	<b>88%</b>	<b>90%</b>	<b>94%</b>	<b>96%</b>
% households (average of operators)	2017	2018	2019	2019
<b>1c2 Mobile broadband take-up</b>	<b>79</b>	<b>81</b>	<b>85</b>	<b>100</b>
Subscriptions per 100 people	2017	2018	2019	2019
<b>1c3 5G readiness</b>	<b>NA</b>	<b>33%</b>	<b>67%</b>	<b>21%</b>
Assigned spectrum as a % of total harmonised 5G spectrum		2019	2020	2020
<b>1d1 Broadband price index</b>	<b>NA</b>	<b>NA</b>	<b>75</b>	<b>64</b>
Score (0 to 100)			2019	2019

EU. Germany has taken a series of initiatives aimed at advancing digitalisation, such as: “a digital innovation competition for business start-ups, the Digital Hub Initiative, GINSEP, Mittelstand 4.0 Centres of Excellence, ‘go digital’, the Town-Country-Digital Initiative, IT Security in the Business Sector and Industrie 4.0” [7, p. 10].

In contrast, Germany’s poorest performance in this dimension pertains to the following indicators: a) 4a2 Social media, with 23%, of enterprises as compared to 25% in the EU;

TABLE 18: Digital Economy and Society Index (DESI) Germany – Human Capital (Source: [7, p. 7])

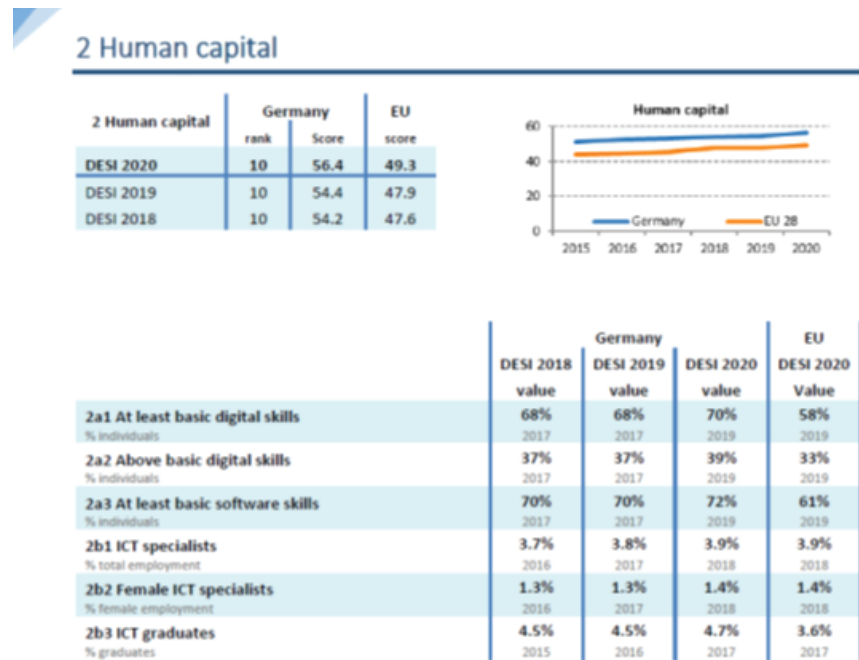


TABLE 19: Digital Economy and Society Index (DESI) Germany – Use of Internet services (Source: [7, p. 9])

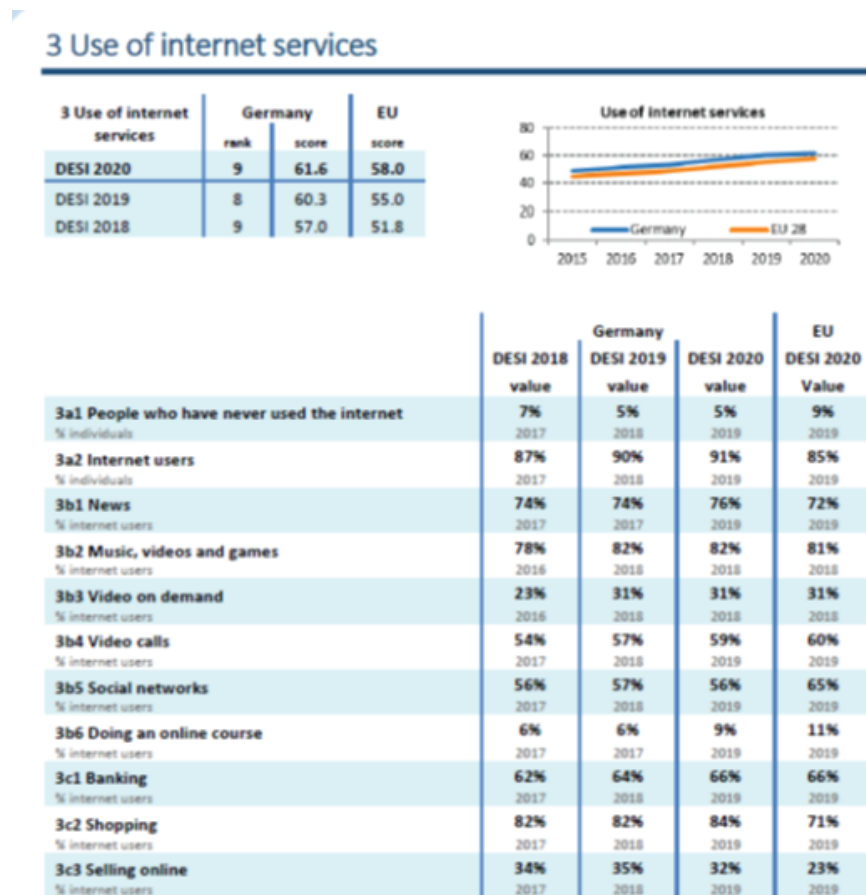
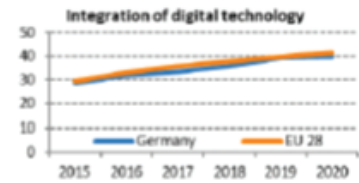


TABLE 20: Digital Economy and Society Index (DESI) Germany – Integration of digital technology (Source: [7, p. 10])

### 4 Integration of digital technology

4 Integration of digital technology	Germany		EU
	rank	score	score
DESI 2020	18	39.5	41.4
DESI 2019	15	39.2	39.8
DESI 2018	17	35.8	37.8



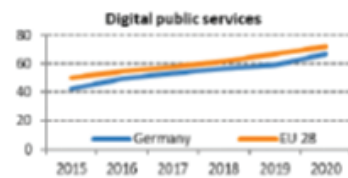
	Germany			EU
	DESI 2018 value	DESI 2019 value	DESI 2020 value	DESI 2020 Value
<b>4a1 Electronic information sharing</b> % enterprises	NA	NA	29%	34%
<b>4a2 Social media</b> % enterprises	16%	16%	23%	25%
<b>4a3 Big data</b> % enterprises	6%	15%	15%	12%
<b>4a4 Cloud</b> % enterprises	NA	12%	12%	18%
<b>4b1 SMEs selling online</b> % SMEs	23%	19%	17%	18%
<b>4b2 e-Commerce turnover</b> % SME turnover	11%	9%	10%	11%
<b>4b3 Selling online cross-border</b> % SMEs	11%	11%	10%	8%

b) 4a4 Cloud, with 12%, as compared to 18% in the EU; and c) 4b2 e-Commerce turnover, with 10% of SME turnover, as compared to 11% in the EU.

TABLE 21: Digital Economy and Society Index (DESI) Germany – Digital public services (Source: [7, p. 12])

### 5 Digital public services

5 Digital public services	Germany		EU
	rank	score	score
DESI 2020	21	66.4	72.0
DESI 2019	22	58.8	67.0
DESI 2018	19	56.4	61.8



	Germany			EU
	DESI 2018 value	DESI 2019 value	DESI 2020 value	DESI 2020 value
<b>Sa1 e-Government users</b> % internet users needing to submit forms	39%	43%	49%	67%
<b>Sa2 Pre-filled forms</b> Score (0 to 100)	38	41	41	59
<b>Sa3 Online service completion</b> Score (0 to 100)	88	88	90	90
<b>Sa4 Digital public services for businesses</b> Score (0 to 100) - including domestic and cross-border	84	80	92	88
<b>Sa5 Open data</b> % of maximum score	NA	NA	68%	66%

In the last dimension of the index, which concerns digital public services, Germany is ranked 21st, with a score of 66.4, as compared to 72.0 for the EU. Germany's strongest

performance pertains to the following indicators: a) 5a4 Digital public services for businesses, with a score of 92, as compared to 88 in the EU; b) 5a5 Open data, with 68%, as compared to 66% in the EU; and c) 5a3 Online service completion, with a score of 90, the same as in the EU. In contrast, Germany's performance is poor in the following indicators: a) 5a1 e-Government users, with 49% of internet users needing to submit forms, as compared to 67% in the EU; and b) 5a2 Pre-filled forms, with a score of 41, as compared to 59 in the EU.

#### 4. The International Digital Economy And Society Index (I-DESI)

The I-DESI represents an effort by the European Commission to expand the DESI, in order to widen the scope of the analysis beyond the 27 member-states of the European Union and include 18 other major economies, thus ensuring the fuller understanding of global digital economy trends. The I-DESI was introduced in 2016, with the initial goal of evaluating the performance of individual EU countries and the EU as a whole, with 15 other countries [8, p. 3]. In the context of this paper, we will analyse US and China, since they are two of the countries under review. The 2020 I-DESI has managed to include data covering the years from 2015 to 2018, making it possible to establish a trend for analytical purposes, as shown in Figure 5 [9].

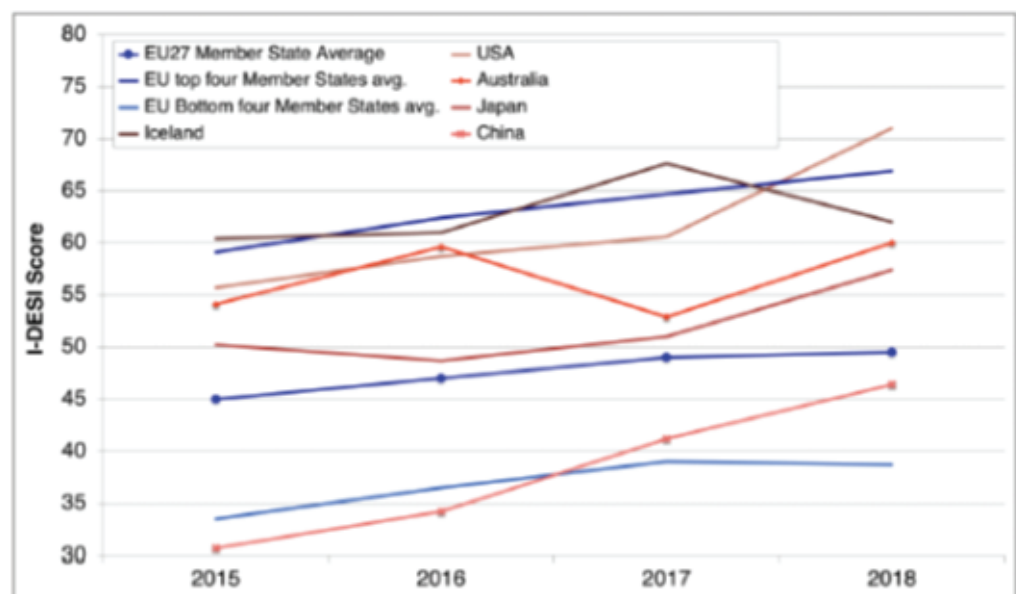


Figure 5: Average scores across all dimensions for I-DESI 2015 to 2018 (Source: [9, p. 17])

Figure 6 provides a comparison of the performance of EU member states to other economies under review. The top performers in the I-DESI during 2015-2018 are also the top-4 performing countries among the EU-27. We can also see that the performance of the US falls below that of the top-performing EU member states, albeit it is much higher than the EU average. In contrast, China's performance score is much lower, well below the EU average, albeit above the average for the bottom four performing countries. As

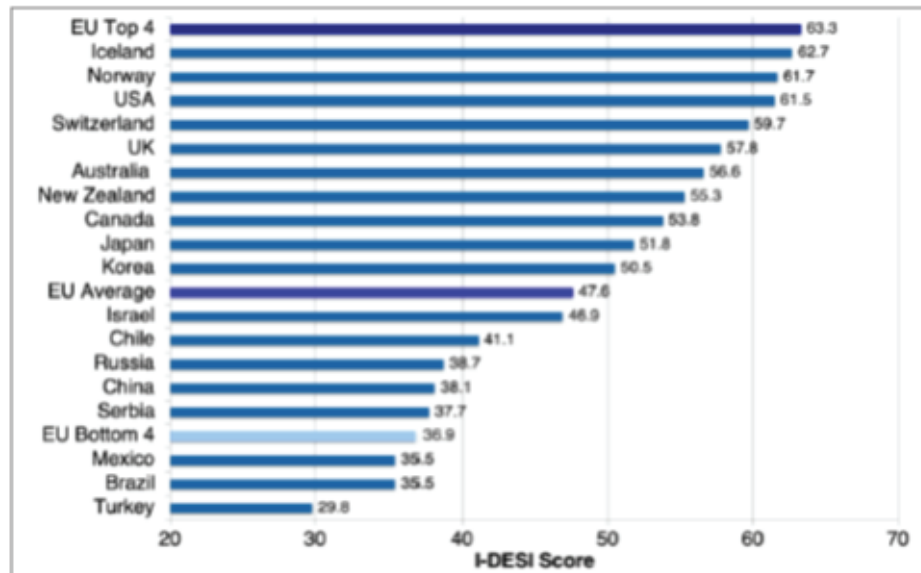


Figure 6: Non-EU countries' performance scores for I-DESI (Source: [9, p. 18])

shown in Figure 6, the performance score of the US during 2015-2018 is 61.5, while that of China is only 38.1.

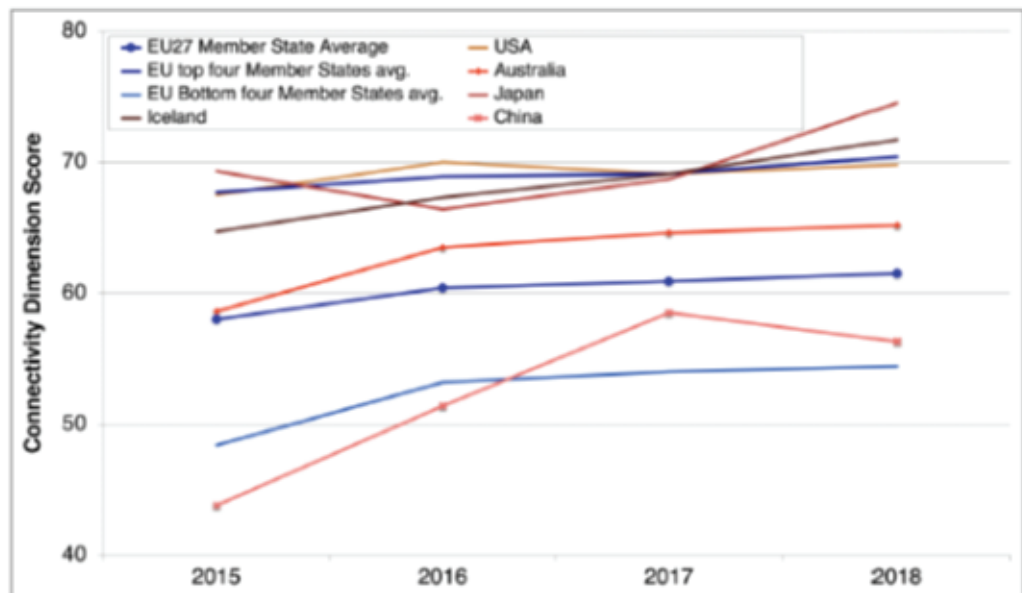


Figure 7: Average performance scores for the connectivity dimension I-DESI 2015 - 2018 (Source: [9, p. 19])

Figure 7 presents the performance scores as regards the connectivity dimension for the 27 member states of the EU, as well as the remaining economies under review, from 2015 to 2018. We can see that the average of the leading four EU27 member states is lower than that of non-EU countries, Japan being the top performer with an average score of 74.5 in all years under review, but steadily rising. Figure 8 demonstrates that the performance score of the US in the connectivity dimension stands at 69.8 in 2018, higher than the EU27 average, which stands at 61.5, albeit below the average of the



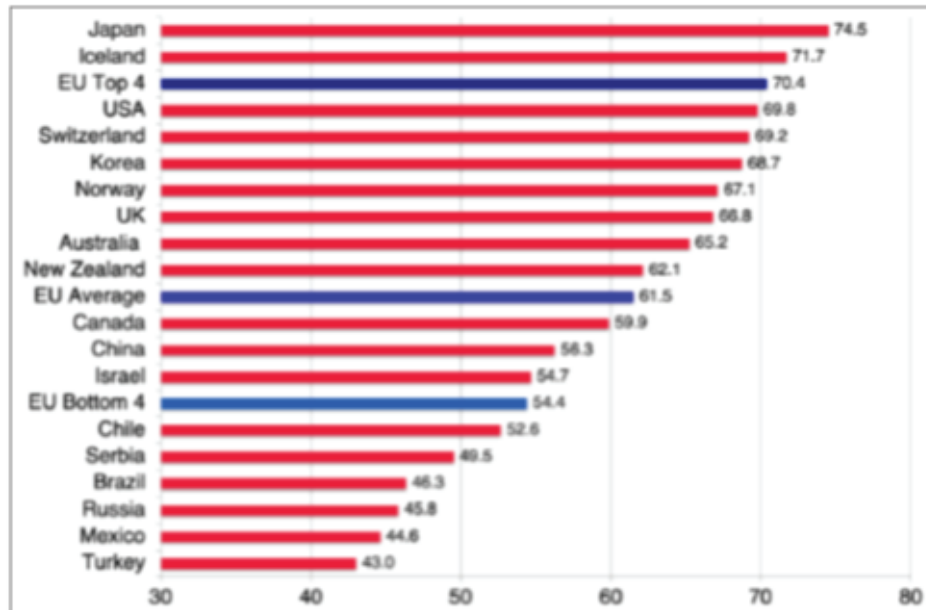


Figure 8: Non-EU countries’ performance scores for r the connectivity dimension in 2018 (Source: [9, p. 20])

top-four EU27 performers, which stands at 70.4. In contrast, China’s performance is very poor, as the country is below the EU27 average, with a score of 56.3.

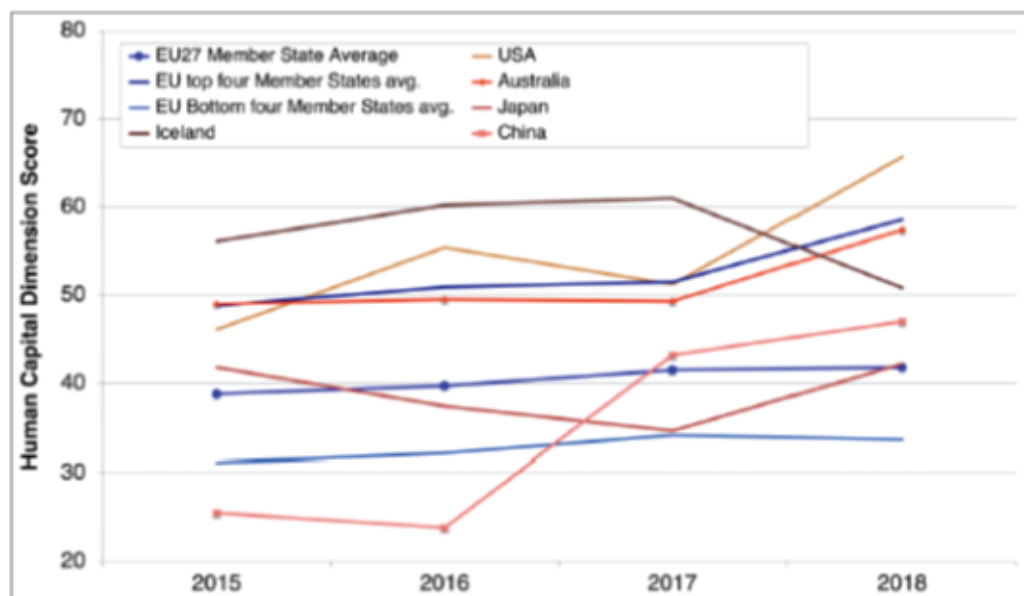


Figure 9: Average performance scores for the human capital dimension I-DESI 2015 - 2018 (Source: [9, p. 22])

Figure 9 presents the performance scores of European Union member states and other major economies from 2015 to 2018, as regards the human capital dimension. We can see that the top-four EU27 member states are also leading performers overall. It is telling that, in 2018, the only non-EU country that had a higher score than the average of the top-four EU27 countries was the US, as shown in Figure 10. Moreover, the average



EU performance score for 2018 stands at 41.8, as compared to 58.6 for the top-four member states and 33.6 for the bottom four member states. China's performance is strong, and with a score of 47.0 is below the top-four EU27 countries.

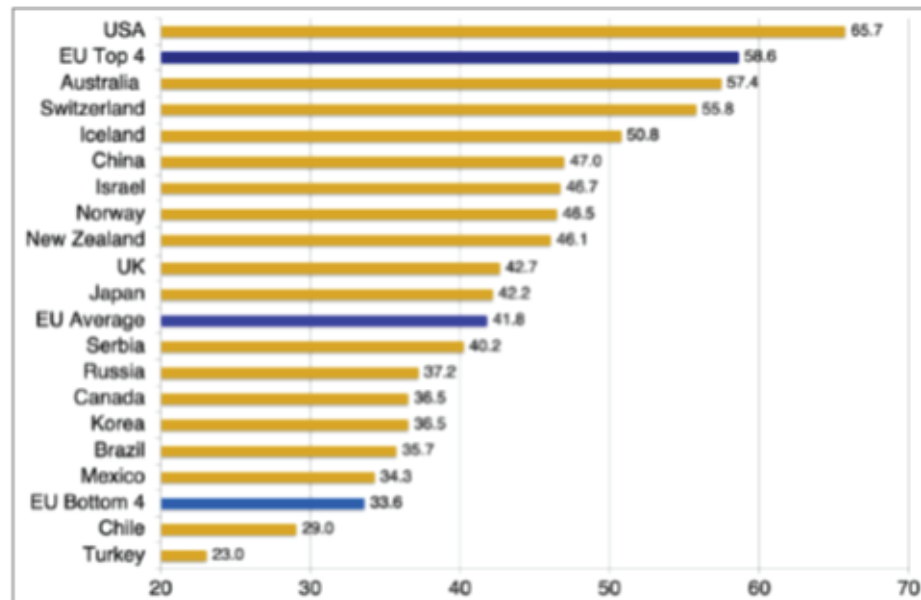


Figure 10: Non-EU countries' performance scores for the human capital dimension in 2018 (Source: [9, p. 23])

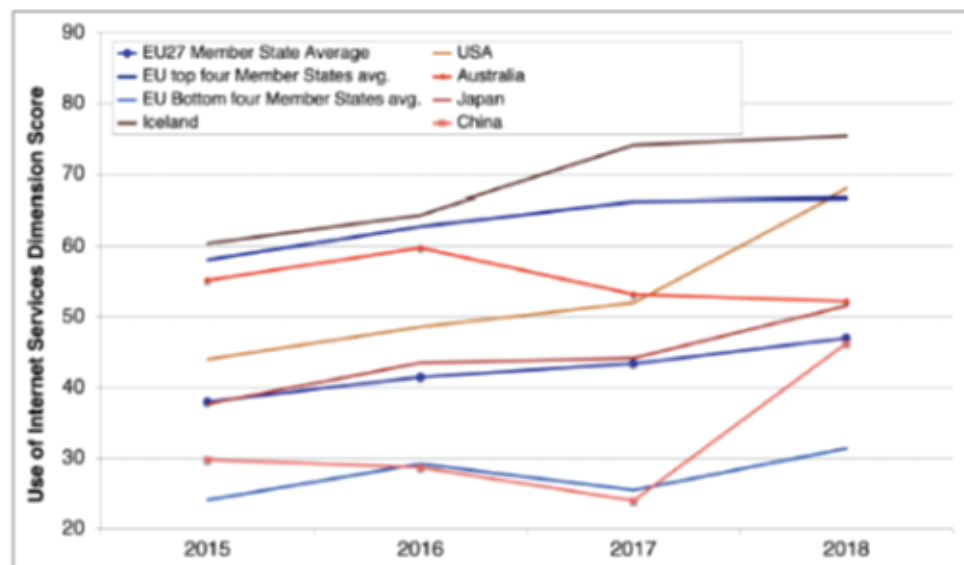
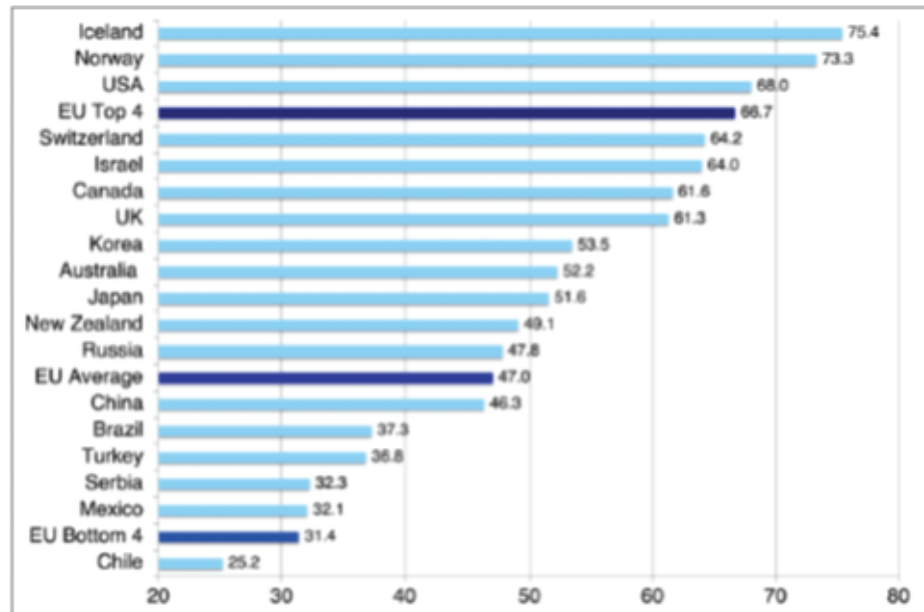


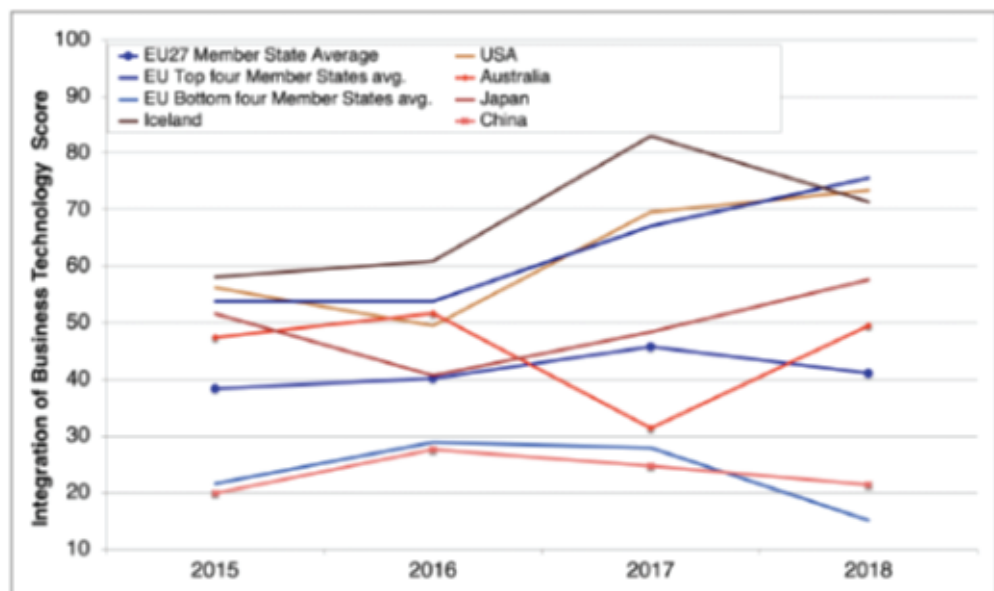
Figure 11: Average performance scores for the Use of Internet Services dimension I-DESI 2015 - 2018 (Source: [9, p. 25])

Figure 11 analyses the countries' average performance scores for the use of internet services dimensions during 2015-2018. In this dimension, the performance score of the top four EU27 countries stands at 66.7, surpassed only by those of Iceland at 75.4, Norway at 73.3, and the US at 68.0. Figure 12 shows that, as regards this dimension,

China is above the average of the bottom-four EU member states, with a performance score of 46.3, as compared to 31.4.



**Figure 12:** Non-EU countries’ performance scores for the Use of Internet Services dimension in 2018 (Source: [9, p. 26])



**Figure 13:** Average scores for the Integration of Digital Technology dimension I-DESI 2015-2018 (Source: [9, p. 28])

Figure 13 presents the average performance scores for the integration of digital technology dimension from 2015 to 2018. We can see that the top-four EU member states are performing strongly throughout this period. Figure 14 shows that, in 2018, Switzerland and Israel outperformed the average of the top-four EU27 countries. The US, with performance score of 73.4, is above the EU average, which stands at 41.1.

Similarly to the previous dimensions, China, with a performance score of 21.4 is much behind, albeit above the average for the bottom-four EU member states, which stands at 15.1.

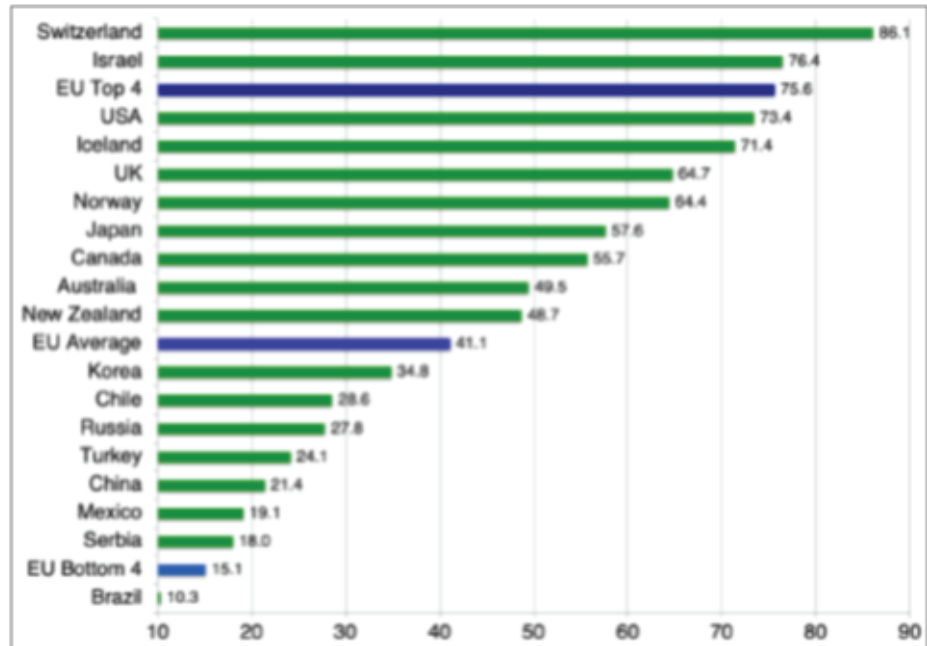


Figure 14: Non-EU countries’ performance scores for the business technology integration dimension in 2018 (Source: [9, p. 29])

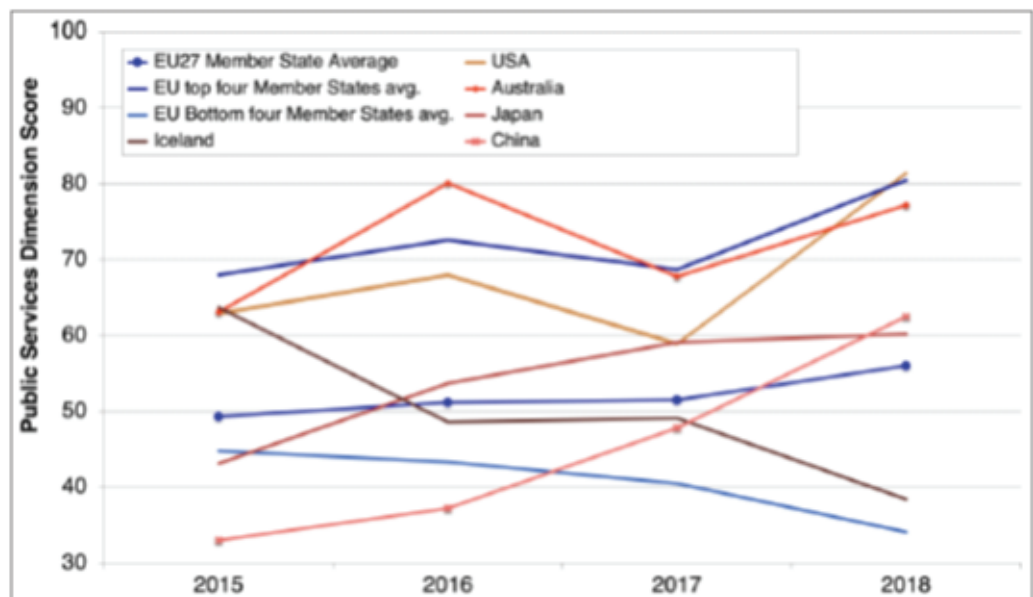
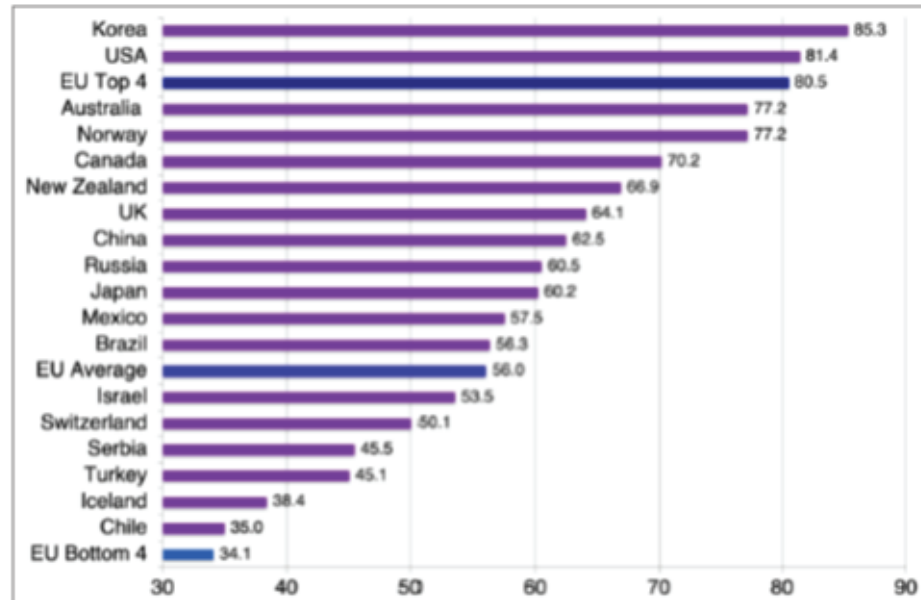


Figure 15: Average performance scores for the public services dimension I-DESI 2015 - 2018 (Source: [9, p. 31])

Figure 15 presents the performance scores for the public services dimension. The performance of the top-four EU member states is strong in all years under review. Figure 16 shows that the performance of the top-four EU countries stands at 80.5 and

falls behind only those of Korea, at 85.3, and the US, at 81.4. China, with a performance score of 62.5, is above the EU average. It is telling that, as regards this dimension, the bottom-four member states of the EU are also the worst performers overall, with an average score of 34.1.



**Figure 16:** Non-EU countries' performance scores for the digital public services dimension in 2018 (Source: [9, p. 32])

## 5. The Bloomberg Innovation Index

Bloomberg is a company that was established in 1981, and provides information and technology services. It is a company with a very strong presence, as it employs 20.000 people in 167 locations, including 5.500 computer engineers, publishes 5.000 news items per day in more than 120 countries, and has 325.000 subscribers worldwide [10]. Since 2015, the company has been publishing the Bloomberg Innovation Index, with the aim of selecting the world's 50 most innovative countries. The Bloomberg Innovation Index is based on seven tangible activities that contribute to innovation in each country [11]. Table 22 analyses the methodology of the Bloomberg Innovation Index

In 2021, the ranking process included more than 200 countries, albeit only 78 countries reported data for at least 6 out of 7 categories [13]. The main sources of classification for the index are the following: Bloomberg, International Labour Organization, International Monetary Fund, World Bank, Organisation for Economic Cooperation and Development, World Intellectual Property Organisation, and the United Nations Educational, Scientific and Cultural Organization [13].

Table 23 analyses the performance of the countries under review for 2020 and 2021. As we can see, Germany is, overall, the top performer among the countries of our sample in 2021, with a score of 86.45. It is ranked 4th in the Bloomberg Innovation Index for 2021, three spots down from 2020. Germany is the top performer in high-tech

TABLE 22: Bloomberg Innovation Index

1. R&D Intensity	2. Manufacturing value-added	3. Productivity	4. High --tech density	5. Tertiary efficiency	6. Researcher concentration	7. Patent activity
Research and development expenditure, as % of GDP	MVA, as % GDP and per capita (\$PPP)	GDP and GNI per employed person age 15+ and 3Y improvement	Number of domestically domiciled high-tech public companies –such as aerospace and defence, biotechnology, hardware, software, semiconductors, Internet software and services, and renewable energy companies – as % domestic publicly listed companies and as a share of world's total public high-tech companies	Total enrolment in tertiary education, regardless of age, as % the post-secondary cohort;	Professionals, including postgraduate PhD students, engaged in R&D per million population	Resident patent filings, total patent grants and patent in force, per million population
				Minimum share of labour force with at least tertiary degrees,		Filings per \$100 billion GDP and total grants by country as a share of world total
				annual new science and engineering graduates as % total tertiary graduates and as % the labor force		

Source: [12]

TABLE 23: Bloomberg Innovation Index – Country performance, 2021

Country	2021 Rank	2020 Rank	Total Score	R&D Intensity	Manufacturing Value-added	Productivity	High-tech Density	Tertiary Efficiency	Researcher Concentration	Patent Activity
<b>Germany</b>	<b>4</b>	<b>1</b>				<b>2021</b>				
			86.45	7	6	20	3	23	12	14
<b>Greece</b>	<b>30</b>	<b>30</b>				<b>2021</b>				
			68.47	34	48	43	29	9	26	47
<b>USA</b>	<b>11</b>	<b>9</b>				<b>2021</b>				
			83.59	9	24	5	1	47	32	2
<b>China</b>	<b>16</b>	<b>15</b>				<b>2021</b>				
			79.56	13	20	45	9	17	39	3

Source: [13]

density, as it is ranked 3rd in the world, while it is ranked 6th in manufacturing value-added and 7th in R&D intensity. Its worse performance for 2021 is recorded in tertiary education efficiency, where it is ranked 23rd.

Greece is, overall, the bottom performer among the countries under review, with a score of 68.47, and is ranked 30th in both 2021 and 2020. The country's best performance is recorded in tertiary education efficiency, where Greece is ranked 9th, and researcher concentration, where Greece is ranked 26th. In contrast, Greece's performance score is very low in manufacturing value-added, where the country is ranked 48th, and in patent activity, where it is ranked 47th.

The United States is ranked second among the countries of our sample, and 11th overall in the Bloomberg Innovation Index, with a performance score of 83.59 in 2021, moving two spots down from 2020. The country's stronger performance lies in high-tech density and patent activity, where it is ranked 1st and 2nd respectively. Moreover, the US scores high in productivity, where it is ranked 5th, and in research and development intensity, where it is ranked 9th. On the other hand, the US is the bottom performer among the countries of our sample in terms of tertiary efficiency, as it is ranked 47th, as well as in researcher concentration, where it is ranked 32nd.

Finally, China is ranked 16th in 2021, one spot down from 2020. China's stronger performance lies in patent activity, where it is ranked 3rd, and high-tech density, where it is ranked 9th. In contrast, its weakest performance is recorded in productivity, where China is ranked 45th, even below Greece, which holds the 43rd place, as well as in researcher concentration, where it is ranked 39th, also below Greece, which holds the 26th place.

## 6. Conclusions

The main purpose of this paper was to analyse the main innovation indices, which fulfill two basic criteria: a) they cover a broad sample of countries, and b) are published at regular intervals on the basis of the latest data. These two criteria ensure that we can understand the most recent changes in terms of innovation in the global economy, by studying its effects on a large number of economies. The indices that were studied were the following: 1) Global Innovation Index (GII); 2) Digital Economy and Society Index (DESI); 3) the International Digital Economy and Society Index (I-DESI); and 4) the Bloomberg Innovation index. The study of these four indices led to certain conclusions about both the global economy, and the performance of the four national economies under review. First, as regards the Global Innovation Index, the three major economies under review, i.e. Germany, China and the US, are more similar to each other in terms of performance than they are similar to Greece. The US is ranked 3rd worldwide in 2020, Germany is ranked 9th, and China is ranked 14th, whereas Greece is ranked much lower, at the 43rd place. The US, Germany, and Greece are high-income countries, while China is an upper middle-income country and its ranking is above expectations for level of development [3, p. xxii] The concept of innovation is closely linked to science and technology clusters, and we can see that China is on the rise, also because of the increase in the number of patent applications during the last three decades.

Then, the study of the Digital Economy and Society Index demonstrated that Germany is far above Greece in terms of performance, in all dimensions of the index. In 2020, Greece is among the bottom performers in the EU, i.e. is ranked 27th out of 28 countries, and is below the European Union average in all dimensions of the index. It is encouraging that Greece's performance has been steadily improving in the last years under review, i.e. from 2015 to 2020. Germany is ranked 12th in 2020, and in three out of five dimensions its performance score is above the European Union average.

The study of the International Digital Economy and Society Index demonstrated that the US outperforms China in all dimensions of the index, during the period 2015-2018. That said, in many dimensions the US fall behind the average performance of the top-four member states of the European Union. Finally, we analysed the Bloomberg Innovation Index, where the three top-performing countries, i.e. Germany, the US, and China are grouped together, whereas Greece falls far behind. It is worth noting, that Germany is ranked 4th worldwide in this index. The study of all four indices demonstrates that the US and Germany, as established economies, have the strongest performance. Moreover, China has dramatically improved its performance as regards innovation, and will soon compete with developed economies. This is strongly corroborated by the fact that while in 1997 China accounted for 2% of all patent applications, in 2017 this percentage represented 44% of the total [4, p. 6]. China, after all, boasts the second largest number of science and technology clusters among the top hundred, falling behind only the US. In conclusion, Greece is ranked lower in comparison with the other countries in all indices under review. Establishing the conditions for the creation and development of science and technology clusters is a key variable, in order for Greece to improve its ranking in these indices in the years to come, as well gain from the modern division of labour, which will increasingly concern innovation-based products and services [14].

## Acknowledgement

The present study has been presented at the 13th International Conference “Economies of the Balkan and Eastern European Countries”, EBEEC 2021, Pafos, Cyprus, that has been held online (<http://ebeec.ihu.gr/>).

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