Digital Economy

DiGiX 2018: A Multidimensional Index of Digitization[1]

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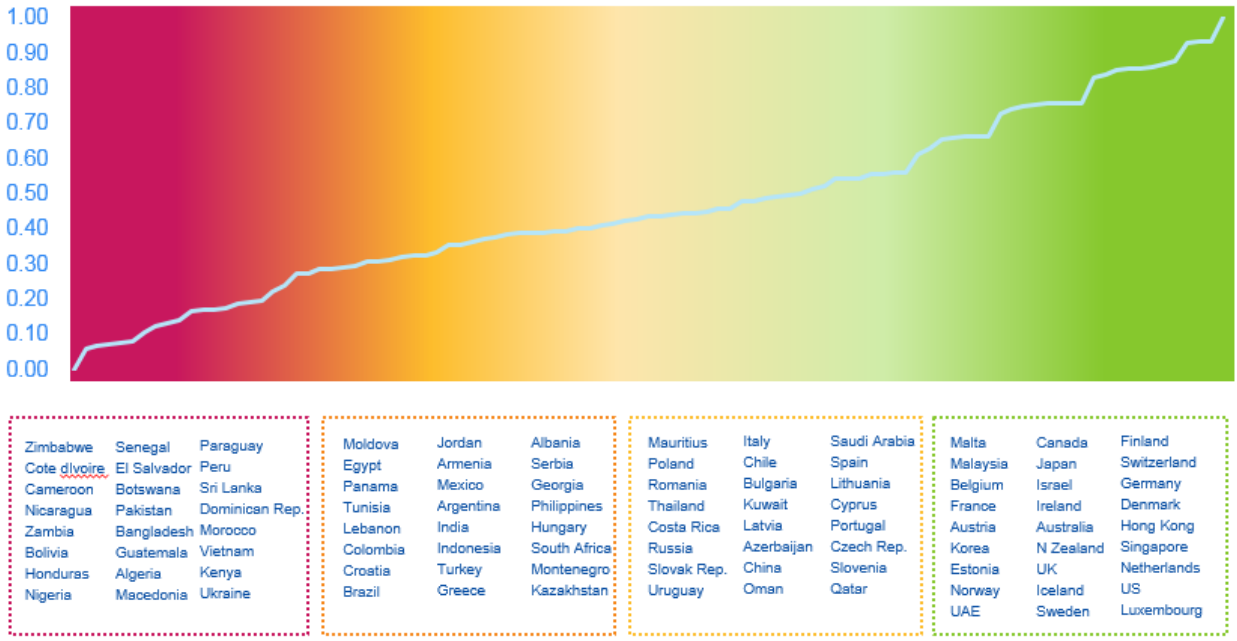
The 2018 release of DiGiX sheds light on the overall digitization level of 99 selected economies:

- The top five countries are Luxemburg, the US, the Netherlands, Singapore and Hong Kong.
- Some countries have reached levels of digitization well above those expected at their income levels, such as Singapore, Korea, Japan, the US, the UK and northern and central European countries.
- Leaders within their respective regions include Malaysia, South Africa, Chile and Costa Rica.

DiGiX metrics have been updated and published every year since 2016.

- The 18 indicators included in the index are grouped in six dimensions that represent three broad pillars: **supply conditions** (infrastructure and costs), **demand conditions** (user, government and enterprise adoption), and **institutional environment** (regulation).
- As in previous releases, the index allows for cross country comparisons but it is **not built for time comparisons**. The reason is that the concept of digitization and its relevant measures are in constant flux and thus need frequent reassessing.

Figure 1 Digital Frontier 2018



Source: BBVA Research

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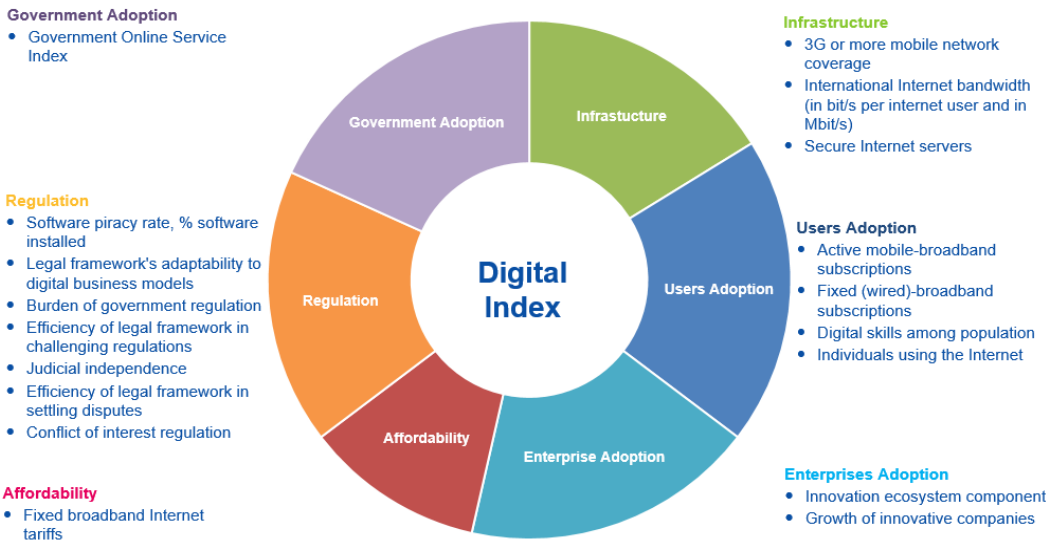
Main results

DiGiX is a composite index that measures the degree of digitization in 99 countries around the world. It classifies information into three broad categories, supply conditions, demand conditions, and institutional environment, which contains the six key dimensions included in DiGiX: infrastructure, affordability, users' adoption, enterprise adoption, regulation and government adoption. Each dimension is in turn subdivided into a number of individual indicators that add up to a total of 18 variables. Source selection and data gathering have been carried out based on data availability, quality and accuracy. Data has been updated to 2018 or 2017 depending on availability. The methodology used to compute DiGiX, as well as dimensions, is two-stage Principal Component Analysis, which is consistent for every period. The size of colored areas in Figure 2 represent the weights of every dimension (see Table 2 in Appendix for more detailed information).

Figure 2 Digital Index 2018: composition and structure



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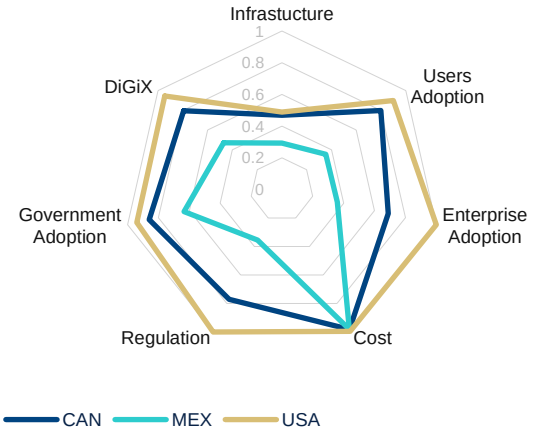
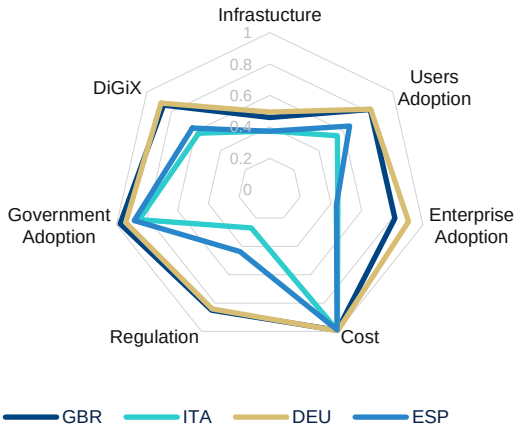
Figures 3 to 8 show the performance, by dimension as well as for the overall index, of selected countries in different regions. We observe some commonalities across dimensions. The affordability dimension represented by the cost of internet broadband is very concentrated for most of the countries in our sample. Once we adjust by purchase power parity, it seems that countries exhibits similar figures. Thus, internet affordability do not exhibit important differences across countries regardless the degree of development. On the other hand, the infrastructure dimension presents a comparably high variation and discriminates well among countries. Luxemburg is in the top of the ranking while most of the countries (except Hong Kong, Netherlands and Singapore) are far below, with Cameroon at the bottom with a large difference. The rest of the dimensions, enterprise, users and government adoption and regulation show some synchrony across countries in the same region. While government and users adoption seem develop faster in the path to digitization, regulation and enterprise adoption seem to be the pinpoints that when reaching a threshold, might characterize those countries that are more advanced in their digital transformation. However, regionally, we observe heterogeneous performance. In North America (Figure 3), Mexico has a large room for improvement in all dimension except affordability. Figure 4 shows that in Europe, Southern countries such as Italy and Spain need to improve the regulatory framework to enhance digitization. The Asian countries exhibited in Figure 5 present a homogeneous performance. China may enhance digitization by improving the regulatory framework related digitization and help firms to be more involved in digitization. In the same line, South and Central American countries (Figure 6) point at regulation and enterprise adoption as the dimensions where improvements are needed

Figure 3 Digitization performance: North America (Selected countries)



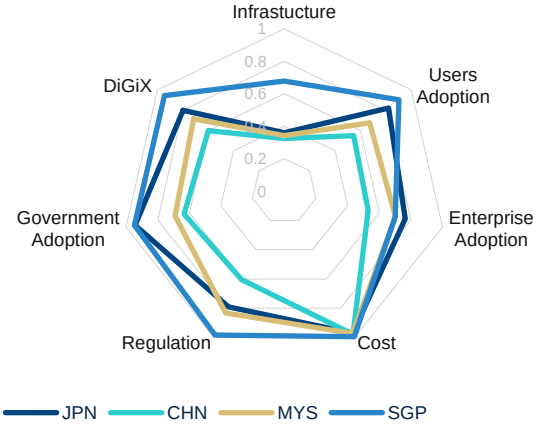
Source: BBVA Research

Figure 4 Digitization performance: Europe (Selected countries)



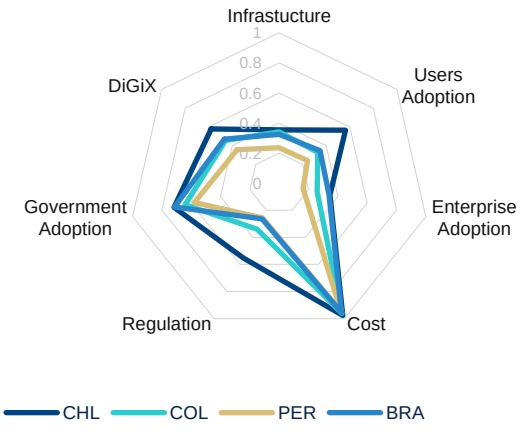
Source: BBVA Research

Figure 5 Digitization performance: Asia (Selected countries)



Source: BBVA Research

Figure 6 Digitization performance: Central and South America (Selected countries)



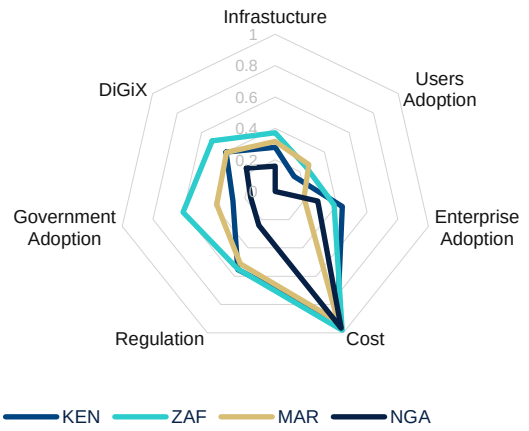
Source: BBVA Research

for advancing digitization. Chile shows the best performance in the group. African countries lag behind in the digital transformation and South Africa outstands because of the public effort of the government for embracing the Govtech ecosystem (Figure 7). Finally, in Figure 8, Eastern European countries exhibit a similar digitization patterns that tend to coincide with Southern European countries, such as Spain and Italy.

DiGiX metrics have been updated and published each year since 2016, allowing for cross comparisons for any given year but not built for time comparisons. The reason is that the concept of digitization and its relevant measures have been constantly evolving. For instance, in 2016 DiGiX indices would consider the percentage of the population covered by a mobile phone network. However, over time, this measure lost its power to track a country's position in the race for digitalization, and had to be substituted by the current "percentage of the population covered by at least a 3G network". In turn, new technologies such as 4G or 5G will soon be better at differentiating the degree of digitization across countries and will probably force another updated in the definition.

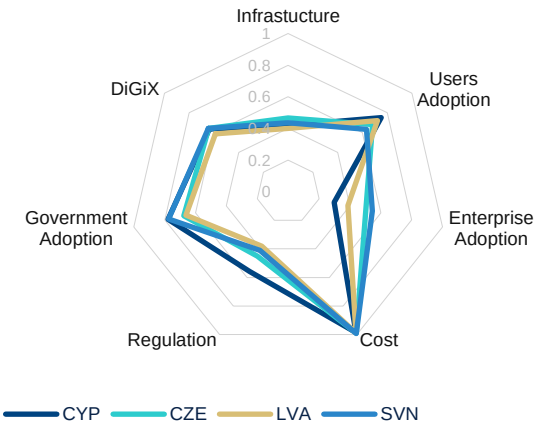
The DiGiX and GDP per capita exhibit a significant non-linear relationship (with decreasing returns to scale, table 3). Figure 9 shows GDP per capita in the horizontal axis and DiGiX scores in the vertical axis, highlighting a group of countries that perform better than the prediction represented by the fit curve. Those **countries include Singapore, Korea, Japan, the US, the UK and northern and central European countries**. On the other hand, on the right hand side under the curve, we observe some high-income Arabic countries such as **United Arab Emirates, Qatar, Kuwait and Oman.** The DiGiX in most countries is relatively close to the GDP benchmark outlined by the orange curve.

Figure 7 Digitization performance: Africa (Selected countries)



Source: BBVA Research

Figure 8 Digitization performance: Eastern Europe (Selected countries)



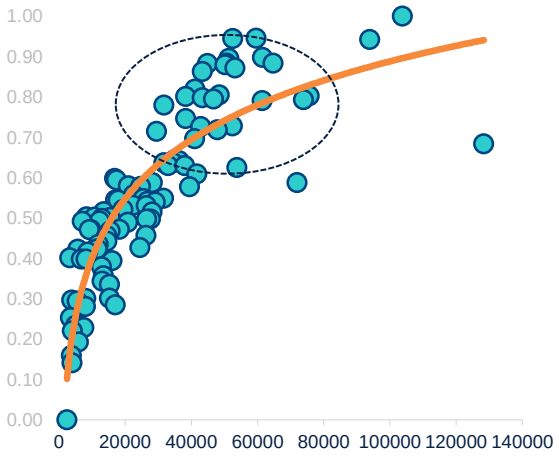
Source: BBVA Research

Table 1 OLS regression of DiGiX over GDP

DiGiX	Coef.	Std. Err.	t	P>|t|
GDP pc	0.0001556	0.0000103	15.04	0.000
GDP pc^2	-9.26E-10	1.03E-10	-9.02	0.000
_cons	-3.238594	0.2001858	-16.18	0.000
Number of obs	99			
F (2,96)	194.16			
Prob > F	0.000			
R-squared	0.8018			
Adj R-squared	0.7977			
Root MSE	0.91359			

Source: BBVA Research

Figure 9 DiGiX over GDP (Quadratic trend)



Source: BBVA Research

For the robustness check and sensitivity analysis, we tested the effect of discarding a variable, the effect of using different normalization strategies and the effect of varying weightings of variables. In general, we observe that the top ranking and bottom ranking countries were the least sensitive to changes in the Index composition with middle ranking countries being more sensitive. This analysis shows that the ranking is relatively stable, even to major changes in variable composition.

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Appendix: Construction of DiGiX 2018

1. Variable Selection and Geographic Coverage

Figure 2 illustrates the structure of DiGiX 2018 – an index made of 18 indicators grouped in six distinct dimensions. Our theoretical framework to define digitization has not changed, so the broad structure of six dimensions remains unaltered. The changes in this version of DiGiX for 2018 consist of three actions:

1. Replacing a handful of variables, which are no longer available, with new data. More specifically, the "enterprise adoption" dimension is now constructed from two rather than three indicators: innovation ecosystem and growth of innovative companies, both elaborated by the World Economic Forum. These variables substitute the former business to business internet use and business to customer internet use. The measure of firm-level technology absorption (belonging to that same dimension) has been eliminated without any replacement. In the "user adoption" dimension, the variable "use of social networks" has been replaced by "digital skills among population".

2. Eliminating variables that are no longer representative, while adding new proxies for capturing some relevant concept. Representativeness is determined by analyzing conditional correlations in the following way. The variables that support the three "demand" dimensions (i.e. users, enterprises and government adoption) are viewed as endogenous/dependent while the variables that support the other three dimensions (i.e. infrastructure, costs and regulation) are thought as exogenous. Representativeness of "endogenous" measures is captured by their statistical significance in explaining related demand measures. Conditional correlation between the number of internet users (one of the most important output variables) and the tariffs of fixed-broadband, although having the expected sign, is not significant anymore. However, we find significant coefficients when doing the regression with mobile-broadband tariffs. [2] The regulation dimension also shows two different variables that lose representativeness (i.e. laws relating to ICTs and effectiveness of law-making

2: Results are in Table A3 in the Appendix of this document. Additional results for GDP conditional correlation are available upon request.

bodies) and are replaced by the legal framework's adaptability to digital business models and burden of government regulation, respectively. We eliminate the variable that defined cost in previous versions of this indicator since it was based on the fixed-broadband internet tariffs. The use of the fixed-broadband is being increasingly replaced by mobile-broadband in all countries so, it is more accurate to reflect the actual cost of internet access that people pay for mobile-broadband. [3]

3. Finally, we drop 4 more variables that were deemed statistically unfit. On the one hand, international Internet bandwidth in Mbit/s, Internet and telephony competition and number of days to enforce a contract. On the other hand, the variable homes with internet was also eliminated because of discrepancies in the data. Given that these changes prevent us from comparing this version of DiGiX with previous periods, we carry out a calculation of DiGiX for 2017 with the variables included in DiGiX 2018. [4]

In terms of geographical coverage, our sample includes 99 developed and developing countries. [5] This is one less that in the previous periods since Bahrain has been dropped from our data base due to the lack of reliable data for 2018. The requirement to be included is having complete information in all the indicators in order to avoid data imputation.

2. Data checking and structure

We collect annual information from different official public data sources. [6] We check different aspects that are relevant for composite index constructions. Firstly, in terms of information, standard correlation structure is explored to examine similarities in information across variables belonging to the same dimension and across dimensions. Since our sample of variables represent the same underlying structure (i.e. digitization), we expect to have acceptable levels of correlation, both within dimensions and between dimensions. [7] Although colinearity is not a concern since our aggregation method of Two Stage Principal Components Analysis (2PCA) is robust to redundant information, we avoid using highly correlated variables in order to keep our indicator as simple as possible. We also check the correlation between the per capita GDP and our sample of variables in order to take decisions to simplify our index. The strategy is to exclude those variables that are highly correlated with GDP since they do not add different information from income conditions.

Secondly, the discriminatory power of the variables across countries is another relevant issue. As any phenomenon advances, it is more likely that countries reach their saturation level for the different indicators involved (i.e. percentage of population covered by at least 3G). Since saturation levels for different variables might coincide at least within the group of developed countries and, at a different level, within developing countries, some indicators might tend to discriminate less and less. They might just reflect the economic development status and do not add any extra information. This feature is tested through standard deviations of the variables. The third column of Table 1 shows that an acceptable variability across countries is still present in all the variables in our sample.

Finally, the treatment for outliers has been done in a conservative manner. We consider a variable with an outlier as those having distributions with a kurtosis greater than 3.5 and an absolute skewness greater than 2. For variables with upper-end outliers, the largest value was transformed to have the same value as the second largest value and for those with lower-end outliers, the smallest value was transformed to have the same value as the second smallest value. This process was iterated until the variable's skewness and kurtosis fell within the commonly acceptable limits.

3: This variable has been constructed by ITU according to the ICT Price Basket Methodology available at: https://www.itu.int/en/ITU-D/Statistics/Pages/definitions/pricemethodology.aspx
4: Results are available upon request.
5: Table A2 in the Appendix presents the list of countries.
6: See Table A1 in the Appendix for a detailed explanation of the variables and data sources.
7: Results are available upon request.

3. Aggregation Strategy and Results

This section briefly describes the methodology applied for the aggregation strategy and the weighting scheme, and focuses on the results in terms of the ranking and discussion.

When constructing a composite index, it is important to carefully assess the suitability of the data by studying the overall structure of the indicators and correlation between them. 2PCA is used to explore the underlying structure of the data and then construct our composite index using the weights obtained from the 2PCA. [8] First, PCA is applied to the indicators belonging to each dimension in order to get the six different dimensions. Then, we apply PCA to our dimensions to compute the overall index. Only the first component is retained in each iteration. However, if we were to apply just PCA to the three first components it would have been necessary to retain similar cumulative variation. By doing it in two stages, we end up with a composite indicator that has desirable properties and helps us in ranking countries according their degree of digitization. Table 2 shows that all dimensions and indicators are nearly equally weighted and our indicators are not biased toward any particular set of information. The only exception is the variable conflict of interest regulation that is under-represented in the regulation dimension (it has half of the weight compared to the rest of the variables in the dimension). We observe, in the first two columns in Table 2, that demand conditions, which include the dimensions for adoption, and are represented by output indicators, have slightly higher weights than supply conditions and institutions in the overall index. They account for 55% of the total index. The third column includes the cumulative variation of the overall data captured by the first principal component for each dimension and for the whole index. All the dimensions except infrastructure (48%) capture nearly 70% or more of the total variation in the data set. The overall index accounts for 69% of the total variation in the data.

8: For more detailed information on this methodology see Cámara and Tuesta (2016).

Table 2 Weights and cumulative variation explained

	Weight		Cumulative Variation
Variable	Stage 1 PCA	Stage 2 PCA	
DiGiX			0.69
Infrastucture		0.16	0.48
3G Coverage	0.31		
International Int. Bandwith	0.31		
Secure Int. Servers	0.38		
Users Adoption		0.19	0.72
Mobile Broadband suscription	0.10		
Fixed Broadband suscription	0.11		
DigitalSkills	0.11		
Internet users	0.13		
Enterprise Adoption		0.18	0.90
Innovarion ecosystem	0.50		
Innovarive companies	0.50		
Cost		0.11	1.00
Mobile Broadband tariffs	1.00		
Regulation		0.17	0.69
Software piracy	0.12		
Efficiency reg.	0.17		
Judicial independence	0.16		
Efficiency disputes	0.17		
Burden reg.	0.14		
Digital business reg.	0.16		
Conflict interest reg.	0.07		
Government Adoption		0.18	1.00
E-government	1.00		

Source: BBVA Research

4. Results and Ranking

Table 3 DiGiX Ranking

Rank	Country	Score	Rank	Country	Score
1	Luxembourg	1.00	51	Mauritius	0.53
2	United States	0.95	52	Kazakhstan	0.53
3	Netherlands	0.94	53	Montenegro	0.52
4	Singapore	0.94	54	South Africa	0.52
5	Hong Kong	0.90	55	Hungary	0.51
6	Denmark	0.90	56	Philippines	0.50
7	Germany	0.88	57	Georgia	0.50
8	Switzerland	0.88	58	Serbia	0.50
9	Finland	0.88	59	Albania	0.50
10	Sweden	0.88	60	Greece	0.50
11	Iceland	0.87	61	Turkey	0.50
12	United Kingdom	0.86	62	Indonesia	0.49
13	New Zealand	0.82	63	India	0.49
14	Australia	0.81	64	Argentina	0.49
15	Ireland	0.80	65	Mexico	0.47
16	Israel	0.80	66	Armenia	0.47
17	Japan	0.80	67	Jordan	0.47
18	Canada	0.80	68	Brazil	0.47
19	United Arab Emirates	0.79	69	Croatia	0.46
20	Norway	0.79	70	Colombia	0.46
21	Estonia	0.78	71	Lebanon	0.44
22	Korea	0.75	72	Tunisia	0.43
23	Austria	0.73	73	Panama	0.43
24	France	0.73	74	Egypt	0.42
25	Belgium	0.72	75	Moldova	0.42
26	Malaysia	0.71	76	Ukraine	0.42
27	Malta	0.70	77	Kenya	0.40
28	Qatar	0.68	78	Vietnam	0.40
29	Slovenia	0.64	79	Morocco	0.40
30	Czech Republic	0.64	80	Dominican Republic	0.39
31	Portugal	0.64	81	Sri Lanka	0.38
32	Cyprus	0.64	82	Peru	0.36
33	Lithuania	0.63	83	Paraguay	0.34
34	Spain	0.63	84	Macedonia	0.34
35	Saudi Arabia	0.63	85	Algeria	0.30
36	Oman	0.61	86	Guatemala	0.30
37	China	0.60	87	Bangladesh	0.30
38	Azerbaijan	0.59	88	Pakistan	0.29
39	Latvia	0.59	89	Botswana	0.28
40	Kuwait	0.59	90	El Salvador	0.28
41	Bulgaria	0.58	91	Senegal	0.25
42	Chile	0.58	92	Nigeria	0.24
43	Italy	0.58	93	Honduras	0.23
44	Uruguay	0.56	94	Bolivia	0.23
45	Slovak Republic	0.55	95	Zambia	0.22
46	Russian Federation	0.55	96	Nicaragua	0.19
47	Costa Rica	0.54	97	Cameroon	0.16
48	Thailand	0.54	98	Côte d'Ivoire	0.14
49	Romania	0.54	99	Zimbabwe	0.00
50	Poland	0.54			

Source: BBVA Research

Table A1 Variable Selection

Short name	long name	Source	Definition
Infrastructure			
i1_3gcoverage	Percentage of the population covered by at least a 3G mobile network	ITU (2018)	Percentage of the population covered by at least a 3G mobile network refers to the percentage of inhabitants that are within range of at least a 3G mobile-cellular signal; irrespective of whether or not they are subscribers. This is calculated by dividing the number of inhabitants that are covered by at least a 3G mobile-cellular signal by the total population and multiplying by 100.
i2_bandwidth	International Internet bandwidth per Internet user	ITU (2018)	International Internet bandwidth refers to the capacity that backbone operators provide to carry Internet traffic. It is measured in bits per second per Internet users.
i3_secservers	Secure Internet servers (per 1 million people)	ITU (2018)	Secure servers are servers using encryption technology in Internet transactions. The number of distinct, publicly-trusted TLS/SSL certificates found in the Netcraft Secure Server Survey.
Users Adoption			
au1_mbroadband	Active mobile-broadband subscriptions per 100 inhabitants	ITU (2018)	Active mobile-broadband subscriptions refers to the sum of standard mobile-broadband and dedicated mobile-broadband subscriptions to the public Internet. It covers actual subscribers. not potential subscribers. even though the latter may have broadband enabled-handsets.
au2_fbroadband	Fixed broadband subscriptions per 100 inhabitants	ITU (2018)	Refers to subscriptions to high-speed access to the public Internet (a TCP/IP connection). at downstream speeds equal to. or greater than. 256 kbit/s. This includes cable modem. DSL. fibre-to-the-home/building and other fixed (wired)-broadband subscriptions. This total is measured irrespective of the method of payment. It excludes subscriptions that have access to data communications (including the Internet) via mobile-cellular networks. It should exclude technologies listed under the wireless-broadband category.
au3_digskills	Digital skills among population	WEF(2018)	In your country, to what extent does the active population possess sufficient digital skills (e.g., computer skills, basic coding, digital reading)? [1 = not all; 7 = to a great extent]
au5_intpeople	Internet users (%)	ITU (2018)	This indicator can include both; estimates and survey data corresponding to the proportion of individuals using the Internet; based on results from national households surveys. The number should reflect the total population of the country; or at least individuals of 5 years and older. If this number is not available (i.e. target population reflects a more limited age group) an estimate for the entire population should be produced. If this is not possible at this stage; the age group reflected in the number (e.g. population aged 10+; population aged 15-74) should be indicated in a note.
Firms Adoption			
ae1_innovation	Innovation ecosystem component	WEF(2018)	Composite index (1-100) that combines business dynamism and innovtion capability
ae2_innofirms	Growth of innovative companies	WEF(2018)	In your country, to what extent do new companies with innovative ideas grow rapidly? [1 = not at all; 7 = to a great extent]
Costs			
n_c1_fbroadband	Fixed broadband Internet monthly subscription (PPP)	ITU and WB	Monthly subscription charge for fixed (wired) broadband Internet service (PPP $)Fixed (wired) broadband is considered any dedicated connection to the Internet at downstream speeds equal to. or greater than. 256 kilobits per second. using DSL. The amount is adjusted for purchasing power parity (PPP) and expressed in current international dollars. PPP figures were sourced from the World Bank's [i]World Development Indicators Online[i] (December 2014) and the International Monetary Fund's [i]World Economic Outlook[i] (October 2014 edition). After computing the indicator. we divide by county GDP per capita in order to make it comparable across countries. This variable is divided by the GDP pc PPP in order to make it comparable.

Source: BBVA Research

Table A1 Variable Selection (*cont.*)

Short name	long name	Source	Definition
Regulation			
n_r1_softpiracy	Piracy rate 2017	GSMA (2018)	% software 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.
r2_efficiencyreg	Efficiency of legal framework in challenging regulations	WEF(2018)	Response to the survey question : In your country, how easy is it for private businesses to challenge government actions and/or regulations through the legal system? [1 = extremely difficult; 7 = extremely easy].
r3_independence	Judicial independence	WEF(2018)	Response to the survey question: In your country, to what extent is the judiciary independent from influences of members of government, citizens, or firms? [1 = heavily influenced; 7 = entirely independent].
r4_efficiencydisputes	Efficiency of legal framework in settling disputes	WEF(2018)	Response to the survey question : In your country, how efficient is the legal framework for private businesses in settling disputes? [1 = extremely inefficient; 7 = extremely efficient].
r5_governmentreg	Burden of government regulation	WEF(2018)	Response to the survey question : In your country, how burdensome is it for businesses to comply with governmental administrative requirements (e.g., permits, regulations, reporting)? [1 = extremely burdensome; 7 = not burdensome at all]
r6_digitalbusinessmodels	Legal framework's adaptability to digital business models	WEF(2018)	Response to the survey question "In your country, how fast is the legal framework of your country adapting to digital business models (e.g. e-commerce, sharing economy, fintech, etc.)?" [1 = Not fast at all; 7 = Very fast]
r7_conflictinterestreg	Conflict of interest regulation	WB (2018)	The Extent of conflict of interest regulation index measures the protection of shareholders against directors' misuse of corporate assets for personal gain by distinguishing three dimensions of regulation that address conflicts of interest: transparency of related-party transactions, shareholders' ability to sue and hold directors liable for self-dealing, and access to evidence and allocation of legal expenses in shareholder litigation.The scale ranges from 0 to 10 [best].
Government Adoption			
co1_gov	E-Government Index	ONU (2018)	0–1 (best). The Government Online Service Index assesses the quality of government's delivery of online services on a 0-to-1 (best) scale. According to the United Nations' Public Administration Network. the Government Online Service Index captures a government's performance in delivering online services to the citizens. There are four stages of service delivery. "Emerging". "Enhanced". "Transactional". and "Connected". Online services are assigned to each stage according to their degree of sophistication. from the more basic to the more sophisticated. In each country. the performance of the government in each of the four stages is measured as the number of services provided as a percentage of the maximum services in the corresponding stage. Examples of services include online presence. deployment of multimedia content. governments' solicitation of citizen input. widespread data sharing. and use of social networking.

Source: BBVA Research

Table A2 OLS regressions for Cost dimension

Internet Users	Coef.	Std. Err.	t	P>|t|
Fixed broadband	-0.0002858	0.000185	-1.54	0.126
_cons	65.7542	2.295336	28.65	0.00
Number of obs	99			
F (1,97)	2.39			
Prob > F	0.1256			
R-squared	0.024			
Adj R-squared	0.014			
Root MSE	22.14			

Internet Users	Coef.	Std. Err.	t	P>|t|
Mobile broadband	-1.906867	0.3484128	-5.47	0.00
_cons	69.803	2.16424	32.25	0.00
Number of obs	99			
F (1,97)	29.95			
Prob > F	0.00			
R-squared	0.2359			
Adj R-squared	0.2281			
Root MSE	19.589			

Source: BBVA Research

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