Introducing the EBRD Knowledge Economy Index

European Bank
for Reconstruction and Development

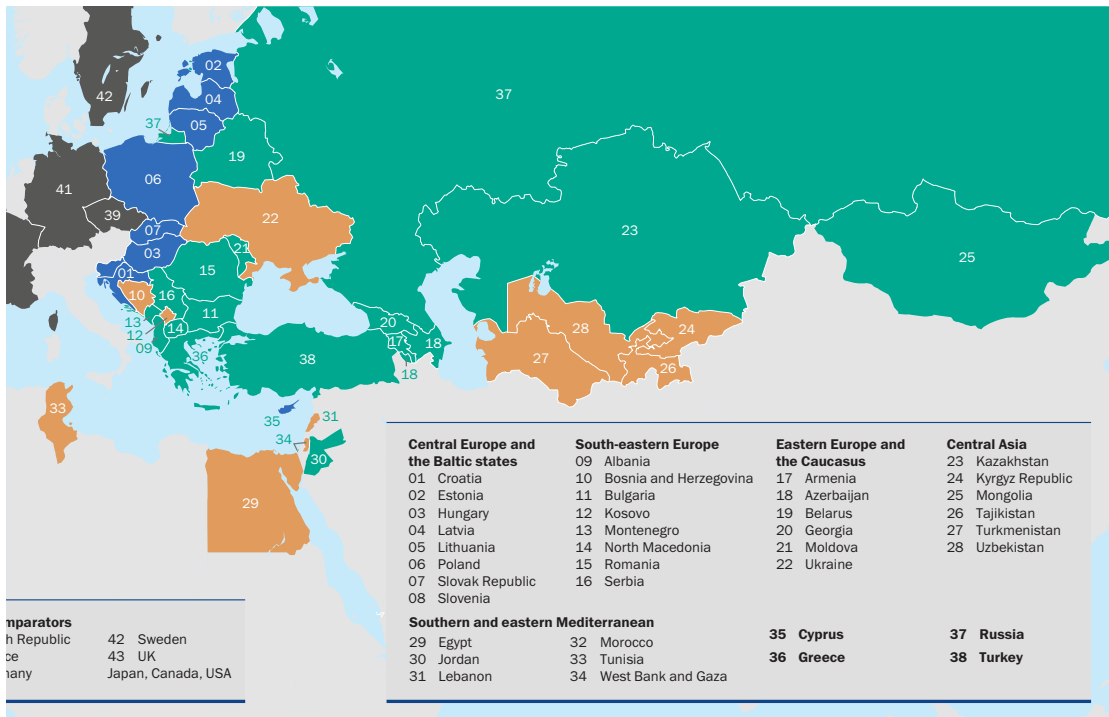# Introducing the EBRD Knowledge Economy Index[1]

Executive summary

The "knowledge economy" (KE) is a concept of economic development, in which innovation and access to information drive productivity growth. New trends, such as the Internet of Things or digitalisation, are examples of key elements of the transition to the knowledge economy. Building the key pillars required to stimulate knowledge-economy development is therefore central to achieving long-term competitiveness.

To measure KE development, the European Bank for Reconstruction and Development (EBRD) has constructed the EBRD Knowledge Economy Index, spanning 46 economies – 38 where the EBRD invests and eight comparators (members of the Organisation for Economic Co-operation and Development, OECD). The new EBRD KE Index contains 38 indicators divided into four pillars: (1) *institutions for innovation*, (2) *skills for innovation*, (3) *the innovation system* and (4) *the ICT infrastructure*. Among the EBRD regions, Estonia scores highest and Turkmenistan lowest. Serbia made the greatest progress between 2011 and 2018. Weak *institutions for innovation* are the most significant drivers of KE gaps between the EBRD regions and their OECD comparators.

Using a cluster analysis, we identify three stages of KE in the EBRD regions. The **early KE group** has weak *institutions* and *skills for innovation*, together with poor *ICT infrastructure*. Improving these three pillars will be instrumental in moving up to the next KE stage. The **intermediate KE group** has somewhat stronger *institutions for innovation* and better *ICT infrastructure*, but still relatively weak *skills for innovation*, constraining KE development. The **advanced KE group** has relatively favourable *institutions for innovation* and *ICT infrastructure*. However, its specialised *skills for innovation* and the efficiency of its *innovation system* remain significantly behind those of the OECD comparator countries. These results indicate that there are no one-size-fits-all policies to promote the development of the knowledge economy. Rather, the EBRD regions should adopt policies that take into account their stage of knowledge-economy development and set priorities accordingly.

Chart 1: The knowledge economy in the EBRD regions

Central Europe and the Baltic states
- 01 Croatia
- 02 Estonia
- 03 Hungary
- 04 Latvia
- 05 Lithuania
- 06 Poland
- 07 Slovak Republic
- 08 Slovenia

South-eastern Europe
- 09 Albania
- 10 Bosnia and Herzegovina
- 11 Bulgaria
- 12 Kosovo
- 13 Montenegro
- 14 North Macedonia
- 15 Romania
- 16 Serbia

Eastern Europe and the Caucasus
- 17 Armenia
- 18 Azerbaijan
- 19 Belarus
- 20 Georgia
- 21 Moldova
- 22 Ukraine

Central Asia
- 23 Kazakhstan
- 24 Kyrgyz Republic
- 25 Mongolia
- 26 Tajikistan
- 27 Turkmenistan
- 28 Uzbekistan

Southern and eastern Mediterranean
- 29 Egypt
- 30 Jordan
- 31 Lebanon
- 32 Morocco
- 33 Tunisia
- 34 West Bank and Gaza

- **35 Cyprus**
- **36 Greece**

- **37 Russia**
- **38 Turkey**

Comparators
h Republic   42 Sweden
ce   43 UK
many   Japan, Canada, USA

■ Advanced KE group ■ Intermediate KE group ■ Early KE group

Acronyms

DTF	Distance to frontier
EBRD	European Bank for Reconstruction and Development
ECI	Economic Complexity Index
EIS	European Innovation Scoreboard
GCI	Global Competitiveness Index

GII	Global Innovation Index
ICT	Information and communications technology
KE	Knowledge economy
OECD	Organisation for Economic Co-operation and Development
TiVA	Trade in value added

Introduction

The "knowledge economy" (KE) is a concept of economic development, in which innovation and access to information drive productivity growth. New trends, such as the Internet of Things or digitalisation, are examples of key elements of the transition towards the knowledge economy. Putting in place the key pillars that support knowledge-economy development is therefore central to achieving long-term competitiveness, including in the EBRD regions.

Building on previous work in the field, we are pleased to introduce the new EBRD Knowledge Economy Index. In 2014, the EBRD defined[2] the following four pillars of the knowledge economy: (1) *institutions for innovation*, (2) *skills for innovation*, (3) *innovation system* and (4) *ICT infrastructure*.[3] Based on this structure, we have developed an index to measure how the EBRD regions and eight OECD comparators are fostering the knowledge economy. The analysis deepens our understanding of the transition gaps in the EBRD regions and can serve as a basis for policy discussions in the innovation and knowledge spheres.

In this paper, we first present the structure and methodology of the EBRD Knowledge Economy Index, then analyse the 2018 results and the changes between 2011 and 2018. We then use a data-driven approach to cluster the EBRD regions into three knowledge-economy stages and provide a brief analysis of potential innovation-policy interventions.

1. EBRD Knowledge Economy Index – structure and results

The EBRD Knowledge Economy Index fills an analytical gap. The motivation to develop a new index stemmed from the EBRD's need to better measure the performance of the regions in which it invests and to compare the gap between the EBRD economies and more advanced countries. Existing international measures of innovation have their limitations (see Table A1 in the Annex), not least the relatively low coverage of some EBRD economies.[4]

Table 1: Structure of the EBRD Knowledge Economy Index				
Pillar	Institutions for innovation	Skills for innovation	Innovation system	ICT infrastructure
Dimensions	Economic openness Business environment Governance	General skills Specialised skills	Inputs Outputs Linkages	ICT availability ICT sophistication

Note: The structure of the EBRD Knowledge Economy Index builds on previous work by the EBRD (2014), existing literature on knowledge-economy development, and the work by the World Bank among others (see, for example, Chen et al, 2006). Previous similar KE indices only measured the four pillars of the knowledge economy. We have deepened the index structure by adding two or three extra dimensions to each pillar. These were selected based on a thorough review of the literary evidence on drivers of long-term innovation and productivity growth. Source: Authors.

As mentioned, we organise the EBRD KE Index into four pillars, each divided in two or three "dimensions" (see Table 1). Here, we describe the rationale behind the structure of the index:

1. *Institutions for innovation:* Economies with good formal and informal institutions are more likely to specialise in innovation-intensive industries. Strong property rights, a judiciary system that ensures the rule of law and proper public governance are key elements on which the private sector relies to develop higher value-added activities.[5] There are three dimensions to this pillar of the KE Index: (i) *economic openness* (economies open to trade[6], labour mobility[7] and investment[8] are better able to capture new ideas and technologies), (ii) *business environment* (for example, rule of law[9] and lack of corruption) and (iii) *governance* (such as political stability[10] and the effectiveness of policymaking).

2. *Skills for innovation*: An adequately trained workforce that chimes with private-sector needs is important for knowledge transfers, innovation and technological upgrade.[11] The two dimensions of this pillar are (i) *general skills* (such as school enrolment[12] and secondary education[13]), which are prerequisites to any economic activity, and (ii) *specialised skills* (such as number of technicians), which are key to more value-added activities.[14]

3. *Innovation system*: The knowledge economy depends heavily on major innovation players, their resources and interactions. The three dimensions of this pillar are (i) *inputs into the innovation system* (for example, research and development (R&D) spending),[15] (ii) *innovation-system outputs* (such as patents)[16] and (iii) *linkages within the innovation system*[17] (such as scientific collaboration,[18] venture capital[19] and value chains).[20]

4. *ICT infrastructure*: A key pillar of any knowledge economy is information and communications technology (ICT) infrastructure and its use, as this underpins effective knowledge exchange.[21] Broadband speed and penetration have a positive impact on growth in the form of productivity gains[22] as innovative firms increasingly require faster and more sophisticated ICT infrastructure. There are two dimensions to this pillar: (i) *ICT availability* and (ii) *ICT sophistication*.

The methodology: from 38 indicators to 10 dimensions to four pillars

The main sources of the 38 indicators used in the EBRD KE Index are the World Bank, the United Nations Educational, Scientific and Cultural Organization (UNESCO), the International Telecommunication Union, the World Economic Forum and the EBRD (the EBRD-World Bank Business Environment and Enterprise Performance Survey, for example).[23] All of the selected indicators are available for at least 90 per cent of the economies in the index and are updated on a regular basis (preferably every year). Most of the data come with a lag (so the 2018 KE Index largely relies on 2017 data). When data are not available, we impute the missing values (please see the Annex for details on imputation methodology). In general, our approach is in line with the EBRD's methodology for the Assessment of Transition Qualities, as described in the EBRD *Transition Report 2018-19*.[24]

To compute the KE Index, we first aggregate the 38 indicators into 10 dimensions, then aggregate those 10 dimensions into four pillars. For each indicator and year, we compute the distance to frontier (DTF)[25], with values on a 1 (theoretical minimum/worst) to 10 (theoretical maximum/best) scale.[26] As discussed, each of the four pillars of the KE Index has two or three dimensions (there are 10 dimensions in total, organised into four pillars). For each of these dimensions, we calculate the average DTF scores of indicators belonging to that dimension. We then aggregate the dimensional scores to obtain pillar-level results. The index is the arithmetic mean of the four pillars. This process is iteratively applied to each economy and each year. The final dataset covers the period from 2011 to 2018 for the 38 economies in which the EBRD invests, plus eight OECD comparator countries (Canada, Czech Republic, France, Germany, Japan, Sweden, the United Kingdom and the United States of America).

For more information on how the Index is constructed, please see the Annex.

EBRD Knowledge Economy Index 2018: Estonia leads the way

The results of the 2018 EBRD Knowledge Economy Index (Chart 2) show that Estonia is the knowledge-economy leader among the EBRD regions; on three of the four index pillars, Estonia is on par with the OECD comparator countries. On the fourth pillar (*innovation system*), it continues to lag. Turkmenistan is the worst-performing EBRD economy, putting in a poor performance on all four pillars of the KE Index. On average, the EBRD regions perform relatively well in terms of *skills for innovation*, but relatively poorly on the other three pillars of the KE Index.

Chart 2: EBRD Knowledge Economy Index 2018 – the best- and worst-performing economies
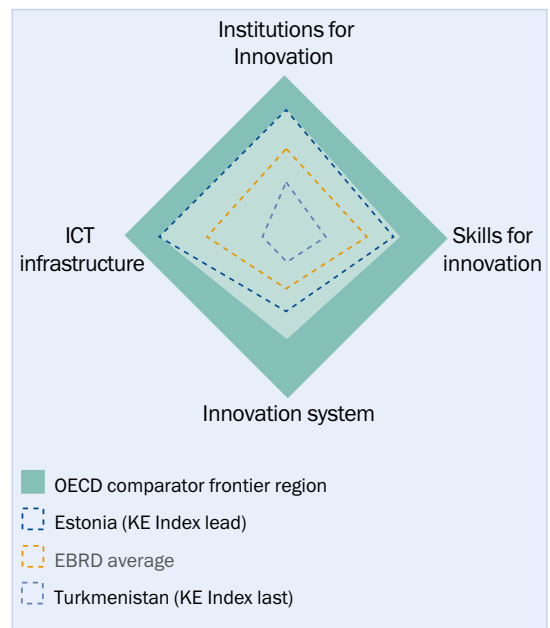
Note: OECD comparator countries (Canada, Czech Republic, France, Germany, Japan, Sweden, the United Kingdom and the United States of America). The OECD comparator frontier region is the distance between the comparators' average score by pillar and the theoretical maximum of 10, based on a hypothetical country that scores highest on all indicators.
Source: Authors' calculations.

Table 2 presents the results of the KE Index (more detailed results for all KE indicators can be found in the Annex). The OECD comparator countries have a KE Index score of 7.36 (out of 10, on average), while the EBRD regions score 4.67 (out of 10, on average). The best-performing EBRD countries are Estonia, Slovenia and Lithuania, with KE Index scores between 6.0 and 6.9. At the other end of the scale are Egypt, the West Bank and Gaza, and Turkmenistan, with KE Index scores between 2.2 and 3.2.

Table 2: EBRD 2018 Knowledge Economy Index – performance by economy

	Economy	Total score (out of 10)	Ranking among EBRD economies	Pillar score (1 min-10 max)			
				Institutions for innovation	Skills for innovation	Innovation system	ICT infrastructure
	OECD comparators (average)	7.36		8.08	7.14	6.48	7.73
	EBRD regions (average)	4.67		5.52	4.96	3.22	5.00
	Difference	*2.69*		*2.56*	*2.18*	*3.26*	*2.73*
Central Europe and Baltic states	Estonia	6.82	1	8.01	6.70	4.58	7.99
	Slovenia	6.65	2	7.40	7.32	5.14	6.73
	Lithuania	6.03	3	7.24	5.85	4.04	6.97
	Latvia	5.88	4	7.36	6.31	3.04	6.80
	Poland	5.63	6	6.80	6.31	3.82	5.58
	Croatia	5.62	7	6.72	5.80	3.81	6.14
	Slovak Republic	5.40	8	6.76	5.48	4.08	5.29
	Hungary	5.33	9	6.55	5.82	3.49	5.47
South-eastern Europe	Cyprus	5.82	5	7.52	5.70	3.80	6.27
	Greece	5.25	10	6.06	5.45	3.78	5.74
	Bulgaria	5.18	12	5.91	5.28	3.27	6.28
	Serbia	5.13	13	5.76	5.46	3.26	6.02
	Montenegro	5.04	14	6.20	5.16	2.88	5.92
	Romania	5.01	15	6.02	4.94	3.41	5.68
	North Macedonia	4.50	22	5.74	3.83	3.27	5.18
	Albania	4.36	25	5.64	4.79	2.36	4.67
	Bosnia and Herzegovina	4.10	29	5.04	4.13	2.88	4.35
	Kosovo	3.22	35	4.81	2.75	3.12	2.20
	Russia	4.93	17	4.83	5.74	3.41	5.73
	Turkey	4.60	19	4.87	4.81	3.82	4.90
Eastern Europe and Caucasus	Belarus	5.21	11	5.50	6.05	3.27	6.01
	Georgia	4.97	16	6.56	5.40	2.71	5.21
	Azerbaijan	4.56	20	4.62	4.90	3.68	5.06
	Armenia	4.51	21	5.44	5.24	3.12	4.24
	Moldova	4.33	26	5.03	4.57	2.77	4.95
	Ukraine	4.29	27	4.33	5.44	2.84	4.56

Central Asia	Kazakhstan	4.85	18	5.80	5.68	2.69	5.23
	Mongolia	4.48	23	5.11	5.10	2.65	5.05
	Kyrgyz Republic	3.98	31	4.38	5.02	2.39	4.15
	Uzbekistan	3.82	33	3.48	4.72	2.57	4.51
	Tajikistan	3.23	34	3.47	4.73	2.96	1.77
	Turkmenistan	2.26	38	3.42	2.47	1.71	1.43
SEMED	Jordan	4.43	24	5.93	3.93	3.44	4.43
	Morocco	4.23	28	5.06	3.83	3.46	4.58
	Lebanon	4.07	30	4.56	3.54	3.45	4.72
	Tunisia	3.96	32	4.38	3.82	3.04	4.59
	Egypt	3.11	36	3.54	3.03	2.46	3.42
	West Bank and Gaza	2.83	37	3.90	3.25	1.83	2.33

Note: Scores represent the distance to frontier (DTF). The colour scale denotes the relative score of EBRD regions under each pillar. Dark green is a high ranking; deep red is a low one. Annex 1 shows a relatively high correlation between GDP per capita and the KE Index.
Source: Authors' calculations.

The gaps between the EBRD region and OECD comparator countries vary from pillar to pillar. Weak *institutions for innovation* appear to be the key constraint to knowledge-economy development in the EBRD regions. Table 2 shows that economies with weak *institutions for innovation* typically do not score well on other pillars of the KE Index either. The KE Index gap between the EBRD regions and the OECD comparators (for 2018, an average difference of 2.56) is primarily down to inefficient public governance and a weak business environment. Government effectiveness, the rule of law and perception of corruption are low, on average, in the EBRD regions (the worst performers in terms of governance are Tajikistan, Turkmenistan and the Kyrgyz Republic). Moreover, KE development in many EBRD economies is limited by a lack of economic openness. Tunisia, Uzbekistan and Kosovo, in particular, have very high tariffs.

Skills for innovation are relatively good, on average, in the EBRD regions. This is mostly due to relatively better general skills; specialised skills remain weak. The gap between the EBRD regions and the OECD comparators for this KE pillar (at 2.18) is the smallest of the four pillars. Still, general skills in some EBRD regions remain weak (for example, Lebanon, Kosovo and Morocco have very low secondary-school enrolment rates). Specialised skills are even more limited in many economies. For instance, very few firms in Jordan, Turkmenistan and Egypt offer formal training to their employees. Albania, Morocco and Moldova have very few technicians in R&D per million inhabitants. At the same time, though, Slovenia, Croatia and Hungary perform relatively well when it comes to specialised skills, on par with some OECD comparators.

The *innovation system* pillar shows the largest gap between the EBRD regions and their OECD comparators (a 3.26 index points difference). The least advanced EBRD regions invest very little in their innovation system. The Central Asian economies, for example, spend only 0.17 per cent of GDP on R&D, on average, significantly less than the 2.4 per cent of GDP spent by the OECD countries. Low input turns into low output by the innovation system. Tajikistan, Jordan and Cyprus have the lowest number of patent applications, for instance, at a mere 0.0002 per 1,000 inhabitants, compared with 0.54 in OECD comparator countries. Moreover, linkages within the innovation system in the EBRD regions are constrained by a lack of academic-corporate research collaboration, for instance, something that is particularly weak in the Kyrgyz Republic, Mongolia and, surprisingly, Greece (on a worst-to-best scale of 1 to 7, these economies score around 2.5, compared with 4.8 in the OECD countries).

Lastly, despite significant improvements in *ICT* infrastructure in recent years, a considerable gap (of 2.73 index points) remains between the EBRD regions and their OECD comparators. The least advanced EBRD regions, in particular, continue to struggle in terms of both ICT availability and sophistication. For instance, Turkmenistan and Tajikistan only have 0.07 broadband subscriptions per 100 inhabitants (compared with 36 in the OECD comparators). On average, broadband reaches only 17 per cent of the population in those economies where the EBRD invests.

2. Knowledge-economy development between 2011 and 2018

We can see from Chart 3 that the EBRD regions have been making progress on knowledge-economy development, with their average KE Index increasing to 4.67 in 2018 from 3.88 in 2011. The vast majority of this improvement was driven by better

ICT infrastructure, which posted a large increase to 5.0 in 2018 from 2.71 in 2011. Some progress was made on *skills for innovation* (which increased to 4.96 from 4.47) and *institutions for innovation* (which increased to 5.52 from 5.12).

Chart 3: EBRD Knowledge Economy Index, 2011 versus 2018
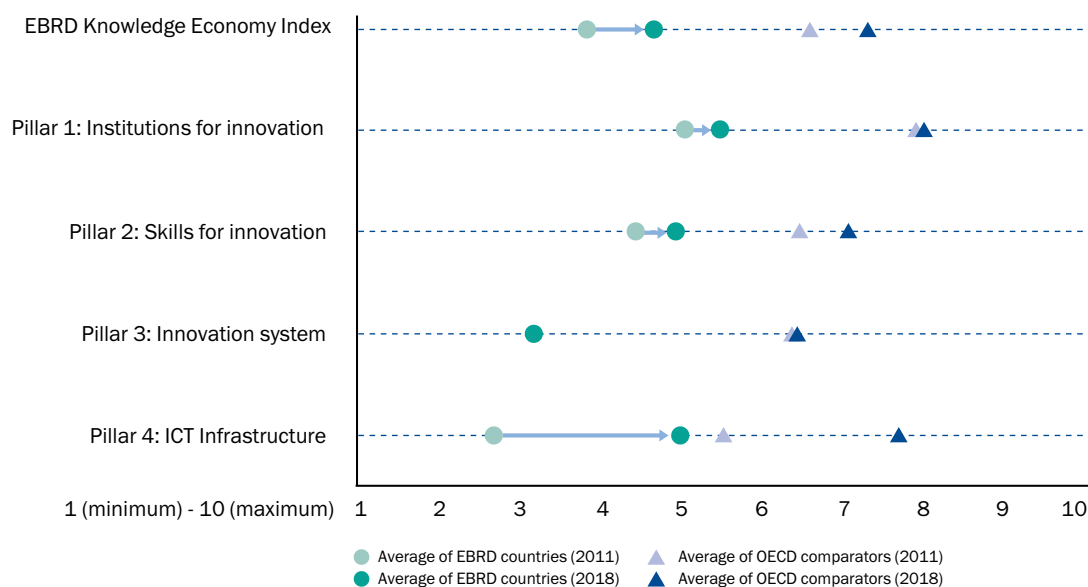
Note: Pillar 3 showed no change in the average for EBRD economies between 2011 and 2018.

Source: Authors' calculations.

While the EBRD regions' performance improved overall between 2011 and 2018, there were large differences from economy to economy. Chart 4 plots the 2018 KE Index results against the overall change in the KE Index between 2011 and 2018. Following the logic of Chakravorti et al (2017), we divide the economies into four zones: "stand out", "stall out", "break out" and "watch out".

"Stand out" economies are relatively developed knowledge economies that exhibit high momentum. They are leaders in driving innovation, building on their

existing advantages. Some OECD comparators (such as Sweden and the United Kingdom) and several EBRD economies (for example, Estonia, Slovenia and Latvia) fall into this group. **"Stall out"** economies enjoy a relatively high state of KE advancement, but show slowing momentum due to the challenges of sustaining KE growth. OECD comparators Canada and Japan, and EBRD economies Cyprus and Poland are in the **"stall out"** zone. **"Break out"** economies are low scorers in terms of their current state of KE development, but are evolving rapidly. Uzbekistan, Azerbaijan and Morocco are examples

of economies in the **"break out"** zone, as they made remarkable progress between 2011 and 2018. The **"watch out"** economies, in contrast, face significant challenges, with a low level of KE development and low momentum. Turkmenistan, Egypt, the West Bank and Gaza, and Kosovo, in particular, made very little progress between 2011 and 2018.

Chart 4: Plotting the EBRD Knowledge Economy Index (2018) versus the change in Index (2011-18)
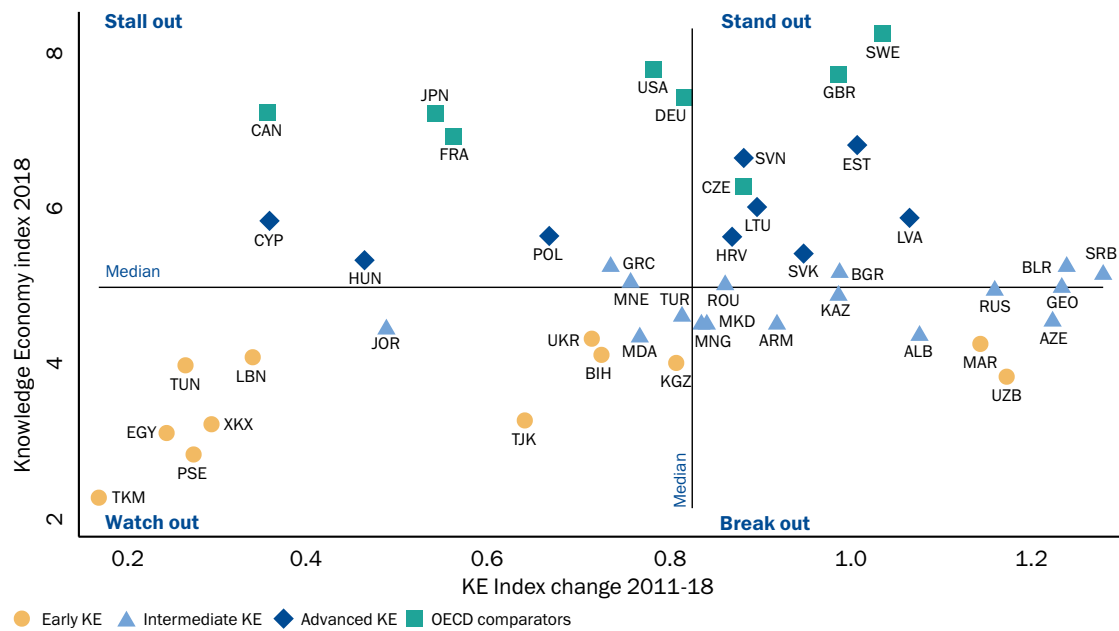
Note: The construction of this chart and the related analysis follow the logic of Chakravorti et al (2017). The definition of early, intermediate and advanced KE groups can be found in section 3 of this paper. The median line is calculated using both EBRD regions and OECD comparators. Source: Authors' calculations.

By looking a bit deeper into the changes in the four pillars of the KE Index between 2011 and 2018, we gain some interesting insights (see Chart 6). Belarus, Kazakhstan and Uzbekistan made the most progress on *institutions for innovation* between 2011 and 2018. These improvements were mostly driven by better business environments and greater economic openness. A number of economies saw their performance in terms of *institutions for innovation* worsen between 2011 and 2018, however. The biggest declines were observed in Egypt, Turkey and Tunisia, largely as a result of worsening governance indicators.[27]
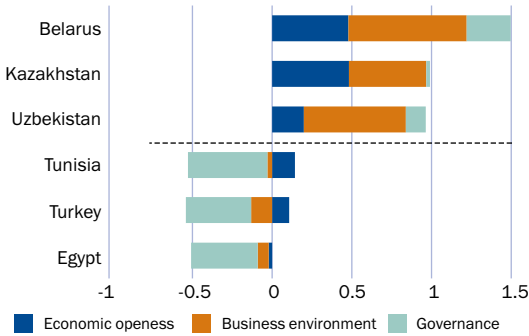
While the EBRD regions improved only slightly, on average, when it came to *skills for innovation* between 2011 and 2018, some economies (such as Uzbekistan, Turkey and Egypt) made a very good progress albeit from a lower base. At the same time, Lebanon, Montenegro and Kosovo saw their performance decline on this measure between 2011 and 2018, mostly due to their relatively lower performance on general skills.

Between 2011 and 2018, Azerbaijan, Tajikistan and Bulgaria improved most in terms of the *innovation system* pillar of the KE Index. The improvements stemmed primarily from stronger linkages within their innovation system. Tunisia, Montenegro and Egypt declined the most on this measure. In Tunisia, the deterioration was driven largely by the perception of flagging academic-industrial links and value chains.
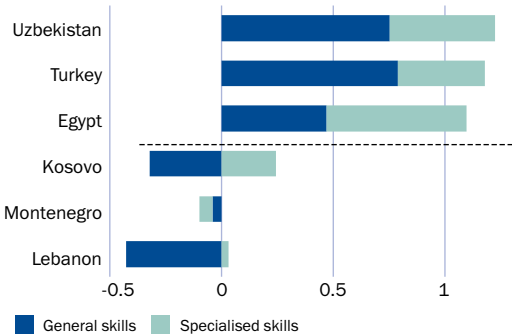
While all EBRD regions improved their *ICT infrastructure* between 2011 and 2018, a few economies made remarkable progress. Serbia, Montenegro and Georgia improved the most in terms of both ICT availability and sophistication. Turkmenistan, Tajikistan and Kosovo, in contrast, showed very limited progress.

Chart 5: KE Index changes by pillar, 2011 to 2018 (most and least improved EBRD economies)
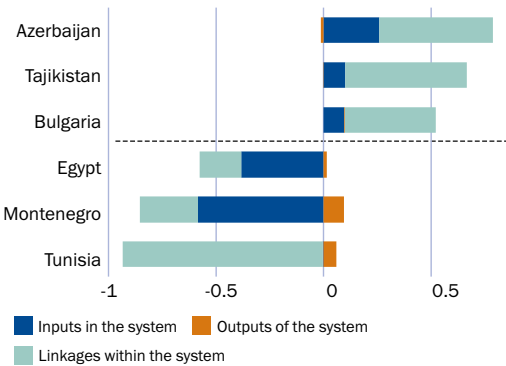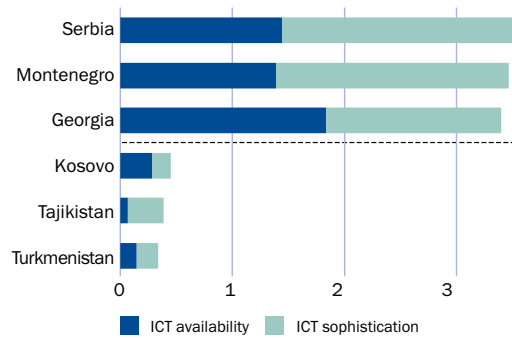
Institutions for innovation

Legend: Economic openess, Business environment, Governance

Skills for innovation

Legend: General skills, Specialised skills

Innovation system

Legend: Inputs in the system, Outputs of the system, Linkages within the system

ICT infrastructure

Legend: ICT availability, ICT sophistication

Note: Charts represent economies with the largest and smallest changes on a particular pillar.

Source: Authors' calculations

3. Three stages of knowledge economy in the EBRD regions

We have identified three stages of knowledge economy in the EBRD regions. The EBRD *Transition Report 2014* already showed that the economies in which the EBRD invests are at varying stages of knowledge-economy development.[28] Following this logic, we use the economies' performance in terms of the 10 "dimensions" of the KE Index to cluster them into **early**, **intermediate** and **advanced** KE groups (Chart 6).[29]

We also conduct a principal component analysis (PCA), which converts all 38 indicators into two values for visual purposes. We reduce all of the indicators belonging to pillars 1 and 2 into a single number (y-axis in Chart 6)[30] and all indicators belonging to pillars 3 and 4 into a single number (x-axis in Chart 6). Chart 6, thus, depicts the results of two separate statistical exercises: the cluster analysis and the PCA. We describe the methodology in more detail in the Annex.

Chart 6: Three clusters of knowledge-economy development in the EBRD regions
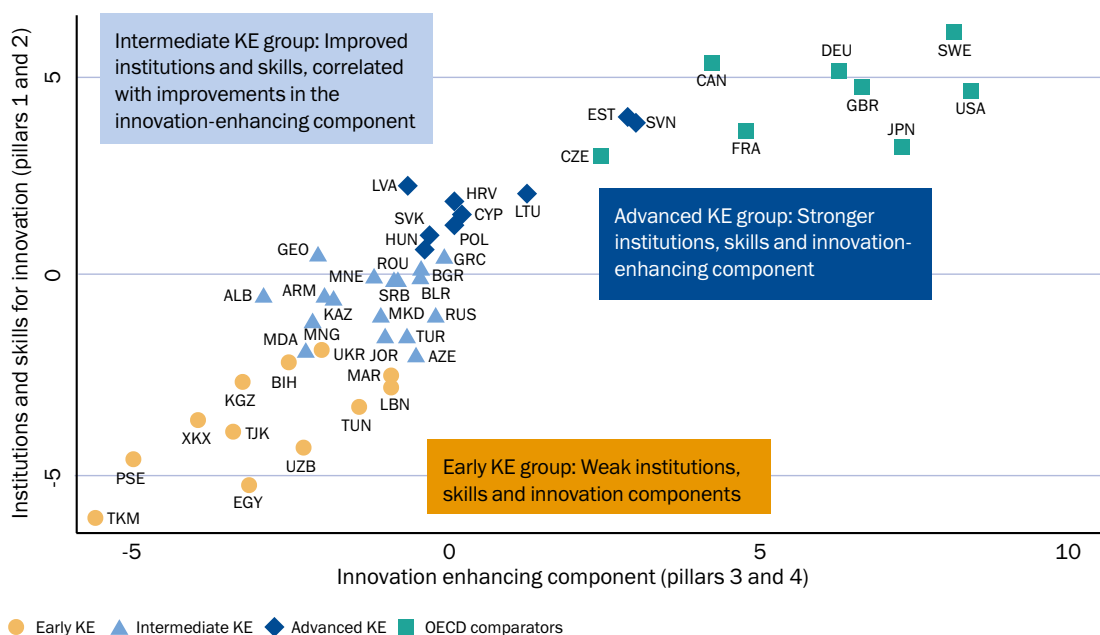
Note: The chart depicts the results of two separate statistical exercises: our cluster analysis and the PCA. The cluster analysis examines variations in the 10 "dimensions" of the EBRD Knowledge Economy Index to find common patterns among economies. Taking the normalised value of each "dimension", initial focal points are initialised. Through an iterative process of readjusting the centre of the cluster, by taking the average of the closest economies, this technique produces the final clusters. The PCA uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a smaller set of values of linearly uncorrelated variables, called principal components. Using the PCA, we obtain two principal variables that form the axes of this figure.
Source: Authors' calculations.

Without any claim on causality, the results show the **early KE group** displaying weak *institutions* and *skills for innovation* components (y-axis), in addition to weak *innovation* components (x-axis). As economies move towards the **intermediate KE** group, institutions improve, which appears to be correlated to improvements in other pillars. The **advanced KE group** has stronger *institutions* and *skills*, together with a stronger innovation-enhancing component. No economy displays a high *innovation* (x-axis) component in tandem with low *institutions* and *skills* components (y-axis). This underlines the importance of having strong institutions and skills to develop a thriving knowledge economy.

The results of the cluster analysis presented in Chart 6 are summarised in Table 3. With some exceptions, the Central Asian and SEMED economies in which the EBRD invests are in the early stages of KE development. The intermediate KE group largely comprises economies in eastern Europe, the Caucasus and the Western Balkans. All of the advanced KE countries are European Union member states. There are a few outliers. Ukraine is classified as being the early KE group, although it performs relatively well in terms of *skills for innovation, ICT infrastructure* and *innovation system*. Its early KE group classification is down to the fact that compared with the intermediate group, Ukraine scores considerably worse on *institutions for innovation*. Similarly, North Macedonia is classified as being in the intermediate KE group, despite having relatively weak *skills for innovation* (compared with other intermediate KE economies). This is down to its relatively good performance in terms of institutional environment – a key factor propelling economies from the early to intermediate stages of KE development. Lastly, both Hungary and the Slovak Republic are classified in the advanced KE group, despite being relatively close to some intermediate KE countries on certain metrics (see Chart 6). This is driven by somehow weaker institutions and ICT.

Table 3: EBRD regions by stage of the knowledge-economy development	
Stage of KE development	**Economies in which the EBRD invests**
Early	Bosnia and Herzegovina, Egypt, Kosovo, Kyrgyz Republic, Lebanon, Morocco, Tajikistan, Tunisia, Turkmenistan, Ukraine, Uzbekistan, West Bank and Gaza
Intermediate	Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Georgia, Greece, Kazakhstan, Jordan, Moldova, Mongolia, Montenegro, North Macedonia, Romania, Russia, Serbia, Turkey
Advanced	Croatia, Cyprus, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic, Slovenia

Note: This table presents the results of the clustering analysis. OECD comparators form a separate cluster.
Source: Authors' analysis.

Drivers of knowledge-economy development are stage dependent

This section looks at the common characteristics of economies at each stage of knowledge-economy development, as well as at what drives KE development from one stage to another. Table 4 shows how each of the four pillars and 10 "dimensions" contributes to changes in the KE Index from stage to stage and how each pillar and dimension explains the change in the KE Index between stages. To support the statements in this section, the Annex shows all KE indicators for all three KE stages.

Table 4: Drivers of the knowledge economy development										
Pillar	**Institutions for innovation**			**Skills for innovation**		**Innovation system**			**ICT infrastructure**	
Dimension	Economic Openness	Business environment	Governance	General	Specialised	Inputs	Outputs	Linkages	Availability	Sophistication
From advanced to OECD comparators	**16.1%**			**17.2%**		**43.1%**			**23.6%**	
	0.4%	9.4%	6.2%	5.8%	11.4%	16.3%	12.8%	14.0%	11.9%	11.7%
From intermediate to advanced	**34.8%**			**23.7%**		**18.1%**			**23.4%**	
	5.3%	13.4%	16.0%	16.7%	7.0%	7.7%	6.9%	3.6%	16.1%	7.3%
From early to intermediate	**29.1%**			**24.8%**		**9.2%**			**36.9%**	
	7.6%	10.2%	11.4%	16.9%	7.9%	3.9%	1.0%	4.3%	21.3%	15.6%

■ High contribution   ☐ Low contribution

Note 1: The first row of the table shows how much each pillar of the KE Index accounts for the advances in knowledge economy observed at different stages. First, we calculate the average score in each pillar for each stage. We than calculate the difference between each stage and the next. Percentages are calculated as the total pillar change over the total change in the KE index from one stage to the next. For example, from the early to the intermediate stage, 36.9 per cent of the observed increase in the average KE index value is attributable to improvements in the ICT pillar.

Note 2: The second row of the table highlights the "dimensions" that contribute most (in darker green) and least (white) to knowledge-economy improvement in each stage.

Source: Authors' calculations.

Early KE economies have weak institutions, skills and ICT infrastructure

In the early KE group, *institutions, skills* and ICT infrastructure are not developed. Weak *institutions for innovation,* such poor business environments (weak rule of law, high levels of corruption) and governance (low regulation or limited government effectiveness) constrain investment, productivity and innovation. Moreover, relatively low economic openness (including high tariffs) acts as a barrier to the flow of ideas and leads to limited access to foreign technologies. Table 4 shows that improvements in *institutions for innovation* account for 29 per cent of the difference of the KE Index between the early and intermediate KE stages.

Skills for innovation are also limited in the early KE group. While on some skills indicators (such as the perceived quality of the education system) economies in the early KE group score on a par with those in the intermediate group, there is a big difference in enrolment rates, especially in tertiary education. Improvements in *skills for innovation* account for almost 25 per cent of the difference in the KE Index between the early and intermediate KE stages.

As the pressure on firms to innovate is relatively low at this stage, the inefficient *innovation system* pillar does not appear to be a binding factor for KE development. The early and intermediate KE groups provide similarly low inputs into the innovation system, while the share of firms that innovate and spend on R&D is also low in both pillars. The low level of innovation of the private sector thus creates only limited demand for a strong innovation system. Only 9 per cent of the change between the early and intermediate KE stages can be attributed to improvements in the *innovation system*.

For early KE economies, the key constraint to KE development appears to be weak *ICT infrastructure*. Both ICT availability and sophistication are very low, which restricts innovation and reduces productivity gains and knowledge spill-over effects. Almost 37 per cent of the index difference between the early and intermediate KE stages can be put down to *ICT infrastructure*.

As the early KE group generally does not meet the conditions for frontier innovation and knowledge creation, innovation policies in those economies should probably focus on better capturing knowledge from abroad (knowledge adoption, technology transfer). This would suggest policy interventions that lead to greater economic openness, easier trade across borders, and the rule of law. These interventions should be accompanied by significant improvements in *skills for innovation* and *ICT infrastructure*.

Intermediate KE group is more open and has better skills

Economies in the intermediate KE stage demonstrate better *institutions for innovation* than those in the early KE group. Their more effective governance (for example, quality of regulation) and better business environment foster more investment and innovation. Intermediate KE economies also tend to be more open, with lower tariffs. Still, they need to do more to catch up with advanced KE economies. Table 4 shows that *institutions for innovation* account for almost 35 per cent of the KE Index difference between the intermediate and advanced KE stages.

While the intermediate KE group is almost on a par with the advanced KE group on some dimensions of *skills for innovation* (such as enrolment in tertiary education), they significantly lag on others (for example, average years of schooling). Skill mismatches are a more pressing problem as firms demand a more sophisticated labour force. The skills deficit is demonstrated by the higher proportion of firms providing training to their employees. Perceived protection of intellectual property rights (IPR) is also low. As firms conduct more sophisticated activities, they appear to become more constrained by weak IPR systems. Enhancing general skills would appear to be the main way of reducing the skills gap between the intermediate and advanced KE groups (improvements in skills account for almost 24 per cent of the KE Index gap between the intermediate and advanced KE stages).

Intermediate KE economies typically "buy" innovation rather than "make" it.[32] A large proportion of firms use foreign licensed technology or import foreign machinery and these countries pay large sums of money for intellectual property. Firms in intermediate KE economies spend slightly more on R&D and are more likely to introduce new products or services than firms in early KE economies. However, R&D activities remain mostly driven by the public sector. Patent applications (0.042 per 1,000 inhabitants) are higher than in early KE economies (0.013), but strikingly far behind the OECD comparators (0.54). To move up to the advanced KE stage, the intermediate KE group needs to further improve its i*nstitutions for innovation* (in particular, governance and the business environment), focus on improving general skills and making ICT more available.

Intermediate KE economies have a significantly better *ICT infrastructure* than those in the early KE group. In some intermediate KE economies, ICT sophistication is almost on a par with that of advanced KE economies. However, broadband availability remains limited (driven by low access in remote areas). More than 23 per cent of the KE Index difference between intermediate and advanced economies can be attributed to *ICT infrastructure*, in large part driven by intermediate KE economies' lower ICT availability.

The innovation policies of intermediate KE economies should focus on catching up with those of the more advanced KE group. This would mean addressing the remaining *institutional* gaps (business environment and economic openness) and promoting general skills and ICT availability.

Advanced KE economies have a favourable KE environment, but frontier innovation remains rare

The advanced KE group has developed more favourable institutional frameworks and better *ICT infrastructure*, providing greater incentives for innovation. Their knowledge economies are stimulated by higher economic openness, which is similar to that of the OECD comparators (low tariffs and easier trade across borders). Some measures of governance have also reached frontier levels (for example, political stability), though significant gaps remain, particularly in relation to the rule of law and government effectiveness. Good ICT infrastructure enables more effective flows of knowledge and information. The internet is more widely available, although there is still a gap to the OECD comparators in terms of ICT sophistication.

While the advanced KE economies possess similar general skills to their OECD comparators, they lag when it comes to specialised skills. Their secondary-education enrolment rates are similar to those of the OECD comparators, for example, but their tertiary enrolment rates remain low.

Weak linkages within the *innovation system* are responsible for the largest gap between the advanced KE group and the OECD comparators. While the advanced KE economies' R&D spending is relatively high (at around 1 per cent of GDP annually), it remains significantly short of the 2.4 per cent of GDP spent by the OECD comparators. The proportion of R&D carried out by the private sector (around 38 per cent of the total) in the advanced KE group also lags that of the OECD comparators (at around 55 per cent). In addition, there is insufficient collaboration between the private sector and universities, venture capital is often not available and value chains remain limited (on a scale of 1 to 7, from worst to best, advanced KE economies score 3.8 compared with the OECD comparators' 5.3; please see the Annex for more detail).

Advanced KE economies tend to "make" their own technology, innovation that is "new to the world" is rare. Firms in advanced KE economies rely less on imports of foreign know-how (net IP receipts are lower than in intermediate KE economies) and they allocate more resources to R&D, which translates into more patents and a higher rate of new product introduction. Still, the advanced KE group clearly lags the group of OECD comparators on number of patent applications and magnitude of R&D spending.

The EBRD KE Index suggests that to close the gap to the OECD comparators, the advanced KE group needs to significantly improve the efficiency of its *innovation system*. Innovation policies should focus on knowledge creation, as well as stimulating private-sector innovation and R&D. Specific focus should be on strengthening links within the innovation system. Interactions between academia and the private sector, the availability of early-stage financing and participation in global value chains are likely to raise the productivity of the resources devoted to innovative activities.

Lastly, 43.1 per cent of the KE Index gap between the advanced KE group and the OECD comparators can be attributed to ineffective *innovation system*. Increased inputs into innovation activities with subsequent improvements in *linkages* across the *innovation system* are the key means of narrowing this gap (Table C1). *Institutions* and *skills* in advanced KE economies are similar to those in the frontier economies, but *ICT infrastructure* continues to lag somewhat due to both limited availability and a lack of sophistication. While general skills appear more important in the early and intermediate KE groups, in the advanced group, specialised skills are a binding constraint.

4. Conclusion

In this paper, we introduced the EBRD Knowledge Economy Index. It showed that *institutions for innovation* is the key pillar of knowledge-economy development, but that other pillars also need to be strengthened in the EBRD regions. The insights gained from the KE Index support our view that a one-size-fits-all policy approach is not appropriate and that interventions need to be prioritised based on the specific challenges of an economy's KE stage. In the **early KE stage**, the emphasis should be on building the basic requirements for KE development, in particular, building better *institutions for innovation* (improving economic openness, governance and the business environment), general *skills for innovation* and *ICT infrastructure*. In the **intermediate KE stage**, economies should make efforts to catch up with those countries at the technological frontier.

This includes improvements in innovation-specific factors, such as the protection of intellectual property rights. Lastly, economies in the **advanced KE group** should focus on building capabilities for frontier innovation globally. This involves enhancing firms' ability to commercialise new products (for example, through accelerators), better channelling of funds to innovative firms (through venture-capital programmes, for instance) and stronger academia-business ties (for example, innovation vouchers). In general, advanced KE economies have room to implement more sophisticated innovation-policy instruments, such as incentives for private-sector R&D and smart specialisation.

Annex

Table A1: 2018 EBRD Knowledge Economy Index by stage of KE development (all indicators)				
Knowledge-economy stage (EBRD regions)	Early	Intermediate	Advanced	OECD comparators
2018 EBRD knowledge economy index (1 = worst, 10 = best)	**3.59**	**4.78**	**5.91**	**7.36**
Pillar 1: Institutions for innovation (1 = worst, 10 = best)	**4.20**	**5.58**	**7.15**	**8.08**
Economic openness (1 = worst, 10 = best)	4.86	5.94	6.67	6.75
Trading across borders (0 = worst, 100 = best)[1]	67.25	86.01	97.92	93.81
FDI, net inflow (% of GDP) [2]	4.06	4.22	7.34	2.51
Average tariff rate (%)[2]	5.32	2.98	1.96	1.95
International migrant stock (% population) [2]	4.71	7.48	9.42	12.34
Business environment (1 = worst, 10 = best)	3.73	5.18	6.99	8.64
Rule of law (-2.5 = worst, 2.5 = best) [3]	-0.68	-0.19	0.82	1.58
Corruption perception index (0 = worst, 100 = best) [4]	30.43	40.00	56.67	75.5
Ease of doing business (distance to frontier, 100 = best) [1]	61.20	71.51	75.80	79.24
Governance (1 = worst, 10 = best)	4.00	5.62	7.79	8.87
Government effectiveness(-2.5 = worst, 2.5 = best) [3]	-0.60	-0.03	0.87	1.59
Regulatory quality (-2.5 = worst, 2.5 = best) [3]	-0.65	0.11	0.93	1.52
Political stability (-2.5 = worst, 2.5 = best) [3]	-0.91	-0.25	0.66	0.71
Pillar 2: Skills for innovation (1 = worst, 10 = best)	**3.89**	**5.07**	**6.14**	**7.14**
General skills (1 = worst, 10 = best)	3.83	5.44	6.94	7.92
Average years of schooling (years) [5]	8.93	10.65	12.36	12.73
Secondary enrolment rate (% of population of enrolment age) [2]	84.10	94.97	103.77	111.93
Specialised skills (1 = worst, 10 = best)	3.96	4.71	5.34	6.66
Years of top managers in sector (years) [6]	17.05	16.33	18.63	17.92
Firms offering formal training (% of firms) [2]	28.97	31.36	35.53	44.66
Tertiary enrolment rate (% of population of enrolment age) [2]	33.00	61.42	64.57	67.44
Technicians in R&D (per million inhabitants) [2]	197.85	295.25	722.30	1443.82
Inadequately trained workforce obstacle to operations (proportion of firms, %) [6]	1.12	0.88	0.89	0.50
Quality of education system (1 = worst, 7 = best) [7]	3.17	3.53	3.57	4.79
Quality of maths and science education (1 = worst, 7 = best) [7]	3.81	4.23	4.47	4.99

Pillar 3: Innovation system (1 = worst, 10 = best)	2.73	3.16	3.98	6.48
Inputs in the innovation system (1 = worst, 10 = best)	2.85	3.41	4.45	7.29
Total expenditure on R&D (% of GDP) [5]	0.41	0.49	0.99	2.41
Gross domestic expenditure on R&D by businesses (% of total R&D) [5]	17.40	28.45	37.69	55.17
Proportion of firms' spending on R&D (%) [6]	10	10	14	27
Researchers in R&D (per million inhabitants) [2]	1048.69	1520.95	2393.79	4710.71
Intellectual property protection (1 = worst, 7 = best) [7]	3.52	3.88	4.35	5.75
Outputs of the innovation system (1 = worst, 10 = best)	2.11	2.25	3.18	5.42
Patent applications (per 1,000 inhabitants) [2]	0.01	0.04	0.07	0.55
Proportion of firms that have introduced a new product/service (%) [6]	0.25	0.23	29	57
Net IP receipts (US$ million at purchasing-power parity) [2]	-790	-592	-375	13986
Scientific and journal articles (per 1,000 people) [2]	0.13	0.29	0.94	1.36
Linkages within the innovation system (1 = worst, 10 = best)	3.22	3.82	4.31	6.73
University-company research collaboration (1 = worst, 7 = best) [7]	3.06	3.25	3.43	4.89
Availability of venture capital (1 = worst, 7 = best) [7]	3.40	2.69	2.91	4.12
Use of foreign licensed technology (proportion of firms, %) [6]	13	15	15	15
Firm-level technology absorption (1 = worst, 7 = best) [7]	4.00	4.38	4.68	5.54
Value-chain breadth (1 = worst, 7 = best) [7]	3.40	3.64	3.88	5.34
Pillar 4: ICT infrastructure (1 = worst, 10 = best)	3.55	5.31	6.36	7.73
ICT availability (1 = worst, 10 = best)	3.29	5.32	6.77	8.15
Broadband subscriptions per 100 inhabitants [8]	7.48	17.37	27.17	35.94
Active mobile broadband subscriptions per 100 inhabitants [8]	44.65	74.03	86.25	99.78
ICT sophistication (1 = worst, 10 = best)	3.81	5.30	5.95	7.32
International internet bandwidth per internet user (bits/second) [8]	32505.55	102371.79	147631.91	204868.77
E-Participation Index [9]	0.46	0.65	0.68	0.85
Online Service Index [9]	0.43	0.60	0.69	0.86

Note: The numbers displayed in the table are an unweighted average of economies in the cluster.

*Data sources: (1) World Bank Ease of Doing Business Report; (2) World Bank World Development Indicators (WDI); (3) World Bank Worldwide Governance Indicators; (4) Transparency International; (5) UNESCO; (6) Business Environment and Enterprise Performance Survey (BEEPS); (7) World Economic Forum Global Competitiveness Index; (8) International Telecommunication Union; (9) United Nations Department of Economic and Social Affairs (UNDESA), Division for Public Institutions and Digital Government.

Table A2: Existing global measures of innovation and knowledge economy	
Measure	**Methodological issues**
Global Innovation Index (GII)	The GII provides a comprehensive view of innovation, but does not cover some of the economies in which the EBRD invests
Global Competitiveness Index (GCI)	The GCI does not focus exclusively on the drivers of innovation, being more centred on the concepts that matter to productivity
European Innovation Scoreboard (EIS)	The EIS is a relevant measure of innovation, but it only covers European economies
Economic Complexity Index (ECI)	The ECI focuses exclusively on the value added in traded goods, providing a biased perception of the capacity of an economy to add value
Trade in value added (TiVA)	The TiVA database measures the value flows of the sector-specific production of goods and services, indicating global value-chain linkages between nations

Source: Authors' analysis.

BOX A1: Data imputation, cluster analysis and principal component analysis (PCA)

Data imputation

We need to impute some data for the Knowledge Economy Index as certain indicators are not available for some economies/years. In the case of our inaugural KE Index, before imputation, 35 per cent of the data points were missing for all years and economies, on average. As data are reported with a lag, there was a larger proportion of missing values for 2017 than for previous years (for example, 22 per cent of values were missing for 2013). The economies with the worst data coverage are Turkmenistan, Uzbekistan, the West Bank and Gaza, and Kosovo. We use two steps for data imputation:

- **Step 1: Replacing a missing data point with its previous or future value:** Where the indicator value is missing for a particular year, but available for the previous year, we use that value. In some cases, where the indicator value is missing, but available for the future year, we replace the missing data point with that value.[33]

- **Step 2: Imputing the value of a missing indicator with a proxy:** For some economies (such as Kosovo and Turkmenistan), certain indicators are simply not available. In these cases, we use a proxy to impute the missing data. The proxy we use is the distance of an economy to Estonia (the EBRD frontier) in the Global Innovation Index (GII). The GII was selected because it covers most of the EBRD regions and, conceptually, is relatively close to the EBRD Knowledge Economy Index. This distance is then applied to impute the missing indicators.

As the year-to-year changes in indicator values are typically small, the imputation using previous-year values (the majority of imputations) gives us confidence in the reliability of our dataset.

Cluster analysis

The technique employed to classify economies into various KE stages is a non-hierarchical cluster analysis. A *k-means* algorithm is used to carry out the analysis. This approach examines the 10 "dimensions" captured by the EBRD Knowledge Economy Index to find common patterns between countries. Taking the normalised value of each dimension, three focal points are initialised for the 10 dimensional spaces. Through an iterative process of readjusting the centre of the cluster by taking the average of the closest economies, the technique reveals common dimensional patterns across the EBRD regions. Convergence is eventually achieved and the initialised points become the centre of each cluster, where the neighbouring countries are categorised. Due to the random initialisation of the cluster centres in this approach, we have ensured the consistency of the results by running the algorithm 1,000 times and contrasting the results.

Principal component analysis

Principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a smaller set of values of variables called principal components. Through PCA, we conduct a dimensionality reduction – a process of reducing the number of random variables under consideration by obtaining a set of principal variables. From all the observed variables, we reduce the number to two, in a way that enables us to plot it graphically. The retained components are obtained in such a way to retain the maximum variance from the original data.

As described earlier in this report, we take all the indicators under *institutions for innovation* and *skills for innovation* (pillars 1 and 2) and extract the principal component. Similarly, for the remaining variables (parts of pillars 3 and 4), we extract their principal component.

Chart A1: Correlation between GDP per capita and the KE Index
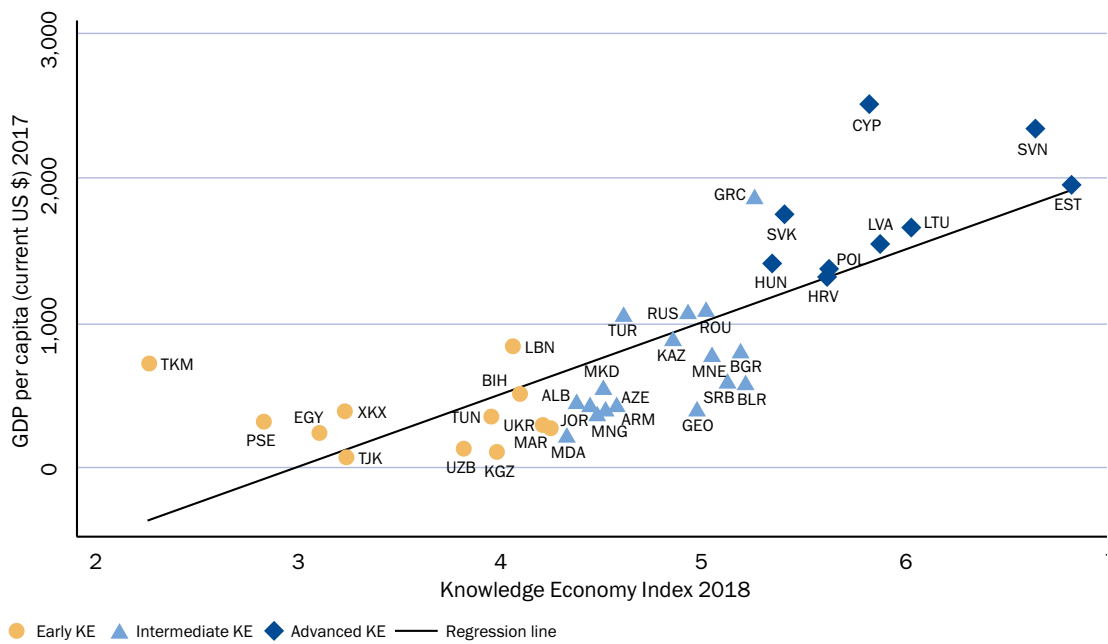
Source: Authors' calculation based on 2018 EBRD Knowledge Economy Index and World Development Indicators.

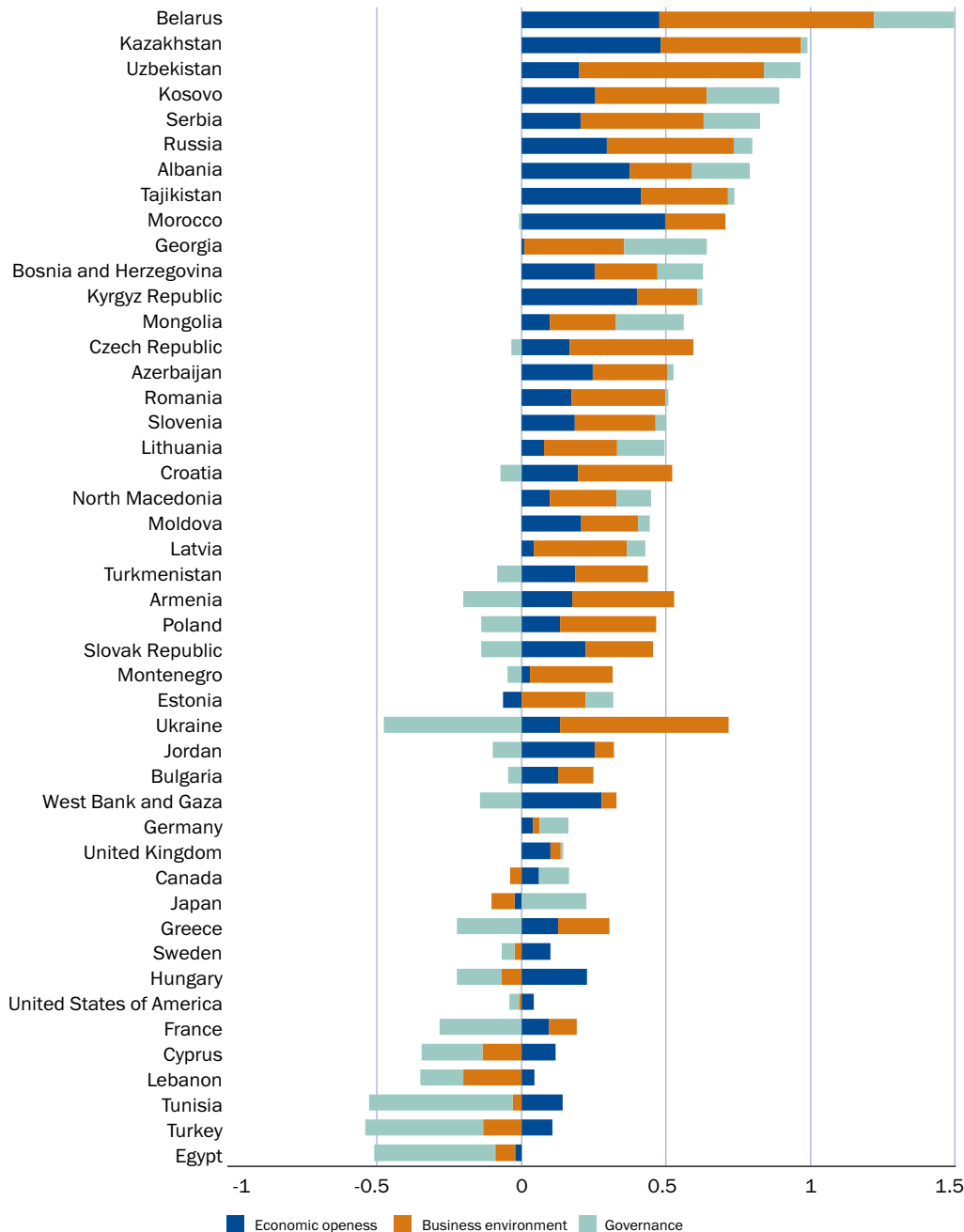## Chart A2: EBRD Knowledge Economy Index change (by pillar), 2011 to 2018

Legend: Institutions for innovation | Skills for innovation | Innovation system | ICT infrastructure
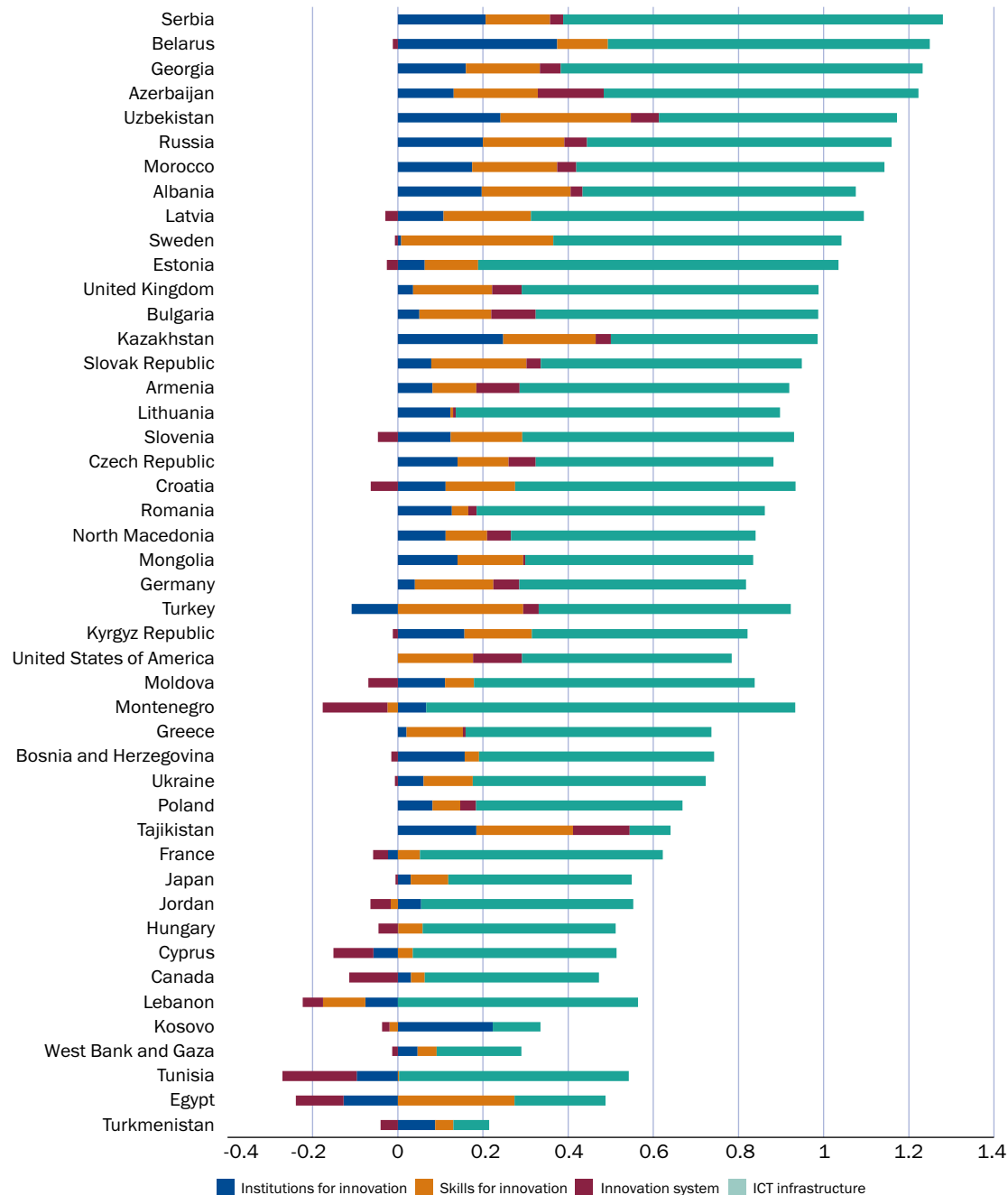
Note: economies are ranked by their total change in EBRD KE Index between 2011 and 2018. Serbia improved the most while Turkmenistan improved the least.

Source: Authors' calculations.

Chart A3: EBRD Knowledge Economy Index change in institutions for innovation, 2011 to 2018

Institutions for innovation

Source: Authors' calculations

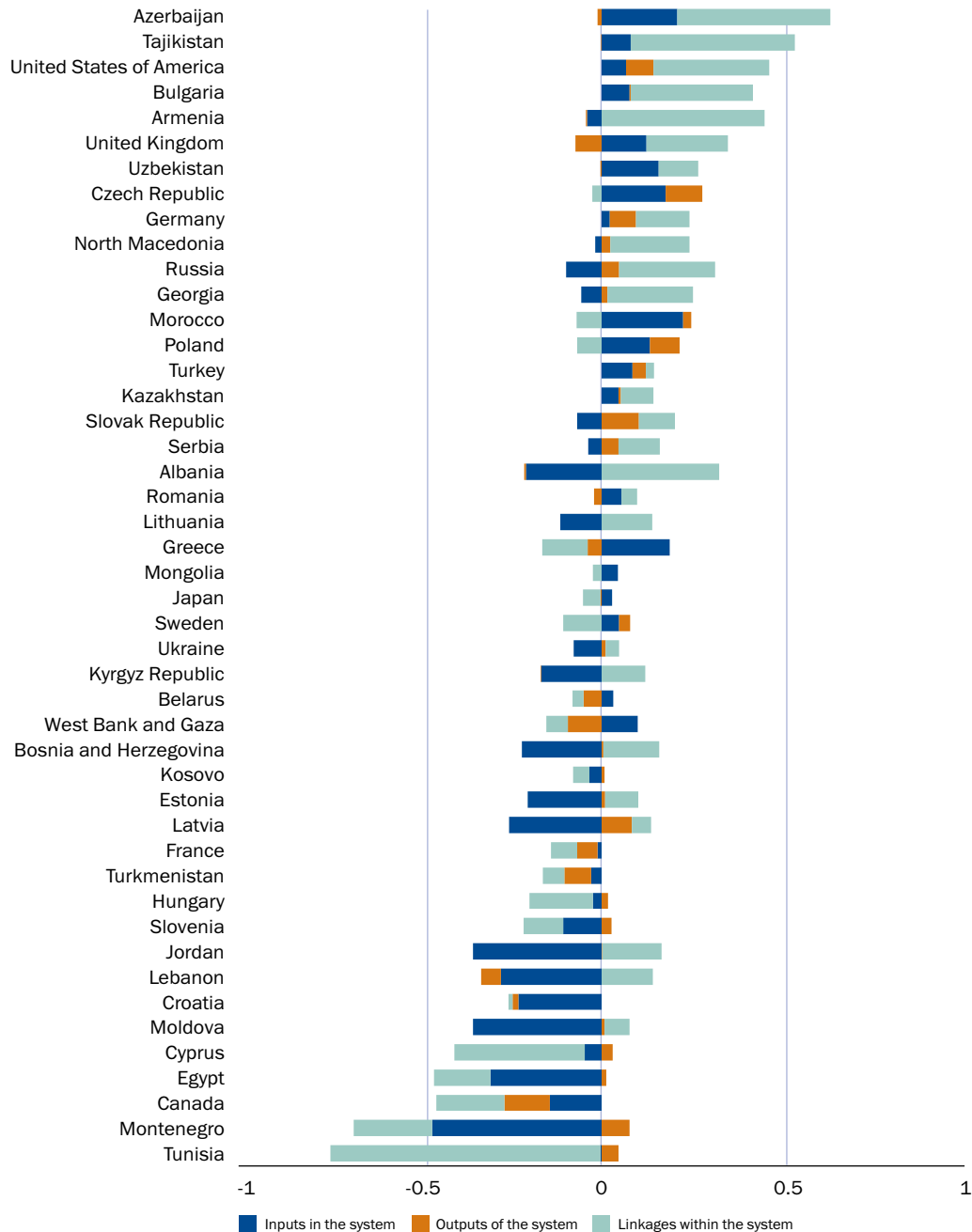## Chart A4: EBRD Knowledge Economy Index change in skills for innovation, 2011 to 2018

Skills for innovation

General skills ■   Specialised skills ■
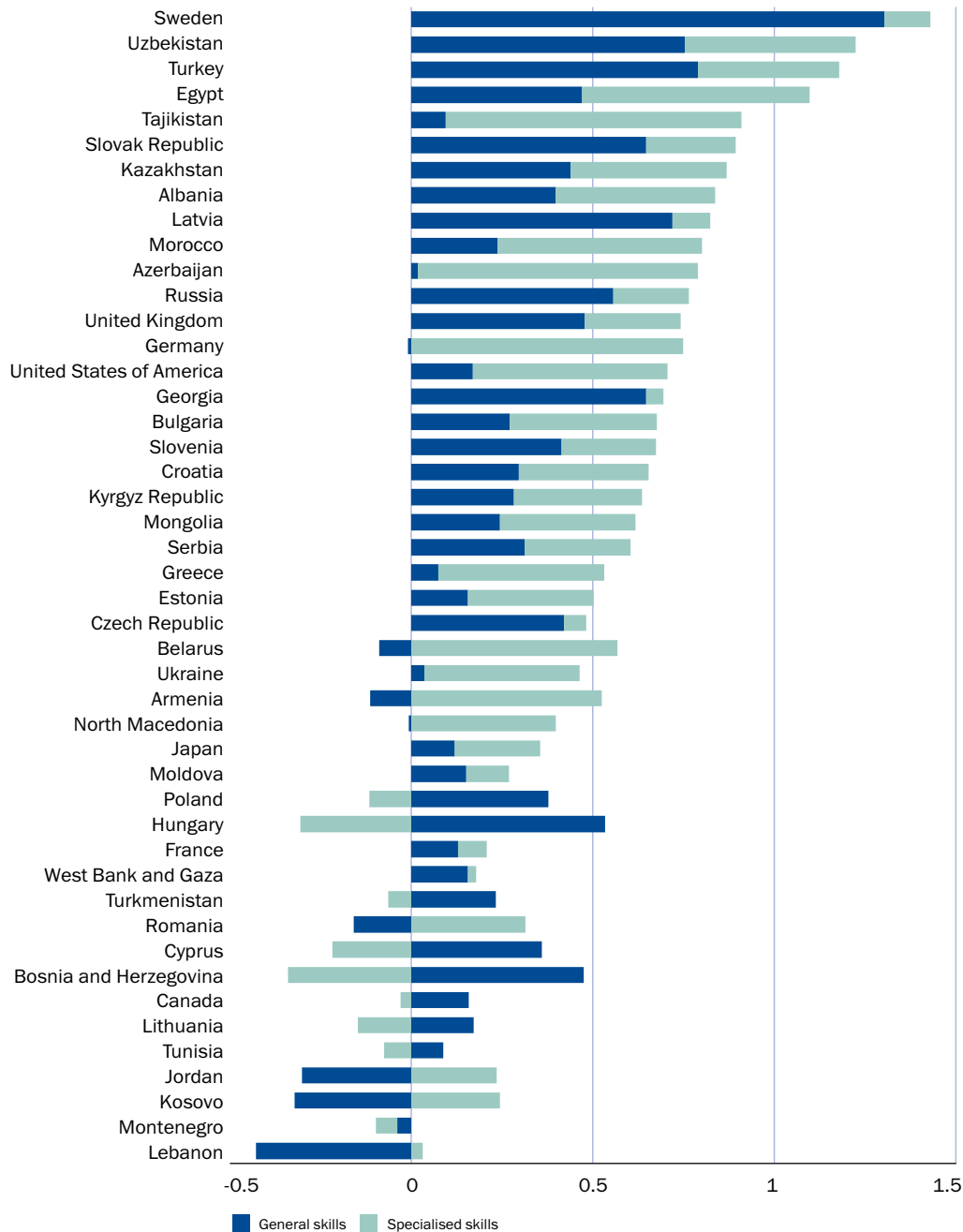
Source: Authors' calculations

Chart A5: EBRD KE Index change in innovation system, 2011 to 2018

Innovation system

■ Inputs in the system	■ Outputs of the system	■ Linkages within the system

Source: Authors' calculations

Chart A6: EBRD KE Index change in ICT infrastructure, 2011 to 2018

	ICT availability	ICT sophistication
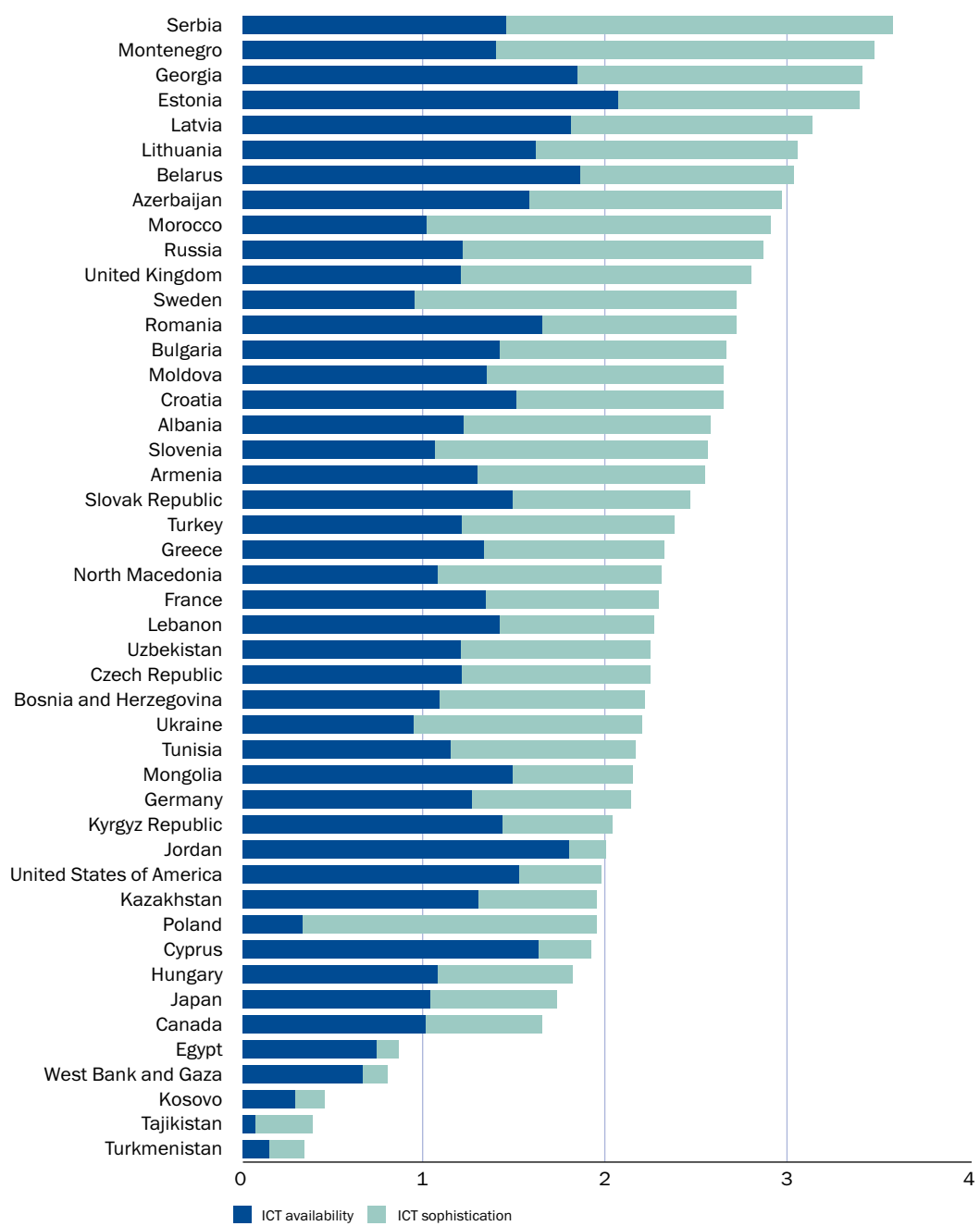
Source: Authors' calculations

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Endnotes

1 Work on the EBRD Knowledge Economy Index was led by Martin Pospisil (pospisim@ebrd.com), who is also the main author of this paper together with co-authors Federica Foiadelli, Pablo Anton and Pavel Dvorak. Comments from Rika Ishii, Olivia Riera, Alexa Tiemann and Philipp Paetzold, Lorenzo Ciari, Umidjon Abdullaev are acknowledged.

2 Supporting the development of the knowledge economy is an integral part of the EBRD's mandate. In particular, creating economic structures and institutions that enhance economies' capacity to generate added value is one of the objectives cited under the *Competitive* quality of a sustainable market economy in the EBRD's transition concept (see EBRD *Transition Report 2015*). The EBRD introduced the concept of the knowledge economy in a 2014 internal paper, entitled "Knowledge Economy Initiative: Boosting Productivity and Competitiveness", which launched the EBRD's Knowledge Economy Initiative.

3 This builds on previous analysis of the knowledge economy (including by the World Bank and the EBRD) and is in line with the latest literature.

4 Our work also fills the gap that arose when the World Bank discontinued its Knowledge Economy Index in 2012. The World Bank's Knowledge Economy Index (KEI) was an aggregate index representing an economy's or region's overall preparedness to compete in the knowledge economy.

5 Acemoglu et al. (2001) show that strong institutions (property rights, rule of law) are instrumental to long-term growth. Landry et al. (2002) show that social capital (especially participational and relational assets) is a powerful explanatory variable of a firm's decision to innovate

6 Trade has a significant positive effect on total factor productivity (see, for example, Alcalá and Ciccone, 2004; Baldwin, 2003; Dollar and Kraay, 2003; MacGarvie, 2006; Branstetter, 2006). Edwards (1998), for instance, shows that trade openness is robustly associated with total factor productivity (TFP) growth in 93 countries.

7 Ozgen et al. (2011) show that patents are positively correlated to the diversity of an economy's immigrant community. Görg & Strobl (2005) show the existence of knowledge spill-overs induced by worker mobility. When a worker has previous experience in other companies, he will be more productive.

8 Damijan et al. (2003) shows that in transition countries, technology is transferred to domestic firms through foreign direct investment linkages.

9 Ramalho (2015).

10 Barro (1991) shows that economic growth is positively correlated with measures of political stability and negatively related to market distortions.

11 OECD Reviews of Innovation Policy (2016 and 2017).

12 Barro (1991) shows that growth is positively correlated to human capital, proxied by enrolment rates, as do Hanushek & Kimko (2000). Schooling and quality have a consistent, stable and strong positive relationship with economic growth. Muysken & Nour (2006) show that skill mismatches are important factors hindering the transfer of knowledge, technological development and economic diversification.

13 Various literature shows a significant effect of initial levels of schooling on growth (for example, Krueger & Lindahl, 2001; Barro, 2002; and Gennaioli et al., 2011)

14 Gelenko (2015).

15 Ulku (2007) shows that R&D investment has a positive impact on the rate of innovation in all sectors except for machinery and transport. Similarly, Lööf & Hesmati. (2004) argue that firm R&D translates into more innovation than public R&D. Yet, public R&D acts as a complement to private-sector R&D.

16 Dakhli & De Clercq (2004) show that R&D and patent applications capture both innovation outputs as the outcome of the innovation system and inputs as a proxy for the future capacity to innovate.

17 OECD (2003) finds that science/industry interactions improve the quality of research and foster industrial innovation. See also the United Nations Economic Commission for Europe's Innovation Performance Review of Belarus (2011).

18 Czarnatzki (2009).

19 See McKenzie & Bruhn (2017) or Bronzini & Piselli (2016). Effective financial systems channelling funds to entrepreneurs are important to TFP growth, especially in the early stages (see, for example, Ang, 2008; Aghion et al. 2007; Levine, 2005; and King and Levine, 1993). Kortum & Lerner (2001), for instance, find that availability of venture capital can causally account for up to 8 per cent of industrial innovation.

20 Humphrey & Schmitz (2002) show that belonging to global value chains promotes fast technology upgrades in the production sphere for firms in developing countries. Parisi et al. (2006) show that technological upgrade positively affects productivity growth.

21 Bygstad & Aanby (2010) show that ICT availability enhances product innovation at firm level. Castaldo et al. (2016) and Fagerberg & Srholec (2007) show that broadband diffusion is both statistically significant and positively correlated with the growth of real GDP per capita.

22 Bouras (2003).

[23] For all BEEPS indicator, data from the 2011-16 (V) and 2009 (IV) survey rounds are used. For two BEEPS indicators (proportion of firms that introduced new products and/or services over the previous three years and proportion of firms using technology licensed from a foreign-owned company), only 2013 data were used. The rationale behind this choice lies in the fact that data points derived from the 2009 survey rounds appear to be systematically higher than in the next survey round. This, in turn, has an impact on the frontier.

[24] Please visit https://2018.tr-ebrd.com/reform/ for detailed information on the Assessment of Transition Qualities (ATQ) methodology.

[25] The rule used to compute the distance-to-frontier (DTF) score of indicator i for economy c at a point in time t is given by:

$$DTF_{ict} = \left[9 * \frac{x_{ict} - min_i}{max_i - min_i} \right] + 1$$

[26] The minimum and maximum correspond to the lowest and highest historical values observed, respectively, for each indicator across the whole 2011-2018 panel. By holding the minimum and maximum constant, a comparison of DTF scores over time becomes possible. The scale of some indicators has been inverted, so that higher values of each indicator always correspond to a more desirable performance. The indicators are: proportion of firms considering an inadequately trained workforce to be a major obstacle to operations and average tariff rates applied (they become negative). In the case of the stock of migrants (as a share of the total population), the historical maximum is replaced with the highest value observable across the comparators (Canada).

[27] Some of this decline can be explained by higher levels of political instability.

[28] See also Veugelers & Schweiger (2016). Similarly, Adamovych (2014) identifies several groups of economies in knowledge-economy development.

[29] We use a k-means algorithm that starts by taking three random points from the 10 "dimensions". The algorithm then readjusts each cluster iteratively based upon the closest countries until a stable cluster centre is reached (see Annex).

[30] The division of the four KE pillars into two distinct groups is conceptual. Pillars 1 and 2 capture the combination of institutional features and basic skill requirements that provide the foundations on which a knowledge-based economy can be built and can thrive. Contrarily, pillars 3 and 4 capture the extent to which a de facto knowledge economy exists in terms of sophistication and availability of ICT infrastructure, innovation inputs, outputs and the existence of fruitful linkages within the society. No statistical procedures were applied to confirm this distinction.

[31] Contributions are computed as follows: X denotes the average score difference between two stages in a given pillar. Y is the average difference in the index score between the same stages. The contribution C is then computed as: C=(X/4)/Y. This process is then applied to the four pillars across all stages, including the frontier.

[32] A parallel can be drawn to the EBRD *Transition Report 2014* classification of EBRD regions, which are either "low innovators", "buyers" of innovation, or "buyers and makers".

[33] This is only done in relation to two BEEPS indicators mentioned in the previous note and the corruption perception index for which no imputation would be possible. The corruption perception index is only available starting from 2012.

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