COLUMBIA | SIPA
School of International and Public Affairs

European Bank
for Reconstruction and Development

SPRING 2023

DIGITALIZATION PATHWAYS AND SPILLOVERS IN THE COUNTRIES WHERE THE EBRD INVESTS

Cases of Ukraine, Estonia, the Kyrgyz Republic, and Poland

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Abstract

We are transitioning into an intelligent, interrelated world where the value of connectivity is unlocked, and the digital economy is thriving. The digital economy is becoming a key driving force behind economic development as the impact of digital technologies goes beyond the traditional tech sectors, and digital investments are spilling over from one company to the next, multiplying their final impact.

The challenge with understanding the linkage between digital transformation and spillover effects is the immense scope of economic synergies arising from digital transformation. Also, there is limited research on the impact of digital transformation because of the difficulty in measuring and monitoring spillovers. To fill this gap in current literature and effectively answer how digital pathways lead to digital spillover effects, the report jointly investigates both quantitative and qualitative inputs with regard to digital transformation.[1]

On the quantitative analysis side, the research evaluated aggregate trends, developed a new Connectivity Score Index, and conducted regression analyses. The Methodology Section provides specifics on the research approach. Then, in the Sectoral Analysis Section, the main results of the regression analysis between the previously mentioned Connectivity Scores and Corruption Perception Index, financial indicators, and agriculture indicators are explained. The analysis indicates that digital transformation has a positive effect on reducing corruption, expanding domestic credit, reducing bank costs, boosting agricultural exports, and enhancing agricultural total factor productivity.

On the qualitative analysis side, we conducted rigorous literature reviews and expert interviews to produce case studies for four countries: Estonia, Ukraine, Poland, and the Kyrgyz Republic. In the Country Profile Analysis Section, we identified drivers and barriers to digital transformation based on economic, environmental and external, regulatory-institutional, technical, and socio-cultural factors, as well as pivotal events in the digital journeys of these countries. A detailed analysis of these case countries has been added in the supplementary document to this report. Ultimately, we found that trust, digital security, data privacy, digital skills, and digital financing are all significant accelerators to a successful digital transformation.

The report concludes with a number of suggestions for maximizing digital spillover effects. The Policy Recommendations Section includes suggestions on utilizing data and monitoring progress, consistency with digital development agendas, targeted investments, next steps in the form of guiding principles and frameworks, and further research themes that would be advantageous to conduct. This report's findings and recommendations aim to assist the EBRD in maximizing digital spillover effects in their future investments.

[1] The report has been prepared as part of the SIPA Spring 2023 capstone deliverables to the European Bank for Reconstruction and Development (EBRD).

Introduction

Project Objectives

This report aims to model digitalization pathways and spillovers in the economies where the European Bank for Reconstruction and Development (EBRD) invests. More specifically, four case countries: Estonia, Ukraine, Poland, and the Kyrgyz Republic—were investigated to better understand the digital spillover effects on the economy. This analysis predominantly focused on two sectors: finance and agriculture. Ultimately, the findings of this paper can be used to guide the EBRD's future investments, policy dialogue, and advisory services. Although this paper focuses more narrowly on the aforementioned four countries, the wide variety of cases investigated supports the applicability of this research to other countries in which the EBRD invests.

Methodology

Literature Review:

We looked at various sources to inform the direction of our research. Our sources include, but are not limited to, the EBRD's transition report, the Organization for Economic Co-operation and Development (OECD), the International Monetary Fund (IMF), the United Nations Conference on Trade and Development (UNCTAD), Oxford Economics, etc. Through a review of the relevant literature, we acquired a deeper understanding of potential research methodologies and potential indicators to incorporate into this research. In addition, a survey of the literature review has assisted us in compiling profiles of the drivers and obstacles behind digital transformation in our selected case countries.

Expert Interview:

More than 20 interviews with subject matter experts were conducted. We interviewed current and/or former government ministers from Estonia, Poland, Ukraine, the Kyrgyz Republic, and Slovenia, university professors, economists from multilateral organizations and consulting firms, and experts on digital developments. In particular, our intensive interviews with practitioners from the Kyrgyz Republic helped provide information to fill up the gap in the literature review and data sources. A wide range of experts was contacted in order to obtain a comprehensive perspective on digital spillovers and digitalization journeys in our case countries and beyond. Common topics discussed across each interview include barriers to digitalization, drivers for digitalization, sector-specific observations, and government-led versus private-led initiatives. Please refer to **Appendix 1** for all interviews conducted with the relevant experts.

Quantitative Analysis:

The insights that we have gained through academic papers and subject matter experts have helped shape the design of our quantitative analysis, which consists of three components: Connectivity Scores, global aggregate outcomes, and sectoral analysis. We designed the Connectivity Scores to reflect 214 countries' development levels in digital infrastructure. Then, we used data to comprehend the overall

economic effects of ICT investments on GDP per capita. Finally, our sectoral analysis analyzed the relationship between Connectivity Scores and indicators reflecting countries' corruption levels, financial stability, and agricultural productivity. The purpose of using quantitative analysis is to empirically examine the effects of digital transformation on countries' overall economic growth and sectoral performance, thereby understanding the scope of digital spillover effects.

Connectivity Score

In its Transition Report 2021-22, the EBRD introduced a new digitalization index to compare the economies of the EBRD's regions with those of a few other comparable economies. The digital enabler index measures infrastructure, skills, regulations, and government provision of digital services. In the earliest stages of our research, we aimed to expand the measurements to include as many countries as possible so that we could help expand the application of the EBRD's digitalization indexes and comprehend global digital pathways. However, we discovered that databases had adopted different methodologies for measuring digitalization and that not all indicators have data for all countries. Specifically, the OECD's "Going Digital Toolkit" evaluates the level of digitalization in seven areas: Access, Use, Innovation, Jobs, Society, Trust, and Market openness. Despite the exhaustive nature of this measurement, the database only contains data for a number of European countries.

In light of the EBRD's indexes on Digital Enablers and Digital Outcomes, we developed a Connectivity Score to measure the availability of mobile and broadband internet. This index can serve as a weather vane to indicate the status of countries' digital infrastructure development and their level of digital transformation. The availability of Internet services is essential for the public to reap the benefits of digital transformation. The score was calculated based on the following factors: individuals using the internet, fixed broadband subscriptions, mobile cellular subscriptions, and fixed telephone subscriptions. Some of these indicators have been utilized by the infrastructure pillar of the EBRD's Digital Enablers Index. In the OECD's Going Digital Toolkit, Internet users and usage fall under the "Use" and "Society" categories, while fixed broadband and mobile broadband penetration fall under the "Access" category.

We downloaded data from the World Bank, whose original source is the International Telecommunication Union (ITU). Please refer to **Appendix 2** for countries' most recent Connectivity Scores and **Appendix 3** for a detailed description of the measurements and sources of the four indicators used in our Connectivity Score.

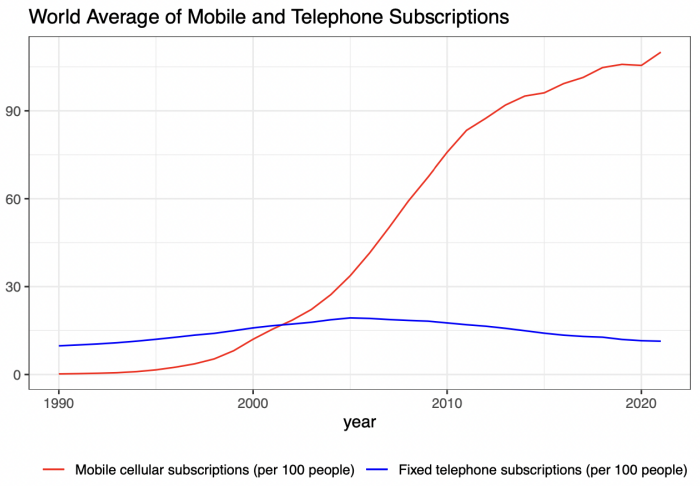
After conducting exploratory data analysis on the four indicators mentioned earlier, we noticed that the number of mobile cellular subscriptions had surpassed the number of fixed telephone subscriptions since the early 2000s, as shown in **Figure 1**. The fact that more and more people use mobile phones instead of fixed telephone lines exemplifies the development of communication technologies. To better capture the technological evolution of digital infrastructure, we decided to design the Connectivity Score using the formula below:

$$Connectivity = \frac{1}{3}\left(Internet + Fixed\_Broadband + max(Mobile\_Cellular, Fixed\_Telephone)\right)$$

Instead of taking the average of these four indicators, we decided to take the highest value from either mobile cellular or fixed telephone subscriptions, add it to the values for internet users and fixed broadband subscriptions, and then take the average of these three segments to determine the final score. We developed the Connectivity Score for 214 countries from 1990 to 2021.

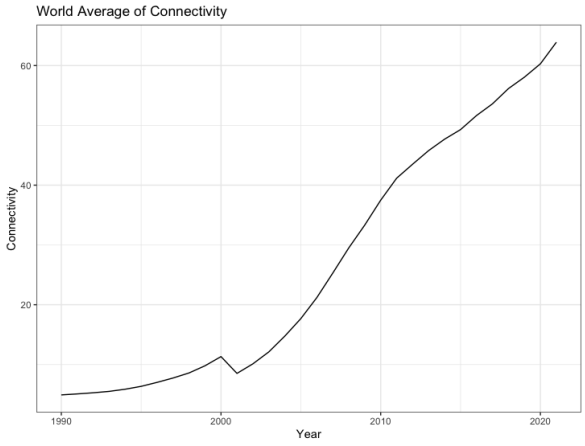
Figure 2 illustrates the average global Connectivity Score. Notably, there was a slight decline at the beginning of the 2000s, followed by rapid growth. The map in **Figure 3** illustrates the geospatial distribution of countries' Connectivity Scores. It demonstrates that many African countries perform poorly in terms of connectivity. **Table 1** presents the rank and percentile of the case countries based on the distribution of the Connectivity Score for 214 countries. Estonia has the most advanced digital infrastructure, followed by Poland, Ukraine, and the Kyrgyz Republic. Later, the connectivity index will be incorporated into the sectoral analyses for finance and agriculture.

Figure 1: World Averages of Mobile and Telephone Subscriptions



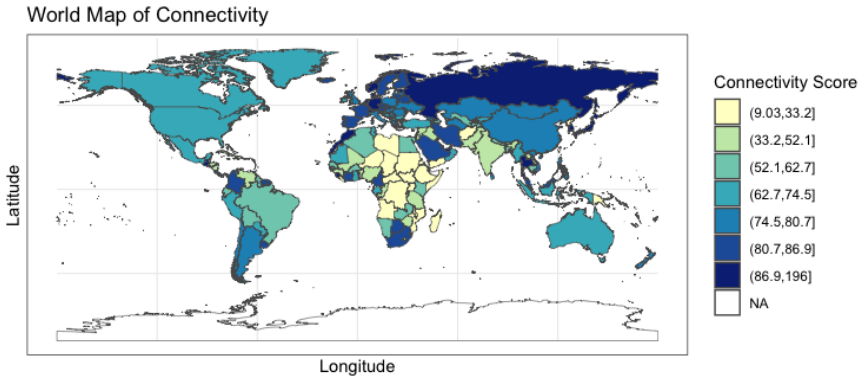
Data Source: World Bank; Graph: Report Team

Figure 2: Global Average of Connectivity Score



Data Source: World Bank; Graph: Report Team

Figure 3: World Map of Connectivity



Data Source: World Bank; Graph: Report Team

Table 1: Countries' Rank and Percentile Based on their Connectivity Scores

Country	Rank	Percentile
Estonia	21	90.65%
Poland	64	70.65%
Ukraine	83	61.68%
Kyrgyz Republic	108	50.00%

Source: Report Team

1. Conclusion and Recommendation:

Our Connectivity Scores can assist the EBRD in capturing the countries' digital development. We decided to consider the maximum value of mobile or fixed telephone subscriptions in our approach. In light of the evolution of technological advancements, the EBRD can consider similar approaches when developing its own indexes on Digital Enablers and Digital Outcomes.

Limitations

Consultations with the professors at Columbia University and the EBRD economists led us to the conclusion that creating a quantitative model to measure the spillover effects of digital transformation on the overall economy may be beyond the scope of our limited time, given the difficulty of finding a comprehensive data set to cover as many countries as possible and train the model. As a result, we utilized available data to analyze digital spillover effects on aggregate and sectoral levels, created the Connectivity Scores to measure digital developments, and conducted case studies to complete country-level analysis.

The spillover effects of digitalization are extraordinarily extensive and impact a vast array of societal and commercial sectors. It influences finance, agriculture, infrastructure, manufacturing and services, energy, social interactions, and firm-level success, to mention a few. Consequently, we acknowledge that our research only examines a minor portion of the digital spillovers that occur. To provide the EBRD with a greater value-add, we decided to focus on and provide a detailed analysis of finance, agriculture, and corruption. These were the areas consistently highlighted by digital experts we interviewed as the most crucial ones where digital transformation caused positive spillovers. Nonetheless, it is essential to consider the context of a country. For instance, Estonia does not have a significant agricultural presence. There was also tremendous data availability in the finance and agriculture sectors compared to other industries.

Furthermore, a few limitations must be mentioned in light of the methodology we adopted. These limitations include:

Time Factor and Omitted Variables

The Connectivity Score is highly correlated with time. For instance, as time has progressed from 1990 to 2021, the Connectivity Score has increased, making intuitive logic given that countries have become increasingly digital over time. Consequently, it is essential to consider that some of the trends investigated in the data interpretation may result from time rather than connectivity. Due to the limited time available for this project, we could not conduct extensive research on potential omitted variables, which could threaten the model's validity. We mitigate potential biases arising from the time factor and omitted variables by employing fixed effect models in our sectoral analysis. The Sectoral Analysis Section provides additional detail.

Connectivity Score Not Sector Specific

As mentioned in the section on methodology, the Connectivity Score comprises a limited number of indicators: individuals using the internet, fixed broadband subscriptions, mobile cellular subscriptions, and fixed telephone subscriptions. These indicators were chosen due to data limitations and the extensive emphasis placed on them in scholarly literature. However, it is essential to recognize that other indicators may be used to explain the trends. Even though our Connectivity Score is used as a proxy for digital transformation, it does not account for every digitalization factor. The connectivity index also considers a general overview rather than sector-specific indexes, and this is essential to keep in mind, as some sectors may be more digitalized than others.

Lack of Reflection on the Russian Invasion of Ukraine

Countries have data on their most recent Connectivity Scores through 2020 or 2021. Consequently, the data analyzed in this paper only partially reflect how the Russian invasion of Ukraine has affected Ukraine's (and other neighboring countries) digital transformation. However, the country profile analysis delves deeper into the impact of the Russian invasion on Ukraine's digitalization.

2. Conclusion and Recommendation

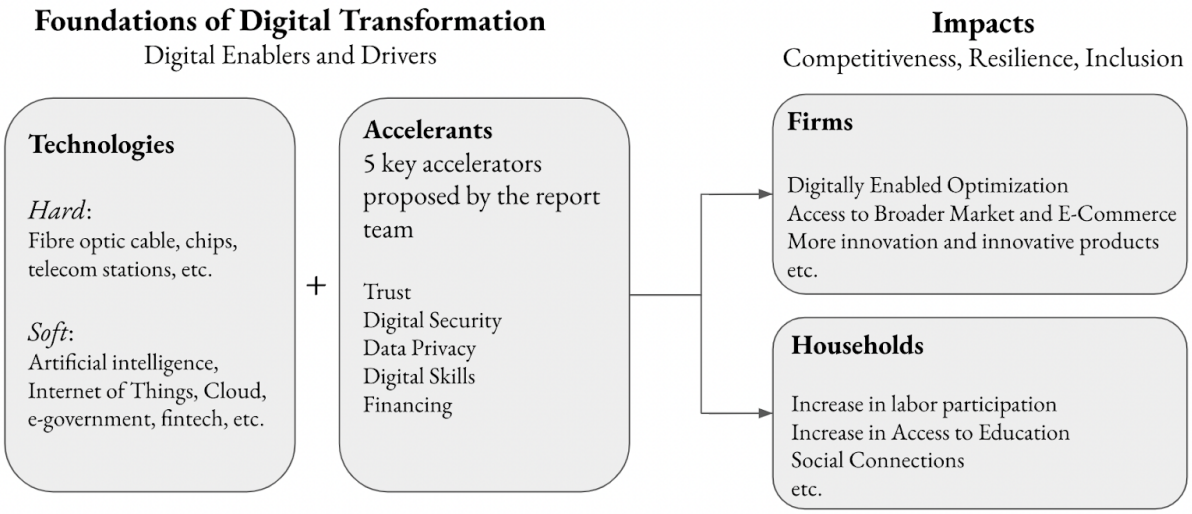
Future research can measure the effects of digital transformation on specific sectors. It may be advantageous to evaluate the level of digital development in a particular sector rather than the level of digital infrastructure as a whole. In the financial sector, for instance, the level of digitalization can be determined by the number and variety of e-banking services, the efficacy of mobile banking applications, and the degree of automation of operational processes in banks and other financial institutions. More precise measurements of each sector's level of digitalization could provide a clearer picture of the impact of digital advancements.

Digital Spillover Effects

Our research focuses primarily on digital transformation. Unlike digitization, which converts analog information to digital format using information technology (IT), digital transformation goes beyond this by utilizing new digital technologies such as social media, mobile technology, and analytics to improve business operations significantly. Digital transformation affects productivity and contributes to economic growth through increasing labor participation, digitally enabling process optimization, increasing access to a broader market space, and boosting innovation and innovative products. This results in improved customer experiences, streamlined processes, and innovative business models. However, digital transformation's success does not depend only on the success of a digital technology innovation alone. On a larger scale, the availability of human resources with capable digital skills, a government ecosystem that supports digital agendas in both the private sector and government services, financial stability, and technical support for companies and the government are crucial.

Through our literature review, we found that digital transformation can exert spillover effects beyond enhancing work productivity and production outputs by providing firms and households with new opportunities that were previously unattainable. In this study, we define spillover effects as the occurrence of economic events and outcomes because of drivers in a seemingly unrelated context.[2]

Figure 4: Diagram on the Pathway of Digital Transformation



Source: Report Team

Figure 4 illustrates our team's vision of the digital transformation process. The network effect is one of digital transformation's most significant spillover effects. Multiple applications have been found for digital platforms such as mobile phones, the Internet of Things (IoT), and artificial intelligence, and their use has increased exponentially. Smartphones, for instance, have evolved from primarily being used for communication to platforms for entertainment, mobile banking, digital identification, and e-government services. Due to the network effect of digital technologies, the value of these technologies

[2] Kenton, Will. "Understanding the Spillover Effect." Investopedia. Investopedia, September 29, 2020. https://www.investopedia.com/terms/s/spillover-effect.asp.

increases as more firms and households adopt them, resulting in even greater adoption. The report identifies five important themes that help accelerate the adoption of digital technologies by establishing the necessary conditions. In the Case Study Overview section, we will elaborate on these five essential themes in greater detail. Governments can play an active role in achieving these conditions by establishing laws and regulations and providing services.

Digital transformation can encourage more individuals to join the formal economy. By eliminating the sometimes inefficient human factor, digital services can facilitate the process of doing business, account opening, and identification verification. In addition, digital payments can facilitate compensation delivery to marginalized populations that may have difficulty accessing financial services. The global average costs of digital remittances have remained lower than those of non-digital remittances, and mobile money has been the least costly instrument to originate and receive remittances.[3] In 2016, India introduced a nationwide Unified Payment Interface (UPI) that facilitates settlements of payments across the country's banking network. Dubey and Purnanandam (2023) discovered that household income has increased significantly in districts with a higher intensity of cashless transactions after the launch of UPI.[4]

E-commerce has also played a critical role in bridging the divide between rural and urban areas by providing access to goods and services that were previously unavailable in remote areas. To a certain extent, China's online trading platforms (e.g., Alibaba's Taobao.com) have served as private regulatory intermediaries (PRIs) that help support the government's role in enforcing contracts, preventing fraud, and settling disputes.[5] The state has outsourced social and political functions to these digital platforms, which provides a viable solution to market failure and a governance deficit. To follow the impacts specific to e-commerce, metrics such as the percentage of the rural population shopping online, the average delivery time to rural households, and the prices of goods in comparison with similar items sold offline can be of research interest.

Measurements

Numerous positive social effects have been generated by digital transformation, some of which may be difficult to measure. Therefore, it is possible that traditional economic indicators, such as a country's gross domestic product (GDP), may not fully capture the benefits brought about by technology synergies, social inclusion, and increased access to services as a result of digital transformation. In other words, the impacts of digital transformation contribute to an extensive array of social benefits.

A few additional indicators can help map investment activities related to digital transformation at the firm level. The EBRD-World Bank Business Environment and Enterprise Performance Survey (BEEPS)[6] and the annual European Investment Bank Investment Survey (EIBIS)[7] are two examples that

[3] "Remittance Prices Worldwide Quarterly- Issue 42, June 2022 - World Bank." World Bank, June 2022. https://remittanceprices.worldbank.org/sites/default/files/rpw_main_report_and_annex_q221.pdf?ref=hackernoon.com.
[4] Dubey, Tamanna Singh, and Amiyatosh Purnanandam. 2023. "Can Cashless Payments Spur Economic Growth?" *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4373602.
[5] Liu, Lizhi. "From Click to Boom: The Political Economy of E-Commerce in China." 2018.
[6] "The EBRD's Economic Surveys." n.d. Ebrd.com. Accessed January 30, 2023. https://www.ebrd.com/what-we-do/economic-research-and-data/data.html.
[7] "EIB Investment Survey (EIBIS)." n.d. Eib.org. Accessed January 30, 2023. https://www.eib.org/en/publications-research/economics/surveys-data/eibis/index.htm?sortColumn=startDate&sortDir=desc&pageNumber=0&itemPerPage=10&pageable=true&language=EN&defaultLanguage=EN&tags=5bf8095afa70f13f9d3b51b3&ortags=true&orCountries=true

can provide insights into the needs of businesses and the difficulties of doing business, the former of which focuses on countries in Eastern Europe and Central Asia, and the latter of which addresses countries across all EU Member States, the UK, and the US.

Additionally, the World Bank's B-Ready project, a new approach for assessing the business and investment climate and a succession to the discontinued Doing Business (DB) report, recognizes the adoption of digital technologies, either by governments or businesses, to enable efficient provision of public services and foster productivity and innovation.[8]

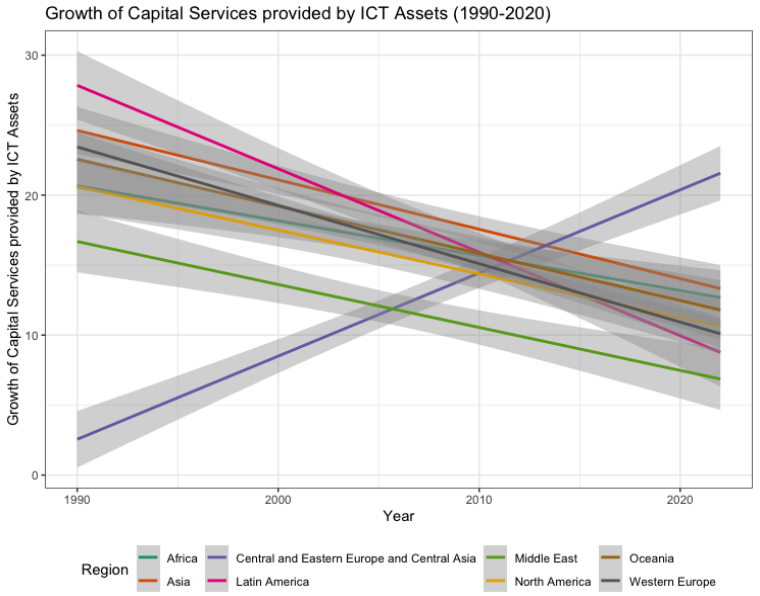
Aggregate Outcomes

Digital transformation can enhance economic outcomes at the aggregate level by increasing labor productivity. According to a report by Oxford Economics, on average, when the digital investment-to-GDP ratio increases by one percentage point, labor productivity is estimated to increase by 0.9 percentage points.[9] After learning about the effects of digital investments on total GDP, we were interested in exploring whether the digital transformation has generated positive impacts on GDP per capita, an estimate of the average income per person in a country. Using GDP per capita allows us to examine whether investments in ICT can improve the standard of living through increased income, employment, and consumption.[10]

Our study uses the Total Economy Database's (TED) ICT capital asset data to measure digital investments. These assets include computer hardware and equipment, telecommunication equipment, and computer software and services.[11] However, it is essential to note that digital investments can extend beyond ICT capital assets to include research and development costs related to technology development and government subsidies for digital infrastructure-building.

[8] The Development Economics Global Indicators Group. 2022. "Business Enabling Environment."
[9] Huawei, and Oxford Economics. "Digital Spillover - Measuring the True Impact of the Digital Economy." Oxford Economics. Accessed May 1, 2023. https://www.huawei.com/minisite/gci/en/digital-spillover/index.html.
[10] Economist Robert Lucas suggests that GDP per capita, as an indicator of per capita income, is a good measurement for economic development because it is closely associated with other indicators that help describe societal advancements, such as the infant mortality rate and the adult literacy rate. However, some economists have argued that per capita income is not sufficient to explain all the variations. For this study, we choose GDP per capita not only because it is widely used in academics, but also given its relevance to the direct impacts of digital transformation. But we would like to acknowledge that it is not the only indicator that can help reflect the changes brought by digital transformation.
[11] The Conference Board Total Economy Database™, April 2022. Retrieved February 5, 2023, from https://www.conference-board.org/data/economydatabase/total-economy-database-productivity

Figure 5: Growth of Capital Services Provided by ICT Assets



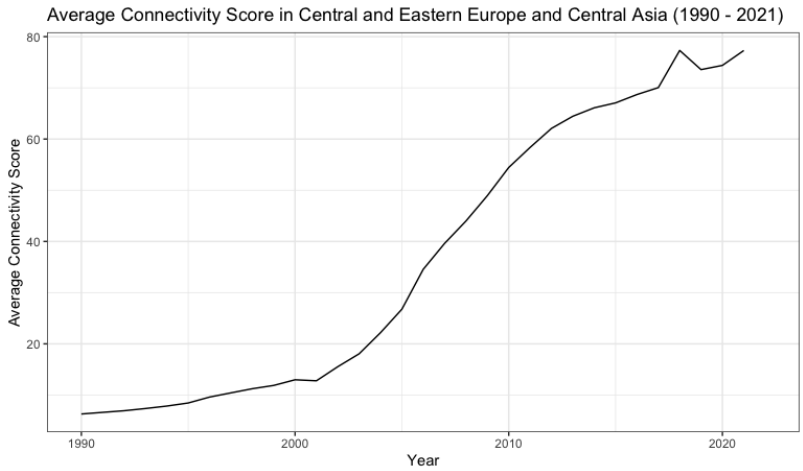
Data Source: Total Economy Database (TED); Graph: Report Team

Based on **Figure 5,** depicting the regional growth of capital services provided by ICT assets over the last thirty years, Central and Eastern Europe and Central Asia[12] is the only region exhibiting a positive trend, in contrast to all other regions. This region appears to possess unique attributes that contribute to its higher incremental growth of capital services provided by ICT assets. During our interview with Dr. Jan Svejnar, Columbia Professor of Economics and International Affairs, he commented that many countries in Central and Eastern Europe and the Central Asia region had experienced a historical legacy of transitioning from centrally planned economies to market systems. Some of these countries might have experienced leapfrogging effects from the latest technologies, and some are actively ramping up their digital infrastructure to ward off potential cyber threats from Russia. **Figure 6** reflects that the average Connectivity Score in Central and Eastern Europe and Central Asia has increased from 1990 to 2021, and there was an uptick in 2017.

Having observed the positive trend in the growth of capital services provided by ICT assets in Central and Eastern Europe and Central Asia, we decided to investigate this region further, especially given the EBRD's investment focus in the region. In particular, we created a scatter plot, shown in **Figure 7**, to explore the relationship between the growth of ICT assets and GDP per capita.

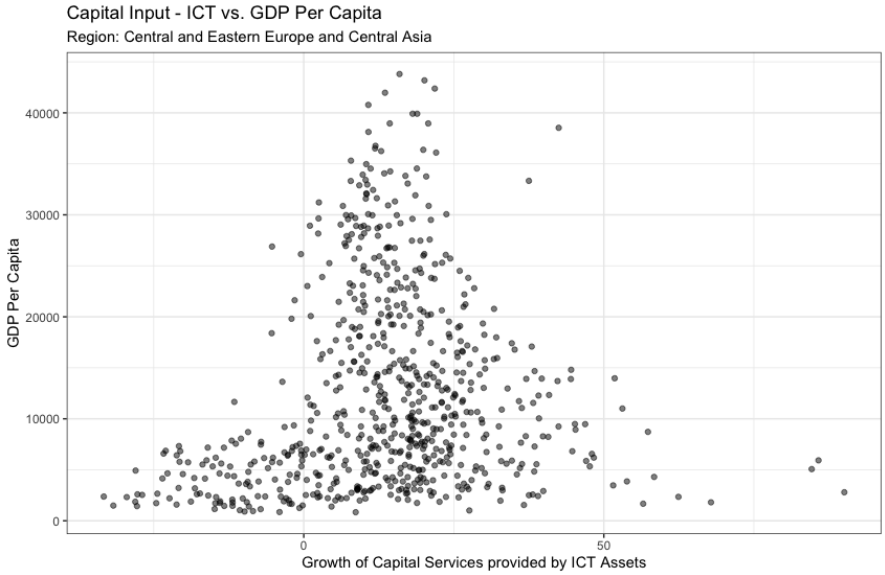
[12] The TED database that we are using specifies this region as Central and Eastern Europe and Central Asia, and we follow this classification.

Figure 6: Average Connectivity Score in Central and Eastern Europe and Central Asia



Data Source: World Bank, Connectivity Score (created by the report team); Graph: Report Team

Figure 7: Growth of ICT Assets and GDP Per Capita



Data Source: Total Economy Database (TED), World Bank; Graph Report Team

3. Conclusion and Recommendation

Although the analysis does not reveal a clear linear relationship between the growth of ICT assets and per capita GDP, it is possible that factors other than ICT investments, such as a more comprehensive adoption and implementation of digital transformation strategies, are required to improve the standard of living. This result supports our proposed diagram of the digital transformation pathway by demonstrating that ICT investments alone may not be strictly correlated with improvements in economic well-being or social welfare. Implementing digital development strategies and adopting new technologies are also essential.

Sectoral Analysis

The following section provides a sectoral analysis focusing on analyzing the finance and agricultural sectors. One of the rationales behind choosing these sectors is the availability of a wide range of indicators that were useful in conducting data analytics. Our primary methodology below involves comparing countries' Connectivity Scores over the past thirty years (1990 - 2021) against indicators that can reflect their performance in the finance and agricultural sectors. Since the connectivity score measures the availability of internet services to the public and helps pinpoint the development stages of countries' digital infrastructure buildup, the following analysis allows us to understand how improvements in the digital infrastructure sector have created spillovers in the finance and agricultural sectors.

Connection with Corruption

One of the benefits provided by digital transformation is to help anti-corruption campaigns. Digitalization of public services lowers corruption by enhancing transparency and minimizing human factors in public governance. Research conducted by Dobrolyubova et al. (2019) on the impact of digitalization on government performance suggests that there is a statistically significant positive correlation between government digitalization and public administration performance, government effectiveness, and control of corruption.[13]

Hence, we analyzed the relationship between the Corruption Perception Index (CPI) by Transparency International[14] and our designed Connectivity Score. The CPI is a comprehensive assessment of the country's corruption level based on surveys considering the opinions of different agents, such as experts, business and civil society representatives, and government authorities. The value of the CPI ranges from 0 to 100, with a higher score meaning a lower level of corruption.[15]

The relationship between countries' Connectivity Scores and CPI Indexes was tested using the following population regression function (PRF):

$$CPI_{ct} = \beta_0 + \beta_1 Connectivity + \phi_c + \theta_t + \mu_{ct}$$

It can be noted that "c" indexes countries and "t" indexes years. We adopted the fixed effect model to control for unobserved factors that:

a) vary between countries but are constant over time (e.g., countries' inherent characteristics, geographic features, and development stages); or

b) vary over time but are shared by all entities (e.g., the introduction of the Internet, smartphones, AI, etc.).

The data for 182 countries, including Estonia, the Kyrgyz Republic, Poland, and Ukraine, was considered for the time period from 2012 to 2021, as the methodology of the CPI calculation changed in 2012.

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[13] Dobrolyubova, Elena, Elena Klochkova, and Oleg Alexandrov. 2019. "Digitalization and Effective Government: What Is the Cause and What Is the Effect?" In *Communications in Computer and Information Science*, 55–67. Cham: Springer International Publishing.

[14] Corruption Perception Index. Transparency.org. Accessed March 26, 2023s. https://www.transparency.org/en/cpi/2022https://www.transparency.org/en/cpi/2022.

[15] "The ABCs of the CPI: How the Corruption Perceptions Index Is Calculated - News." 2021. Transparency.org. December 20, 2021. https://www.transparency.org/en/news/how-cpi-scores-are-calculated.

Table 2: Regression Results of Connectivity Scores vs. Corruption Perception Index

	cpi
connectivity	0.038**
	(0.011)
Num. obs.	1744
Num. groups: factor(year)	10
Num. groups: factor(country)	158
R^2 (full model)	0.981
R^2 (proj model)	0.010
Adj. R^2 (full model)	0.979
Adj. R^2 (proj model)	0.009

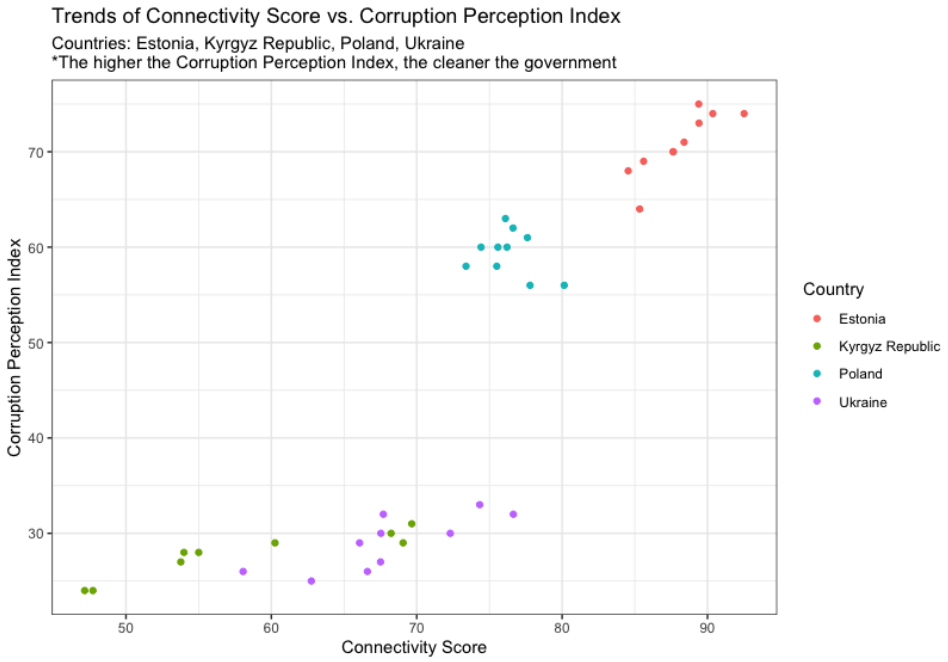
$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Source: Report Team

Table 2 illustrates the regression analysis results and suggests a statistically significant positive association between Connectivity Scores and CPI Indexes. The coefficient of 0.038 with a p-value less than 0.01 demonstrates that improving the country's digital infrastructure tends to lower the level of corruption.

After analyzing the relationship on a global level, we examined the relationship between Connectivity Score and CPI among the four case countries (Estonia, the Kyrgyz Republic, Poland, and Ukraine). The relationship is the same for the larger sample; a positive relationship between Connectivity Score and the CPI for the four case countries can be observed.

Figure 8: Connectivity Score vs. Corruption Perception Index (Case Countries)



Data Source: Transparency International, Connectivity Score (created by the report team); Graph: Report Team

Figure 8 illustrates that among these four case countries, countries with higher Connectivity Scores tend to have higher CPIs, meaning that countries with higher levels of digital development have a lower level of corruption. However, there are differences in the impact of the Connectivity Score on the CPI of each country.

In the case of Ukraine and the Kyrgyz Republic, we can observe a weaker impact of digital transformation on the corruption level of the country in comparison with Estonia and Poland. Despite the rapid growth of digitalization in Ukraine and the Kyrgyz Republic, it does affect corruption slower. Compared to Poland and Estonia, Ukraine and the Kyrgyz Republic are in the early stages of digital transformation; the Connectivity Score for Ukraine and the Kyrgyz Republic ranges from 47 to 76.

However, digital transformation is developing rapidly in Ukraine and the Kyrgyz Republic: the growth rates of Ukraine's and the Kyrgyz Republic's Connectivity Scores are 32% and 47%, respectively, from 2012 to 2021, whereas the growth rates in Estonia and Poland are slower at 8% and 9%, respectively. Ukraine and the Kyrgyz Republic initially have the highest levels of corruption, with a CPI of 33 and 27, respectively; Estonia and Poland have considerably higher CPIs, at 55 and 74, respectively. In the case of Estonia, the country with the highest digitalization level among the case countries, we can see that it is benefiting the most from the marginal increase in digitalization with respect to corruption levels. Although the Connectivity Score growth rate is only 8%, the improvement in CPI is from 64% to 74%, or 16%.

In Poland, the trend of digitalization and corruption is unexpectedly the opposite. Despite the initial higher level and growth of the Connectivity Score, the CPI is decreasing. The CPI in Poland started to decline in 2015, from 64 to 55 as of 2022. According to the assessment of the European Commission in 2022, the main reasons for the recent corruption deterioration in Poland are the weakening of judicial independence due to political interference[16] and the deterioration of women's and LGBTQI+ rights.[17]

The significant impact of digital infrastructure development on corruption in Estonia may provide additional motivation for developing countries such as Ukraine and the Kyrgyz Republic to invest in digital development. When the country has reached a higher level of digitalization, it is anticipated that the subsequent positive effects of digital transformation will be more pronounced, as the implementation of digital innovations supported by a more robust digital infrastructure will have greater coverage and impact.

4. Conclusion and Recommendation

There is a statistically significant positive correlation between the Connectivity Score and the level of the Corruption Perception Index in the country, indicating that digital transformation is an effective instrument for reducing corruption. Similar associations can be observed in our case study countries; however, the effect of digital transformation is slower in countries with lesser levels of digitalization, such as Ukraine and the Kyrgyz Republic, compared to more digitally advanced countries, such as Estonia. In Poland, the opposite trend is observed due to factors unrelated to the digital transformation: a decline in judicial independence and human rights. Consequently, it is recommended to target the

[16] N.d. Europa.Eu. Accessed February 20, 2023o. https://commission.europa.eu/system/files/2022-07/48_1_194008_coun_chap_poland_en.pdf.
[17] "CPI 2021 for Western Europe & European Union: Trouble Ahead for Stagnating Region - News." 2022. Transparency.org. January 25, 2022. https://www.transparency.org/en/news/cpi-2021-western-europe-european-union-trouble-ahead-for-stagnating-region.

EBRD investments in digital transformation projects aimed at enhancing transparency and adding impact to the transparency component of the project's metrics to represent the comprehensive impact of the digitization projects.

Finance Sector

Digital transformation in the finance sector accelerates the development of financial services. One of the examples is e-banking, which facilitates the expansion of credit and consumption. Digital infrastructure creates favorable conditions for the advancement of financial technologies, which makes financial services more accessible and promotes the expansion of financial inclusion in the country.[18]

For the financial sector, we tested the relationship between Connectivity Scores and the below three indicators:

1) Domestic Credit to Private Sectors (% of GDP) (denoted by the variable name "*credit"*): financial resources provided by financial corporations to the private sector through instruments such as loans, non-equity securities, trade credits, etc.[19] We are interested in exploring the changes in domestic credit because they have a significant effect on economic growth by stimulating investments and fostering entrepreneurship and innovation;

2) Bank Cost to Income Ratio (denoted by the variable name "*bcost"*): the ratio of a bank's operating expenses to the sum of net-interest-revenues and other operating income.[20] The hypothesis is that the development of digital infrastructure should create proper conditions for digitalization in financial institutions, which in turn is expected to lower bank costs. The indicator of Cost-to-Income reflects the level of banks' profitability;

3) Bank Concentration (%) (denoted by the variable name "*conc"*): share of the three largest commercial banking assets in total commercial banking assets.[21] It is expected that the improvement of digital development will increase competition among financial institutions, as financial institutions will have a higher capacity to expand their customer base with the widespread adoption of e-banking. This indicator is of interest because it assists policymakers and regulators in comprehending financial stability, competition, and efficiency.

We tested the relationship between countries' Connectivity Scores and the above-mentioned indicators using the following population regression function (PRF), where "c" indexes countries and "t" indexes years.

[18] Zhang, Tao. ay 8 2018. "Digitization of Money and Finance: Challenges and Opportunities." International Monetary Fund. ay 8 2018. https://www.imf.org/en/News/Articles/2018/05/08/sp050818-digitization-of-money-and-finance-challenges-and-opportunities.
[19] "Domestic Credit to Private Sector (% of GDP)." n.d. World Bank Open Data. Accessed March 15, 2023. https://data.worldbank.org/indicator/FS.AST.PRVT.GD.ZS.
[20] "Bank Cost to Income Ratio." n.d. Worldbank.org. Accessed March 15, 2023. https://databank.worldbank.org/metadataglossary/global-financial-development/series/GFDD.EI.07.
[21] "Bank Concentration (%)" n.d. Worldbank.org. Accessed March 20, 2023. https://databank.worldbank.org/metadataglossary/global-financial-development/series/GFDD.OI.01#:~:text=Bank%20concentration%20(%25),of%20total%20commercial%20banking%20assets.

$$Credit_{ct} = \beta_0 + \beta_1 Connectivity + \phi_c + \theta_t + \mu_{ct}$$
$$Bcost_{ct} = \beta_0 + \beta_1 Connectivity + \phi_c + \theta_t + \mu_{ct}$$
$$Conc_{ct} = \beta_0 + \beta_1 Connectivity + \phi_c + \theta_t + \mu_{ct}$$

Similar to our previous approach to analyzing the relationship between Connectivity Scores and CPI Indexes, we adopted the fixed effect model here to control for unobserved factors and minimize the biases brought by the lack of control variables in the model. **Table 3** shows the regression analysis results and suggests a statistically significant positive association between Connectivity Scores and CPI Indexes.

Table 3: Regression Results for Connectivity Scores and Financial Indicators

	credit	bcost	conc
connectivity	0.381***	−0.093***	−0.027
	(0.043)	(0.024)	(0.031)
Num. obs.	4655	3667	3768
Num. groups: factor(year)	27	22	22
Num. groups: factor(country)	181	172	173
R^2 (full model)	0.904	0.502	0.741
R^2 (proj model)	0.058	0.005	0.001
Adj. R^2 (full model)	0.900	0.474	0.727
Adj. R^2 (proj model)	0.057	0.005	0.000

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Source: Report Team

We can see that only Domestic Credit to Private Sectors and Bank Cost-to-Income Ratio hold statistically significant associations with Connectivity Scores. In the following analysis, we would like to focus more on these two variables.

Firstly, the results suggest that higher levels of digital transformation are associated with more credit granted to the private sector. Digital channels can ease the credit application process and enable banks to reach more customers. For example, the rise in popularity of digital wallets, partly accelerated by the COVID-19 pandemic, facilitates the provision of payment options, including Buy-Now-Pay-Later (BNPL), a type of installment loan that divides purchases into multiple payments. Bian et al. (2023) noted that e-wallet credit provided through BNPL has increased consumer spending and expanded FinTech-based credit to underserved consumers.[22]

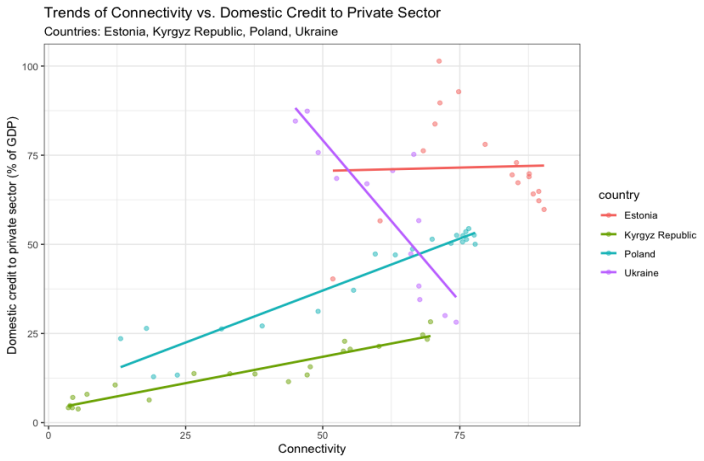
Second, the results suggest that higher levels of digital transformation are associated with fewer bank costs, which strengthens our previous hypothesis that digital transformation can help reduce banks' costs by reducing costs, enhancing customer experiences, improving risk management, and increasing revenues. McKinsey found a correlation between the profitability of banks and the extent to which they have embraced digitalization in certain specific areas.[23] Profitable banks tend to invest in a few common areas, such as back-office automation of processes, digitization of document management, credit decision automation, and the application of big data analytics in sales campaigns. Banks with higher digital connectivity and enablement levels in these areas are more likely to enjoy higher profit margins.

[22]Bian, Wenlong, Lin Cong, and Yang Ji. 2023. "The Rise of E-Wallets and Buy-Now-Pay-Later: Payment Competition, Credit Expansion, and Consumer Behavior." *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4407023.
[23] Caldo, Giuliano, Matthias Hoene, and Tunde Olanrewaju. 2014. "How Winning Banks Refocus Their IT Budgets for Digital." Mckinsey.com. McKinsey & Company. December 1, 2014.
https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/how-winning-banks-refocus-their-it-budgets-for-digital.

We further analyze the relationship between these two financial indicators and our case countries' Connectivity Scores. **Figure 9** suggests that countries with a higher level of Connectivity Scores have a higher level of Domestic Credits to the Private Sector. Estonia, a leader in digitalization among the case countries, has the highest share of domestic credit. But it is interesting to note that Ukraine and Estonia have experienced some fluctuations in their domestic credits to the private sector despite increases in their Connectivity Scores.

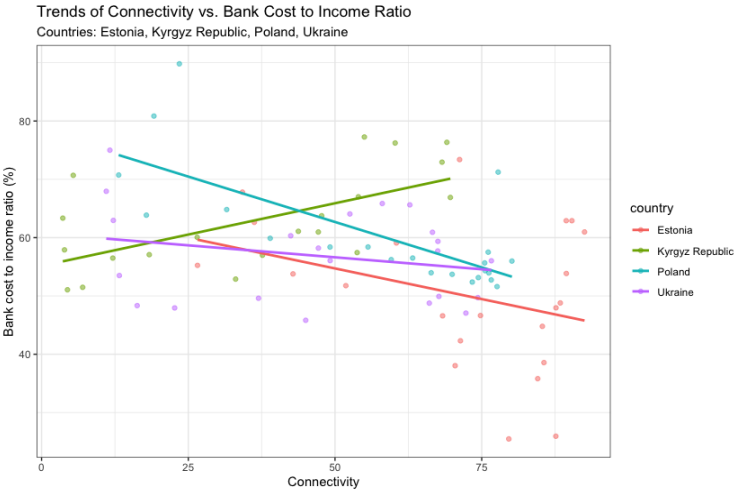
As seen in **Figure 10**, the scatterplot of connectivity trends and bank cost-to-income ratio shows downward trends for all countries except for the Kyrgyz Republic. Our approach to examining case countries' performance for these two financial indicators is limited since other factors, including macroeconomic trends or financial recessions, can impact the result. Future research on how countries exhibit different trends in the relationship between their digital development levels and financial indicators might be worth investigating.

Figure 9: Connectivity vs. Domestic Credit to the Private Sector (Case Countries)



Data Source: World Bank; Graph: Report Team

Figure 10: Connectivity vs. Bank Cost to Income Ratio (Case Countries)



Data Source: World Bank; Graph: Report Team

5. Conclusion and Recommendation

To assess the effect of digital transformation on the finance sector, we considered domestic credit, bank profitability, and competition in the banking sector. As a result of regression analysis, we observe a statistically significant positive association between the Connectivity Score and Domestic Credit to GDP and Bank's Cost to Income ratios; for the Bank's Concentration ratio, the relationship is not statistically significant. Hence, we conclude that developing digital infrastructure can expand domestic credits and cut bank costs. Hence, we believe that investments in Fintech-related projects can further drive countries' financial stability and efficiency and stimulate overall economic growth, and the EBRD can consider continuing its activities in these projects.

Agriculture Sector

The agriculture and food sectors can be impacted by a wide range of digital technologies, many of which do not require substantial user investments. These range from low-tech investments and the use of mobile devices and platforms to facilitate user access to services supporting farm management decisions to high-tech digital farms or logistics management services utilizing integrated systems involving drones, robotics, the Internet of Things (IoT), sensors, and big data analytics. Whether investments in technologies are made on-farm or by service providers, either private or public, the primary reasons to use digital technologies in the agriculture sector include facilitating automated data collection through technology like Radio-Frequency Identification (RFID) tags and other mobile computing solutions. These data can then be shared with the relevant management and other supply chain partners, improving operational efficiency and creating visibility throughout the food supply chain.

Additionally, digital transformation in this sector can allow better monitoring of the health of their livestock and crops, assess soil quality, and plan seed planting patterns. Moreover, the digital technologies used can enhance the reporting process for the framers and the parties involved in the supply chain. Overall, data obtained from these digital technologies could provide enhanced and detailed insights to understand the industry's performance better and make informed decisions.

Furthermore, some other benefits can be achieved due to the agricultural sector's digital transformation. These could be indirect and include reducing costs, reducing the use of chemical products, conserving water resources, increasing per-unit output and environmental sustainability, or providing solutions to old or new constraints and requirements in an environment that is constantly changing.[24]

The subsequent analysis considers three agriculture-related indicators that we claim to be indirectly impacted by the agricultural sector's digital transformation. Hence, they may indicate a pattern associated with digital spillovers.

We again used the fixed effects model to assess the relationship between Connectivity Scores and Agricultural Indicators. Below is our population regression function (PRF), where "c" indexes countries and "t" indexes years.

[24] Fu, Wenqiang, and Rongwu Zhang. 2022. "Can Digitalization Levels Affect Agricultural Total Factor Productivity? Evidence from China." *Frontiers in Sustainable Food Systems* 6. https://doi.org/10.3389/fsufs.2022.860780.

$$Agex_{ct} = \beta_0 + \beta_1 Connectivity + \phi_c + \theta_t + \mu_{ct}$$
$$Methane_{ct} = \beta_0 + \beta_1 Connectivity + \phi_c + \theta_t + \mu_{ct}$$
$$TFP_{ct} = \beta_0 + \beta_1 Connectivity + \phi_c + \theta_t + \mu_{ct}$$

Our analysis focuses on the following indicators:

1) Agricultural raw materials exports (% of merchandise exports) (denoted by the variable name "*agex*"): the share of agricultural products among total merchandise exports, under SITC section 2.[25] Our rationale to consider this variable stems from the literature review indicating that digital technologies help generate data that can potentially connect the players of the agriculture sector and suppliers to new markets, monitor and ensure compliance with standards, and to take trade decisions accordingly[26];

2) Methane emissions (kt of CO2 equivalent) (denoted by the variable name "*methane*"): methane emissions from human activities such as agriculture and from industrial methane production.[27] This variable was considered given that agriculture contributes around 40 - 46% of global methane emissions.[28] Hence, digital transformation projects in the agriculture sector could carry the potential of reducing emissions by streamlining operations and enhancing efficiency;

3) Agricultural Total Factor Productivity (denoted by the variable name "*tfp"*): the amount of agricultural outputs from the combined set of land, labor, capital, and material resources.[29] Digital technology can make agricultural production, the supply of consumables, the transportation and sale of finished products, and other value chains more efficient.[30][31]

Table 4: Regression Results for Connectivity Scores and Agricultural Indicators

	agex	methane	tfp
connectivity	0.024**	2.115	0.138***
	(0.008)	(31.551)	(0.034)
Num. obs.	5246	6423	5430
Num. groups: factor(year)	32	30	31
Num. groups: factor(country)	192	191	156
R^2 (full model)	0.770	0.984	0.580
R^2 (proj model)	0.003	0.000	0.007
Adj. R^2 (full model)	0.760	0.984	0.565
Adj. R^2 (proj model)	0.003	−0.000	0.007

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Source: Report Team

Variables "*agex*" and "*tfp*" in **Table 4** demonstrate statistically significant associations with Connectivity Scores. Hence, the following analysis reflects some insights into these two variables.

[25] "Agricultural Raw Materials Exports (% of Merchandise Exports)." n.d. World Bank Open Data. Accessed March 26, 2023. https://data.worldbank.org/indicator/TX.VAL.AGRI.ZS.UN.
[26] *Technology and digital in agriculture - OECD*. OECD. (n.d.). Accessed March 26, 2023, https://www.oecd.org/agriculture/topics/technology-and-digital-agriculture/
[27] "Methane emissions (kt of CO2 equivalent)." n.d. World Bank. Accessed March 26, 2023. https://data.worldbank.org/indicator/EN.ATM.METH.KT.CE.
[28] Searchinger, T., Herrero, M., & Yan, X. (2021). *Opportunities to Reduce Methane Emissions from Global Agricultur*e. Accessed March 26, 2023.https://scholar.princeton.edu/sites/default/files/methane_discussion_paper_nov_2021.pdf
[29] Fuglie, Keith, Jeremy Jelliffe, and Stephen Morgan. n.d. "International Agricultural Productivity." Usda.gov. Accessed March 26, 2023. https://www.ers.usda.gov/data-products/international-agricultural-productivity/.
[30] Wolfert, Sjaak, Lan Ge, Cor Verdouw, and Marc-Jeroen Bogaardt. 2017. "Big Data in Smart Farming – A Review." *Agricultural Systems* 153: 69–80. https://doi.org/10.1016/j.agsy.2017.01.023.
[31] Creydt, M., and M. Fischer. 2019. "Blockchain and More - Algorithm Driven Food Traceability." *Food Control* 105: 45–51. https://doi.org/10.1016/j.foodcont.2019.05.019.

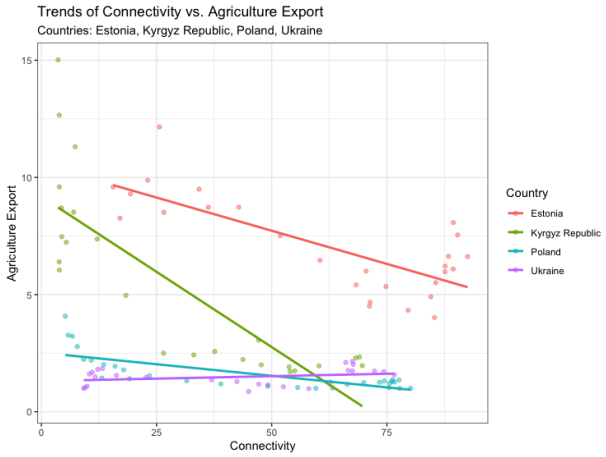
1. Agricultural Exports

Digitalization helps channel more information to farmers and allows them to improve their domestic and international commercial activities. The improved efficiency to create and share data in the agriculture sector and trade of agriculture products provides an opportunity to reduce some long-standing regulatory restrictions on trade and associated market failures, such as missing information and information asymmetries[32], which increase transaction costs, hence impeding beneficial transactions.

Furthermore, new actors are entering the international agro-food value chain due to digital transformation. For example, smaller producers are increasingly having access to a variety of digital technologies that enable them to obtain information regarding product prices, standards, and a variety of services, such as payment services, more easily and at a lower cost, thereby making trade negotiations and transactions more feasible. Further, customers can now directly participate in the trade of agricultural goods, and small agribusinesses have the potential to "go global," given the creation of digital intermediaries that facilitate the flow of money and outputs between farmers and the market. Finally, with complete consumer traceability, production processes can be registered and evaluated, enabling producers to obtain a price premium for customer preferences related to quality or positive externalities resulting from production practices or through "fair trade" systems for producers.[33]

As shown in **Table 4**, agricultural exports (as a percentage of merchandise exports) have a statistically significant positive relationship with Connectivity Scores, suggesting that countries with higher levels of Connectivity Scores are more likely to have increased their share of agricultural exports. Hence, it is possible that countries' improvements in digital infrastructure can have some association with improvements in agricultural exports.

Figure 11: Connectivity Scores vs. Agricultural Exports (Case Countries)



Data Source: World Bank; Graph: Report Team

However, when examining the relationship between Connectivity Scores and Agricultural Exportamong the four case countries, as illustrated in **Figure 11,** we noticed that all four countries except Ukraine had shown a negative pattern. While many other factors can potentially contribute to the decline of agriculture exports, including macroeconomic shocks, shifts in national strategies, and allocation of

[32] Different stakeholders in the supply chain may have divergent preferences and incentives - misalignment of incentives.
[33] Different stakeholders in the supply chain may have divergent preferences and incentives - misalignment of incentives.

economic resources, we cannot conclude much based on these trends. However, the EBRD might consider investigating them, especially if it is interested in investing in the agricultural sector of these four case countries.

2. Agricultural Total Factor Productivity

Digital technologies, including GPS, drones, and sensors, have enhanced agricultural production through precision farming, better crop monitoring, and efficient resource management. Digital tools that help track the delivery of goods from farmers to consumers reduce the need for intermediaries, improve logistics, and enable farmers to increase their profits. The results from our regression model further validate the positive spillover effects of digital technologies. **Table 4** demonstrates that agricultural total factor productivity (TFP)[34] has a statistically significant and positive association with Connectivity Scores.

We further analyze the relationship between agricultural TFP and Connectivity Scores among the four case countries. Based on **Figure 12**, Poland, Ukraine, and the Kyrgyz Republic showed a positive trend between the two indicators. The slope increase appears to be the greatest in Ukraine, suggesting that Connectivity Scores might have spawned a large amount of spillover effects in the country's agricultural sector. A closer analysis of Ukraine's agricultural sector can help us draw important insights based on this observation. Soil erosion and land degradation have led Ukraine to lose about 50,000 hectares of farmland every year, costing the country around $10 billion annually. Precision farming technologies, such as those adopted by Ukrainian company Agrieye, can help address these issues by creating a precise map that helps describe the chemical composition of the soil, predicting crop yields, and recommending how to irrigate and fertilize croplands. Skokagro's technology helps farmers detect soil compression and potentially avoid an annual loss of 15% of the harvest. Furthermore, Agtech Ukraine is promoting the role of IT in agriculture to help root out mismanagement. By utilizing digital technologies in the agricultural sector, Ukraine can further increase productivity and profitability while also reducing its negative environmental impact.

However, the pattern between these two indicators is not strictly linear in the case of Estonia, whose TFP has relatively declined over the years as Connectivity Scores have increased. We hypothesize that the lack of a linear pattern for Estonia can be attributed to agriculture not being a significant sector of its economy. There are many other factors that could have influenced the results. For example, when Estonia had low Connectivity Scores in 1990 and 1991, its agricultural TFP was very high. Considering Estonia's transition from a planned economy to a market economy in the 1990s, it is possible that the changes in the country's agricultural TFP are related to its land, property, and agricultural reforms during the 1990-1995 period.[35] For the purpose of this report, we will not delve in-depth into the history of Estonia's agricultural reforms. Academics in the field of economic development could conduct further research in this area, and our analysis can be helpful in terms of illustrating the general trends.

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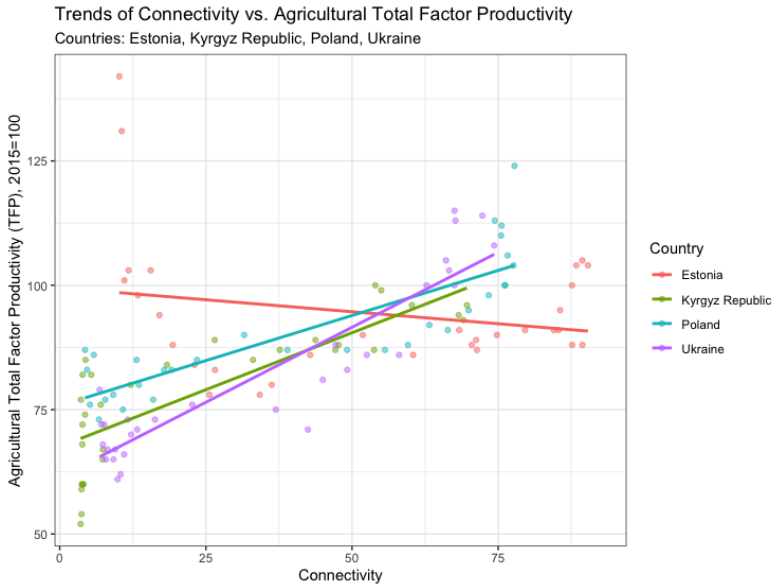
[34] TFP is the agricultural output from the combined land, labor, capital, and material resources used in farm production. Studies suggest that if total output grows faster than total inputs, the total productivity of the factors of production (also known as total factor productivity) rises. (Fuglie, Keith, Jeremy Jelliffe, and Stephen Morgan. n.d. "International Agricultural Productivity." Usda.gov. Accessed April 19, 2023. https://www.ers.usda.gov/data-products/international-agricultural-productivity/.)

[35] Gonzalez-Corzo, Mario A. n.d. "Estonia's Post-Soviet Agricultural Reforms: Lessons for Cuba Estonia's Post-Soviet Agricultural Reforms: Lessons for Cuba." Cuny.edu. Accessed April 4, 2023. https://academicworks.cuny.edu/cgi/viewcontent.cgi?article=1085&context=le_pubs.

Figure 12: Connectivity Scores vs. Agricultural Total Factor Productivity (Case Countries)



Data Source: The US Department of Agriculture; Graph: Report Team

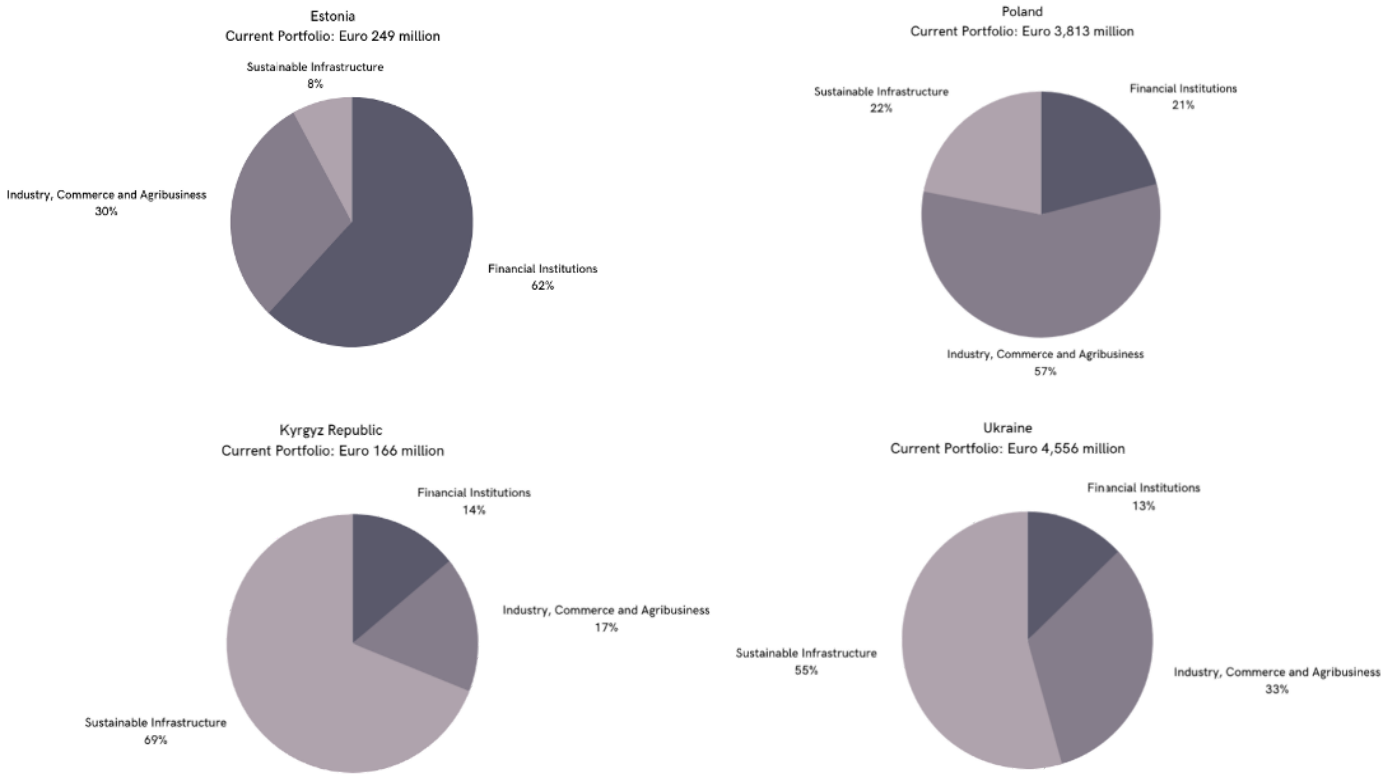
6. Conclusion and Recommendation

Connectivity Scores have demonstrated a positive association with enhancing agricultural exports and total factor productivity in the agricultural sector. Digital technologies and data transparency have supported agricultural production by facilitating interaction between producers and the market. In this study, we aimed to identify possible interventions to support agricultural production. The online advisory can aid producers in disseminating best practices and market prices. Technologies that monitor weather and climate conditions generate satellite images, and automate machinery and irrigation systems to contribute to increased agricultural production and output. E-commerce can enhance the activities of producers in both domestic and international contexts. Lastly, software that monitors inventory management, on-time procurement, and product delivery contributes to the optimization of the supply chain. Future research can be conducted to examine the specific impacts of these digital tools.

Case-Study Overview

This report examines Estonia, Ukraine, Poland, and the Kyrgyz Republic in greater detail. The EBRD has invested in all four of these countries, which has undoubtedly contributed to their economic growth. As of 31 December 2022, the EBRD had cumulatively invested €905 million in Estonia[36], €18,123 million in Ukraine[37], €12,624 million in Poland[38], and €879 million in the Kyrgyz Republic.[39] On average, the EBRD has cumulatively invested €4,777 million in each country.[40] Compared with the average, there has not been enough investment in the Kyrgyz Republic and Estonia. The private sector share of the portfolio has been 98% in Estonia, 39% in Ukraine, 96% in Poland, and 31% in the Kyrgyz Republic. **Figure 13** illustrates the EBRD's current investment portfolio for the selected case countries. Within the EBRD's current investment portfolio in Estonia, most of its investments are allocated toward financial institutions. In contrast, the largest component of the EBRD's investment portfolio in Poland is industry, commerce, and agribusiness. Lastly, the EBRD's investments in Ukraine and the Kyrgyz Republic are significantly skewed toward sustainable infrastructure.

Figure 13: EBRD's Current Investment Portfolio in the Selected Case



Despite the fact that digital transformations are in different phases, digitalization has already played a significant role in the development of each of these countries. For the purpose of this report, the

[36] "Data on EBRD Work in Estonia." n.d. Ebrd.com. Accessed February 10, 2023. https://www.ebrd.com/estonia-data.html.
[37] "The EBRD in Ukraine." n.d. Ebrd.com. Accessed February 10, 2023. https://www.ebrd.com/ukraine.html.
[38] "The EBRD in Poland." n.d. Ebrd.com. Accessed February 10, 2023. https://www.ebrd.com/poland.html.
[39] "The EBRD in Kyrgyz Republic." n.d. Ebrd.com. Accessed February 10, 2023. https://www.ebrd.com/kyrgyz-republic.html.
[40] The number is not available for West Bank and Gaza, and thus we calculated the average data on 38 countries and regions except for the West Bank and Gaza.

Digital Quality of Life (DQL) index was used as an initial proxy for the progress and digitalization status of each country.[41] The index comprises five pillars, including internet affordability, internet quality, electronic infrastructure, electronic security, and electronic government. According to DQL 2022, Estonia ranked 14th, followed by Poland, which ranked 23rd, Ukraine, which ranked 50th; and the Kyrgyz Republic, which ranked 91st. By investigating countries at different stages of digital transformation, we provided a more comprehensive overview of how digitalization impacts economies.

The differences between the four countries can also be demonstrated through other macroeconomic and geographic factors. As demonstrated in **Appendix 4**, Estonia has the highest GDP per capita, which was $27,944 in 2021, compared to Poland ($18,000), Ukraine ($4,836), and the Kyrgyz Republic ($1,277). In terms of geography, Estonia, Ukraine, and Poland are all located in Europe, and the Kyrgyz Republic is located in Central Asia. In terms of population, Ukraine is the most populated country (43.8 million people), followed by Poland (37.7 million people), the Kyrgyz Republic (6.7 million people), and Estonia (1.3 million people).[42]

Country Profile Analysis

The following section examines the drivers that enable, facilitate, and accelerate digital transformation, as well as the barriers that block and impede this transformation across the four case countries. It details this synthesis from the perspectives of economic, environmental and external, technical, regulatory-institutional, and socio-cultural factors. **For detailed analysis, please refer to the supplementary document 1.**

Drivers

1. Economic Drivers

The economic drivers for the digital transformation in these countries interestingly span around the countries' economic situation and agenda, access to investments and funding, affordability of the ICT workforce, and favorable business environment.

Estonia's economic situation after the collapse of the Soviet Union was one of the reasons behind its government's pivot to digitalization. Being a small country with a small population and without access to natural resources, the country introduced an ambitious plan to provide its people with high-quality services that are digitally enabled, easy to use, and low in cost.[43] For Ukraine, global trends and its integration into the EU Digital Market Strategy have intensified its focus on digital transformation. Specifically, the global transition towards Industry 4.0 has been driving the digital transformation of the Ukrainian economy, as these technologies offer new opportunities for businesses to improve their operations, reduce costs, and increase productivity. Additionally, Ukraine's integration into the EU Digital

[41] "DQL Compare." 2022. Surfshark. July 25, 2022. https://surfshark.com/dql2022/dql-compare?table=true&country1=EE&country2=UA&country3=PL&country4=KG.
[42] "Population, Total - Estonia, Poland, Ukraine, Kyrgyz Republic." n.d. World Bank Open Data. Accessed February 10, 2023. https://data.worldbank.org/indicator/SP.POP.TOTL?locations=EE-PL-UA-KG.
[43] Schulze, Elizabeth. 2019. "How a Tiny Country Bordering Russia Became One of the Most Tech-Savvy Societies in the World." CNBC. February 8, 2019. https://www.cnbc.com/2019/02/08/how-estonia-became-a-digital-society.html.

Single Market Strategy has been opening new opportunities for Ukrainian businesses to generate digital services for foreign markets and expand their customer base.[44] The trends in IT and tech businesses in Ukraine are further enhancing the digital transformation in the country. For example, Ukraine is one of the largest exporters of information technology (IT) services globally. Prior to the Russian invasion of Ukraine, segments such as IT outsourcing, cybersecurity, artificial intelligence (AI), mobile applications, blockchain, and e-government were growing rapidly in Ukraine.[45] There were also several successful digital private businesses, such as Monobank, Airbnb, and Uber in Ukraine. Whereas for the Kyrgyz Republic, its digital transformation agenda is driven by its economic status as an emerging outsourcing market for international tech startups and companies seeking business process services due to its low overhead costs and skilled local IT workforce.[46] In Poland, the labor cost per skilled Full-time Equivalent (FTE) in the ICT sector is 47-70% lower than in most Western European countries, making the ICT workforce cost in the country relatively affordable.[47] Moreover, the Polish economy has limited labor reserves left to integrate into the economy, as unemployment is low in Poland (3.37% in 2021).[48] All of these factors present an economic case for the need to adopt digital transformation as a new engine to continue its economic growth.

The economic agenda of fighting corruption, cost management, productivity improvement, and increasing the efficiency and competitiveness of the economy is another driving force for digital transformation in these countries. For example, the government's priority in Estonia was to deliver high-quality services and increase efficiency. Tasks pertaining to public procurements, signatures, company establishment, report sharing, and tax collection were completely digitized. Hence, resulting in cost reductions for both the government and businesses, the removal of the middleman, and increased efficiencies. It is estimated that these reforms and initiatives have provided savings amounting to 2% of Estonia's GDP."[49] As for Ukraine, due to corruption, the country has accelerated its digital transformation process, aiming to reduce the inefficiencies brought about by human factors. According to the Transparency International assessment, Ukraine ranked 122nd out of 180 countries in 2021, the second most corrupt country in Europe, with Russia ranking the most corrupt at 136. Nonetheless, Ukraine has been working to address this and seeks to mitigate a corruption scheme worth $3 billion annually for every service. [50]

The Kyrgyz Republic has been aiming to address corruption and lower the share of the shadow economy. Hence, this economic agenda is driving the digital transformation in the country. The corruption level is substantial in the Kyrgyz Republic, and according to the Transparency International assessment, the country scores 27/100 on the Corruption Perception Index.[51] This corruption level has resulted in an increased share of the shadow economy in the country, accounting for about 25-50% of the Kyrgyz

[44] "Ukraine's Integration into the EU's Digital Single Market." 2021. FREE NETWORK. February 14, 2021. https://freepolicybriefs.org/2021/02/15/ukraines-integration-single-market/.
[45] Bandura, Romina, and Janina Staguhn. 2023. "Digital Will Drive Ukraine's Modernization." Center for Strategic and International Studies.
[46] "Kyrgyz Republic - Information and Communication Technology (ICT)." n.d. International Trade Administration | Trade.gov. Accessed April 19, 2023. https://www.trade.gov/country-commercial-guides/kyrgyz-republic-information-and-communication-technology-ict.
[47] N.d. Mckinsey.com. Accessed April 9, 2023k. https://digitalchallengers.mckinsey.com/files/Rise_of_Digital_Challengers_Perspective_Poland.pdf.
[48] "Unemployment, Total (% of Total Labor Force) (Modeled ILO Estimate) - Poland." n.d. World Bank Open Data. Accessed April 10, 2023. https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS?locations=PL.
[49] Schmidt, Annie. 2016. "Estonia PM: Country Saves 2% of GDP by Going Digital." International Peace Institute. May 3, 2016. https://www.ipinst.org/2016/05/information-technology-and-governance-estonia.
[50] Jackson, Mariel. 2023. "Ukrainian Director General Details Digital Transformation in War-Time Ukraine." McCourt School of Public Policy. March 27, 2023. https://mccourt.georgetown.edu/news/digital-transformation-war-ukraine/.
[51] Travel Journal Publishers. 2019a. *Kyrgyzstan: Country Flag A5 Notebook to Write in with 120 Pages*. Independently Published.

Republic's GDP.[52] Consequently, this harms tax and customs payment collection, the level of country risk, and investment growth, especially since these funds could be used towards the digital transformation agenda, leading to further deterioration of poverty and inequality in the country.

With its digital transformation 2022-2023 agenda, the Kyrgyz government has introduced measures to improve tax and payment collection, mainly by implementing the electronic patent system, online cash registration machines, and electronic customs declarations.[53] As a result, the government taxe revenues in 2022 increased significantly by +144.7%.[54] Also, the improvements were noticed in the customs statistics, where the gap between statistics on bilateral trade volume published by China and the Kyrgyz Republic has been shrinking (by 53% between 2019-2020) because of the digitalization of the customs procedures.[55] As for Poland, its aim to increase productivity is driving this transformation agenda. When compared to other Western European countries, Poland's productivity lags behind them.[56]

Another driver of digital transformation in some countries is access to finance for digital projects, investments, and funding for tech businesses. Estonia spends between 1.1% and 1.3% of its national budget on digitalization. Nevertheless, the OECD estimates that an increased allocation of resources to the digitalization transition is necessary at a rate of 1.5%.[57] In Poland, government IT spending is estimated to be 2.2% of GDP, but it is significantly supplemented by EU funding, accounting for 85% of a project's actual value. Poland's National Recovery Plan, which was approved by the EU in June 2022, anticipates $3.4 billion for digital development projects.[58] According to BMI Research, total IT expenditures in Poland were estimated to increase by 16.8% to $22.3 billion by 2021. Companies like Google, Amazon, Microsoft, and other international and domestic players have invested significantly in Polish data centers. As a result, Poland could become one of Central and Eastern Europe's leading colocation data center hubs by 2026.[59] Furthermore, in Estonia, the government has created a startup fund that provides grants and loans to technology companies in their early stages.[60] Ukraine also created a startup fund that provides grants and loans to technology companies in their early stages.[61]

Moreover, the supportive environment for ICT businesses was another driver for digital transformation in some of these countries. Estonia, for example, has introduced tax incentives to attract investors and venture capital investments. It is home to several international venture capital firms. As underscored by Erika Piirmets, the Digital Transformation Advisor at e-Estonia, the paperless and hassle-free ex-taxation environment allows entrepreneurs to start a company in less than three hours in Estonia.[62] Overall, Estonia ranks first in terms of entrepreneurial activity, 18th in terms of ease of doing business, and first in the international tax competitiveness index. This favorable business environment has

[52]"Shadow Economy in Kyrgyzstan Ranges from 20% to 50% of GDP - Cabinet Head." n.d. Akipress.com. Accessed April 10, 2023. https://akipress.com/news:672850:Shadow_economy_in_Kyrgyzstan_ranges_from_20__to_50__of_GDP_-_Cabinet_head/.
[53] "Action Plan of the Digiatalzation of Management and Development of Digital Infrastrcutur in the Kyrgyz Republic For." n.d., 2022–23.
[54] "The growth of the total income of the republican budget for 10 months of 2022 amounted to 144.7%." n.d. Minfin.kg. Accessed April 2, 2023. https://www.minfin.kg/posts/rost-obschego-dohoda-respublikanskogo-byudzheta-za-10.
[55] "Download Data: GDP Growth, Inflation, and Other Indicators." n.d. Theglobaleconomy.com. Accessed February 27, 2023. https://www.theglobaleconomy.com/download-data.php.
[56] N.d. Mckinsey.com. Accessed April 19, 2023k. https://digitalchallengers.mckinsey.com/files/Rise_of_Digital_Challengers_Perspective_Poland.pdf.
[57] "Case Study 8: Estonia e-Government and the Creation of a Comprehensive Data Infrastructure for Public Services and Agriculture Policies Implementation." 2019. In Digital Opportunities for Better Agricultural Policies, 207–13. OECD.
[58] "Poland - Digital Technologies." n.d. International Trade Administration | Trade.gov. Accessed April 10, 2023. https://www.trade.gov/country-commercial-guides/poland-digital-technologies.
[59] Ibid.
[60] N.d. Com.Ua. Accessed March 9, 2023g. https://usf.com.ua/en/#usf-sc-2.
[61] Ibid.
[62] Interview with Erika Piirmets, Digital Transformation Adviser - e-Estonia

made Estonia a popular destination for startups and technology companies aiming to establish a presence in Europe. Additionally, in the Kyrgyz Republic, a tax relaxation policy for IT services was implemented on the export-oriented platform of HighTech Park: a 2% digital services tax, which replaced the 12% standard VAT.[63] As of 2021, 169 domestic companies were providing IT services abroad, and revenues reached $25 million, which was only 1.5% of overall exports, but it has been growing rapidly and demonstrating future potential; also, about 1,700 jobs were created.[64]

2. Environmental and External Drivers

The environmental and external drivers for the digital transformation in these countries span around the climate change mitigation agenda, exposure to COVID-19, migration of IT businesses and talents, and international cooperation in the field of digitalization.

Estonia's efforts and agenda towards climate change mitigation and adoption have expedited its digital innovation. Estonia's eighth national communication document under the UNFCCC notes Estonia's agenda for enhancing a safe circular material use rate and its work towards a circular economy, all of which require adopting technological solutions. Similarly, Ukraine's commitment to reducing carbon emissions and mitigating the effects of climate change has also motivated the digital transformation in the country. Overall, the Ukrainian government has recognized the potential of digital technologies to help achieve these goals by improving energy efficiency, reducing waste, and enabling the transition to renewable energy sources.

The recent COVID-19 pandemic has also accelerated the digital transformation in these countries. The outbreak of COVID-19 and the Russian invasion of Ukraine made Poland recognize the importance of mobility and digitalization. The outbreak of COVID-19 encouraged the Polish government to start an initiative called "Recovery and Resilience Plan for Poland", aiming to strengthen the country's resilience. One of the most important agendas of this initiative was the promotion of digital transformation, focusing on the digitalization of public policy and the development of digital infrastructure. The plan dedicated about €23.9 billion in the form of grants and €11.5 billion in loans.[65] Also, in the Kyrgyz Republic, the COVID-19 pandemic accelerated the adoption of digital technologies, with many businesses and organizations changing their operations format and shifting online in the country.

Some of these countries benefited from the talent inflows, especially in the ICT field, which has also contributed to driving digital transformation. For example, after the collapse of the Soviet Union, Estonia was left with a wealth of research and development talent in ICT through various highly advanced science institutions, as with the collapse, much talent poured into emerging private and telecom companies.[66] Furthermore, the upcoming trend in digital transformation may turn out to be positive in the Kyrgyz Republic due to the migration of IT businesses and specialists from Russia amid Russia's invasion of Ukraine. According to estimates, about 700,000 people left Russia aiming for the Kyrgyz Republic as

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[63] "Update - Kyrgyzstan's New 2% Tax on Activities in the Field of e-Commerce and VAT Requirements for Foreign Providers of Electronic Services — Orbitax Tax News & Alerts." n.d. Orbitax.com. Accessed March 7, 2023. https://www.orbitax.com/news/archive.php/Update---Kyrgyzstan-New-2-T-49036.

[64] Spalmalo. n.d. "About." Htp.Kg. Accessed March 7, 2023. http://htp.kg/about.

[65] "Recovery and Resilience Plan for Poland." n.d. European Commission. Accessed March 3, 2023. https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility/recovery-and-resilience-plan-poland_en.

[66] Mission Mystique. n.d. "Estonia's Digital Transformation." D-Nb.Info. Accessed February 16, 2023. https://d-nb.info/120400515X/34.

one of their destinations[67], given the dominance of the Russian language in the country and the availability of the Nomad visa with simplified procedures[68]; as well as the tax preferences for the IT sector stimulation.

International cooperation in the field of digitalization has allowed the sharing of best practices in this area and could expedite the digital transformation in these countries. Most recently, the Kyrgyz Republic partnered with Estonian cyber experts to increase the capacity of institutions, create an appropriate management model and either develop or adjust a single standard for cybersecurity and ICT risk management. Moreover, the Republic's e-government platform, Tunduk was based on the practice of Estonian X-Road. Similarly, Ukraine has partnered with Estonia and Poland to share its best practices and digital services and help these countries create a platform similar to Diia.

Moreover, other environmental and external digital transformation enablers are relevant to these countries' individual characteristics. For example, Estonia's geographical proximity to Scandinavia was a factor that allowed the country access to joint ventures, attracting expertise, and investment from these Scandinavian partners, hence contributing to its digital transformation journey.[69] Additionally, improved transparency, accountability, and trust between citizens and public workers are other enablers of digital transformation in Estonia. The country's "No Citizen Left Behind Program," which aims to give access to e-government services to as many people as possible, has increased the number of households with computers and internet access from 45% to 67%, access to free public wifi both in rural and urban areas, and created about 700 Public Internet Access Points (PIAPs) in the country.[70] Consequently, people's access to good quality, relevant information has increased, subsequently empowering them to avoid and denounce the corrupt behavior of government employees. According to the Corruption Perceptions Index, Estonia's ranking improved from 27 in 2000 to 14 in 2022 globally.[71]

3. Regulatory and Institutional Drivers

Digital-related regulatory and institutional progress is important to driving digital transformation in these countries. Most of these enablers include political commitment and the introduction of relevant laws and frameworks. Overall, government support for digital transformation could be sensed in all of these countries, and it is evident in their government-led initiatives that set the blueprints for further digital projects. In Estonia, for example, several regulations and laws have been adopted and amended for a very long time, aiming to achieve Zero Bureaucracy and reduce the administrative burden on the public and private sectors.

For instance, Estonia's Management System of the State Information System (RIHA) is used as a "national registry of systems, components, services, data models, semantic assets, etc."[72] This system is enforced by law. The Public Information Act has also been enacted into national law, which deals with interoperability-related factors. Examples include "the prohibition to collect duplicate data," "the concept

[67] *Reuters*. 2022. "Factbox: Where Have Russians Been Fleeing to since Mobilisation Began?," October 6, 2022. https://www.reuters.com/world/europe/where-have-russians-been-fleeing-since-mobilisation-began-2022-10-06/.
[68] Andy. 2023. "Kyrgyzstan Introduces Digital Nomad Visa for Citizens of Select Countries." Andy Sto. January 23, 2023. https://andysto.com/kyrgyzstan-introduces-digital-nomad-visa-for-citizens-of-select-countries/.
[69] ibid
[70] Eugeniu. 2016. "E-Governments vs. Corruption. The Case of Estonia." Technology and Operations Management. November 18, 2016. https://d3.harvard.edu/platform-rctom/submission/e-governments-vs-corruption-the-case-of-estonia/.
[71] "Estonia." 2019. Transparency.org. November 1, 2019. https://www.transparency.org/en/countries/estonia.
[72] "Digital Public Administration Factsheet 2021 Estonia." n.d. Europa.Eu. Accessed February 5, 2023. https://joinup.ec.europa.eu/sites/default/files/inline-files/DPA_Factsheets_2021_Estonia_vFinal.pdf.

of base data," and "the mandatory consultation process with IT coordination, data protection, and statistics bodies when preparing legal acts establishing new public sector databases or introducing changes to existing ones." [73]

In Ukraine, the country introduced "the Law on Security of Information Infrastructure" in 2017 to help ensure the security of critical information infrastructure.[74] It passed the Law on Electronic Trust Services[75] and implemented key principles of the eIDAS Regulation,[76] which help establish identification tools including electronic digital signatures, mobile IDs, electronic stamps, and electronic timestamps.[77] In the same year, the State Agency for eGovernance launched the State Registry of Registries (RoR), designed to store and process state registries and information systems, thereby easing the delivery of digital public services to citizens and businesses.[78] To further complement the regulatory drivers of digital transformation, Ukraine introduced "On Personal Data Protection" in 2019 and set the legal framework for processing personal data.[79] The digital transformation in Ukraine is also driven by the existing digital government institutions. Additionally, the digital ecosystem of Diia, meaning "action in English," has been one of the major innovations brought by the Ministry of Digital Transformation in Ukraine. Diia encompasses several national digital projects, including a mobile application to access digital documents, a state portal of public services, an education project to enhance digital literacy (Diia.Digital Education), a national project for SME and export (Diia.Business), and a legal and tax space for IT companies (Diia.City).

Moreover, to foster digital transformation, the Polish government has adopted and amended several legislations, completed several long-term government digital transformation initiatives, and will launch and expand new ones. For example, in 2011, Poland introduced the Electronic Platform of Public Administration Services portal "ePUAP" to provide the public with wide access to a range of online government services, thereby allowing its citizens and businesses to complete official matters and administrative procedures for free.[80] In 2014, the Polish government launched the National Broadband Plan to provide universal access to high-speed internet by 2020. The plan included investments in infrastructure, regulatory reforms, and financial incentives for broadband providers to expand their networks. In 2019, Poland introduced its digital transformation strategy, named "Digital Roadmap 2020-2030". This is followed by introducing the 5G strategy for Poland in 2021, which outlines the government's plans to develop and implement 5G technology in the country.

Digital transformation has always been one of the priorities in the Kyrgyz Republic government's strategy, namely, the 2026 National Development Program, which aims to enhance digital skills and

[73] ibid
[74] Chislova, Olga, and Marina Sokolova. 2021. "Cybersecurity in Russia." *International Cybersecurity Law Review* 2 (2): 245–51. https://doi.org/10.1365/s43439-021-00032-9.
[75] Pogrebna, Anna, Ihor Olekhov, Diana Valyeyeva, and Bohdan Ilchenko. 2022. "Ukraine Amends Electronic Trust Services Regulation." Lexology. CMS Ukraine. December 28, 2022. https://www.lexology.com/library/detail.aspx?g=dc5c9079-b48d-416d-b29d-d280fbacf10e.
[76] N.d. Dataguidance.com. Accessed March 1, 2023u. https://www.dataguidance.com/news/ukraine-cabinet-approves-technical-regulations.
[77] N.d. Europa.Eu. Accessed March 19, 2023i. https://joinup.ec.europa.eu/sites/default/files/inline-files/Digital_Government_Factsheets_Ukraine_2019.pdf.
[78] ibid
[79] Kobrin, Artem, Dmitry Korchynskyi, Vlad Nekrutenko, Artem Kobrin, Dmitry Korchynskyi, Vlad Nekrutenko, Artem Kobrin, Dmitry Korchynskyi, and Vlad Nekrutenko. 2020. "Ukrainian GDPR: The Reality and Future of Privacy Legislation in Ukraine." International Association of Privacy Professionals. September 28, 2020. https://iapp.org/news/a/ukrainian-gdpr-the-reality-and-future-of-privacy-legislation-in-ukraine/.
[80] ePUAP2 "What is ePUP?". Accessed March 20, 2023 https://epuap.gov.pl/wps/portal/english

create the required infrastructure for digital development.[81] Also, the reforms related to personal data protection, cybersecurity, and eCommerce promotion have been driving digital transformation in the country. The country adopted the Personal Data Protection Law to regulate the collection, use, and processing of personal data in 2008, which was further amended in 2022. Hence, it ensures that individuals' personal data is stored securely. In 2018, the Kyrgyz Republic passed a draft law on ratification of the cooperation agreement on the fight against cybercrime, which criminalizes a range of activities related to cybercrime, including hacking, identity theft, and cyber espionage.[82] Further, a national eCommerce law was passed in 2021 and came into effect in June 2022 to promote e-commerce in the country and the use of e-payment systems.[83]

4. Technical Drivers

Technical drivers are crucial for digital transformation in some of these countries. Whether through digital infrastructure, data management, or accelerated development of critical digital infrastructure.

Estonia, a leading country in digital transformation, has the highest uptake of high-speed mobile internet (3G and 4G) in the OECD, among about 90% of the population. This includes multiple subscriptions and illustrates the high diffusion of mobile technologies to access the Internet. Further, Estonia has a very high fast-speed Internet uptake among enterprises, at 96% of enterprises, which means that even the smallest enterprises show an uptake rate of over 95% [84]. Similarly, Ukraine invested heavily in the country's fiber optic infrastructure. As of January 1, 2022, Ukraine has an 89% fiber-optic network coverage of its rural population.[85] The fiber optic network provides a high-speed, reliable backbone for the country's digital infrastructure and helps Ukrainians connect to international data networks. This has helped the country's digital sector remain resilient despite the Russian invasion. As of November 2022, Elon Musk said that there are approximately 25,000 Starlink terminals in Ukraine.[86]

Whereas for Poland, the efforts to develop the digital infrastructure could be found in its 5G strategy in 2021, which outlines the government's plans to develop and implement 5G technology in the country. Furthermore, the Kyrgyz Republic is undergoing rapid developments to enhance its technical infrastructure. The results could be seen in the change in the number of mobile broadband subscriptions, which has increased by 60% and reached 8.5 million or 132 per 100 people since 2010, and fixed broadband subscriptions, which has increased from 0.42 to 42.5 per 100 people since 2010.[87] Additionally, the Kyrgyz Republic established its National Payment System to centralize the e-payments,

[81] "Decree of the Cabinet of Ministers of the Kyrgyz Republic of January 12, 2022 No. 2-r (On Approval of the Action Plan for Digitalization of Management and Development of Digital Infrastructure in the Kyrgyz Republic for 2022-2023)." n.d. Gov.Kg. Accessed April 4, 2023. http://cbd.minjust.gov.kg/act/view/ru-ru/218797?cl=ru-ru.

[82] "Cooperation Agreement on Cybercrime Fight between CIS States Passed in 1st Reading at Parliament of Kyrgyzstan." n.d. Akipress.com. Accessed March 20, 2023. https://akipress.com/news:625397:Cooperation_agreement_on_cybercrime_fight_between_CIS_states_passed_in_1st_reading_at_Parliament_of_Kyrgyzstan/.

[83] "Kyrgyz Republic - ECommerce." n.d. International Trade Administration | Trade.gov. Accessed March 20, 2023. https://www.trade.gov/country-commercial-guides/kyrgyz-republic-ecommerce.

[84] OECD. (n.d.-a). ESTONIA: Fostering Strategic Capacity across Governments and Digital Services across Borders. PUBLIC GOVERNANCE AND TERRITORIAL DEVELOPMENT. https://www.oecd.org/gov/key-findings-estonia.pdf

[85] The National Council for the Recovery of Ukraine from the Consequences of the War. 2022. "Draft Ukraine Ukraine Recovery Plan." https://www.kmu.gov.ua/storage/app/sites/1/recoveryrada/eng/justice-eng.pdf.

[86] Wall, Mike. 2022. "1,300 SpaceX Starlink Terminals with Ukraine's Military Went Offline Due to Funding Shortfall: Report." Space. November 8, 2022. https://www.space.com/ukraine-spacex-starlink-terminals-offline-funding-shortfall.

[87] "Fixed Broadband Subscriptions (per 100 People) - Kyrgyz Republic." n.d. World Bank Open Data. Accessed March 20, 2023. https://data.worldbank.org/indicator/IT.NET.BBND.P2?locations=KG.

which enables both individuals and businesses to make payments towards bills and purchase the sale of goods and services online.[88] This is a key facilitator for digital transformation, enabling e-commerce while reducing reliance on cash transactions.

Moreover, some of the technical enablers are in the form of the work toward deploying the data management infrastructure. This has been advanced in Estonia with the X-Road, the data management infrastructure that has enabled data management to be centralized, combining and synthesizing public and private sector e-service databases.[89] By centralizing the data and passing a law that ensured that government entities could not duplicate a request for data, costs and time were saved. In fact, the X-Road "allows Estonians to save annually over 820 years of work time. And these savings come from only 5% of the queries done via X-Road.[90] The X-Road data platform and its connected applications have created a high level of interoperability in Estonia.[91] Moreover, the increasing trend of cloud technology adoption in Poland has allowed data formerly stored within physical hubs on the company's property to be transmitted to an internet-based network. In 2021, the market for cloud computing services in Poland was valued at 886 million U.S. dollars. By 2026, the market value will grow to 2.4 billion U.S. dollars.[92] Finally, with the ongoing Russian invasion of Ukraine, Ukraine has added enhancing its critical infrastructure as one of its key priorities. The country has taken steps to enhance national security and protect against cyber threats. In March 2022, the government moved some sensitive data to an unidentified private cloud in Poland and was negotiating similar terms with Estonia and France.[93] In addition, Microsoft spent $107 million to help Ukraine strengthen its computing infrastructure and keep its cloud services in a safe place.[94] Kyiv's cyber strategy over the past year has been bolstered through three aspects: transitioning data to the cloud, establishing partnerships with Western companies, and utilizing Elon Musk's mobile Starlink terminals for Internet connection.[95] These measures have effectively strengthened the country's resilience. Overall, Ukraine is now prioritizing the development of military tech, cybersecurity, and the connectivity of critical infrastructure.

5. Socio-Cultural Drivers

Our preliminary research has also indicated that socio-cultural factors play a role in driving digital transformation in countries. These factors include the pool of the educated population and countries' efforts towards enhancing digital skills and literacy. The research also suggested that the demographic structure of some countries is the driving force behind their digital transformation.

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[88] "Kyrgyz Republic Launches Comprehensive National Strategy to Boost Financial Inclusion." n.d. IFC. Accessed March 21, 2023. https://pressroom.ifc.org/all/pages/PressDetail.aspx?ID=26947.
[89] "How Do Estonians Save Annually 820 Years of Work without Much Effort?" E-Estonia. December 12, 2017. https://e-estonia.com/how-save-annually-820-years-of-work/.
[90] Ibid.
[91] Mission Mystique. n.d. "Estonia's Digital Transformation." D-Nb.Info. Accessed February 5, 2023. https://d-nb.info/120400515X/34.
[92] "Value of the Cloud Computing Services Market in Poland 2021-2026." n.d. Statista. Accessed April 5, 2023. https://www.statista.com/statistics/1328188/poland-cloud-computing-services-market-value/.
[93] N.d. Datacenterdynamics.com. Accessed February 12, 2023j. https://www.datacenterdynamics.com/en/news/amid-russian-invasion-ukrainian-government-moves-data-to-poland-negotiating-with-france-estonia-and-others/.
[94] Passeri, Paolo. 2022. "The Role of Cloud Services in the Hybrid War in Ukraine." Infosecurity Magazine. September 14, 2022. https://www.infosecurity-magazine.com/blogs/cloud-services-hybrid-war-ukraine/.
[95] Huber, Nick. 2022. "What Ukraine's Cyber Defence Tactics Can Teach Other Nations." *Financial Times*, November 9, 2022. https://www.ft.com/content/9635c4a0-1f42-44f1-bc9a-503b192f809f.

Most of the four countries have an educated population. For example, the Kyrgyz Republic has a relatively young population, with the median age being 27.3 years old,[96] and a high literacy level as 99.6% of the population is educated.[97] Moreover, the country's active development in education under the IT sector, where a great focus is being made on incorporating programming classes at schools and increasing the number of IT courses for adults, has allowed these talents to shift in their careers or obtain additional qualifications.

Additionally, according to Mckinsey, in 2016, Poland had the largest educated talent pool and the fourth-largest pool of science graduates in the European Union, despite being only the sixth most populous country. Moreover, its digitally enabled talent pool is of high quality – and 47%-70% more affordable than in Western Europe. This means that a large workforce that is digitally enabled can perform digital-related jobs.[98]

The governments of these countries have been working towards elevating digital skills. For example, in Estonia, there was an early focus on integrating IT education with general school education. More specifically, narrowing the digital skills gap among the Estonian public has been a government focus since the 1990s when the Tiger Leap Programme was initiated in 1996. The program was funded by both public and private sector organizations to bring all Estonian schools online.[99] The ambitious goal of computers for all schools was achieved in 2000, and the goal of internet access for all schools was achieved in 2001. Further, another program was achieved via a public-private partnership called Look@World. Both programs affected the Estonian youth and led to the emergence of a vibrant IT startup sector, as well as improvements in government operations in recent years.[100] Furthermore, Estonia has a lifelong learning strategy that also includes a digital transformation program to help develop the digital competence of both the teachers and the students.[101] These digital-minded government initiatives have helped foster an environment that is focused on transparency and being citizen-centric, resulting in increased trust in digital services in Estonia. Overall, according to the World Bank's statistics, Estonia has the highest year-on-year average growth rate at 0.32% for the time period 2017–2019 with respect to digital skills among the population.[102]

Whereas in Ukraine, it has a highly skilled population, particularly in the fields of IT and engineering. To further support Ukraine's digital literacy and improve Ukrainian citizens' access to digital services, a digital education portal via Diia offers free learning tutorials from experts and celebrities.[103] According to our interview with a Ukrainian student studying at Columbia University, the public tends to

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[96] "Population Growth in Kyrgyzstan." n.d. Worlddata.Info. Accessed March 6, 2023. https://www.worlddata.info/asia/kyrgyzstan/populationgrowth.php.
[97] "Kyrgyz Republic Literacy Rate 1999-2023." n.d. Macrotrends.net. Accessed March 6, 2023. https://www.macrotrends.net/countries/KGZ/kyrgyz-republic/literacy-rate.
[98] N.d. Mckinsey.com. Accessed April 1, 2023d. https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Digital%20Poland/Digital%20Poland.ashx.
[99] "How It All Began? From Tiger Leap to Digital Society." n.d. Education Estonia. Accessed February 9, 2023. https://www.educationestonia.org/tiger-leap/.
[100] Mission Mystique. n.d. "Estonia's Digital Transformation." D-Nb.Info. Accessed February 5, 2023. https://d-nb.info/120400515X/34.
[101] (N.d.). Retrieved February 27, 2023, from E-estonia.com website: https://e-estonia.com/solutions/education_and_research/research_iinformation_system/
[102] GCI 4.0: Digital skills among population [Data set]. (n.d.). [Data set]. https://tcdata360.worldbank.org/indicators/h945a9708?country=UKR&indicator=41400&countries=EST,POL,KGZ&viz=line_chart&years=2017,2019&indicators=944
[103] Gagarin News. 1679666400. "What Is Diia. Digital Education?" Gagarin News. 1679666400. https://gagarin.news/news/alex-bornyakov-we-possess-the-capacity-to-create-our-own-trends/.

have trust in the government's e-government services and offerings provided in Ukraine.[104] The student expressed confidence in storing personal information with the government rather than private companies.

In 2021, digital communication and information skills were above the basic level in Ukraine. More specifically, 79.2% of the population has communication skills above the basic level, and 78.9% has information skills that are at the basic level.[105] Additionally, there is no gender disparity among digital skills assessments for youth aged 10-17.[106]

An interesting socio-cultural driver for Poland-oriented digital transformation is that Poland has reached its peak employment level and is undergoing negative demographic trends, including declining birth rates, emigration, and an aging population, all of which can hinder the further development of the country. Nonetheless, these negative trends are now driving the need for digital transformation and the deployment of automation technologies, closing the gap between digital supply and demand.

Barriers

1. Economic Barriers

The economic barriers to digital transformation vary to some degree in these countries, where some are facing the high cost of technological adoption and lack of sufficient funds, while others are facing challenges owing to the high cost of maintaining the digital technologies and infrastructure, as well as increasing corruption.

Ukraine's current economic climate may hinder its digital transformation agenda. Grappling with the ongoing Russian invasion, Ukraine is facing a decline in interest and hesitations from IT firms with respect to continuing to outsource globally. Whereas for Estonia, the main economic barrier to its digital transformation is the need for substantial financial and human resources to acquire and maintain the digital technologies and infrastructure and the need for substantial data storage and processing capacities. For Poland, it is the high cost of digital adoption, especially for enterprises, and for the Kyrgyz Republic, it is the high cost of implementing digital tools.

Additionally, the increase in corruption in Poland can potentially hinder the country's digitalization journey. According to the Transparency International assessment, Poland was given its lowest ever score (56) and ranking (45th) in 2022, compared to the previous year, the level of corruption slightly raised in the country.[107] This downfall could reduce the country's competitiveness and, thus, the implementation of new digital solutions.

Finally, attracting foreign investments in the field of ICT is another challenge. The Kyrgyz Republic is potentially facing this challenge because of its high level of sovereign risk. According to Moody, the Kyrgyz Republic's current rating is (B3-)[108], which disincentivizes the inflow of foreign

[104] Interview with Filipe, Ukraine Student at Columbia SIPA
[105] "Digital Literacy of the Population of Ukraine." n.d. Gov.Ua. Accessed March 20, 2023. https://osvita.diia.gov.ua/uploads/0/2623-research_eng_2021.pdf. p. 31
[106] Ibid.
[107] "Extent of Public Corruption in Poland." n.d. Worlddata.Info. Accessed April 1, 2023. https://www.worlddata.info/europe/poland/corruption.php.
[108] "Kyrgyz Republic, Government Of." n.d. Moodys.com. Accessed April 1, 2023. https://www.moodys.com/credit-ratings/Kyrgyz-Republic-Government-of-credit-rating-808496867.

investments to the country. Overall, limited access to financing can be a substantial barrier to innovation and development in the technology sector.

2. Environmental and External Barriers

Similar to the economic factors, the environmental and external barriers to digital transformation vary to some degree in these countries. Among the key ones are political instability, geographical landscape and location, and pressure due to the negative environmental impact of digital technologies. According to Mr. Dastan Dogoev, the Kyrgyz Republic's former Minister of Digital Development, digital transformation may potentially be hindered by the political instability in the country. Political revolutions and frequent changes in the top government positions significantly complicate and disrupt the process of digital transformation due to the lack of consistency in the strategy and its implementation. In 2021, the Kyrgyz Republic's Political Stability Index was -0.43 (where -2.5 is weak; +2.5 is strong).[109]

The sustainability of Estonia's mass digitization initiatives could be hindered by concerns around the increasing carbon footprint, the negative environmental impact of ICT, and surging energy consumption. If unchecked, Estonia may face societal and financial costs. The same poses challenges to Poland and Ukraine's digital agenda, especially with the rise of digital technologies and data centers, the carbon footprint of the ICT sector has expanded in recent years in Poland and Ukraine. According to the Global E-waste Monitor 2020, these two countries, following Russia, are among the largest e-waste generating countries in the Eastern Europe region, with Poland generating about 443kt of waste and Ukraine generating 324kt.

Furthermore, geography may have a role in hindering the digital transformation in these countries. The mountainous geographical landscape of the Kyrgyz Republic has been creating additional costs in building the required digital infrastructure, as 93% of the country's surface is mountainous, and the elevation ranges between 1,000 meters and 7,400 meters above the sea.[110] In the context of Estonia and Poland, their proximity to Ukraine and its shared border with Russia, given the ongoing Russian invasion, make these countries vulnerable to cyberattacks, hence posing a threat to their digital infrastructure. Additionally, the ongoing Russian invasion could disrupt the region's supply chains or trade routes. The impact could be, for example, if key technology components or hardware were to become scarce or unavailable due to trade disruptions, this could negatively impact these countries' efforts and progress in digital transformation.

3. Regulatory and Institutional Barriers

The regulatory and institutional barriers span around two components found in some of these countries. One of which is the bureaucracy and the rigid regulations in combination with the political instability, which create obstacles to the implementation and spread of digital transformation in the Kyrgyz Republic. The development of a legal framework is still in its initial stages, and existing legislation is not yet adequately enforced due to a lack of commencement orders and specialized enforcement authorities.

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[109] "Kyrgyzstan Political Stability - Data, Chart." n.d. Theglobaleconomy.com. Accessed April 1, 2023. https://www.theglobaleconomy.com/Kyrgyzstan/wb_political_stability/.
[110] Hays, Jeffrey. n.d. "Land, Geography and Weather of Kyrgyzstan." Factsanddetails.com. Accessed April 10, 2023. https://factsanddetails.com/central-asia/Kyrgyzstan/sub8_5e/entry-4798.html.

Whereas, Poland's digital transformation is challenged by an overwhelming amount of regulatory changes. This is primarily due to current and upcoming EU regulations. In 2020, Polish companies' main barriers to digital transformation were regulations and legislative changes, difficulties obtaining valuable information due to data/information overload, and lack of budget/resources. This uncertainty makes markets, particularly financial institutions, believe that various EU restrictions make them unwilling to use digital technologies, such as cloud computing, due to growing concerns over data confidentiality, integrity, and availability.

4. Technical Barriers

Technical barriers to digital transformation still exist in these countries. Despite Estonia's efforts in developing its digital infrastructure, some rural areas of the country still lack the infrastructure that supports its digital transformation initiatives, potentially creating a digital divide between urban and rural areas. Ukraine's digital transformation could be hindered as the country's digital infrastructure, such as broadband internet access, is not yet fully developed in many areas of the country. In terms of the Connectivity Score, Ukraine is ranked 83rd, at the 61.83% percentile among 214 countries. With the ongoing Russian invasion, there has been an urgency to restore Internet and mobile connection,[111] as the Russian troops destroyed more than 4,000 base stations of Ukrainian telecommunications providers and more than 60,000 kilometers of fiber-optic lines.[112]

Furthermore, Poland's digital agenda could be challenged by the slow improvement of its digital infrastructure. According to data from the European Commission, 64% of Polish households had access to high-speed broadband in 2020, compared to 75% of EU households on average. In rural areas, access to high-speed internet is even more limited, with only 35% of homes having it. The lack of such basic technology will hinder citizens from using different types of technology. The same is true for the Kyrgyz Republic, as the country's technical infrastructure is in its early stages of development and relatively low compared to developed countries. For example, the Kyrgyz Republic scores 59.8 in the GSMA Mobile Connectivity Index[113]; and it is still falling behind in the adoption of 5G, while 4G network coverage is 90% of the population[114], broadband internet speed is 51.07 Mbps; and mobile internet speed is 24.71 Mbps[115]. Moreover, the number of personal computers per capita is 19.44 per 1000 people, which is still low.[116]

Finally, the threat of cyberattacks is a challenge that not only the four case countries face but is also an imminent threat for countries outside of the countries researched in this paper. In Estonia, for instance, in 2007, the coordinated Distributed Denial of Service (DDoS) cyber attack posed an immense roadblock to Estonia's digital transformation.[117] The continued attacks led to the establishment of NATO's

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[111] Bergengruen, Vera. 2022. "The Battle for Control over Ukraine's Internet." *Time*, October 18, 2022. https://time.com/6222111/ukraine-internet-russia-reclaimed-territory/.
[112] Ibid.
[113] N.d. Mobileconnectivityindex.com. Accessed March 2, 2023n. https://www.mobileconnectivityindex.com/.
[114] *Kyrgyzstan: Country Flag A5 Notebook to Write in with 120 Pages*. Independently Published.
[115] "Internet Speeds by Country 2023." n.d. Worldpopulationreview.com. Accessed March 4, 2023. https://worldpopulationreview.com/country-rankings/internet-speeds-by-country.
[116] "Countries Compared by Media > Personal Computers > Per Capita. International Statistics at Nationmaster.com." n.d. Nationmaster.com. Accessed March 6, 2023. https://www.nationmaster.com/country-info/stats/Media/Personal-computers/Per-capita.
[117] Schulze, Elizabeth. 2019. "How a Tiny Country Bordering Russia Became One of the Most Tech-Savvy Societies in the World." CNBC. February 8, 2019. https://www.cnbc.com/2019/02/08/how-estonia-became-a-digital-society.html.

cyber security center.[118] Cyber attacks have continued to occur in Estonia. For example, there were approximately 2,672 cyber incidents in 2022, which was an increase of ⅕ from the previous year.[119]

Additionally, Poland is concerned with the increasing susceptibility to cyberattacks. According to the multinational firm KPMG's 2022 "Cyber Security Barometer," 29% of Polish enterprises were victims of at least one hack during 2021. This problem is exacerbated by the increasing trend toward digitalization on both the economic and administrative fronts and Covid-19, which demands that all services be performed online. The government has attempted to take action in response to cyberattacks. The National Framework of Cybersecurity Policy of the Republic of Poland for 2017-2022 is one of them. It is a strategic document in a continuous process of actions taken by the governmental administration to raise the level of cybersecurity in the Republic of Poland, including the Policy for the Protection of Cyberspace of the Republic of Poland adopted by the government in 2013.

5. Socio-Cultural Barriers

Despite the aforementioned drivers, a few socio-cultural barriers to digital transformation persist in these countries. Ukraine, Poland, and the Kyrgyz Republic's main challenge is maintaining the growth in digital skills. According to the World Bank's statistics, Ukraine has the lowest (compared to the other three case countries) year-on-year average growth rate at -2.92% for the time period 2017–2019 with respect to digital skills among the population.[120] Overall, there is also a lack of perceived importance of learning digital skills among certain demographic groups in Ukraine.[121]

Also, there are still types of digital skills that are lagging, and people with auditory disabilities have additional challenges in becoming digitally literate in Ukraine. To start, digital skills for solving life problems (55.8%) and digital content creation skills (36.8%) are above the basic level. These are, therefore two areas of digital skills that need to be improved upon.[122] Second, people with auditory disabilities face obstacles when using the internet. More specifically, "73% of them say that they are concerned about the use of the websites / tools where they have to enter their personal data. 72% of respondents feel anxiety when they do not have access to the Internet and 70% are concerned about the amount of time they spend online. Among other groups, these figures do not exceed 46%."[123] As for Poland, although it has a digitally enabled talent pool, it still ranks below the EU average in every category of human capital, from basic digital skills in the public to the percentage of available ICT specialists. According to the World Bank's statistics, Poland experienced a year-on-year average growth rate of -0.76% for the time period 2017 to 2019 with respect to digital skills among the population.[124] Whereas for the Kyrgyz Republic, according to the World Bank's statistics, the country experienced a

[118] Mission Mystique. n.d. "Estonia's Digital Transformation." D-Nb.Info. Accessed February 5, 2023. https://d-nb.info/120400515X/34.
[119] "STARTUp Day Panel: Cybersecurity for Businesses —." n.d. Startup Estonia. Accessed February 6, 2023. https://startupestonia.ee/blog/startup-day-panel-cybersecurity-for-businesses.
[120]"GCI 4.0: Digital Skills among Population." n.d. Accessed March 25, 2023. https://tcdata360.worldbank.org/indicators/h945a9708?country=UKR&indicator=41400&countries=EST,POL,KGZ&viz=line_chart&years=2017,2019&indicators=944
[121] Ibid.
[122] "Digital Literacy of the Population of Ukraine." n.d. Gov.Ua. Accessed March 18, 2023. https://osvita.diia.gov.ua/uploads/0/2623-research_eng_2021.pdf.
[123] Ibid.
[124] "GCI 4.0: Digital Skills among Population." n.d. Accessed April 19, 2023. https://tcdata360.worldbank.org/indicators/h945a9708?country=UKR&indicator=41400&countries=EST,POL,KGZ&viz=line_chart&years=2017,2019&indicators=944

year-on-year average growth rate of -1.47% for the time period 2017 to 2019 with respect to digital skills among the population.[125]

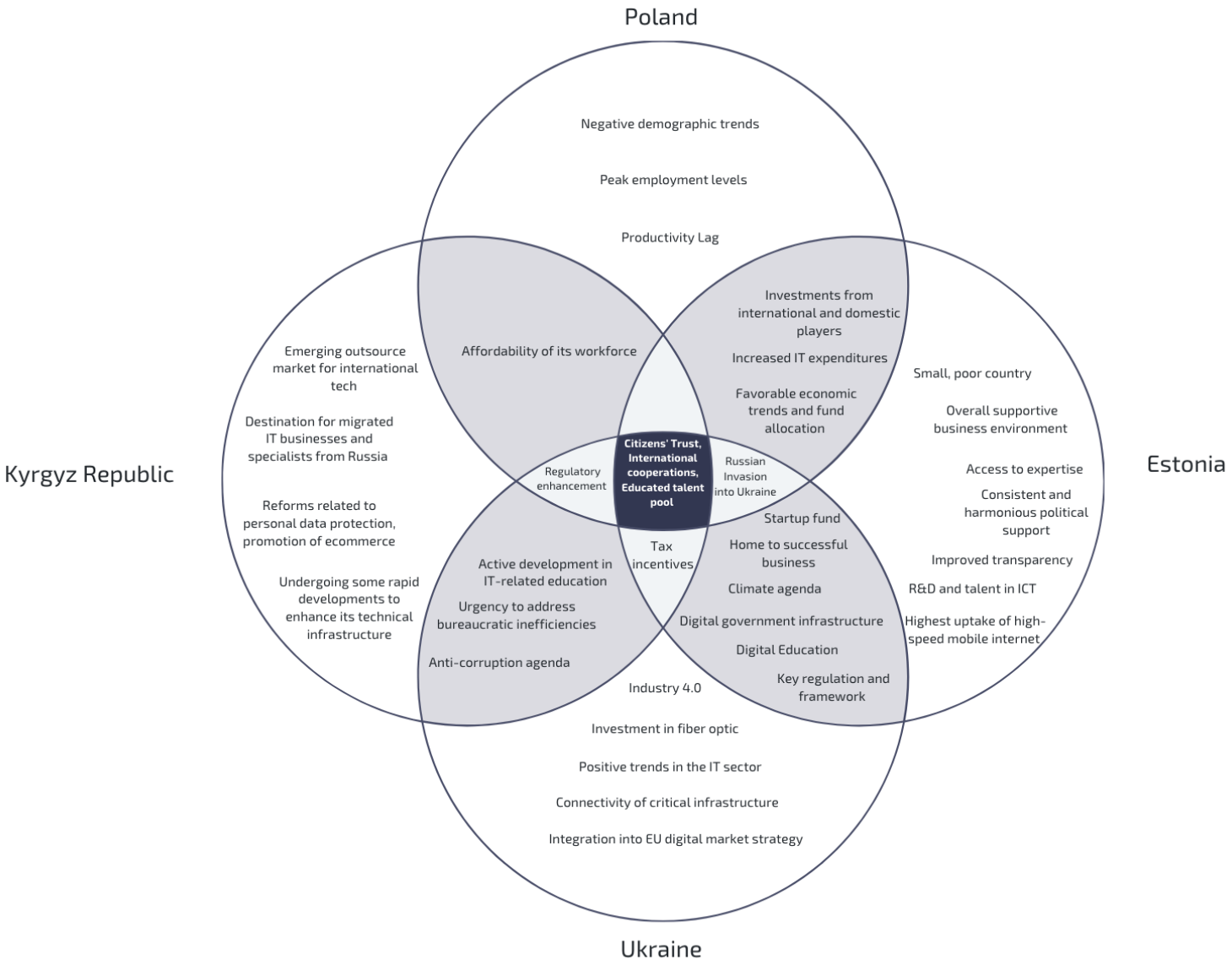
Estonia has a small population and a shortage of skilled IT professionals, making it difficult for businesses to find the required talent and drive initiatives related to digital transformation. This could lead to higher costs for hiring these professionals and hinder the adoption of new technologies. Another barrier is attracting young talent in response to the high share of aging teachers.[126] Furthermore, the pool of digitally skilled workers is diminishing in Ukraine, as many Ukrainians are leaving the country due to the ongoing Russian invasion. The Kyrgyz Republic is also facing challenges in terms of the migration of skilled professionals to more developed countries with more favorable economic conditions - especially brain drain after capacity building. The county scores 6.7/10 on the Human Flight and Brain Drain Index is 6.7/10,[127] which has the potential to further hinder the digital transformation in the country.

Moreover, the IT-related education systems are outdated in Poland, and it lacks in providing any sort of incentives that encourage people to pursue ICT careers. Although Polish businesses are investing in ICT training, fewer than one-fifth (18%) provide specialized ICT training to their employees.[128] This could create a digital supply challenge in the country, as the firms in Poland have invested significantly less in assets and employ fewer professionals in digital jobs when compared to Western European countries. If not addressed, it will challenge further digital transformation in the country.

Figures 14 and 15 illustrate the key drivers and barriers to digital transformation across Estonia, Poland, Ukraine, and the Kyrgyz Republic.

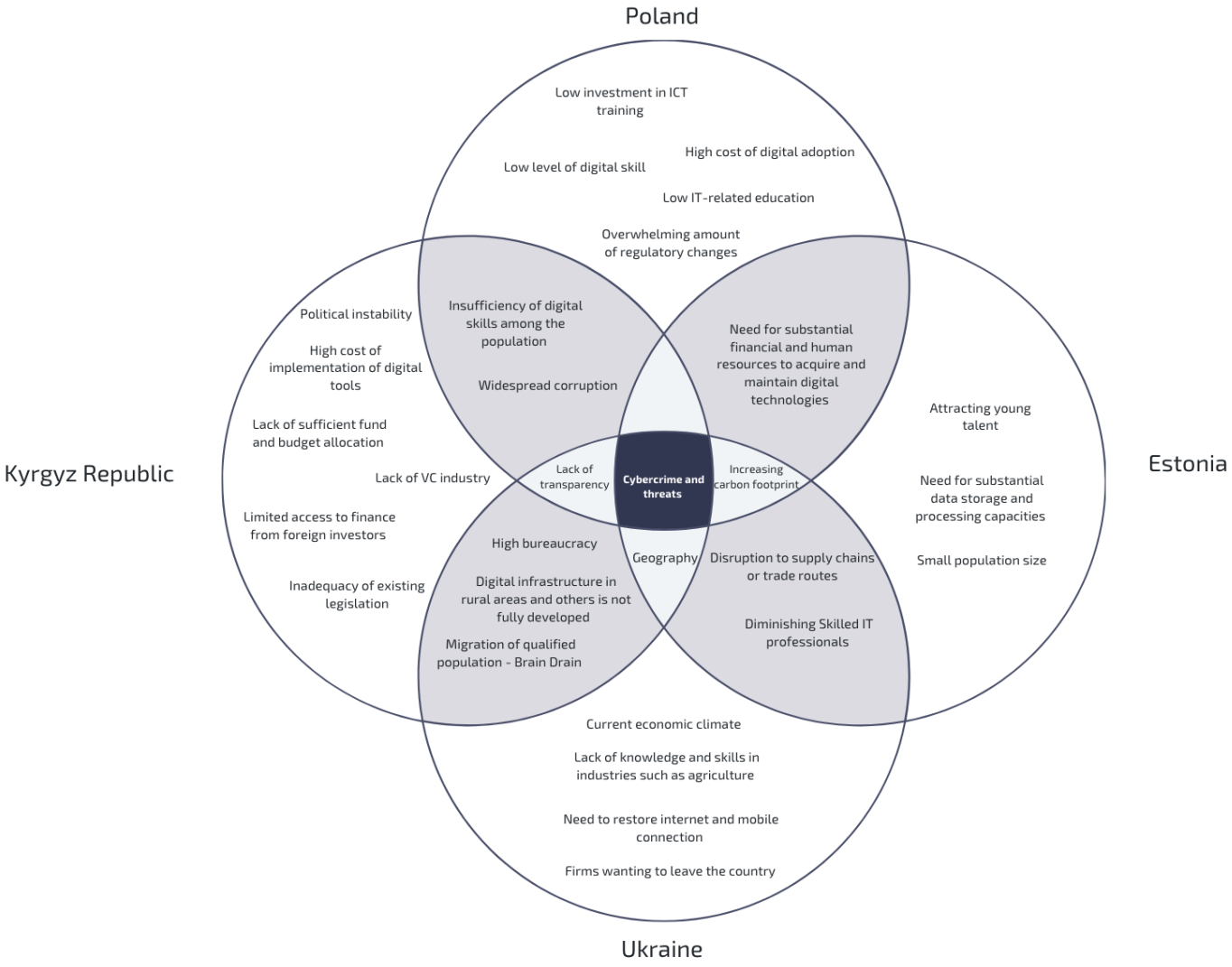
[125]"GCI 4.0: Digital Skills among Population." n.d. Accessed April 25, 2023.
[126] "Education and Training Monitor 2020." n.d. Europa.Eu. Accessed February 20, 2023. https://op.europa.eu/webpub/eac/education-and-training-monitor-2020/countries/estonia.html.
[127]"Kyrgyzstan Human Flight and Brain Drain - Data, Chart." n.d. Theglobaleconomy.com. Accessed March 8, 2023. https://www.theglobaleconomy.com/Kyrgyzstan/human_flight_brain_drain_index/.
[128]"Digital Economy and Society Index (DESI) 2022." n.d. Shaping Europe's Digital Future. Accessed April 28, 2023. https://digital-strategy.ec.europa.eu/en/library/digital-economy-and-society-index-desi-2022.

Figure 14: Summary of the Key Drivers Across All Four Countries



Source: Report Team

Figure 15: Summary of the Key Barriers Across All Four Countries



Source: Report Team

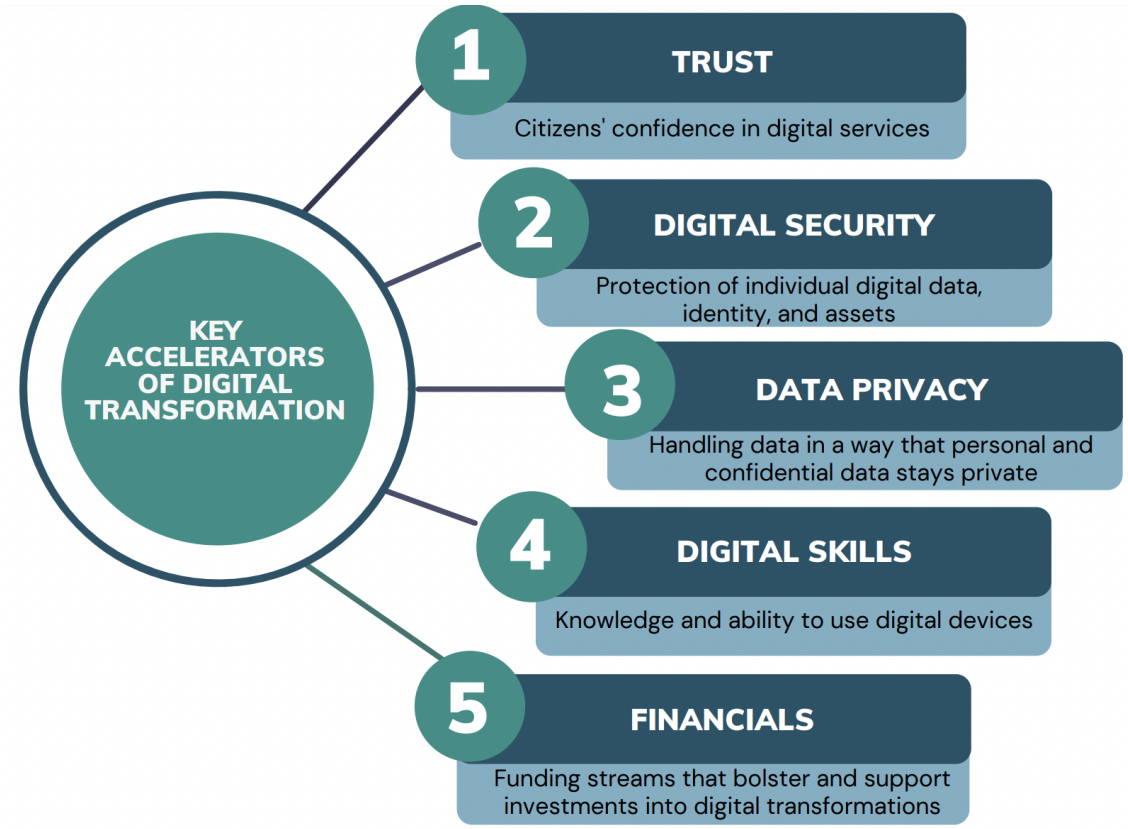
7. Conclusion and Recommendation

Mapping out the drivers and barriers to digital transformation allows these countries to understand the factors that can expedite or hinder their digital agenda. Overall, this sort of input is useful and could be incorporated into a country's national digital development strategy. This strategy could serve as the EBRD's reference when determining its investment priorities and ensuring that its projects exert the greatest spillover effects.

Five Key Accelerators of Digital Transformation

Across the four case countries, five key elements have emerged as accelerators of digital transformation: Trust, digital security, data privacy, digital skills, and financing (please see Figure 10 for an overview). These five factors were themes that continued to arise in our literature review and expert interviews. Please refer to **Appendix 6** for a brief overview of how the four case countries have made progress in each of these five accelerants. Other organizations have expressed similar accelerators. For instance, our discussion with World Bank representatives affirmed that these were similar accelerants that they have framed as enablers of digitalization.[129]

Figure 16: 5 Key Accelerators of Digital Transformation



Source: Literature Review, Expert Interviews, Team Analysis

Trust

For the purpose of this framework, we define trust as the citizens' confidence in digital services. To determine a country's citizens' trust in digital services, we considered factors such as transparency and corruption. For instance, active anti-corruption measures in the government are likely to increase the perceived integrity of the digital services offered. In turn, this will increase citizens' trust in digital services.

[129] Interview with World Bank economics: Christine Zhenwei Qiang, Natalija Gelvanovska-Garcia, Yan Liu.

The concept of trust was a phenomenon particularly highlighted by Jenik Radon, a Columbia Professor at the School of International Affairs and a previous winner of the Medal of Distinction of the Estonian Chamber of Commerce. He stressed that trust in digital services and the government enables digitalization to occur more rapidly, with Estonia as a model example. Without foundational trust established, the uptake of digital services and tools will be limited. For instance, trust was pivotal in getting Estonian citizens on board with e-identification, e-citizenship, and digital health.

Digital Security

Within digital security, we consider the protection of individual digital data, identity, and assets, but also broader cybersecurity. It is, therefore, the actions taken to prevent an unauthorized party from accessing digital data, identity, and assets. Protection may come in the form of the development and usage of biometrics, blockchain, antivirus software, and cyber workforces. To determine a country's digital security capacity, we also investigated the types of external partnerships established.

Digital security is an important factor to consider since the threat of cybersecurity has increased as the world has become increasingly digital. Statistics concerning annual digital cybersecurity threats or hacks underscore the grave of an issue this. As a result, governments need to take appropriate measures to tackle security issues that threaten individuals' online identities, data, and assets. Some of the best practices to do this have included partnering with multilateral development banks and other countries to strengthen a country's capability to tackle digital security threats.

Data Privacy

Data privacy means appropriately handling data so that personal and confidential data stays private. This includes properly collecting, storing, and sharing data in alignment with data protection laws.[130] As private information and data on national security are stored and shared online, data privacy has become progressively more critical. For the latter, a breach of privacy can significantly negatively impact national security. With the ongoing Russian invasion of Ukraine, there is also the risk of loss of data that a physical invasion would bring about, which could pose a significant threat to the economy of countries that rely on the data stored digitally to operate.

Digital Skills

Digital skills is the knowledge and ability to use digital devices.[131] At the basic level, this may look like understanding how to use online applications. At the advanced level, this may look like utilizing AI, machine learning, and data analytics for ICT tasks.[132] A basic level of digital skills is essential to effectively uptake digital services and platforms. A lack of digital literacy prevents individuals from using cheaper and faster services online. Some demographics may be more vulnerable than others, such as the elderly or disabled. As a result, educational initiatives are imperative to drive digital literacy.

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[130] "5 Things You Need to Know about Data Privacy [Definition & Comparison]." 2023. Data Privacy Manager. January 10, 2023. https://dataprivacymanager.net/5-things-you-need-to-know-about-data-privacy/.
[131] "Digital Skills Critical for Jobs and Social Inclusion." 2023. Unesco.org. March 20, 2023. https://www.unesco.org/en/articles/digital-skills-critical-jobs-and-social-inclusion.
[132] Ibid.

Digital Financing

We define digital financing as funding streams that bolster and support investments into digital transformations. Digital transformations require significant upfront capital and investment. This is, therefore, a pain point for many governments in becoming more digital. A variety of different sources of funding are utilized by governments, including their own budgets but also from multilateral development banks and institutions. In countries where digital transformation is still developing, there is greater dependence on international grants/loans. For instance, Ukraine and Poland look to the EU for funding. The Kyrgyz Republic also relies on external funding sources to support digital transformation. Funding through the private sector also immensely supports the transformation to a digital economy. Moving forward, greater research could be conducted to break down public and private stakeholders' funding sources and spending. This data was limited in availability to the public; however, it could be useful in helping the EBRD understand where their investments could be most useful and complement existing sources of investments and funding.

8. Conclusion and Recommendation

The five key accelerators could be used to investigate a country's digital transformation journey. These accelerators were also used to underscore the importance of utilizing data, monitoring progress, and ensuring consistency with a country's digital development strategy. Further elaboration is included in the recommendations section.

Conclusion

Our research aimed to determine how to measure and model digital spillover effects. After conducting literature reviews and expert interviews, we realized that it is rather difficult, given the time we have, to construct a comprehensive model that traces the effects of digital transformation, given that digital integration has been observed in numerous sectors and aspects of our society.

Therefore, instead of attempting to encapsulate digital transformation's overall economic and social effects, we focused on sectoral and country-level dynamics. The Connectivity Scores that we developed allowed us to construct regression models to determine the relationship between countries' level of digital transformation and their performance in the financial and agricultural sectors. Higher levels of digital infrastructure are associated with credit expansion, bank cost reduction, increases in the proportion of agricultural exports, and agricultural total factor productivity, according to our regression analysis, which was conducted utilizing data from all available countries.

Digital spillovers occur when technological advances in the IT sector positively impact other sectors. In addition, our analysis revealed a correlation between the digital tools that are driving these changes, such as data analytics, the Internet of Things, SmartPhones, e-commerce, artificial intelligence, etc. Lastly, the adoption of digital transformation has both economic and social consequences. Providing assistance to the Fintech sector can assist in incorporating formerly unemployed individuals. The availability of digital tools to facilitate farmland management and the development of digital intermediaries to strengthen the connection between producers and the market contribute to the agricultural sector's efficiency.

After undertaking sectoral analysis, we delved into case country profiles and identified the economic, environmental and external, regulatory-institutional, technical, and socio-cultural factors that serve as drivers and barriers to digital transformation. It is interesting to observe how internal characteristics and external events have shaped the digital transformation journeys of these countries. Moreover, trust, digital security, data privacy, digital skills, and digital financing are the five key accelerators for digital transformation identified across these four countries' case studies. Combining digital technology advancements with the five key accelerators can maximize the digital transformation's spillover effects.

In light of what we have learned about digital spillover effects, the following part highlights the insights gleaned from our investigation. We believe that constructing a measurement or model of the overall economic benefits of digital transformation is not only difficult but also insufficient, particularly if we are seeking both internal and external validity in the model. Additionally, the incalculability of many outcomes brought about by digital transformation on a global scale, such as the enhancement of social inclusion, the benefits brought about by knowledge sharing via digital platforms, and the intimate feelings generated by digital communication, are some of the primary obstacles. Moreover, measuring the global economic effects of digital transformation cannot accurately depict how technology has altered firms' operations and the lives of households. Consequently, we propose that more research be devoted to comprehending digital spillover effects during the implementation of investment projects or analyzing the drivers of digital transformation in particular sectors.

Policy Recommendations

The last section of this report highlights some policy recommendations that could be further investigated by the EBRD. These recommendations include: 1) utilizing data and monitoring progress, 2) consistency with digital development strategy, 3) more targeted investments, and 4) guiding principles to follow when looking at the five accelerators framework.

1. Utilizing Data and Monitoring Progress

As famously stated by Peter Drucker, a renowned management expert, “If you can’t measure it, you can’t manage it”.[133] This is extremely fitting for our narrative, as the lack of data collection and metrics was a recurring observation in our research. The research shed light on the current gaps when measuring trust, digital skills, the unclarity of the target indicators, and the monitoring of digital development projects.

1.1 Measuring Trust

Our research and interview outcomes emphasized the role of trust as one of the fundamental accelerators of digital transformation. However, thus far, limited steps have been taken to measure progress on trust in digital services in some of the case countries. **Appendix 6** indicates that data on trust in digital services is only readily available for Estonia and Poland. For Estonia, statistics on trust are

[133] Patrinos, Harry A. 2014. “You Can’t Manage What You Don’t Measure.” *World Bank Blogs* (blog). World Bank Group. December 1, 2014. https://blogs.worldbank.org/education/you-can-t-manage-what-you-don-t-measure.

estimated by the digital transformation advisor from e-Estonia. For Poland, the trust data were an outcome of the Fletcher School at Tufts University's study on trust in the digital economy investigating Poland alongside other countries. Nevertheless, similar statistics were unavailable for both the Kyrgyz Republic and Ukraine, hence, indicating a gap in the trust-related data collection that needs to be addressed.

Our case for the need to address the aforementioned gap is vital, as improvements in trust data collection will allow these governments to identify their current standing when it comes to their citizens' trust in the offered digital services, and act accordingly. Ultimately, we claim that given the interconnectedness of the accelerators of digital transformation, any improvements in trust will indirectly drive improvements in the remaining accelerators of digital transformation, which include trust, digital security, data privacy, digital skills, and financing.

Overall, without measuring trust, a country cannot substantially evaluate whether trust is a pain point or not. They also cannot track whether trust in digital services has increased or decreased. Hence, it remains critical for the EBRD to carry out a digital investment that simultaneously incorporates a **harmonization or standardization** of measurements, such as trust.

1.2 Measuring Digital Skills

Measuring digital skills is another important component of digital transformation. Having a more comprehensive overview of a country's digital skill status would enable the EBRD to tailor its projects more specifically and accelerate the digital transformation process in its operations. Traditionally, national statistics have measured digital skills based on the level of educational attainment, the availability of vocational training, etc. Nonetheless, countries in general could have different approaches towards measuring or not measuring digital skills. Our research highlighted that the measurement levels of digital skills vary in the four case countries. For example, in the Kyrgyz Republic, the level of digital skills is not being measured by the relevant bodies.

Hence, efforts need to be taken to ensure that digital skills are measured in the countries receiving any investments. New insights could be obtained by **leveraging and harmonizing** detailed national surveys on digital tasks and skills and by collaborating with the business community to define new metrics of digital skill gaps.

Addressing the skills gap could potentially enhance the current digital skills and generate a two-fold positive spillover effect. First, it can shape the demand for new high-skilled jobs. Second, it will strengthen the skills of individuals to succeed at their jobs.

Additionally, it is recommended that these efforts are also made to expand the scope of collected and publicly disclosed data. These steps will allow countries to make more efficient and timely decisions, assess the impact of digitalization processes, and enhance transparency.

In the context of the Kyrgyz Republic, the country does not currently measure digital skills, these steps may take the form of conducting a survey assessing the basic digital skills, such as using mobile applications; online communication; and advanced digital skills such as coding; web design; data analysis. The country could also refer to the existing best practices in other countries such as Ukraine.

Ukraine has done an exceptional job in measuring digital skills. For instance, in 2021, a report was published outlining the results from a national survey on the digital literacy status of the population of Ukraine.[134] A mass poll was conducted with 1800 respondents ranging from 18 to 70 years old through face-to-face interviews. Additionally, the report also investigates results from a youth survey (410 respondents from 10 to 17 years old), a survey of the occupied territories of Donetsk and Luhansk oblast (401 respondents from 18 to 60 years old), a survey of individuals with auditory disabilities (349 respondents from 18 to 59 years old), and a survey on focus groups (including health care workers, education workers, and the elderly). The survey meticulously looks into digital skills, by investigating digital communication skills, information skills, skills of solving life problems, and digital content creation skills. Ukraine's report on digital literacy, therefore, can be used as guidance for other countries wishing to undertake digital skills measurements and how to effectively utilize national surveys to measure digital skills status.

1.3. Target Indicators and Monitoring for Digital Development Projects

As previously mentioned, the collection and use of data is essential to monitoring and evaluating the digital transformation in a country. However, setting target indicators is also crucial for ensuring the efficiency of investments. This would allow timely corrective actions and enhance the accountability of the management by setting clear, measurable goals, and ensuring consequences in case the goals are not achieved. The indicators might be used as covenants that the beneficiary needs to comply with to ensure the maximum efficiency of the investments.

During the research, we explored projects funded by foreign investors, including the EBRD's projects on digitalization development in the Kyrgyz Republic. Projects such as the implementation of an electronic patent system, online registration of legal entities, and remote identification of customers in payment transactions undoubtedly have crucial value to the development of the country's digital economy. However, it is worthwhile to consider the implementation of target indicators for these projects to measure the success and monitor the progress of the project to provide maximum efficiency of the invested resources. These target indicators could include, the number of e-patents and the amount of taxes paid by the owners of the e-patents; the share of the legal entities registered online to the total number of registered legal entities within a certain period of time; the number/share of the transactions conducted using remote identification; and the total value of transactions being conducted through remote identification.

On the other hand, Poland's government target indicators can be used as an example of how specific target indicators have been used for both EBRD and government initiatives. The EBRD projects on the digital transition in Poland have multi-dimensioned indexes including "competitive", "integrated", "resilient", "inclusive", "Green", and "well-governed".[135] Moreover, in terms of government initiatives, one of the interviewed experts pointed out that Poland's government projects also use KPIs, but they are not sufficient. Their broadband projects use the number of households connected to high-speed broadband as a KPI. Also, for a recent government initiative, providing a computer for every 4th-grade student, its KPI is clearly the number of 4th-grade students who have a computer. However, these come with caveats.

[134] "Digital Literacy of the Population of Ukraine." n.d. Gov.Ua. Accessed February 14, 2023. https://osvita.diia.gov.ua/uploads/0/2623-research_eng_2021.pdf.
[135] EBRD, "Transition Report 2021-2022 System Upgrade: Delivering the Digital Dividend, Country Assessment: Poland"

During our conversation with Janusz Cieszyński, the Polish Secretary of State, Government Plenipotentiary for Cyber Security, it was noted that although the broadband project was successful in spreading the infrastructure, the private companies that took part in the project focused on low-cost areas and it resulted in the uneven distillation of the broadband. That is to say, there is unevenly more broadband infrastructure in populated areas but less so in rural areas, where the cost of installation is higher. In the case of computer distributions, it is important not only to deliver on the main purpose, equipping all 4th-grade students with a computer, but also to prepare teachers with the necessary digital skills and guidelines to teach properly using digital technologies.

As illustrated by the above examples, KPIs for each project should be specific but broad enough to make it successful while incorporating the equality perspective in a balanced way. The EBRD should continue to use and refine its multi-dimensioned indexes and coordinate with the Polish government or other governments that do not have the indexes they need to help them develop their indexes.

2. Consistency with Digital Development Strategy

Our country-level analysis and interviews allowed us to drive some observations on the importance of developing and implementing a national digital development strategy, which serves as one of the key drivers of digital transformation. These national strategies could be used as the EBRD's reference when determining its investment priorities and ensuring that its projects exert the greatest spillover effects.

For example, one of Estonia's digital transformation accelerating factors has been its consistent digital development strategy throughout the different political parties and leaders. By having a unified and consistent vision for the development of the country's digital capacity, the government has garnered a reliable reputation and trust of a variety of stakeholders and citizens. In 2021, the Ministry of Economic Affairs and Communications published Estonia's Digital Agenda for 2030, which will serve as Estonia's roadmap for the rest of the decade. General concepts included in the roadmap are a description of the current state of the development of digital society, vision, principles, general objectives and metrics, next leaps, and directions, trends in connectivity, trends in cyber security, and estimated costs.[136]

Similarly, a consistent digital development strategy is seen in Ukraine. The creation of the Ministry of Digital Transformation in Ukraine helps streamline the process of building a convenient digital state and set strategic goals to be accomplished by 2024. These strategic objectives help guide the journey of Ukraine's digital transformation and create timeframes for key achievements. For example, the Ukraine Recovery Plan, drafted by the National Council for the Recovery of Ukraine from the Consequences of the War, reiterates the importance of achieving these strategic goals and outlines key activities specific to Ukraine at different stages: war-time (2022), recovery (2023 - 2025), and modernization (2026 - 2032).

The Polish government has recognized the importance of developing a digital agenda. Its current programs include the Operational Programme Digital Poland (2014 - 2020), the National Broadband Plan, and the National Interoperability Framework. The government has stayed consistent in the implementation of its digital development strategies. Moreover, the government recently added the Digital

[136] "Estonia's Digital Agenda 2030." n.d. Mkm.Ee. Accessed March 25, 2023. https://www.mkm.ee/media/6970/download.

Competency Development Program (2020-2030) and Strategy for Responsible Development, the former of which focuses on developing digital skills and the latter of which helps draft medium- and long-term economic policies. By maintaining a consistent and aligned digital strategy, Poland will continue to make progress toward its digital transformation goals and reap the benefits of a more digitized economy and society.

Digital transformation roadmaps make a huge difference in digital transformation. In fact, BCG found that "Digital transformation is hard – only 30% of digital transformations succeed in reaching their goals. But grounding your plans and priorities in clear strategic insight can flip the odds of success from 30% to 80%".[137] However, roadmaps can be difficult to follow for numerous reasons, one of which is the emergence of unexpected and yet conflicting priorities. People in different positions of power may also have divergent priorities or perspectives on when and how the roadmap should be implemented.

Countries such as the Kyrgyz Republic have struggled to implement a consistent digital development strategy, mostly due to political instability, which led to frequent changes in the top management position. As a result, it led to an inconsistent strategy in digital development and an inefficient use of resources as each new manager would pursue different goals, undermining the previous work.

Our recommendations concerning national digital development strategies are two-fold. Firstly, the EBRD can leverage its expertise to assist countries that lack a comprehensive digital development plan and strategy in drafting a roadmap, developing a timeline for the agenda, and setting key targets for each phase. Secondly, during the implementation phase of countries' digital strategies, the EBRD can promote consistency in the decision-making of digital public policies through actively engaging with country leaders and industry experts, stressing the need to adhere to the previously established agenda, thereby reducing the risk of discontinued interest in digital transformation from the management level. By offering support during both the planning and implementation stages, the EBRD can play a vital role in ensuring the success of national digital development strategies.

3. Targeted investments - Finance and Corruption

Future investments should be grounded in improving not only specific digital gaps that a country is grappling with but should also be targeted based on areas that have proven to have immense impact and positive spillover effects.

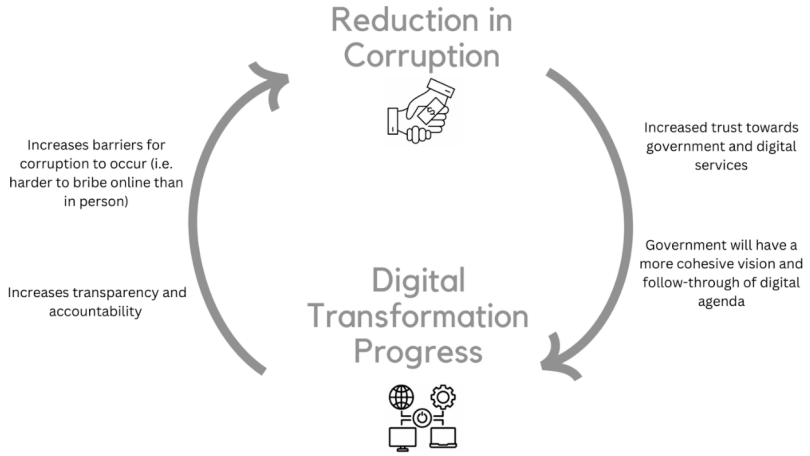
In particular, our research underscores that digital transformation can have positive spillover effects on lowering corruption levels, which in turn facilitates the economic prosperity of the country by enhancing transparency; lowering the share of the shadow economy; improving tax collection, and reducing the level of risks in the economy overall. Moreover, digital transformation tends to lead to domestic credit expansion, which further stimulates the economic development of the country by providing greater leverage for the development of the real sector; expanding financial inclusion; and increasing consumption levels. Consequently, we claim that investments in Fintech-related projects can

[137]"Digital Strategy Roadmap." n.d. BCG Global. Accessed April 3, 2023. https://www.bcg.com/capabilities/digital-technology-data/digital-strategy-roadmap.

further drive countries' financial stability and efficiency, as well as stimulate overall economic growth, and the EBRD may wish to continue its involvement in these projects.

The effects of digital innovations in finance are closely interconnected with anti-corruption campaigns, and the spread of digital payments is one of the proven tools to reduce corruption levels. There is an ongoing loop, as illustrated in **Figure 17** below: targeted digital transformation initiatives drive anti-corruption through a reduction in discretion and an increase in transparency and accountability.

Figure 17: Relationship between Corruption and Financial Digital Transformation



Hence, we suggest that future EBRD investments be targeted towards anti-corruption and finance projects, aiming, for instance, at:

- Simplification and optimization of government services: registration of legal entities; tax reporting and collection;
- Automation of processes in government ministries and agencies to minimize the human factor;
- Incentivizing digital payments and cashless transactions: providing benefits for the financial institutions offering e-banking services.

Additionally, it is suggested to include the “Impact on Transparency’ component in the digital transformation projects, because one of the great spillover effects of digitalization is the enhancement of transparency. Measuring and demonstrating this component might, to a better extent, represent the impactfulness of the EBRD’s projects in digital transformation.

4. Guiding Principles to Follow When Looking at the Five Themes Framework

The following section aims to contribute value to other countries that the EBRD may be considering investigating further. This section contains metrics and questions that would be beneficial to ask and investigate when examining the Five Accelerators framework. By doing so, the EBRD will be able to identify areas of vulnerability where they can make more significant investments.

	Questions	Potential Sources
Trust	What percentage of the country's population trusts the digital systems set in place?	Some countries conduct national surveys/polls. Other countries may have a digital trust index that can be investigated.
	What is the country's level of transparency? And what government initiatives have been put in place to increase transparency?	Could investigate the Transparency Index from Corruption Risk Forecast.[138]
	What is the country's level of corruption? And what government initiatives have been put in place to decrease corruption?	Could investigate the Corruption Perception Index from Transparency International.[139]
	Using internet usage as a potential proxy for trust, what percentage of the population uses the internet?	Could investigate the World Bank's data on Individuals using the Internet (% of population).[140]
Digital Security	What is the current status of the country's cyber security situation?	Could investigate the National Cyber Security Index.[141]
	How many cyber incidents occurred in the last year? vs. past 5 years?	Individual government website or news sources
	What government initiatives have been put in place to improve digital security? What percentage of the government's budget is allocated towards digital security?	Individual government website or news sources
Data privacy	What laws have been put in place to facilitate greater data privacy?	Individual government website or news sources
	What cloud protection services have been implemented?	Individual government website or news sources
Digital Skills	What is the current digital skill gap?	Could investigate the Digital Skill Gap Index (DSGI).[142]
	Is there digital literacy among all demographic groups, including race, ethnicity, gender, age, and disabilities?	Individual government website or news sources
	What educational programs have been put in place to increase digital literacy?	Individual government website or news sources
Financing	What funding is already provided to the country from bilateral or multilateral agreements?	Individual government website or news sources

[138] "Transparency Index." n.d. Corruptionrisk.org. Accessed March 1, 2023. https://corruptionrisk.org/transparency/.
[139] "2022." 2023. Transparency.org. January 31, 2023. https://www.transparency.org/en/cpi/2022.
[140] "Individuals Using the Internet (% of Population)." n.d. World Bank Open Data. Accessed February 5, 2023. https://data.worldbank.org/indicator/IT.NET.USER.ZS.
[141] "NCSI :: Ranking." n.d. Ega.Ee. Accessed February 5, 2023. https://ncsi.ega.ee/ncsi-index/.
[142] "Global Rankings for Digital Skills." 2021. Wiley. June 9, 2021. https://dsgi.wiley.com/global-rankings/.

	How is the country allocating its own budget?	Individual government website or news sources
	How is the private sector contributing to and funding digital sectors?	Individual government website or news sources

5. Further Research

Despite the fact that this research makes a substantial contribution to the EBRD's existing knowledge on digital transformations, it has also yielded insights into the next stages that the EBRD digital hub may wish to investigate further.

Through our conversations with a wide range of experts in the field, such as representatives from government ministries, the World Bank, Oxford Economics, Mastercard, EBRD, and e-Estonia, we came to recognize the immense value that conversations with experts bring. Although data provides an essential lens for digital transformation and enables more precise tracking of digital progress, it does not provide a comprehensive view. Through interviews, we acquired invaluable insights that the data do not capture. In the future, we recommend continuing to engage in dialogues that include academics, practitioners, multilateral professionals, government officials, and business representatives.

One interview that particularly stood out was our conversations with the representatives of Mastercard, Arturo Franco and Payal Dala. Mastercard, in collaboration with the Fletcher School at Tufts, has developed a digital intelligence index that maps the digital evolution and digital trust of numerous countries.[143] This multidisciplinary toolkit may be of interest to the EBRD. Mastercard has also leveraged transformative relationships with non-profit organizations to increase its global community impact.

Expanding the spectrum of outcomes used to measure digital spillover effects is one of the suggested research areas. The majority of recent literature focuses on quantifying the digital spillover effects by analyzing outcomes such as changes in productivity and economic growth. Nonetheless, it is worthwhile to investigate the impact of digital spillover on trade (by analyzing indicators such as the number of cross-border transactions, the number of online marketplaces, online exports, and changes in the volume of exports and imports), innovation (by analyzing indicators such as the number of patents filed and improvements in research and development projects), and investments (by analyzing indicators such as the value of venture capital investments and changes in venture capital investment value).

We also recommend executing a narrower analysis within sectors, as each sector is extremely expansive. Due to the vast scope of each sector, we concentrated our sectoral analysis predominantly on the finance and agriculture sectors. These two sectors have been identified because they were consistently highlighted as impactful in interviews conducted during this project and the literature used. However, it would be beneficial to investigate additional industries, including the Infratech, manufacturing & services, and energy sectors. These fundamental sectors appeared to have an effect on the digital economy as a whole.

Moreover, it may be advantageous for future research to measure digital transformation in specific sectors and at the firm level. On the firm level, it could be beneficial to analyze the network

[143] "Digital Intelligence Index." n.d. Tufts.edu. Accessed April 9, 2023. https://digitalintelligence.fletcher.tufts.edu/trajectory.

effects of the digital transformation, which impact the firm's profitability, optimize the operational performance, and might have other unintended spillover effects. More specific measurement of digitalization, for instance in the financial sector, the level of digitalization can be determined by the number and variety of e-banking services, the efficacy of mobile banking applications, and the degree of automation of operational processes in banks and other financial institutions. This approach could provide more precise measurements of the level of digitalization in each sector and more in-depth conclusions regarding the spillover effects between sectors.

Appendix 1: List of Experts Interviewed During the Project

	Expert	Country Focus	Title	Organization
1	Azis Abakirov	Kyrgyz Republic	Owner and Founder	Unique Technologies
2	Sharda Cherwoo	Not country-specific	Retired Partner	Ernst & Young, LLP (EY)
3	Eric Livny	Central Asia	Regional Lead Economist	European Bank for Reconstruction and Development (EBRD)
4	Dastan Dogoev	Kyrgyz Republic	Former Minister of Digitalization in the KR	Ministry of Digitalization in the KR CEO & Founder of MyData.coin
5	Arturo Franco	Not country-specific	Senior Vice President, Thought Leadership	Mastercard
6	Payal Dalal	Not country-specific	Senior Vice President of Social Impact, International Markets	Mastercard
7	Tilek Toktogaziev	Kyrgyz Republic	Chairman	Greenhouse Association of Kyrgyzstan
8	Mirgul Umetalieva	Kyrgyz Republic	Associate Counselor	European Bank for Reconstruction and Development (EBRD)
9	Talant Sultanov	Kyrgyz Republic	United Nations Internet Governance Forum, Multistakeholder Advisory Group (MAG) Member Digital Development Expert	United Nations The World Bank
10	Alexander Plekhanov	Not country-specific	Director, Transition Impact and Global Economics	EBRD
11	Dr. Laurence Wilse-Samson	Not country-specific	Lead Economist	Oxford Economics
12	Mark Boris Andrijanič	Ukraine/Slovenia	Head of global policy for Uber; Former Minister	Uber; Ministry of Digital Transformation of Slovenia
13	Janusz Cieszyński	Poland	Secretary of State, Government Plenipotentiary for Cyber Security	The Chancellery of the Prime Minister of Poland
14	Christine Zhenwei Qiang	Not country-specific	Director, Digital Development Global Practice	The World Bank
15	Eli Noam	Not country-specific	Special Research Scholar in the Faculty of Business	Columbia Business School
16	Erika Piirmets	Estonia	Digital Transformation Adviser	e-Estonia
17	Jenik Radon	Estonia	Adjunct Professor	SIPA, Columbia University
18	Natalija Gelvanovska-Garcia	Not country-specific	Senior ICT Policy Specialist	World Bank
19	Yan Liu	Not country-specific	Economist	World Bank
20	Fillipe	Ukraine	Student from Ukraine	Columbia SIPA
21	Jan Svejnar	Not country-specific	Professor of Economics and International Affairs	Columbia SIPA

Appendix 2: Countries' Most Recent Connectivity Scores

Country	Year	Connectivity
Afghanistan	2020	25.5527969
Albania	2021	63.7463712
Algeria	2021	57.9539091
American Samoa	2020	21.6501765
Andorra	2020	84.2985843
Angola	2021	22.6070371
Antigua and Barbuda	2020	103.600104
Argentina	2021	80.2336738
Armenia	2021	72.8401447
Aruba	2020	75.0574659
Australia	2021	69.7743389
Austria	2021	81.184174
Azerbaijan	2021	62.410191
Bahamas, The	2020	74.0215513
Bahrain	2021	80.841725
Bangladesh	2021	56.4216694
Barbados	2021	74.5371622
Belarus	2021	81.161262
Belgium	2021	78.7583256
Belize	2020	37.9823762
Benin	2021	49.0596446
Bermuda	2020	71.0604404
Bhutan	2021	62.0204001
Bolivia	2021	54.4788423
Bosnia and Herzegovina	2021	71.3555022
Botswana	2021	84.2901837
Brazil	2021	60.9270306
British Virgin Islands	2020	67.7790359

Country	Year	Connectivity
Latvia	2021	77.5589515
Lebanon	2020	55.818102
Lesotho	2021	40.2433711
Liberia	2020	19.448796
Libya	2020	24.4516709
Liechtenstein	2021	86.823433
Lithuania	2021	83.1521048
Luxembourg	2021	98.8269674
Macao SAR, China	2020	177.283047
Madagascar	2021	28.2036965
Malawi	2021	30.0496985
Malaysia	2021	82.8213454
Maldives	2021	75.035861
Mali	2021	50.2794387
Malta	2021	83.9679366
Marshall Islands	2020	19.5789377
Mauritania	2021	70.7650791
Mauritius	2021	88.5431302
Mexico	2021	62.7240524
Micronesia, Fed. Sts.	2020	12.4881808
Moldova	2021	76.1473602
Monaco	2021	87.1858475
Mongolia	2021	78.5602987
Montenegro	2021	96.8680214
Morocco	2021	113.702709
Mozambique	2021	21.4354493
Myanmar	2021	63.9642966
Namibia	2021	59.1378934

Brunei Darussalam	2021	76.6664122
Bulgaria	2021	74.2180913
Burkina Faso	2021	55.8684227
Burundi	2021	30.8513886
Cabo Verde	2021	52.7876005
Cambodia	2021	60.9922387
Cameroon	2021	82.5130371
Canada	2021	64.4418589
Cayman Islands	2020	98.053781
Central African Republic	2020	22.3345045
Chad	2020	20.8638972
Chile	2021	79.1360868
China	2021	77.3809282
Colombia	2021	81.0324639
Comoros	2021	52.0093692
Congo, Dem. Rep.	2020	19.1906676
Congo, Rep.	2021	47.755143
Costa Rica	2021	85.0999902
Cote d'Ivoire	2021	81.6946997
Croatia	2021	71.8344263
Cuba	2021	45.6216996
Curacao	2020	62.6030176
Cyprus	2021	92.6243938
Czechia	2021	81.6911151
Denmark	2021	89.2890576
Djibouti	2021	22.7902315
Dominica	2020	63.8942134
Dominican Republic	2021	48.6615966
Ecuador	2021	54.1365793
Egypt, Arab Rep.	2021	52.3103837

Nauru	2020	81.2017864
Nepal	2020	57.4103318
Netherlands	2021	86.8750715
New Caledonia	2020	54.9924407
New Zealand	2021	74.5372659
Nicaragua	2021	47.6881676
Niger	2020	29.2825089
Nigeria	2021	45.7340609
North Macedonia	2021	57.7996796
Northern Mariana Islands	2020	40.3339652
Norway	2021	99.0000036
Oman	2021	73.3311342
Pakistan	2021	41.4119889
Palau	2020	133.541064
Panama	2021	75.5660708
Papua New Guinea	2020	24.8163009
Paraguay	2021	68.8191218
Peru	2021	69.3717307
Philippines	2021	75.9583622
Poland	2021	80.1450947
Portugal	2021	81.824198
Puerto Rico	2021	112.443013
Qatar	2021	77.9021737
Romania	2021	77.9241135
Russian Federation	2021	93.6423798
Rwanda	2021	40.6142549
Samoa	2020	16.4454308
San Marino	2021	77.0461684
Sao Tome and Principe	2021	43.1770406
Saudi Arabia	2021	85.2710876

El Salvador	2021	92.5258708
Equatorial Guinea	2020	20.2374739
Eritrea	2020	25.3946434
Estonia	2021	92.5199831
Eswatini	2020	53.1484642
Ethiopia	2021	16.6981031
Faroe Islands	2020	74.0780311
Fiji	2020	55.1139586
Finland	2021	85.2111469
France	2021	86.0954858
French Polynesia	2021	62.8613106
Gabon	2021	68.5038179
Gambia, The	2020	46.9110232
Georgia	2021	80.0347414
Germany	2021	87.7374094
Ghana	2021	64.0534581
Gibraltar	2021	60.0382614
Greece	2021	76.997821
Greenland	2021	74.130114
Grenada	2020	60.4773314
Guam	2020	21.5681524
Guatemala	2021	88.2452003
Guinea	2020	43.4914583
Guinea-Bissau	2021	54.3453966
Guyana	2020	59.6461123
Haiti	2020	33.1683727
Honduras	2021	38.8095954
Hong Kong SAR, China	2021	150.486008
Hungary	2021	76.3409353
Iceland	2021	85.4694555

Senegal	2021	59.4555548
Serbia	2021	77.0263458
Seychelles	2021	105.870668
Sierra Leone	2021	97.7015052
Singapore	2021	85.6480157
Sint Maarten (Dutch part)	2012	195.907681
Slovak Republic	2021	85.5500323
Slovenia	2021	81.237539
Solomon Islands	2020	34.3610295
Somalia	2021	26.2604596
South Africa	2021	85.8888528
South Sudan	2020	9.5859006
Spain	2021	82.680067
Sri Lanka	2021	76.5845302
St. Kitts and Nevis	2020	113.345368
St. Lucia	2020	61.6564141
St. Vincent and the Grenadines	2021	68.4181268
Sudan	2021	18.3094871
Suriname	2021	83.9488469
Sweden	2021	83.6352512
Switzerland	2021	89.6441922
Syrian Arab Republic	2021	43.5350719
Tajikistan	2020	60.7238217
Tanzania	2021	43.4729356
Thailand	2021	90.7961774
Timor-Leste	2021	52.4731214
Togo	2020	33.9368424
Tonga	2021	33.5512229
Trinidad and Tobago	2021	77.3728864
Tunisia	2021	69.8905222

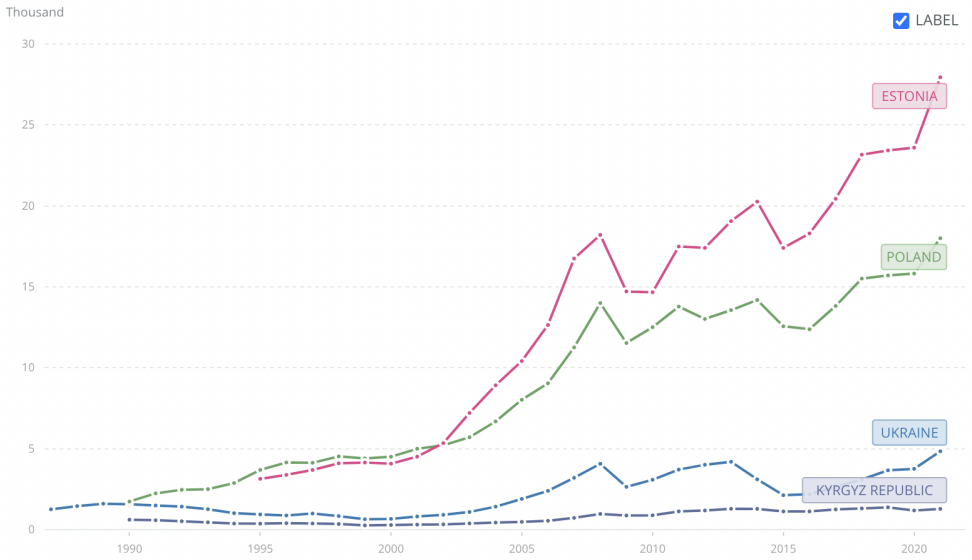
India	2021	41.9734633
Indonesia	2021	66.7639115
Iran, Islamic Rep.	2021	81.7637141
Iraq	2021	50.8085193
Ireland	2021	69.6961973
Israel	2021	85.1497333
Italy	2021	79.4223152
Jamaica	2021	58.6857701
Japan	2021	98.4830362
Jordan	2021	35.8557079
Kazakhstan	2021	77.3404276
Kenya	2021	62.1393764
Kiribati	2021	21.2905629
Korea, Dem. People's Rep.	2020	23.1951586
Korea, Rep.	2021	94.1351352
Kosovo	2018	89.443032
Kuwait	2021	88.0447908
Kyrgyz Republic	2020	69.6558889
Lao PDR	2021	42.9952375

Turkiye	2021	68.1954488
Turkmenistan	2020	75.0907376
Turks and Caicos Islands	2020	9.03423977
Tuvalu	2020	81.3081579
Uganda	2021	32.8938926
Ukraine	2021	76.6467416
United Arab Emirates	2021	110.962106
United Kingdom	2021	79.8969517
United States	2021	72.5003628
Uruguay	2021	84.5927484
Uzbekistan	2021	61.429291
Vanuatu	2021	39.6421902
Venezuela, RB	2021	34.037722
Vietnam	2021	77.6352612
Virgin Islands (U.S.)	2020	79.647956
West Bank and Gaza	2021	42.6784903
Yemen, Rep.	2020	24.1125291
Zambia	2021	52.1942497
Zimbabwe	2021	45.2149351

Appendix 3: Detailed Description of Indicators Included in the Connectivity Score

Indicator	Long definition	Data Source
Individuals using the Internet (% of population)	Internet users are individuals who have used the Internet (from any location) in the last 3 months. The Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.	International Telecommunication Union (ITU) World Telecommunication/ICT Indicators Database
Fixed broadband subscriptions (per 100 people)	Fixed broadband subscriptions refers to fixed 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, fiber-to-the-home/building, other fixed (wired)-broadband subscriptions, satellite broadband and terrestrial fixed wireless broadband. 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 include fixed WiMAX and any other fixed wireless technologies. It includes both residential subscriptions and subscriptions for organizations.	International Telecommunication Union (ITU) World Telecommunication/ICT Indicators Database
Mobile cellular subscriptions (per 100 people)	Mobile cellular telephone subscriptions are subscriptions to a public mobile telephone service that provide access to the PSTN using cellular technology. The indicator includes (and is split into) the number of postpaid subscriptions, and the number of active prepaid accounts (i.e. that have been used during the last three months). The indicator applies to all mobile cellular subscriptions that offer voice communications. It excludes subscriptions via data cards or USB modems, subscriptions to public mobile data services, private trunked mobile radio, telepoint, radio paging and telemetry services.	International Telecommunication Union (ITU) World Telecommunication/ICT Indicators Database
Fixed telephone subscriptions (per 100 people)	Fixed telephone subscriptions refers to the sum of active number of analogue fixed telephone lines, voice-over-IP (VoIP) subscriptions, fixed wireless local loop (WLL) subscriptions, ISDN voice-channel equivalents and fixed public payphones.	International Telecommunication Union (ITU) World Telecommunication/ICT Indicators Database

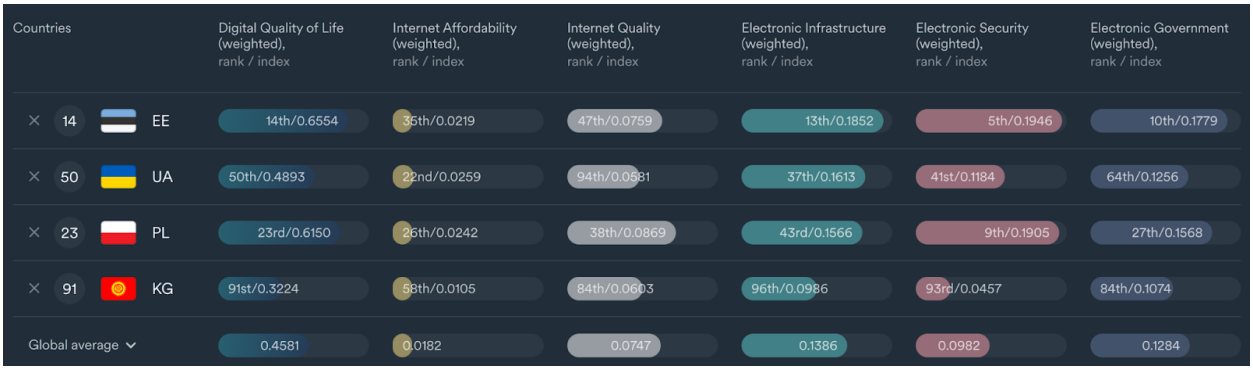
Appendix 4: GDP Per Capita (Current US$)[144]



Source: World Bank

[144] "GDP per Capita (Current US$) - Ukraine, Poland, Kyrgyz Republic, Estonia." n.d. World Bank Open Data. Accessed April 19, 2023. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?end=2021&locations=UA-PL-KG-EE&start=1987&view=chart.

Appendix 5: Digital Quality of Life Index Comparing the 4 Countries[145]



Countries	Digital Quality of Life (weighted), rank / index	Internet Affordability (weighted), rank / index	Internet Quality (weighted), rank / index	Electronic Infrastructure (weighted), rank / index	Electronic Security (weighted), rank / index	Electronic Government (weighted), rank / index
14 EE	14th/0.6554	35th/0.0219	47th/0.0759	13th/0.1852	5th/0.1946	10th/0.1779
50 UA	50th/0.4893	22nd/0.0259	94th/0.0581	37th/0.1613	41st/0.1184	64th/0.1256
23 PL	23rd/0.6150	26th/0.0242	38th/0.0869	43rd/0.1566	9th/0.1905	27th/0.1568
91 KG	91st/0.3224	58th/0.0105	84th/0.0603	96th/0.0986	93rd/0.0457	84th/0.1074
Global average	0.4581	0.0182	0.0747	0.1386	0.0982	0.1284

[145] "DQL Compare." 2022. Surfshark. July 25, 2022. https://surfshark.com/dql2022/dql-compare?table=true&country1=EE&country2=UA&country3=PL&country4=KG.

Appendix 6: Five Key Accelerators of Digital Transformation

Key Theme		Estonia	Ukraine	Poland	Kyrgyz Republic
Trust	% of citizens or trust index regarding digital services	80% of Estonians are estimated to trust digital systems (2021).[146]	N/A	Digital Trust: Environment index of 58.31 (rank 18 out of sample size 42)[147] Digital Trust: Attitudes index of 58.25 (rank 13 out of sample size 42)	N/A
	Other descriptions for trust status	High trust in digital services due to ● Transparency ● Consistent long term strategy among different government parties ● Continuous good government practice and lack of corruption	The government has been working to develop a trusted digital civic engagement system. Furthermore, the Ukraine Recovery Plan also emphasizes the need to improve the government regulation of the use of electronic trust services, both during and after the war.[148]	The GDPR on data protection has helped improve consumers trust[149]	The level of trust is assumed to be low due to: - Political instability - High level of corruption and low level of transparency - Low level of digital skills and digital literacy
Digital Security	Nation Cyber Security Index[150]	Index: 93.51 Country Rank: 4th	Index: 75.32 Country Rank:24	Index: 87.01 Country Rank: 10	Index: 37.66 Country Rank: 87
	Current Situation	Cyber incidents are still prevalent. 2,672 cyber incidents happened in 2022.	Cyber attacks tripled in 2022 due to Russian hacking during Russia's invasion of Ukraine.[151]	Since 2021, 29% of Poland's businesses have been the subject of at least one cyber-attack. This marks a 5% increase compared to 2020, indicating that cyber threats and cyber-attacks in the country are rising.[152]	100,000 cyberattack victims in 2021.[153] "Every 67th resident of Kyrgyzstan has faced cyberattacks at year-end 2021"[154]
	Improvements/ actions taken	Big investments into digital and cyber security have been made. ● NATO CCDCOE established in 2008 ● 50% of government spending on technology is allocated to cybersecurity. This is an additional €60 million towards cybersecurity in 2022 compared to the previous year.[155]	Steps have been taken to improve Ukraine's cybersecurity protection capabilities. ● Partnership with U.S. Cyber Command's Cyber National Mission Force[156]	Steps have been taken to reduce cybersecurity threats in Poland ● Digital Poland program launched in 2016 which includes investments in cybersecurity	The Kyrgyz Republic has a "Cybersecurity Strategy of the Kyrgyz Republic for 2019-2023"[157]

[146] Stone, Mark. 2021. "How Estonia Created Trust in Its Digital-Forward Government." Security Intelligence. September 17, 2021. https://securityintelligence.com/articles/estonia-trust-digital-government/.
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[156] Vergun, David. n.d. "Partnering with Ukraine on Cybersecurity Paid off, Leaders Say." U.S. Department of Defense. Accessed April 19, 2023. https://www.defense.gov/News/News-Stories/Article/Article/3235376/partnering-with-ukraine-on-cybersecurity-paid-off-leaders-say/.
[157] N.d. Asia-news.com. Accessed April 19, 2023e. https://central.asia-news.com/en_GB/articles/cnmi_ca/features/2018/12/31/feature-01.

Data Privacy	Laws	General Data Protection Regulation (Regulation (EU) 2016/679) (GDPR)[158] Personal Data Protection ACT 2018 (PDPA)	Data Protection Law No.2297 enacted in 2010.[159] Law "On Personal Data Protection" no.5628 was drafted on 7 June 2021[160]	General Data Protection Regulation(Regulation (EU) 2016/679)(GDPR)[161] Protection of Personal Data (2018)	Law of the Kyrgyz Republic of 14 April 2008 No. 58 on Personal Information[162]
	Actions taken outside of law	Has taken secure measures to protect data privacy from breaches and risks such as physical invasions, large cyber attack, or natural disasters: ● Established data center in Luxembourg[163]	Increased emphasis on data privacy to work towards EU integration.	Office of personal data protection to supervise[164]	No general data protection authority.[165]
Digital Skills	Digital Skill Gap Index (DSGI) [166] 2021	Score: 7.0/10 Country rank: 16	Score: 4.8 Country rank: 69	Score: 5.6 Country rank: 42	N/A
	World Bank database on Digital Skills Among Population (1-7) 2019	5.43	4.45	4.27	3.85
	Initiatives put in place / achievements	Heavy emphasis on teaching digital skills through education ● Tiger Leap Programme in the 1990s ● Internet and computer access at all schools	Focus on digital skills through education ● Dija. Digital Education project to improve digital literacy[167]	There is still a shortage of digital skills and expertise. 43% of polish workers have basic digital skills The Digital Poland program launched in 2016 also includes investments in digital skills training.	One of the main goals in the 2026 National Development Program is the enhancement of digital skills.[168]
Financing		In 2019 Estonia spent 1.1-1.3% of its state budget on digitalization divided into IT expenses, R&D cost, and ICT and IT solutions. In 2023, Estonia allocated 1.5% of the state budget on ICT and IT solutions.[169]	Ukraine heavily relies on loans and grants to fund its digital transformation due to the Russian invasion. With a budget of € 17,4 million, the EU is assisting developments. In Ukraine, the e-Governance Academy runs four projects with a total budget of € 41 million. Since 2016, the EU has contributed more than € 51 million to Ukraine's digital transformation.[170]	Poland likewise finances its digital transformation with external funds, specifically from the EU. Digital agendas will get up to one-third of Poland's national Recovery and Resilience Plan (RRP) budget of EUR 11.1 billion, or 1.9% of GDP, in 2021.[171] Poland has a growing framework supporting start-ups in financing digital deployment in enterprises, with a greater share of ICT start-ups than the OECD average. Venture capital funding is rapidly expanding.	Digital transformation of Kyrgyz Rep. has been financed by external sources. For example, a US$ 50 million loan from the World Bank to fund the Digital CASA Project in 2018. Another project was the Technical Assistance Program on Digital Resilience which was funded by a $25 million grant and a $25 million credit from Korea-World Bank Partnership Facility (KWPF).[172]

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