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Digital economies and evolving regulations: A parametric and non-parametric approach with bad output across countries

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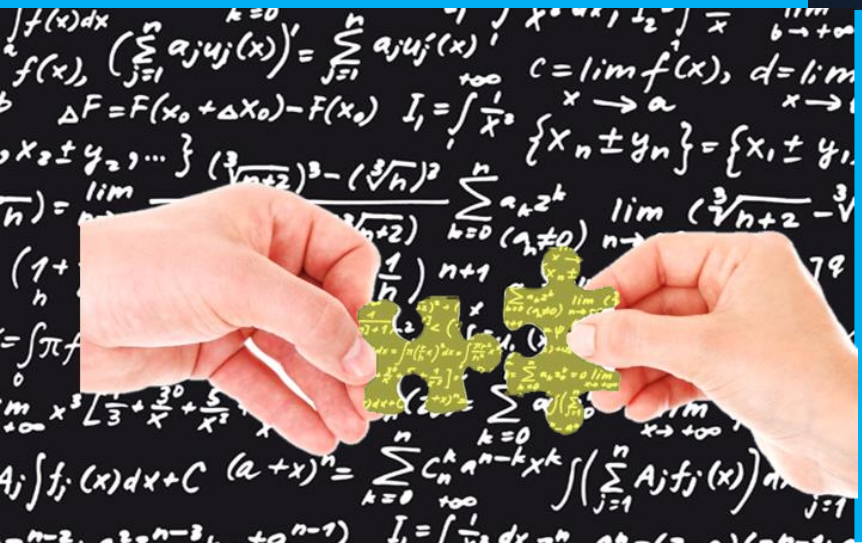
Digital economies and evolving regulations: A parametric and non-parametric approach with bad output across countries



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ASIA-PACIFIC RESEARCH AND TRAINING NETWORK ON TRADE

WORKING PAPER

Digital economies and evolving regulations: A parametric and non-parametric approach with bad output across countries

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Abstract

We use the non-parametric Data Envelopment Analysis (DEA) and the parametric Stochastic Frontier Analysis (SFA) to workout efficiency and productivity of the ICT sector across 50 countries for the time period 2016 and 2020. By considering OECD - DSTRI index as bad output, the study intends to estimate the influence of digital trade regulations (or digital services trade restrictiveness) on productivity and efficiency of the ICT sector across countries. The SFA scores are compared with the DEA efficiency scores and Malmquist Index based on four DEA problems are used to work out the total factor productivity of the ICT sector across countries and over two time periods. Cross country regression is run to understand the impact of ICT efficiency and productivity on average annual growth rate of GDP per-capita among other control factors. We use network readiness index of the World Economic Forum along with OECD-DSTRI index as our database. Broadly, our results are three-fold. Firstly, we find that trade restrictiveness has very little to do with technical efficiency based on SFA frontier analysis. Secondly, we find no statistical difference in the technical efficiency scores of high and middle-income countries based on DEA analysis. We also found evidence of Asian countries faring better than the European Union countries in context of technical efficiencies. Thirdly, from our empirical results it seems that adoption of ICT and the so-called disruptive 4IR technologies–have replaced labour and henceforth, we hypothesize that higher unemployment leads to higher growth rate along with a positive impact of network readiness on the growth rates. It seems that net neutrality and addressing pernicious regulations related to the ICT sector - barrier to competition, among others like foreign entry, mobility of people, regulatory transparency across countries can improve the productivity and efficiency of the ICT sector.

Keywords: Network Readiness Index; Digital Services Trade Restrictions; Data Envelopment Analysis; DEA- based Malmquist Productivity Index; Stochastic Frontier Analysis; Technical efficiency; Productivity.

JEL Codes: L51, C14, D24

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Acronyms and Abbreviations

ICT	Information and Communication Technology
OECD	Organisation for Economic Co-operation and Development
DSTRI	Digital Services Trade Restrictions
DEA	Data Envelopment Analysis
SFA	Stochastic Frontier Analysis
UN	United Nations
DMU	Decision Making Units
I-O	Input Oriented
O-O	Output Oriented
MPI	Malmquist Productivity Index
GDP	Gross Domestic Product
TFP	Total Factor Productivity
IPR	Intellectual Property Rights
NRI	Network Readiness Index
VRS	Variable Returns to Scale
CRS	Constant Returns to Scale
DDF	Directional Distance Functions
GITR	Global Information Technology Report
WDI	World Development Index
TE	Technical Efficiency

VRSTE	Variable Returns to Scale Technical Efficiency
BCC	Banker, Charnes and Cooper
CRSTE	Constant Returns to Scale Type
M-W test	Two-sample Wilcoxon rank-sum test also called Mann-Whitney test
K-S test	Kolmogorov-Smirnov Test
IRS	Increasing Returns to Scale
EFFCH	Technical Efficiency Change
TECHCH	Technology Change

1. Introduction

"In a free trade, an effectual combination cannot be established but by the unanimous consent of every single trader, and it cannot last longer than every single trader continues of the same mind."

(The Wealth of Nations, Book IV Chapter VIII, p. 145, para. c27)

Referring to technology as a "great, growling engine of change," Alvin Toffler, in his book, *Future shocks* (1970), underscored the indispensable role of technology. In the recent past, some of the breakthrough innovations have been centered around either internet of things, connectivity and device development, Artificial Intelligence, or cloud computing, and today they pervade all the aspects of the economy, business, and society. There are multiple infrastructural components to the digital transformation ranging from digital access, institutional enablers, adequate and ubiquitous bandwidth, regulatory mechanism within a country, ease of doing business, etc. Since the digital transformation creates positive externalities, eases efficient international trade, and allows the effective use of dataflow, any digital disruption would potentially break the social contracts and cause an imbalance in the economies. The Information Technology industry is marked by huge overheads, significant switching, and low marginal costs of production costs for users, and strong network effects (Varian, Farrell and Shapiro, 2004).

Interestingly, owing to the 'unusual economic characteristics' of the digital sector (i.e., intangible have synergies), it has been considered as intangibles and thus, could be instrumental in explaining secular stagnation, inequality, the role of financial institutions and infrastructure (Haskel & Westlake. 2017). Alongside the opportunities created by digital transformation, it is also a time of Digital Darwinism when the gap between the early adopters of technology and the others has widened. Due to globalization, the impact of policies adopted by any country is experienced by all countries, sectors, and companies. This has been a great challenge for many countries across the world. The governments are faced with the trade-off between the digital regulations to safeguard the interest of domestic businesses on the one hand and the economic growth led by digital transformation.

Reaffirming fundamental freedoms and human rights, the United Nations enacted a resolution backing "*The promotion, protection, and enjoyment of human rights on the Internet*" in 2016. Despite this, globally, there have been several instances of digital regulatory measures adopted by the government like internet clampdown, blocking a particular application, disrupting the mobile telecommunication services, and turning off mobile telecommunications services owing to fake news, preventive response, integrity, combating terrorism, national security, or safeguarding local businesses. As per a report by Brookings (2016), economic losses due to internet clampdown include $72 mn in the Republic of the Congo, $465 mn in Saudi Arabia, $48 mn in Syria, $968 mn in India, $320 mn in Morocco, $69 mn in Pakistan, $209 mn in Iraq and $35 mn in

Turkey, among other places. Talking about the regulatory regimes countries adopt worldwide (Refer to Appendix Table 9: Pattern of reforms in the digital sector across 50 countries), Singapore is not a signatory to the multilateral initiative named Open Government Partnership, which aims to harness new technology and promote open government[4]. The nation has a licensing authority to control the content on the internet. The country also has a well-functioning public education program to encourage the supervision of parents of children's internet use. In the Republic of Korea, there are many incidents of internet censorship and low data accessibility because of stringent data localization laws that restrict information about spatial and location. Specifically, three government agencies- Broadcasting Regulation Committee, the Korean Media Rating Board, and the Korea Internet Safety Commission- regulate the digital platforms. In another case, as per OECD's Digital Trade Restrictiveness Index Report, 2016, China is the most restricted country in digital trade, which applies restrictive regimes for digital trade in all aspects of digital trade and movement of data and technicians. After China comes to a list of other countries like India, the Russian Federation, Viet Nam, and Indonesia, the Great Firewall blocked most services offered by Google China, in China. Referring to the restrictions imposed, The Economist observed that "*China has become a laboratory for digital technology*." Electronic bulletin service providers are governed under the Electronic Bulletin Services Provisions of 2000 in China (Qi, 2010). The Mexican government has come under the scanner for becoming one of the "world's worst abusers of Pegasus spyware" (Freedomhouse Report, 2020). In a developing country like India, the Apex court has reiterated that Internet access is read into the fundamental right to life and liberty (*Anuradha Bhasin vs. Union of India, 2020*) and privacy under Article 21 of the Indian Constitution. Surprisingly, India's internet restrictions accounted for more than 70% of a total loss to the global economy in 2020 (According to Top10VPN[5]). According to data on India's shutdown numbers published by Software Freedom Law Center of India, 2021[6] out of the total 549 internet shutdowns in India, 535 have been imposed after 2014 (specifically, 317 in Jammu and Kashmir). In another world's largest democracy, the United States, *Net Neutrality*[7] has been a bone of contention between Internet Service Providers and network users. According to Freedom House 2020[8], Internet freedom in the United States took a hit for the fourth successive year in 2020.

In the wake of the Fourth Industrial Revolution, it becomes imperative to probe how efficiently the countries worldwide use ICT to augment welfare and competitiveness.

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[4] https://www.opengovpartnership.org/our-members/, accessed on 25th November 2021
[5] https://www.thehindu.com/sci-tech/technology/internet-shutdowns-in-2020-costs-india-28-billion/article33501483.ece
[6] https://internetshutdowns.in/, accessed on 25th November 2021
[7] According to FreePress.net "Net Neutrality is the basic principle that prohibits internet service providers like AT&T, Comcast and Verizon from speeding up, slowing down or blocking any content, applications or websites you want to use. Net Neutrality is the way the internet has always worked. But when left to their own devices, these companies have violated people's basic online rights."
[8] https://freedomhouse.org/country/united-states/freedom-net/2020

Given that ICT is part and parcel of the current paradigm, the benefits are being harnessed by the government, businesses, and households, driven primarily by the level of infrastructure, affordability, and technical skills. This interaction of demand and supply has a significant bearing on the economy and society. So, any indicator that could gauge ICT utilization, the environment making the ICT conducive, and the outcome of ICT should determine the *Network Readiness* of the countries. Apart from the factors enabling the ICT usage, some other factors stifle the digital transition and could probably have severe ramifications for the expected outcome of the ICT. One such component is the Digital Service Trade Restrictions which adds to the cost of ICT and impedes the competition.[9] Digital service trade liberalization can boost innovation and sharpen the competition. In increasing ICT impact and its usage, the governments worldwide have pursued protectionist policies as mentioned above in the paper. As per the objective of the World Trade Organization; any self-defeating protectionist policy needs to be prevented. Following the argument, we consider digital service trade restrictions as an undesirable/bad output in our study. The analysis of ICT usage and ICT impact with less bad output like digital trade restriction deserves attention, especially from the lens of production frontier methodology. One such methodology which is often used in the literature is Pareto optimality-based data envelopment analysis. It is a non-parametric method that can incorporate multiple input and multiple outputs to compare the performance of decision-making units (DMUs) based on the technical efficiency scores. In economics, technical efficiency is concerned with obtaining the maximum output for a given level of input (output-oriented model) or by minimizing the input given the level of output (input-oriented). Technical efficiency is a necessary but not a sufficient condition. In data envelopment analysis, the technical efficiency score derived from a set of input(s) and output(s) helps determine the best performing DMU.

Against this backdrop, the third world industrial revolution coupled with the pronounced expansion of international poses some inevitable normative questions like- How technically efficient are the Network Readiness of the countries? In the realm of bad output, namely, the Digital Service Trade Restrictiveness Index, have the countries experienced deterioration or improved technical efficiency scores between 2016 and 2020? Are the countries imposing restrictions on the digital service Trade faring better in terms of technical efficiency of Network Readiness? Is there any diversity in the technical efficiency of Network Readiness among High-income countries and Middle-income countries? What factors explain the ICT usage of nations, and does Digital Trade restrictiveness impact the technical efficiency when ICT Usage is considered? Addressing wide-ranging crucial questions on digital transformation and inequality, “surveillance capitalism,” and the potential of digital transformation to transform lives, The Network Readiness Index Report, 2020 reviews over 30 variables on ICT Usage,

[9] Refer to Table 2 for a brief explanation of the variables.

Impact, Readiness, and Environment and compared the network readiness of 134 countries. Integrating a unique Digital Service Trade Restrictiveness Index (OECD-DSTRI) of countries, trade of ICT services, and the dataset on the disaggregated indices of Network Readiness Index Report, we endeavour to address the first four questions by developing our hypotheses and henceforward, use Data Envelopment Analysis (DEA) and DEA-based Malmquist Productivity Index (MPI) by considering an undesirable output (OECD-DSTRI). Emrouznejad and Yang (2018) reported that DEA-related research articles have gone up exponentially. To further address the last question, we would be employing SFA (Stochastic Frontier Analysis). Measurement of the performance of network readiness can assess the relative efficiency and identify underpinning factors to inefficiency engendered in the government's policies across the world.

The technical efficiency of Network Readiness of countries encompasses technical efficiency and allocative efficiency. Technical efficiency is the capability of a firm to derive maximum output from a limited set of input (s) whereas, the Allocative efficiency is the firm's potential to employ optimal inputs given the input prices. To estimate this efficiency, we need to determine an unknown production frontier. DEA offers a non-parametric approach to assess the production frontier, and SFA provides a parametric framework (Coelli et al., 2005). These methods do not have presumptions regarding the technical efficiency of all the firms (Coelli et al., 2007). We intend to buttress our research results with the application of DEA, MPI, and SFA ensuing the literature review.

Additionally, applying these methodologies, we intend to present some critical directions for the stakeholders in enhancing the performance of Network Readiness of the countries. Taking a cue from the literature on the efficiency analysis, we explore the technical efficiency of network readiness of 50 countries for the period 2016 and 2020.

The study proceeds as follows. In “Literature Review,” we talk about the nexus between trade restrictiveness and the ICT usage of the countries. Further, we present “Research gap and contribution of the study” followed by “Methodology,” “Data and variable selection.” The results and outcome of the DEA, Malmquist Productivity Index, and SFA will be presented in “Empirical results.” Finally, based on results obtained, we would provide insights from a policy perspective and conclude the study in “Conclusions and Policy Implications”.

2. Literature review

Digital service trade restrictions (which include trade transportation costs, policy barriers, contract cost, information cost, among others) add to the trade costs that have economic and welfare implications. Any reduction in trade cost can increase the number of trading partners and exporters' profit; induce differences in equilibrium wage rate, and decrease fixed or variable costs (Melitz, 2003). Additionally, a reduction in

trade costs is associated with the increase in relatively productive firms and, thus, a simultaneous job creation in some sectors and job destruction in others.

The literature in economics that talks about the nexus between digital service trade restrictions, ICT usage, ICT readiness, ICT environment (Political, regulatory, business, and innovative environment), and ICT impact (Impact of ICT on the economy, realizing Sustainable Development goals) are scarce. This is primarily due to the infrequent publication of the Network Readiness Index report[10] and the Digital Services Trade Index published by OECD[11]. It is also probably because this topic is relatively new. Nevertheless, an essential strand of literature has explored some segments of the tripartite association between the flow of data, policies pertaining to data, and trade of intangibles (Ferracane & Marel, 2019). There is also a burgeoning stream of literature investigating the influence of the internet on international trade (e.g., Fernandes et al., 2019; Freund and Weinhold, 2002, 2004; Vemuri and Siddiqi, 2009; Wunsch-Vincent, 2003). Moreover, some studies explored the digital trade growth across the world (Fernandes et al., 2018; Ma et al., 2019). Pursuing the set of explorations indicated earlier, we strive to construct the literature through three sections; empirical studies, the contribution of the present study, with the conceptual framework followed.

2.1 Empirical studies

In Table 1, we present the review of selected literature.

Table 1: Review of literature

Author(s)	Area	Variables	Methodology	Findings
Hardy (1980)	60 nations (15 developed& 45 developing)	GDP & energy consumption per capita, radios (per 1000), telephones (per million)	Cross-sectional time-series regression analysis	The telephone supports the organization of economic activity, and thus, it contributes to economic development.
Freund & Weinhold (2002)	The United States	Growth of U.S. trade, Internet, growth of GDP, initial level of trade appreciation in real exchange-rate	Gravity model and regression	Internet affects the economic growth directly via productivity, and it is likely to have an indirect effect via openness.

[10] Network Readiness Index Report has been published for 2020, 2019, 2016, 2015, 2014, 2013, 2011-12, 2009-10, 2008-09, 2007-08, 2006-07.
[11] OECD. Stats has release DSTRI for the period 2014 to 2020.

Vemuri & Siddiqi (2009)	64 countries	Distance, Language dummy variable, Contiguity dummy, colonial connections, Volume of Trade, GDP, Population, Telephone Lines, Personal Computers, Internet Users	Gravity model, Panel data model,	Availability of the internet and the infrastructure required for ICT impacts the volume of international trade.
Freund & Weinhold (2004)	34 countries	Annual export growth includes import-country GDP growth, competition and Internet growth, market proximity, and distance between exporter and importer.	Theoretical model, Panel regressions.	The Internet has a substantial impact on the trade, and it has been observed that the trade growth is lower for countries located at a distance.
Cardona et al. (2015)	EU Member States	Dummies for restrictions, distance, language, home bias, exports,	Macro-economic general equilibrium model, logit regression, Gravity model, PCA	Compared to offline trade, international e-commerce induced redistribution and reduced the cost of a trade.
Falk & Hangsten (2015)	14 European countries	Stock of capital and ICT usages, output, employment, employment, e-sales, additional ICT usage	OLS and System GMM	The growth in labor productivity is positively associated with the changes in e-sales activities. TFP was coupled with the increase in e-commerce sales and was prominent for smaller firms.
Ferracane (2017)	64 countries	87 measures collected by ECIPE	Exploratory	Proposes a comprehensive taxonomy of these restrictions, which has a bearing on international trade law.
Fernandes et al. (2018)	firm-level manufacturing data of China	Exports' participation, and Intensity, Real Output, Labor Productivity, TFP,	Panel regression	Internet rollout amplified exports of manufacturing firms before the emergence of crucial e-commerce platforms. Internet enhances trade, improved overall firm performance.
Ferracane, Lee-Makiyama, et al. (2018)	64 countries	Fiscal restrictions, establishment restrictions, trading restrictions and restrictions on data.		Digital trade positively affects the economy, businesses, and consumers. It also helps in augmenting productivity. The index shows that

				policy responses to digitalization have been very diverse. In emerging economies, digital trade restrictions impede growth.
Ma et al. (2019)	111 countries with particular emphasis on China	Internet, solutions of payment, the performance of logistics, e-commerce infrastructure, legal vigilance, and potential of trade	Word cloud technology	To develop digital trade countries, attach significant relevance to digital technology, government guidance in developing digital trade and data. Furthermore, "service," "development, and "construction" are used frequently in Chinese documents.
Ferracane et al. (2019)	Firm-level (countries)	Number of patents/employees, number of recorded subsidiaries, value-added, capital, materials, and investments	Data linkage index, augmented baseline specification, base line specification with a demeaned NRI.	Stringent data policies negatively impact the performance of downstream firms dependent on electronic data. It is more substantial for countries with robust technology networks.
Ferracane & Marel (2020)	64 countries	DPRI, the share of ICT capital services in value-added and productivity growth.	Regression	Nation's level of development cannot accurately explain the restrictiveness of countries pertaining to online platforms. Countries with high restrictions on online. Platforms also have a lower productivity growth.
Marel & Ferracane (2021)	64 countries	Data policy, domestic regulations, air, and sea transport, financial, insurance and pension, postal, construction, maintenance and repair, charges of IPR, computer, information, professional and management consulting trade-related technical, audiovisual, and other services.	Panel regression, Data linkage index	The study develops a data linkage index and concludes that the countries with restrictive data policy suffer from services trade.

Source: Based on author's analysis

2.2 Novelty of the present study

The study constructs a unique framework for a cross-country comparison, viewed as production units here. There are some noticeable characteristics of the analysis that discerns them from the literature. The novelty of the current study is five-fold. Firstly, we don't just merely rely on the data across countries for one period but explore the dynamic nexus between NRI and the OECD-DSTRI to ascertain and compare the technical efficiency of network readiness of 50 countries for the years 2016 and 2020. Based on the literature reviewed so far, this is the first study to understand the nexus between ddigital trade restrictions and the critical indicators of network readiness- ICT impact, ICT usage, ICT environment, and ICT readiness. Secondly, a dearth of literature incorporates an undesirable output like Digital Service Trade Restrictiveness (subsuming electronic transactions glitches, infrastructure and connectivity issues, payment system IPR, among other barriers affecting trade in digitally-enabled services). Through this study, we aim to address this research gap. Fourthly, taking a cue from Mathur (2009), we present a combination of three methodologies in the current context, a rare incidence; thus, we delve into employing two non-parametric methods, namely, DEA and DEA-based MPI and a parametric method called Stochastic Frontier Model. Therefore, we strive to pin down the changes within countries over time, in the realm of restrictions imposed by institutions across the world—the reason for undertaking this exercise stem from the inherent advantages of these methodologies. Fifthly, we have endeavored to consider multiple outputs and multiple inputs in our analysis.

3. Methodology

3.1 Non-parametric approach

3.1.1 Data Envelopment Analysis (DEA)

To address the questions posed in the current study, we employ Data Envelopment Analysis. Charnes, Cooper & Rhodes (1978) proposed the term DEA *(Data Envelopment Analysis)*. DEA has become a strong quantitative, analytical tool for assessing and comparing the relative efficiency of firms (Cooper, Seiford & Tone, 2007). DEA is a linear programming and a deterministic way of measuring technical efficiencies of the DMUs. The latter is about judicious conversion of inputs into outputs. The economic efficiency is bifurcated into allocative efficiency (price measure) and technical efficiency. In our study we will be concentrating on input-oriented (I-O) and output-oriented (O-O) technical efficiency. Input-oriented (I-O) technical efficiency by definition is the ratio of minimum input usage by actual input usage. The value of I-O technical efficiency varies from zero to one. In the DEAP the O-O technical efficiency score have been rescaled between zero and one (inverse of output-oriented theoretical model scores). Output-oriented technical efficiency is the ratio of maximum output to actual output. The value varies from 1 to infinity. If the technical efficiency scores are 1 then the DMU is on the best practice frontier. The relevance of DEA could also be

understood from its wide-ranging applications in the field of health economics (Athanassopolous and Gounaris, 2001; Andrews, 2020; Pereira et al., 2021; Hu et al., 2012), insurance (Wanke and Barros, 2016), judiciary (Mattson and Tidana, 2018; Giacalone et al.,2020), ports (Cullinane et al., 2004), banks (Mustafa et al., 2020; Dar et al., 2021), city planning (Zhang and Cui, 2020; Zhu et al., 2019), Public administration (Gujardo, 2020; Ma et al., 2020), agriculture (Li et al., 2018, 2017), environment (Neves et al., 2020; Wang et al., 2020) among others. DEA has been applied to estimate the technical efficiency of the DMUs[12] by determining the maximum potential output given the inputs or by minimizing the inputs for the given level of output without assuming any specific functional form of the production process. These DMUs could be cities, countries, states, factories, hospitals, and non-profit organizations. Given the non-parametric nature of DEA, a distinctive feature of employing DEA is its flexibility to incorporate multiple inputs and outputs. Furthermore, DEA can provide technical efficiency scores based on the projection path to the enveloped surface (dependent on the nature of model). DEA also provides the flexibility to address the returns to scale assumptions placed, i.e., whether the production function exhibits Variable Returns to Scale (VRS) or Constant Returns to Scale (CRS). Fare, Grosskopf, and Logan (1983) and Banker, Charnes, and Cooper (1984) proposed a DEA model with VRS assumption. It is worth mentioning that where Productivity (or Total Factor Productivity) is a descriptive measure expressed as the ratio of output to input (in case of single output and input), Technical Efficiency is a normative concept. Thus, a technically efficient DMU can still increase its productivity by make use of its scale economies (Coelli et al., 2005).

In the present study, we have employed Banker, Charnes & Cooper (1984) model, which didn't require any transformation function and considered that the decision-making units could operate under increasing, constant, and DRS (decreasing returns to scale), i.e., VRS could also be a situation—considering DMU as countries consuming m inputs to produce output (s). These outputs, as stated, could be desirable(s) and undesirable (k). Here, the bad output needs to be reduced but, in a standard Banker, Charnes, and Cooper (1984) model, both these kinds of outputs are to be increased.

$$s_{in}(1 = 1,2,3 \dots, m),$$

$$y_{rn}(r = 1,2,3 \dots., s)$$

$$and\ b_{tn}(t = 1,2,3.., k).$$

[12] Decision-Making Units

Now we assume that there won't be any change in the desirable output and that the inputs and wrong outputs can be controlled proportionately; the relative efficiency of any DMUs can be determined as:

Input oriented model (CRS) with undesirable outputs

$$\min \theta_p$$

Subject to

$$\sum_{n=1}^{N} \lambda_n x_{in} \leq \theta_p x_{ip}, \quad i = 1,2,3 \dots, m;$$

$$\sum_{n=1}^{N} \lambda_n y_{rn} \geq y_{rp}, \quad r = 1,2,3 \dots, s;$$

$$\sum_{n=1}^{N} \lambda_n b_{tn} \geq \theta_p b_{tp}, \quad t = 1,2,3 \dots, k;$$

$$\lambda_n \geq 0, n = 1,2, \dots, N \qquad (CRS - CCR\ model)$$

and by Imposing the restriction, $\sum \lambda_n = 1$ $(VRS - BCC\ model)$. The dual; of the above-mentioned model is the output-oriented CCR.

Output Oriented model(O-O) with undesirable outputs

$$Max \sum_{r=1}^{s} u_r y_{rp}$$

Subject to

$$\sum_{r=1}^{s} u_r y_{rn} - \sum_{i=1}^{m} v_{in} - \sum_{t=1}^{k} \omega_t b_{tn} \leq 0, \ \forall_n$$

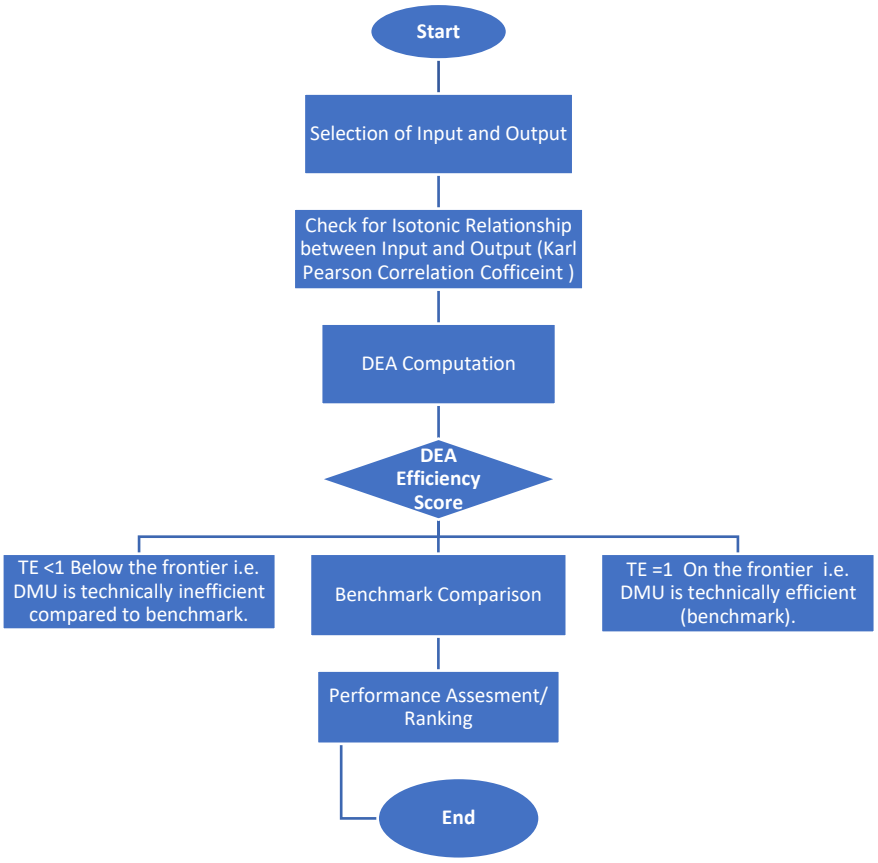
$$\sum_{i=1}^{m} v_i x_{ip} + \omega_t b_{tp} = 1,$$

$$u_r, v_i, \omega_t \geq 0, \forall_r \forall_i, \forall_t$$

Scale Efficiency

$$SE = \frac{TE^{CRS}}{TE^{VRS}}$$

Figure 1: Schema chart of DEA algorithm



Treatment of bad outputs in DEA:

Based on the previous studies reviewed, Halkos & Petrou (2019) summarized four approaches to incorporate an undesirable output in DEA. These four approaches are classified according to the two disposability technologies: weak disposal technology and strong disposal technology.

- Ignoring the undesirable output: Here, the undesirable output is overlooked altogether from the production function, seriously affecting the efficiency scores.
- Treating undesirable output(input) as input(output): Here, the output (input) variable is shifted to the input (output) side of the model from the output (input) (Dyson et al., 2001).
- Considering the undesirable output in the non-linear model: Färe et al. (1989) have proposed and implemented a performance index (a hyperbolic efficiency measure) that treats undesirable outputs and desirable outputs differently.
- Applying necessary transformation: In this approach, a monotone decreasing transformation is applied. Halkos & Petrou (2019), in their study, have summarized three methods of transformation based on Ali and Seiford (1990), Golany and Roll (1989), Koopmans (1951), Scheel (2001), Seiford and Zhu (2001) and Lovell et al. (1995).

- Developing a new model: Some new models based on DDF-DEA, ZSG-DEA, among others, have been proposed to tackle the problem of undesirable output.
- Inverse of anti-isotonic factor: The method can destroy the ratio (or interval scale) of the data, after which the resulting data demands transformation (Dyson et al., 2001).
- Subtracting the undesirable factor from a significantly larger number (Dyson et al., 2001).

The choice of output(s) and input(s) variables is a critical phase under DEA. The cardinality constraint sets the restrictions on the number of output and input variables. The efficiency or inefficiency of DMU becomes questionable if the degrees of freedom are inadequate. According to Peyrache et al. (2020), the maximum number of variables that can be chosen must be derived from a general rule of thumb which considers a number of inputs and outputs:

$$sample\ size \geq \max\{input\ \times output, 3(\ input + \ output)\}$$ [13]

It is still ambiguous as to which variables should be selected. Peyrache et al., 2020 developed a method where variable selection is made by minimizing the information loss based on economic principles. The current study uses a heuristic way to select inputs and outputs. For any country, given the ICT environment and the ICT readiness, the aim is to maximize the impact and usage of ICT. The rationale is not just to incorporate the network readiness framework but also to link it with evolving regulations. We consider a multiple input and multiple output model with undesirable output called OECD-DSTRI (recognized as an input in DEA following the approach of Dyson et al. (2001)) to assimilate the regulatory framework. The other approach is when bad outputs lead to radial reduction in the 'good' outputs.

3.1.2 Malmquist Productivity Index (MPI)

The DEA- based Malmquist Productivity index was constructed by Fare et al. (1992), which was developed as a Geometric Mean of two Malmquist Productivity Index (Chen & Ali, 2004). It is decomposed into catching-up effect (which represents the firm's managerial condition) and frontier-shift effect (which indicates average technological progress/regress). As stated earlier that productivity is a normative concept, and efficiency is a normative concept. When we intend to compare the performance of DMUs over a time span, the productivity change (i.e., change in TFP) could be either on account of efficiency improvement or the technical change or by exploiting scale economies. Thus, a measure that gauges these three indicators is the Malmquist Productivity Index. As per Fare et al. (1994), output-oriented MPI is given by:

[13] Here, inputs and outputs variables indicate the total number of input and output used in the study.

$$m_o(y_{t+1}, x_{t+1}, y_t, x_t) = \left[\left(\frac{Y_{t+1}}{f_{t+1}(X_{t+1})}\frac{f_t(X_t)}{Y_t}\right) \times \left(\frac{f_{t+1}(X_{t+1})}{f_t(X_{t+1})}\frac{f_{t+1}(X_t)}{f_t(X_t)}\right)\right]^{\frac{1}{2}}$$

$$\frac{Y_{t+1}}{f_{t+1}(X_{t+1})}\frac{f_t(X_t)}{Y_t} = Change\ in\ Eficiency\ (catching - up\ effect)$$

$$\frac{f_{t+1}(X_{t+1})}{f_t(X_{t+1})}\frac{f_{t+1}(X_t)}{f_t(X_t)} = Change\ in\ Technology\ (Frontier - shift)$$

$$if\ Malmquist\ index(M_o) < 1 : Dterioration\ in\ \ productivity$$

$$if\ Malmquist\ index(M_o) > 1 : Improvement\ in\ \ productivity$$

$$if\ Malmquist\ index(M_o) = 1 : No\ change\ in\ \ productivity$$

3.2 Parametric approach

ICT usage by Government, businesses, and individuals is a function of the political and regulatory environment, business and innovation environment, trust, inclusion, infrastructure, affordability, skills, and the nature of the content. These independent factors could be majorly categorized into ICT Environment and ICT readiness. In other words, the factors influencing ICT usage $(Usage)$ are governed by the ICT environment $(Envt.)$ and ICT readiness $(Readiness)$.

$$Usage = f(\ Readiness, Envt.)$$

$$Usage_{ICT} = A_t \cdot f_t(\ Readiness_t, Envt._t\ )$$

$$A_t = Hicks - Neutral\ Technology = TFP\ index$$

Taking log on both the sides,

$$\ln Usage_t = \alpha_{0t} + \alpha_{1t} lnReadiness_t + \ln Envt._t$$

$$\alpha_{0t} = \ln(A_t) = \log(TFP)$$

$$\beta = \alpha_1 + \alpha_2 - 1$$

$$\beta\ indicates\ the\ extent\ of\ deviation\ from\ Constant\ Returns\ to\ Scale.$$

If $\beta > 0$ $(Production\ function\ exhibits\ Increasing\ Returns\ to\ Scale)$

In case we have a panel set-up, we could include a time trend to incorporate technological change over time; our framework would be:

$$\ln(Usage_t) = b_0 + b_{1t} + \gamma_1 ln(Readiness_t) + \gamma_2 \ln(\ Envt._t\ ) + \epsilon_t$$

$$b_0 + b_{1t} = Logarithmic\ index\ of\ TFP = \ln(\hat{A})$$

$$\epsilon_t = disturbance\ term$$

$\ln(\hat{A})$ is the Technical Change which is the log or potential Total Factor Productivity. The Malmquist Productivity Index $TFPChange$ comprises two mutually exclusive components: technological change, which indicates a shift in the PPF, and Technical Efficiency Change (TC), indicating the movement towards or away from the PPF, i.e., the difference between actual and potential output. Now, if we incorporate the Stochastic Frontier Model proposed by Aigner, Lovell, and Schmidt (1977), and Meeusen and van den Broeck (1977) to gauge both, Technology Change and Technical Efficiency Change and we decompose the ϵ_t into random noise components and random variables associated with technical inefficiency.

$$\ln(Usage_t) = d_0 + d_1 \cdot t + \gamma_1 ln(Readiness_t) + \gamma_2 \ln(\ Envt._t\ ) + v_t - u_t$$

$$v_t = time\ specific\ random\ error\ component \sim iid = N(0, \sigma_v^2)$$

$$u_t = -\ln(\check{\varepsilon})$$

$$\check{\varepsilon} = \ level\ of\ efficiency$$

$$d_0 + d_1 \cdot t = \text{Log (TFP) or } \ln(\hat{Z}_t)$$

3.2.1 Stochastic Frontier Analysis (SFA)

One of the primary criticisms of applying DEA is that it is a non-parametric technique, which cannot be applied to test hypotheses. DEA does not explicitly incorporate the effects of data noise and thus attributes all the frontier deviations to the efficiency component only. Additionally, there is no statistical framework for modeling the performance of DMUs outside the sample (Theodoridis & Anwar,2011). To overcome the limitations of DEA, we apply a parametric model we follow the stochastic frontier production of Battese and Coelli (1995); in a cross-section setup, the stochastic frontier production is:

$$y_i = \exp(x_i\beta + v_i - u_i)$$

$$i = 1, \ldots\ldots N$$

$$\epsilon_i = v_i - u_i$$

$$v_i \sim N(0, \sigma_v^2)$$

$$u_i \sim truncated\ normal$$

$$y_i = output\ for\ the\ i^{th}\ country$$

$$x_i = (1 \times k)\ vector\ of\ inputs\ known\ for\ the\ i^{th}\ country$$

$$\beta = (k \times 1)\ vector\ of\ unknown\ parameters$$

$$v_i \sim N(0, \sigma_v^2)$$

$u_i s$ are non-negative variables following truncated normal distribution (truncated as zero).

$$u_i \sim truncated\ normal\ (z_i\delta, \sigma_u^2)$$

The advantage of assuming truncated normal distribution stems from the fact that it consists of a parameter μ and thus provides a flexible representation of efficiency in the data (Kumbhakar and Lovell, 2003)

$$z_i = (1 \times m) = explanatory\ variables\ for\ technical\ inefficiency$$

$$\delta = (m \times 1\ vector\ of\ unknown\ coefficients)$$

TE of the i^{th} country can be estimated as:

$$TE_i = \exp(-u_i)$$

SFA uses the MLE procedure to estimate the technical efficiency of the network readiness across countries. The variance parameter is:

$$\sigma_U^2 = \sigma_u^2 + \sigma_v^2$$

$$\lambda^2 = \frac{\sigma_u^2}{\sigma_v^2}$$

$$\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}\ \ where\ \ 0 \leq \gamma \leq 1$$

In this study, we would consider ICT usage as output and ICT readiness, ICT Environment, and income status of the countries as variables explaining the production frontier. To incorporate undesirable output in our model, we consider an inefficiency component, namely, OECD-DSTRI.

4. Data and variable selection

Based on the normative questions posed in the current study for the *Network Readiness Index (NRI)*, we have essentially relied on two reports. One is GITR-2016 *(The Global Information Technology Report)*, and the other is NRI-2020 (*Network Readiness Index Report)*, and for OECD-DSTRI, we follow the OECD's OECD-DSTRI index. Furthermore, for DEA and DEA- based Malmquist Productivity Analysis, we have considered three output variables and three input variables for 2016 from GITR-2016. The detail of the indices can be seen from Table 2 of Data descriptions (For a

detailed description of the indices, refer to Appendix Table 9), and the description of summary statistics of the variables can be understood from Appendix Table 1.

OECD-DSTRI for 2016 and 2020 identifies, catalogs, and quantifies barriers that affect trade in digitally-enabled services across countries. The information on ICT service trade (%) has been extracted from of World Development Indicators (WDI-World Bank), which does not contain data for the year 2020. Due to incongruency in the sample size of NRI and OECD-DSTRI, we considered the sample size of OECD-DSTRI for our study. It is worth mentioning that we are considering 2016 and 2020 for the analysis to provide a comparative analysis due to data deficiency. However, the results obtained from the methodology adopted in the current study remain unaffected. To ensure that the data is uniform across variables over the years, we have modified the indices to adjust the scale, which does not impact the technical efficiency scores of the counties.

Table 2: Data description of the variables used in DEA analysis[14]

Year	Input or Output	Variables	Description	Source
2016	Outputs	ICT Service Trade	ICT service exports (% of exports service, BoP).	WDI
		ICT Usage	The level of ICT adoption by government, businesses, and individuals.	GITR-2016
		ICT Impact	ICTs' Socio-economic impacts.	GITR-2016
	Inputs	OECD-DSTRI	OECD-DSTRI captures cross-cutting impediments that affect all types of services traded digitally.	OECD Stats
		ICT Environment	Market conditions, regulatory framework, innovation, and ICT development.[15]	GITR-2016

[14] Though the sub variables explaining the inputs and outputs match with other variables but broadly variables in 2016 and 2020 have remained the same. It is worth mentioning that we have closely followed the indices of NRI report 2016 and 2020. Our empirical results seem to be robust across ICT variables whose descriptions have marginally changed over the years.

[15] ICT environment in 2020 as per Network Readiness Index Repot 2020 considers three pillars namely trust (secure internet servers, cyber security, online access to financial account and internet shopping),

		ICT Readiness	The Readiness measures the degree to which a country has infrastructure and factors supporting the uptake of ICTs.	The Global Information Technology Report 2016
2020	Outputs	ICT Usage (People)	Application of ICT by people at individuals, businesses, and governments levels.	Network Readiness Index Report 2020
		ICT Impact	Socio-economic and human impact of participating in the digital economy (accruing from ICTs).	Network Readiness Index Report 2020
	Inputs	OECD-DSTRI	OECD-DSTRI	OECD Stats
		ICT Environment (Governance)	Trust, regulation, and inclusion issues.	Network Readiness Index Report 2020
		ICT Readiness (Technology)	Digital technology produced in countries, communications infrastructure and affordability, and the content that can be deployed locally, country's preparedness for Internet of Things and AI).	Network Readiness Index Report 2020

Source: Based on Author's Analysis

Software

We have used DEAP 2.1 provided by the University of Queensland for DEA and Malmquist Productivity Index and STATA 12 for Stochastic Frontier Analysis.

regulation (regulatory quality legal framework, legislations related to E-commerce, privacy protection by law) and inclusion (E-participation, socio economic gap in digital payment usage, gender gap in internet usage). On the other hand, OECD- DSTRI provides information on regulations affecting trade in services in 22 sectors across all OECD members. These restrictions range from restrictions on foreign ownership and other market entry conditions, restrictions on the movement of people, other discriminatory measures and international standards, barriers to competition and public ownership, to regulatory transparency and administrative requirements.

5. Discussion of results

5.1 DEA

The DEA efficiency scores in the current study are obtained by employing output-oriented DEA assuming VRS. Before using DEA, we performed a correlation test among the variables of interest (inputs and outputs) as shown in Appendix and Appendix Table 3. It seems from the Appendix table that ICT usage and ICT impact are highly correlated with ICT environment and ICT readiness. We now ascertain the efficiency of network readiness of 50 countries for the years 2016 and 2020 according to the four identified methods, which are as follows:

1. Firstly, we analyze the results by ignoring the undesirable output, namely OECD-DSTRI, and compare the results with the model incorporating OECD-DSTRI as output.

2. Secondly, we examine and compare the technical efficiency with and without observing ICT Trade as one of the outputs in DEA for the year DEA.

3. Thirdly, we compare the technical efficiency scores of network readiness based on the undesirable output for the years 2016 and 2020. Comment on the performance of the countries and the variability in the technical efficiency scores of High and middle-income countries.

Finding 1: DEA model with one bad output and one good output and various inputs

The DEA model with one good output (ICT Usage) and one bad output (OECD-DSTRI) with various inputs like ICT readiness and ICT environment show that the technical efficiency score for India across 50 countries increased from 0.77 in 2016 to 0.84 in 2020. A technical efficiency score of 0.84 in output-oriented DEA means that given the input level, we need to scale up all the outputs radially by 16% (1-0.84). The ICT productivity based on the Malmquist Index for India between 2016 through 2020 was 11%. The leading performers were Peru, Turkey, Mexico, among others. The countries that achieved the technical efficiency score of 1 were the US, Italy, Costa Rica, Brazil, Peru, Japan, Switzerland, Canada, Lithuania, and Estonia.

Finding 2: The model with undesirable output shows higher average technical efficiency scores than the model without undesirable output.

According to Appendix Table 7, when undesirable output was considered in DEA as an input, we observed that the average TE score was 0.944, higher than 0.93 when the bad output was ignored. Specifically, the correlation between the model with and without OECD-DSTRI was 0.94, which is quite close to 1. 17 countries had attained perfect technical efficiency scores when undesirable output was considered in DEA, and 12 countries recorded similar technical efficiency scores when undesirable output was ignored. At an individual level, we observed that the efficiency scores increase or remain unchanged when an undesirable output is incorporated in the O-O DEA model.

Similar results are also observed in the findings of You & Yan (2011), Seiford & Zhu (2002), and Hua & Bian (2007).

Finding 3: The model with ICT trade as output shows a marginally higher technical efficiency score than the model without.

Let us consider the technical efficiency scores of the countries in both these models. We will find either there is no change or the scores are marginally higher than the model ignoring ICT trade as output (See Appendix Table 8). Seventeen countries have scored perfect unity technical efficiency scores in both cases. Since we have the data for the ICT trade till the year 2018 and given the close to 1 correlation in the technical efficiency scores (0.96) for further analysis, we will not be considering ICT trade as one of the outputs.

Finding 4: The countries, on average, witnessed a surge in technical efficiency between 2016 and 2020.

Finding 5: Trade restrictiveness has very little to do with the technical efficiency of countries.

In Table 4 we present the average TE scores, with VRSTE (Variable Returns to Scale Technical Efficiency-BCC model) assumptions for 2016 and 2020. It is worth mentioning that in an O-O model, we maximize the output given the level of inputs. Currently, we consider two outputs: ICT Usage, ICT Impact, and two inputs: ICT Readiness and ICT Environment. Since we aim to understand the technical efficiency scores in trade restrictiveness, an idiosyncratic shock, we assume this variable to be an undesirable output. To treat undesirable output, we follow Dyson et al. (2001) and keep it under the input side of the model. In DEA, the technical efficiency scores typically range between 0 and 1, where a score closer to 1 signifies that the DMU is significantly close to the frontier vice or versa. On the other hand, a perfect unity technical efficiency score shows that a DMU is on the frontier.

The mean CRS technical efficiency was 0.901 for 2016, which rose to 0.913 in 2020, and the mean VRS technical efficiency score surged from 0.94 to 0.95. We can infer from both the kinds of TE scores that when all the inputs and outputs were considered, the countries, on average, could improve their output up to 1% (given the levels of inputs).

Our findings from the DEA are five-fold. Firstly, VRSTE for Canada, Costa Rica, Estonia, Japan, Republic of Korea, Mexico, Peru, and Sweden remain unchanged for both years. Furthermore, seven countries have managed to maintain 100% efficiency. Secondly, though there is an inverse correlation between the trade restrictiveness index and the VRSTE score (-0.1544 in 2016 and -0.141 in 2020), some middle-income countries like Costa Rica, Mexico, and Peru have maneuvered to stay 100% technically efficient in both years. Additionally, China stands out as a contradiction and anomaly. Being a middle-income country, China imposed the highest restriction on digital trade (OECD-DSTRI =0.51) in 2016, but the nation still has 100% technical efficiency

compared to other countries. In 2020, China had the second-highest restrictiveness index (at par with 2016), but its technical efficiency plummeted to 0.936. China is a challenging market for many international businesses because of many regulatory, digital economy laws. Thirdly, in 2020, Kazakhstan had the highest restrictiveness index, but the country gained technical efficiency over 2016. One thing that is evident from this exercise is, trade restrictiveness has very little to do with the technical efficiency of countries. Fourthly, among the high-income countries, VRSTE scores of Greece, Israel, Italy, Luxembourg, Netherlands, New Zealand, Slovak Republic, Spain, United Kingdom, and the US have dropped between 2016 and 2020. Fifthly, for 2020, India is the only country to witness Increasing Returns to Scale, and the rest of the other countries experienced either decreasing or constant returns to scale. The top 4 performers as per NRI report 2020 were Sweden, Denmark, Singapore, Netherlands. However, as per the technical efficiency scores determined from DEA, the top performers are Canada, Switzerland, Costa Rica, Denmark, Ireland, Japan, Republic of Korea, Mexico, Norway, Peru, Russian Federation, Sweden (See Table 3 for the classification).

Finding 6: No statistically significant difference in the technical efficiency scores of High-income counties and Middle-income counties

To investigate the difference in the TE scores we have conducted some non-parametric tests like the t-test, M-W test (Two-sample Wilcoxon rank-sum test also called Mann-Whitney test), and K-S test (Kolmogorov-Smirnov test) for equality of distribution functions. From Table 5 we can find statistically no significant difference between the VRSTE score of high and middle-income countries.

Table 3: Summary of technical efficiency score (output oriented DEA) of countries for the years 2016 and 2020

Country	2016					2020			
	Income status	Constant Returns to Scale (CRSTE)	Variable Returns to Scale (VRSTE)	Scale	OECD-DSTRI	Constant Returns to Scale (CRSTE)	Variable Returns to Scale (VRSTE)	Scale	OECD-DSTRI
Argentina	0	0.933	1	irs	0.281	0.961	0.992	drs	0.34
Brazil	0	0.953	1	irs	0.267	0.97	0.997	drs	0.245
China	0	0.92	1	crs	0.51	0.908	0.936	drs	0.51
Colombia	0	0.898	0.982	irs	0.299	0.924	0.937	drs	0.299
Costa Rica	0	1	1	crs	0.043	1	1	crs	0.043
India	0	0.834	1	irs	0.304	0.818	0.877	irs	0.343
Indonesia	0	0.805	0.919	irs	0.307	0.881	0.881	crs	0.227
Kazakhstan	0	0.835	0.86	irs	0.268	0.962	0.991	drs	0.647
Malaysia	0	0.949	1	irs	0.126	0.935	0.975	drs	0.126
Mexico	0	0.827	1	irs	0.101	1	1	crs	0.101
Peru	0	0.811	1	irs	0.242	1	1	crs	0.242
South Africa	0	0.732	0.776	irs	0.342	0.734	0.764	drs	0.342

Country	2016					2020			
	Income status	Constant Returns to Scale (CRSTE)	Variable Returns to Scale (VRSTE)	Scale	OECD-DSTRI	Constant Returns to Scale (CRSTE)	Variable Returns to Scale (VRSTE)	Scale	OECD-DSTRI
Thailand	0	0.812	0.854	irs	0.3	0.874	0.908	drs	0.3
Turkey	0	0.772	0.795	irs	0.202	0.891	0.915	drs	0.264
Australia	1	0.922	0.929	drs	0.083	0.91	0.954	drs	0.083
Austria	1	0.93	0.93		0.083	0.906	0.945	drs	0.202
Belgium	1	0.859	0.887	drs	0.162	0.869	0.927	drs	0.162
Canada	1	1	1		0.043	1	1		0.043
Chile	1	0.859	0.885	irs	0.263	0.92	0.939	drs	0.263
Czech Rep.	1	0.81	0.818	irs	0.141	0.863	0.926	drs	0.141
Denmark	1	0.946	0.983	drs	0.104	0.945	1	drs	0.104
Estonia	1	0.953	0.953	crs	0.083	0.927	0.953	drs	0.083
Finland	1	0.923	0.983	drs	0.101	0.93	0.979	drs	0.101
France	1	0.923	0.935	drs	0.123	0.883	0.963	drs	0.123
Germany	1	0.916	0.952	drs	0.144	0.911	0.973	drs	0.144
Greece	1	0.873	1	irs	0.144	0.895	0.9	irs	0.144
Hungary	1	0.845	0.895	irs	0.166	0.849	0.901	drs	0.166
Iceland	1	0.879	0.933	drs	0.148	0.946	0.961	drs	0.267
Ireland	1	0.859	0.892	drs	0.144	0.916	1	drs	0.144
Israel	1	0.994	0.996	drs	0.18	0.965	0.985	drs	0.18
Italy	1	0.938	1	irs	0.126	0.871	0.934	drs	0.126
Japan	1	1	1	crs	0.064	1	1	crs	0.104
Republic of Korea	1	1	1	crs	0.123	1	1	crs	0.145
Latvia	1	0.843	0.865	irs	0.104	0.805	0.887	drs	0.223
Lithuania	1	0.906	0.942	irs	0.104	0.947	0.95	drs	0.104
Luxembourg	1	0.965	1	drs	0.083	0.904	0.94	drs	0.083
Netherlands	1	0.959	1	drs	0.104	0.89	0.983	drs	0.104
New Zealand	1	0.877	0.932	drs	0.18	0.83	0.91	drs	0.18
Norway	1	0.945	0.99	drs	0.083	0.957	1	drs	0.061
Poland	1	0.81	0.822	irs	0.263	0.825	0.965	drs	0.263
Portugal	1	0.86	0.873	irs	0.145	0.873	0.904	drs	0.145
Russian Federation	1	0.912	0.934	irs	0.281	1	1	crs	0.341
Saudi Arab.	1	0.942	0.955	irs	0.206	0.965	0.992	drs	0.405
Slovak Rep.	1	0.896	0.945	irs	0.281	0.826	0.941	drs	0.341
Slovenia	1	0.871	0.876	irs	0.083	0.883	0.953	drs	0.242
Spain	1	0.9	0.942	irs	0.123	0.852	0.904	drs	0.123
Sweden	1	0.941	1	drs	0.144	0.917	1	drs	0.144
Switzerland	1	0.939	0.983	drs	0.083	0.943	1	drs	0.083

Country	2016					2020			
	Income status	Constant Returns to Scale (CRSTE)	Variable Returns to Scale (VRSTE)	Scale	OECD-DSTRI	Constant Returns to Scale (CRSTE)	Variable Returns to Scale (VRSTE)	Scale	OECD-DSTRI
United Kingdom	1	0.969	0.984	drs	0.083	0.916	0.966	drs	0.083
U.S.	1	1	1	crs	0.083	0.949	0.981	drs	0.083
average	0.72	0.9009	0.944		0.169	0.91292	0.95378		0.19524
max	1	1	1		0.51	1	1		0.647
min	0	0.732	0.776		0.043	0.734	0.764		0.043

irs=increasing returns to scale; drs=decreasing returns to scale
*0= middle-Income country, 1= High-income country

Source: Based on Author's Analysis

Table 4: Classification of VRSTE score

Range of VRSTE	Countries	
	2016	**2020**
0.7-0.9	South Africa, Turkey, Czech Republic, Poland, Thailand, Kazakhstan, Latvia, Portugal, Slovenia, Chile, Belgium, Ireland, Hungary	South Africa, India, Indonesia, Latvia
0.90-0.99	Indonesia, Australia, Austria, New Zealand, Iceland, Russian Federation, France, Spain, Lithuania, Slovak Republic, Germany, Estonia, Saudi Arabia, Colombia, Switzerland, Denmark, Finland, United Kingdom, Norway, Israel	Greece, Hungary, Spain, Portugal, Thailand, New Zealand, Turkey, Czech Republic, Belgium, Italy, China, Colombia, Chile, Luxembourg, Slovak Republic, Austria, Lithuania, Estonia, Slovenia, Australia, Iceland, France, Poland, United Kingdom, Germany, Malaysia, Finland, United States, Netherlands, Israel, Kazakhstan, Argentina, Saudi Arabia, Brazil
1	Argentina, Brazil, Canada, China, Costa Rica, Greece, India, Italy, Japan, Republic of Korea Luxembourg, Mexico, Malaysia, Netherlands, Peru, Sweden, United States	Canada, Switzerland, Costa Rica, Denmark, Ireland, Japan, Republic of Korea, Mexico, Norway, Peru, Russian Federation, Sweden

Source: Based on Author's Analysis

Table 5: Statistical tests to check for the difference in TE scores across groups and across time

Statistical tests for the difference between the groups	For the difference in high and middle-income countries		For the year 2016 and 2020
	Value for 2016	Value for 2020	
t-test with equal variance	0.1496	-1.2175	-0.8856
t-test with unequal variances (t-value)	-0.1228	-0.9308	-0.8856
W-S test (Z-value)	0.750	-0.587	-0.209
K-S test	0.3214	0.2500	0.1800

Source: Author's analysis

5.2 Analysis through Malmquist Productivity Index (MPI)

In the present study, an O-O DEA-based MPI has been estimated. Table 6 reports the results of 50 countries through a TFP index decompose into innovation/frontier shift (technological change) and catch-up component (technical change). Additionally, the efficient change is also further broken down into Pure Efficient Change and Scale Efficient Change. A value of MPI (TFPCH) >1 indicates gain in total productivity vice or versa. Between 2016 and 2020, 20 countries exhibited Productivity growth. To be Precise these countries are Argentina (5.9%), Brazil (4.3%), Canada (9.8%), Chile (10.3%), Colombia (5.7%), Costa Rica (8.3%), Indonesia (17.3%), India (0.1%), Ireland (0.6%), Kazakhstan (17.7%), Malaysia (3.3%), Mexico (26.2%), Norway (3.8%), Peru (30.4%), Poland (5.2%), Russian Federation (7.6%), Saudi Arabia (6.8%), Thailand (11%), Turkey (15.2%) and South Africa (8.9%). Furthermore, the average score is 0.995<1: implying that the TFP declined for most of the countries. The situation demands attention toward improving technical expertise, organizational restructuring, investment planning, among others. The TFP for the countries exceeding one implies that they have been using best practice technology. The breakdown of TFPCH into PTECH (pure technical efficiency change) and SECH (scale efficiency change) shows that most of the countries have invested in organizational factors like improvement in quality of ICT infrastructure and have maneuvered to have a better balance between the inputs (ICT readiness, ICT environment) and output (ICT impact and ICT usage). Improvement in the value of scale efficiency change greater than one indicates optimal utilization of little available resources. The countries with fewer ICT inputs are also making better utilization of resources and have obtained economies of scale. The value of average technological change (EFFCH) is less than one, which could probably be on account of innovation deterioration. In other words, there is sufficient room for a change in procedure, techniques or skill up-gradation in the countries related to ICT.

Combination of catch-up effect and frontier-shift effect

Considering the intertemporal variation in Network Readiness Efficiency obtained from MPI, we can summarize the results through four combinations. The results circumscribe all four possible combinations:

1. There is a list of countries that have managed to maintain internal managerial efficiency (Technical efficiency) and could even gain from the shift in the frontier (Technology progress). These countries are Argentina, Brazil, Colombia, Costa Rica, Indonesia, Kazakhstan, Mexico, Peru, Thailand, Turkey, South Africa, Australia, Canada, Chile, Norway, Poland, and Saudi Arabia. These countries have been the best-performing countries. They have improved the best possible ICT input (less skilled employees and have incurred low cost) and have maintained the balance between input and outputs.

2. There are countries where technical efficiency has improved, but there was a decline in technological change. These countries are, Belgium, Czech Republic, Finland, Greece, Hungary, Iceland, Japan, Republic of Korea, Lithuania, Portugal, Russian Federation, Slovenia, Switzerland, and Turkey. Though these countries were able to elevate the organizational factors, they can introduce advanced technologies. These countries should amass advanced technologies and augment their performance through necessary skill advancement programs.

3. Some countries are had experienced deteriorating technical efficiency along with the improvement in technological change. These countries are India, Australia, Malaysia, and the Slovak Republic. It is evident from these countries that they have managed to invest in new technologies but were unable to strike a fine balance between inputs and outputs.

4. However, there are also some countries where deteriorating technical efficiency was present along with deteriorating technological change. This group comprises China, Germany, Denmark, Spain, Estonia, Finland, France, United Kingdom, United States, Italy, Israel, Luxembourg, Latvia, Netherlands, and New Zealand. These countries should merit their attention towards the organizational factors about stabilized utilization of input and output and introduce new technologies.

Peru is a middle-income country, holds the first rank among the total sample. We have performed a Positive average increase in TFP of 30.4%. This increase is due to 23.4% efficiency Progress (movement in the efficiency frontier) and 5.7% technological Progress of 5.7% (shift in the Production frontier). On the other hand, Sweden has the lowest rank and has the highest decline of 16% between 2016 and 2018. Nine countries have technical efficiency scores below 0.9 (Austria, Germany, Spain, France, Italy, Luxembourg, Netherlands, Sweden, and the US.

From the results of the Malmquist index, we can deduce that where all the middle-income countries have maneuvered to move up the ladder, as evident from the Positive and greater than unity TFP change, 28 high-income countries have experienced deterioration in TFP. This could primarily be on account of the dearth of investments from the governments' side for innovation, leading to technological inefficiency. The findings contrast with the fact that most of the countries in the dataset experiencing deteriorating technological performance are high-income countries. These countries are considered to have advanced ICT usage. Based on the statistical test performed to compare the change in total factor productivity, we can infer that there is a statistically significant difference in TFPCH between the middle- and high-income countries (refer to Appendix Table 4)

Table 6: Decomposed productivity change between 2016 and 2020

Country	High/Middle Income Country	Technical Change (EFFCH)	Technological Change (TECHCH)	Total Productivity Change (TFPCH)	Pure Technical Change (PECH)	Scale Efficient Change (SECH)
Argentina	0	1.03	1.028	1.059	0.992	1.038
Brazil	0	1.018	1.025	1.043	0.997	1.021
China	0	0.987	0.989	0.975	0.936	1.054
Colombia	0	1.029	1.027	1.057	0.954	1.079
Costa Rica	0	1	1.083	1.083	1	1
Indonesia	0	1.095	1.071	1.173	0.959	1.142
India	0	0.981	1.02	1.001	0.877	1.119
Kazakhstan	0	1.152	1.022	1.177	1.152	1
Mexico	0	1.21	1.043	1.262	1	1.21
Malaysia	0	0.986	1.048	1.033	0.975	1.011
Peru	0	1.234	1.057	1.304	1	1.234
Thailand	0	1.077	1.031	1.11	1.064	1.012
Turkey	0	1.155	0.998	1.152	1.15	1.004
South Africa	0	1.003	1.086	1.089	0.985	1.018
Australia	1	0.988	1.001	0.988	1.026	0.963
Austria	1	0.974	0.912	0.888	1.016	0.959
Belgium	1	1.011	0.92	0.93	1.046	0.967
Canada	1	1	1.098	1.098	1	1
Switzerland	1	1.005	0.967	0.971	1.018	0.987
Chile	1	1.071	1.029	1.103	1.061	1.009
Czech Rep.	1	1.065	0.936	0.997	1.131	0.941
Germany	1	0.994	0.886	0.881	1.023	0.972

Country	High/Middle Income Country	Technical Change (EFFCH)	Technological Change (TECHCH)	Total Productivity Change (TFPCH)	Pure Technical Change (PECH)	Scale Efficient Change (SECH)
Denmark	1	0.999	0.948	0.947	1.017	0.982
Spain	1	0.946	0.937	0.887	0.96	0.986
Estonia	1	0.974	0.988	0.962	1.001	0.973
Finland	1	1.008	0.953	0.961	0.995	1.013
France	1	0.956	0.934	0.893	1.031	0.928
United Kingdom	1	0.945	0.968	0.915	0.982	0.962
Greece	1	1.025	0.928	0.951	0.9	1.138
Hungary	1	1.005	0.973	0.978	1.006	0.999
Ireland	1	1.066	0.943	1.006	1.121	0.951
Iceland	1	1.076	0.864	0.93	1.03	1.044
Israel	1	0.971	0.928	0.901	0.989	0.982
Italy	1	0.928	0.953	0.884	0.934	0.993
Japan	1	1	0.952	0.952	1	1
Republic of Korea	1	1	0.939	0.939	1	1
Lithuania	1	1.045	0.95	0.993	1.009	1.036
Luxembourg	1	0.936	0.955	0.894	0.94	0.996
Latvia	1	0.954	0.996	0.951	1.025	0.931
Netherlands	1	0.928	0.938	0.87	0.983	0.944
Norway	1	1.013	1.025	1.038	1.01	1.002
New Zealand	1	0.946	0.995	0.941	0.977	0.969
Poland	1	1.017	1.034	1.052	1.173	0.867
Portugal	1	1.015	0.925	0.939	1.036	0.98
Russian Federation	1	1.097	0.981	1.076	1.071	1.024
Saudi Arabia	1	1.023	1.043	1.068	1.039	0.985
Slovak Republic	1	0.922	1.021	0.941	0.996	0.926
Slovenia	1	1.013	0.97	0.983	1.087	0.932
Sweden	1	0.974	0.869	0.847	1	0.974
US	1	0.949	0.945	0.896	0.981	0.967
mean		1.014	0.981	0.995	1.011	1.002

*0= middle-Income country, 1= High-income County

Source: Based on the author's analysis

5.3 Stochastic Frontier Analysis

The results of the Maximum Likelihood Estimate for SFA are reported in. The results are three-fold. First, the ICT environment and ICT readiness have a statistically significant positive impact on ICT usage in the year. Secondly, though a dummy variable indicating high-income countries positively influence ICT usage, it was not statistically significant in any of the years. Thirdly, OECD-DSTRI, an undesirable output considered an inefficiency component, has a negative impact on technical efficiency, but this variable was again found to be statistically insignificant. Furthermore, in 2016 technical inefficiency accounts for about 72% variation in Output and 83 % in 2020. To investigate the appropriateness of SFA in 2016, we employed the likelihood ratio test, and the evidence provides enough justification for the application of Stochastic Frontier Analysis (LR =2.831>2.7, tabulated values from Kodde &Palm (1986)). Furthermore, Appendix Table 5 shows the results of TE scores. Based on the TE scores derived from SFA, we could comprehend a statistically significant difference between the high and middle-income countries in 2016. Surprisingly, no such difference was observed in 2020 (See Appendix Table 6).

Table 7: Results of SFA

VARIABLES	2016	2020
Frontier		
L_environment	0.67***	0.44**
	(0.08)	(0.20)
L_readiness	0.32***	0.279**
	(0.12)	(0.14)
High_income	0.0412	0.0204
	(0.027)	(0.0432)
Constant	-0.0141	1.081**
	(0.455)	(0.494)
Mu		
L_oecd-dstri	0.162	0.224
	(0.348)	(1.634)
Constant	0.189	-0.139
	(0.215)	(1.919)
U-Sigma		
Constant	-5.064**	-3.776
	(2.034)	(7.079)
VSigma		
Constant	-6.056***	
	(0.483)	(0.434)
Sigma U	0.079	0.151
	(0.080)	(.535)
Sigma V	0.048***	0.067***
	(0.011)	(.014)
Lambda	1.642***	2.226***
	(0.080)	(0.531)

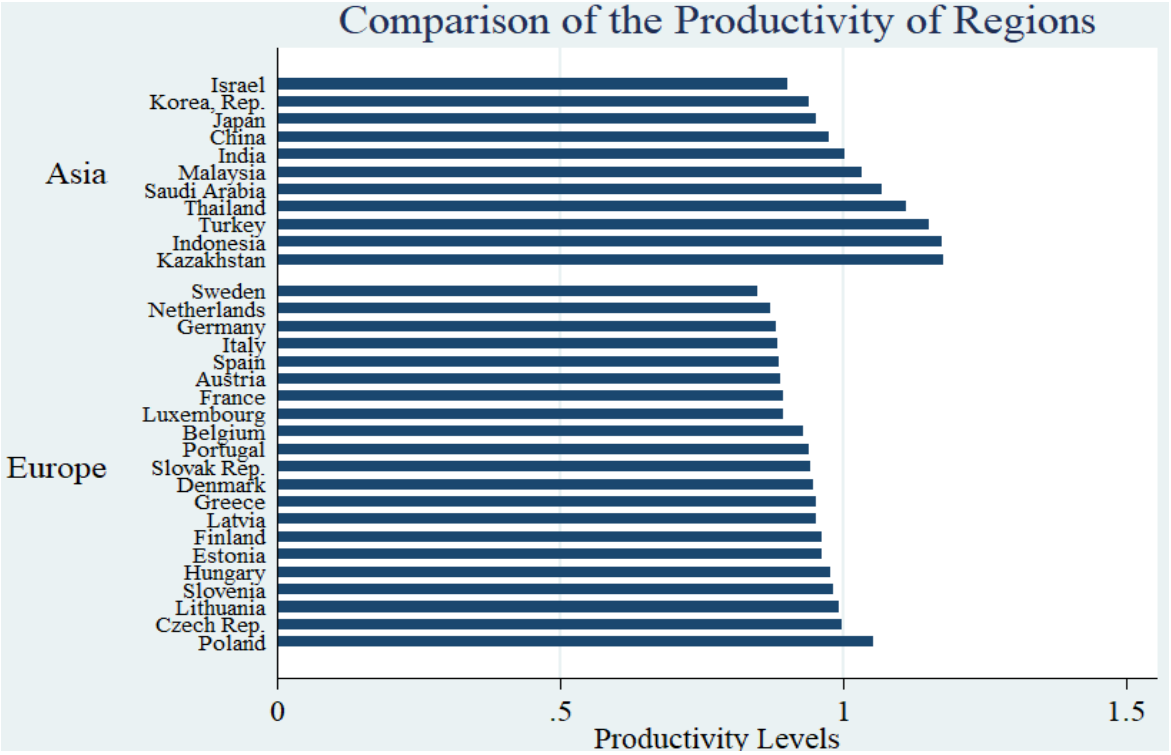
Observations	50	50

Standard errors in parentheses
*** p <0.01, ** p <0.05, * p <0.1

5.3.1 Comparison of European Union and Asian countries

The international economic arena at the dawn of the 21st century was characterized by economic and political integration coupled with the digital revolution sweeping across countries. As the world is undergoing a digital transformation on an unprecedented scale, on the one hand, there is a fully integrated European Union, and on the other Asian countries have lagged in economic and political integration. In this section, we illustrate a comparative analysis of European Union nations and Asian countries.

Figure 2: European Union and Asian Countries



Source: Author's calculation

For a comparative analysis of the productivity of network readiness of EU and Asian Countries, we have considered 11 Asian countries and 21 countries belonging to the EU (Refer to Figure 2: European Union and Asian Countries). It can be inferred from the Malmquist productivity index of the Asian Countries (1.04) that, on average, there has been an increase in the productivity of Asian countries over the analysis period and a decline in the EU countries (0.93). Furthermore, the degree of variation in the productivity of Asian Economies (0.09) is higher than that of EU Countries (0.051). The results conform with the UNESCAP (2016) report titled, "State of ICT in Asia and the Pacific 2016: Uncovering the Widening Broadband Divide," which confirmed the

widening gap between the advanced nations and developing countries of Asia and warned about the detriment of future opportunities for development unless the policies are framed in this direction. Thus, given the dataset, we can conclude that despite a relatively widening digital divide among the Asian economies, as far as network readiness is concerned, these countries have fared better than the countries belonging to European Union over the analysis period. Our study is in line with the UNCTAD (2021) report which emphasized the falling behind of the EU due to digital developments and simultaneously contradicted the studies[16] that are skeptical about the positive outcomes of the same on the Asian Countries by reporting the productivity gains on an average of Asian Countries.

5.4 Regression results

Following the work of X. Sala-i-Martin (1997) and Barro (1991), wherein the studies found the influence of a substantial set of variables on the growth of an economy, we also intend to investigate the impact of productivity of Network Readiness of countries along with other variables on the Average annual growth rate. Conducting regression analysis stems from the fact that there is still ambiguity over the variables that influence economic growth. Though there is a consensus over the impact of technology on economic growth, a strand of literature argues that it is over the change towards a no-growth steady-state (X. Sala-i-Martin, 1997). We assume ICT as a meta-infrastructure, a variable that tends to contribute to economic and sustainable development. In addition, ICT facilitates the mobility of people, money, goods, and services across countries and buttresses the emerging digital economy (UNESCAP, 2016).

Furthermore, X. Sala-i-Martin (1997) pointed towards identifying and estimating the variables influencing economic growth. In this study, we consider 16 variables consisting of 7 variables on ICT and nine variables ranging from trade to GDP, Multiple Dimensional Poverty Index (MDPI), Unemployment rate, Financial Development Indicators (FD), Democracy indicators, Current health expenditure, Inflation, income status of the country, and initial level of income.

We have found evidence of a positive impact of productivity change (derived from the MPI) on the Average Annual Growth rate, which indicates the level of technological development (Solow,1956). Additionally, the average technical efficiency also positively influences growth. Interestingly, the regression results show that if a country imposes digital service trade restrictions, it gives impetus to economic growth. It could probably be based on the states' argument to reduce its susceptibility to external shocks or protect domestic enterprise by capacity augmentation (Black, 1959). The results contradict the findings of Ferracane & Marel (2020), where the study found that the countries with high restrictions on digital platforms negatively affect the ICT sector's

[16] Study for GSMA on the Responsible use of Artificial Intelligence in Emerging Markets in Africa and APAC

share in the overall productivity growth. ICT readiness, which indicates the country's preparedness in terms of accessibility, affordability infrastructure, and other variables, has a significant positive impact on the growth. ICT readiness leads to productivity gains, which positively impacts growth (Pena-Lopez, 2004). In line with the arguments of the disruptive nature of 4IR technology, we have found evidence of a positive impact of unemployment on the countries' economic growth. Due to technological breakthroughs, labor worldwide is getting displaced by automation that can further exacerbate the gap between capital returns and labor returns (WEF, 2016)[17]. Health expenditure has a negatively significant impact on the growth, pointing towards the need for a significant infrastructural overhaul.

Moreover, columns 5 and 6 show that a country's political structure also influences the average annual growth rate. To be precise, a democratic country fares better in terms of average annual growth rate. Thus, the thrust needs to be placed on ensuring civil liberties and pluralism for economic growth. This is an important finding given the "democratic backsliding by the state and the "crackdowns on civil liberties" (EIU, 2020). The FD (Financial Development) regression coefficient is having a negative impact on the economic growth of countries on an average. This might be due to the inclusion of ICT terms in the regression as these technologies help in accessing and efficient utilization of funds available through financial institutions and financial markets. The coefficient of the dummy variables for the high-income group is also turning out to be negative, implying post 2016 Global recession due to US China Trade war, BREXIT and India not sighing RCEP deal may have had negative impact on the growth rates of the high-income countries in comparison with it's middle-income cohorts. ICT usage and ICT impact is having a negative impact on economic growth while the OECD-DSTRI is having a positive impact on economic growth rates. This may be due to the fact that ICT usage and Impact have differential impact across individuals, businesses and governments and hence the digital regulations tend to protect the interest of the stake holders. Health expenditures are coming out to be negative, may be due to endogeneity issue between economic growth and health expenditures. Even during the Covid times, economies with better health capacities were impacted more in terms of lives and livelihoods.

[17] https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

Table 8: Cross-country estimates of the factors determining economic growth

VARIABLES (Dependent Variable: Average Annual Growth Rate)	All variables	Without GFCF	Without Usage and GFCF	Robust All variables	Robust without GFCF	Robust without Usage and GFCF	Only ICT related var
Productivity	2.553**	2.301**	3.272***	2.553**	2.301**	3.272**	2.462
	(-0.832)	(-1.013)	(-1.062)	(-0.915)	(-1.032)	(-1.129)	(-2.236)
Technical Efficiency	4.373**	4.531**	2.259	4.373**	4.531**	2.259	-5.697
	(-1.584)	(-1.942)	(-1.923)	(-1.41)	(-1.459)	(-1.369)	(-5.5)
OECD-DSTRI	0.425***	0.387**	0.421**	0.425***	0.387***	0.421***	0.0877
	(-0.114)	(-0.139)	(-0.16)	(-0.0787)	(-0.105)	(-0.122)	(-0.387)
ICT Usage	-2.359*	-3.261**		-2.359**	-3.261*		-0.732
	(-1.229)	(-1.445)		(-0.994)	(-1.701)		(-3.506)
ICT Environment	2.645	2.012	-0.787	2.645	2.012	-0.787	1.69
	(-1.49)	(-1.803)	(-1.515)	(-1.888)	(-1.721)	(-1.446)	(-4.059)
ICT Readiness	6.907***	6.916***	5.988***	6.907***	6.916***	5.988***	-1.502
	(-1.26)	(-1.545)	(-1.725)	(-0.95)	(-1.264)	(-1.781)	(-3.629)
ICT Impact	-2.395	-1.769	-1.524	-2.395*	-1.769	-1.524	4.407
	(-1.536)	(-1.86)	(-2.15)	(-1.158)	(-1.477)	(-1.409)	(-4.055)
GFCF	0.0632**			0.0632**			
	(-0.0247)			(-0.0264)			
Unemployment	0.316*	0.238	0.324	0.316*	0.238	0.324	
	(-0.153)	(-0.183)	(-0.208)	(-0.164)	(-0.221)	(-0.249)	
FD	-0.90***	-0.796***	-0.864***	-0.909***	-0.796***	-0.864**	
	(-0.191)	(-0.228)	(-0.262)	(-0.143)	(-0.256)	(-0.307)	
GDP constant (2016)	0.0472	0.0577	0.118	0.0472	0.0577	0.118	
	(-0.0583)	(-0.0714)	(-0.0767)	(-0.0524)	(-0.0684)	(-0.0687)	
Trade to GDP	0.215	0.0971	0.226	0.215	0.0971	0.226	
	(-0.119)	(-0.134)	(-0.141)	(-0.143)	(-0.169)	(-0.165)	
MDPI	0.292	0.307	0.208	0.292	0.307	0.208	
	(-0.197)	(-0.241)	(-0.275)	(-0.191)	(-0.255)	(-0.315)	
Inflation	0.0797	0.251	0.22	0.0797	0.251	0.22	
	(-0.148)	(-0.162)	(-0.187)	(-0.189)	(-0.198)	(-0.215)	
Democracy Indicator	0.538	1.042	1.412	0.538	1.042*	1.412*	
	(-0.664)	(-0.778)	(-0.88)	(-0.659)	(-0.5)	(-0.728)	
Health Expenditure	-0.831**	-0.855**	-0.985**	-0.831*	-0.855*	-0.985*	
	(-0.297)	(-0.364)	(-0.416)	(-0.383)	(-0.445)	(-0.533)	
High-Income	-0.512*	-0.577*	-0.426	-0.512**	-0.577**	-0.426*	
	(-0.247)	(-0.301)	(-0.34)	(-0.212)	(-0.208)	(-0.238)	
Constant	-21.2***	-15.75***	-16.52***	-21.29***	-15.75***	-16.52**	-14.24**
	(-3.445)	(-3.289)	(-3.788)	(-2.765)	(-4.18)	(-5.441)	(-5.99)
Observations	28	28	28	28	28	28	49
R^2	0.966	0.943	0.917	0.966	0.943	0.917	0.185

S.E in parentheses *** p<0.01, ** p<0.05, * p<0.1

Note: For regression analysis, we have estimated the logarithmic average of all the variables for 2016-20. High-income is a dummy variable which is one if the country happens to be a high-income nation and zero if the i^{th} nation is middle-income. GFCG is the gross fixed capital formation (Investment). Unemployment is the % unemployment of the total labor force (ILO estimate). GDP constant (2016) captures the initial level of income. Inflation captures consumer prices (annual %),

6. Conclusions and policy implications

The novelty of the current study is five-fold. Firstly, we exploit the annual reports on network readiness index published by WEF and the OECD digital trade restrictiveness index to ascertain and compare the technical efficiency of network readiness of 50 countries for the years 2016 and 2020. Based on the literature reviewed so far, this is the first study to understand the nexus between Digital trade restrictions and the critical indicators of network readiness- ICT impact, ICT usage, ICT environment, and ICT readiness. Secondly, a dearth of literature incorporates an undesirable output like Digital Service Trade Restrictiveness (subsuming electronic transactions glitches, infrastructure and connectivity issues, payment system IPR, among other barriers affecting trade in digitally-enabled services). Fourthly, the combination of three methodologies in the current context is a rare incidence; thus, we delve into employing two non-parametric methods, namely, DEA and DEA-based Malmquist productivity index, and Stochastic Frontier Model. The reason for undertaking this exercise stem from the inherent advantages of these methodologies. Fifthly, we have endeavored to consider multiple outputs and multiple inputs in our analysis.

Based on DEA results, we have received four pieces of evidence. In line with previous research findings like You & Yan (2011), the model with undesirable output shows higher average technical efficiency scores than the model without undesirable output. Second, the model with ICT trade as output shows a marginally higher technical efficiency score than the model without ICT trade. Thirdly, the countries, on average, witnessed a surge in technical efficiency between 2016 and 2020. Fourthly, trade restrictiveness has very little to do with the technical efficiency of countries. Fifthly, there is no variability in the technical efficiency scores of High and Middle-income nations. From the results of the Malmquist index, we can deduce that where all the middle-income countries have maneuvered to move up the ladder, as evident from the positive and greater than unity TFP change, 28 high-income countries have experienced deterioration in TFP. The counties need to have better governance, transparency, and accountability to achieve the technical and technological efficiency observed in 50 countries for 2016 and 2020. From the maximum likelihood estimation results of SFA, ICT environment and ICT readiness have a statistically significant positive impact on ICT usage. Thirdly, OECD-DSTRI, an undesirable output considered an inefficiency component, negatively impacts the technical efficiency but was found to be insignificant (statistically). Gathering actionable insights from the methodology adopted, we can infer that though the technical efficiency scores might

have gone up, the total factor productivity change has gone down across 50 countries. This might probably be because of a trade war, deepening democratic recession, and the rising cases of authoritarianism.

The results from regression pin down the positively significant impact of technical efficiency, accessibility, affordability infrastructure, and other variables, which has an isotonic and substantial influence on the growth. If a country imposes digital service trade restrictions, it gives impetus to economic growth. It could probably be based on the states' argument to reduce its susceptibility to external shocks or protect domestic enterprise by capacity augmentation. In line with the arguments of the disruptive nature of 4IR technology, we have found evidence of a positive impact of unemployment on the countries' economic growth. Due to technological breakthroughs, labor worldwide is getting displaced by automation that can further exacerbate the gap between capital returns and labor returns. We have also found evidence of democratic countries faring better in terms of average annual growth rate.

For future research, we suggest an economic analysis of the regulatory framework adopted by countries worldwide. Further, there is sufficient scope for studies investigating the impact of the digital service trade restrictiveness index on the economy and international trade. We also suggest the implementation of other frontier methodologies to have a deeper understanding of the technical efficiencies of Network Readiness of countries. In the end, we emphasize the persistent attempts by the policymakers to make the ICT environment conducive and ramp up the digital infrastructure and other factors to ensure ICT readiness is improved. We also suggest that the countries either do away with the digital service trade restrictions. In other words, governments need to make every attempt to facilitate ICT usage. These policies would pave the way for the inclusive growth of countries across the world. It seems that net neutrality, pernicious regulations related to the ICT sector, and adopting competition policies across countries can ameliorate the technical productivity and efficiency of the ICT sector.

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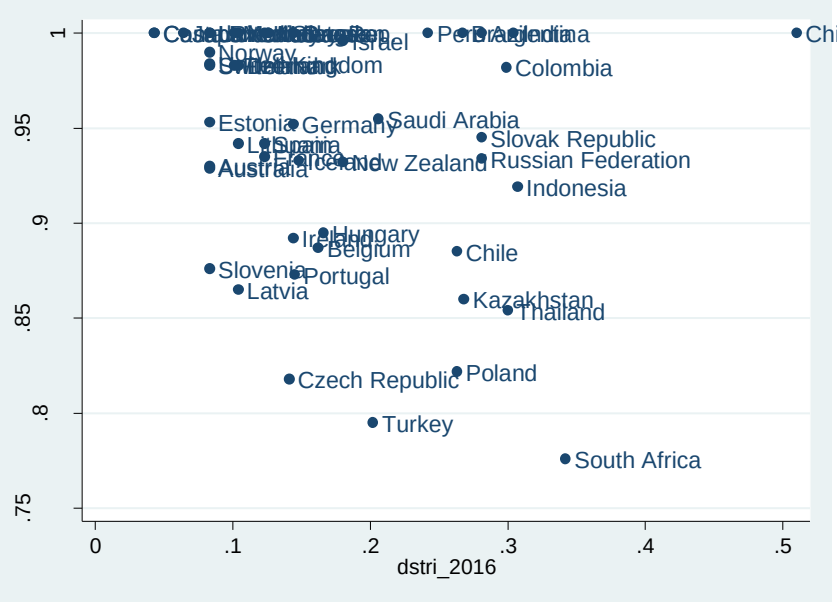
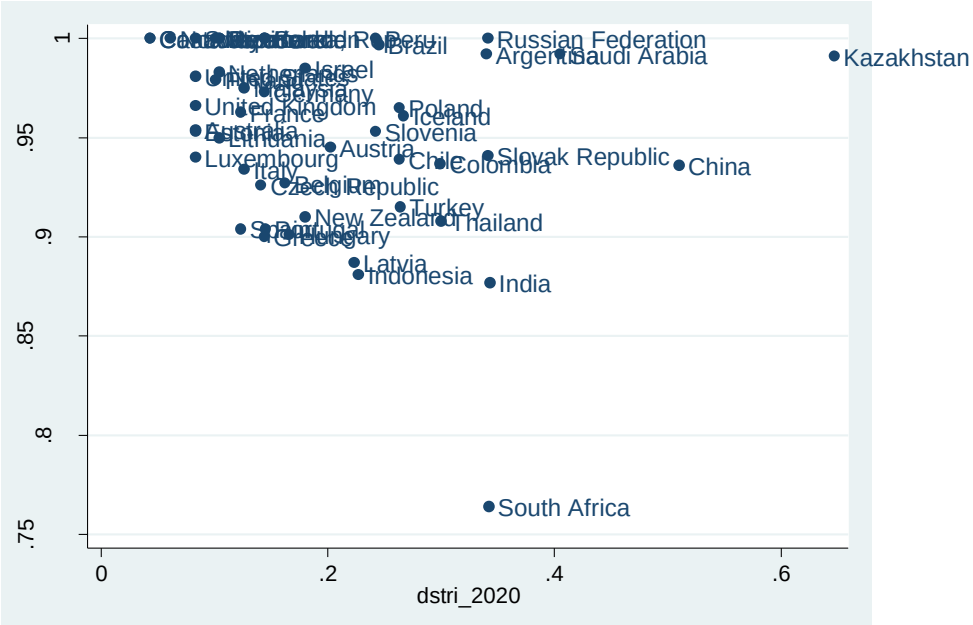
Appendix

Appendix Figure 1: Relationship between restriction and technical efficiency scores for the year 2016



Appendix Figure 2: Relationship between restriction and technical efficiency scores for the year 2020



Appendix Table 1: Summary statistic of variable used

Variable	Observations	Average	Standard. Deviation	Minimum	Maximum
High Income	50	0.72	0.4535574	0	1
2016					
ICT Trade services	50	9.655003	10.22172	0.341046	47.3008
ICT Usage	50	48.46	7.643084	33	59
ICT Impact	50	46.24	7.818241	34	60
OECD-DSTRI	50	0.169	0.0958498	0.043	0.51
ICT Environment	50	46.56	6.509522	33	56
ICT Readiness	50	55.24	6.045947	44	66
2020					
ICT Usage	50	61.3754	10.74921	40.15	80.81
ICT Impact	50	63.9262	10.71938	38.8	80.93
OECD-DSTRI	50	0.19524	0.1225094	0.043	0.647
ICT Environment	50	73.2222	11.8479	49.98	91.3
ICT Readiness	50	59.5146	15.41181	31.44	85.67

Appendix Table 2: Correlation between the variables for the year 2016

	ICT Trade services	ICT Usage	ICT Impact	OECD-DSTRI	ICT Environment	ICT Readiness
ICT Trade services	1					
ICT Usage	0.0593	1				
ICT Impact	0.1806	0.9571	1			
OECD-DSTRI	0.0398	-0.6421	-0.6304	1		
ICT Environment	0.1015	0.898	0.8803	-0.5841	1	
ICT Readiness	0.0705	0.8036	0.7586	-0.6289	0.7318	1

Appendix Table 3: Correlation matrix of variables for the year 2020

	ICT Usage	ICT Impact	OECD-DSTRI	ICT Enviro	ICT Readiness
Usage of ICT	1				
ICT Impact	0.8804	1			
OECD-DSTRI	-0.5214	-0.5942	1		
ICT Environment	0.8857	0.9022	-0.5981	1	
ICT Readiness	0.8829	0.9322	-0.6039	0.9355	1

Appendix Table 4: Statistical tests value

Statistical Test to compare High Income and Middle-Income Countries	**For Total factor Productivity (Malmquist Index)**	**For Technical Efficiency Score (SFA)**
t-test with equal variance	6.4252***	-3.0795***
t-test with unequal variances (t-value)	5.4644***	-2.2205***
W-S test (Z-value)	4.538***	-2.074***
K-S test	0.7341***	0.4008***

Note: *** means test statistics is significant at 1% level

Appendix Table 5: Technical efficiency (sfa) for 2016 and 2020

Country name	**SFA_2020**	**SFA_2016**
Argentina	0.972	0.977
Australia	0.975	0.974
Austria	0.971	0.978
Belgium	0.958	0.959
Brazil	0.973	0.978
Canada	0.973	0.969
Switzerland	0.965	0.977
Chile	0.969	0.938
China	0.969	0.959
Colombia	0.96	0.973

Country name	SFA_2020	SFA_2016
Costa Rica	0.975	0.983
Czech Rep.	0.953	0.942
Germany	0.967	0.976
Denmark	0.98	0.981
Spain	0.965	0.976
Estonia	0.973	0.98
Finland	0.979	0.972
France	0.969	0.978
U K	0.971	0.982
Greece	0.962	0.967
Hungary	0.925	0.951
Indonesia	0.943	0.925
India	0.926	0.891
Ireland	0.929	0.955
Iceland	0.969	0.968
Israel	0.977	0.98
Italy	0.957	0.978
Japan	0.984	0.987
Kazakhstan	0.965	0.956
Korea, Rep. Republic of Korea	0.984	0.987
Lithuania	0.973	0.977
Luxembourg	0.968	0.983
Latvia	0.944	0.959
Mexico	0.976	0.967
Malaysia	0.976	0.982
Netherlands	0.969	0.982
Norway	0.975	0.978
New Zealand	0.968	0.958
Peru	0.972	0.934
Poland	0.938	0.912
Portugal	0.958	0.957
Russia Russian Federation	0.98	0.965
Saudi Arabia	0.978	0.974

Country name	SFA_2020	SFA_2016
Slovak Rep.	0.906	0.962
Slovenia	0.963	0.955
Sweden	0.975	0.98
Thailand	0.947	0.934
Turkey	0.964	0.927
United States	0.975	0.986
South Africa	0.876	0.855
Mean	**0.962**	**0.962**

Appendix Table 6: Statistical test to compare high- and middle-Income countries

Statistical Test to compare High Income and Middle-Income Countries	For Total factor Productivity (Malmquist Index)	For Technical Efficiency Score (SFA) 2016	For Technical Efficiency Score (SFA) 2020
t-test with equal variance	6.4252***	-3.0795***	-1.2288
t-test with unequal variances (t-value)	5.4644***	-2.2205***	-1.0068
W-S test (Z-value)	4.538***	-2.074***	-0.907
K-S test	0.7341***	0.4008***	0.1944

Note: *** means test statistics is significant at 1% level

Appendix Table 7: Comparison of technical efficiency scores for 2016

Country name	with undesirable output	without undesirable output
Argentina	1	1
Australia	0.929	0.918
Austria	0.93	0.922
Belgium	0.887	0.887
Brazil	1	1
Canada	1	0.908
Switzerland	0.983	0.966
Chile	0.885	0.885

Country name	with undesirable output	without undesirable output
China	1	1
Colombia	0.982	0.98
Costa Rica	1	0.911
Czech Rep.	0.818	0.816
Germany	0.952	0.952
Denmark	0.983	0.983
Spain	0.942	0.923
Estonia	0.953	0.926
Finland	0.983	0.983
France	0.935	0.935
United Kingdom	0.984	0.972
Greece	1	0.969
Hungary	0.895	0.886
Indonesia	0.919	0.919
India	1	1
Ireland	0.892	0.892
Iceland	0.933	0.933
Israel	0.996	0.996
Italy	1	0.966
Japan	1	1
Kazakhstan	0.86	0.86
Korea, Rep. Republic of Korea	1	1
Lithuania	0.942	0.922
Luxembourg	1	1
Latvia	0.865	0.849
Mexico	1	0.949
Malaysia	1	1
Netherlands	1	1
Norway	0.99	0.983
New Zealand	0.932	0.932
Peru	1	1
Poland	0.822	0.822

Country name	with undesirable output	without undesirable output
Portugal	0.873	0.871
Russia Russian Federation	0.934	0.934
Saudi Arabia	0.955	0.955
Slovak Rep.	0.945	0.945
Slovenia	0.876	0.838
Sweden	1	1
Thailand	0.854	0.854
Turkey	0.795	0.795
US	1	1
South Africa	0.776	0.776
mean	0.944	0.934

Appendix Table 8: Comparison of VRSTE scores for the year 2016

Country name	with trade	without trade
Argentina	**1**	1
Australia	0.929	0.929
Austria	0.959	0.93
Belgium	0.889	0.887
Brazil	1	1
Canada	1	1
Switzerland	0.987	0.983
Chile	0.885	0.885
China	1	1
Colombia	0.982	0.982
Costa Rica	1	1
Czech Rep.	0.851	0.818
Germany	0.954	0.952
Denmark	0.983	0.983
Spain	0.95	0.942
Estonia	0.968	0.953
Finland	1	0.983

Country name	with trade	without trade
France	0.936	0.935
United Kingdom	0.986	0.984
Greece	1	1
Hungary	0.899	0.895
Indonesia	0.92	0.919
India	1	1
Ireland	1	0.892
Iceland	0.933	0.933
Israel	1	0.996
Italy	1	1
Japan	1	1
Kazakhstan	0.86	0.86
Korea, Rep. Republic of Korea	1	1
Lithuania	0.942	0.942
Luxembourg	1	1
Latvia	0.88	0.865
Mexico	1	1
Malaysia	1	1
Netherlands	1	1
Norway	0.99	0.99
New Zealand	0.932	0.932
Peru	1	1
Poland	0.845	0.822
Portugal	0.873	0.873
Russia Russian Federation	0.94	0.934
Saudi Arabia	0.955	0.955
Slovak Rep.	0.951	0.945
Slovenia	0.881	0.876
Sweden	1	1
Thailand	0.854	0.854
Turkey	0.795	0.795
US	1	1
South Africa	0.776	0.776

Country name	with trade	without trade
mean	0.95	0.944

Appendix Table 9: Pattern of reforms in the digital sector across 50 countries

Country	Act, practice (laws regulating content on digital platforms, intellectual property rights, and other barriers affecting trade in digitally enables services)
Argentina	• Argentina: Data Protection Laws and Regulations, 2021 • National Direction of Digital Services, 2015 • Argentina has signed the Convention 108+ for the Protection of Individuals with regard to Processing of Personal Data. • General Data Protection Regulation (Regulation (EU) 2016/679) ('GDPR'),
Australia	• Cyber Security Strategy, 2016 • The Australian Privacy Principles (APPs), 1988 • The Broadcasting Services Act, 1992 • Australian Competition and Consumer Commission (ACCC). • Copyright Act 1968 (Act No. 63 of 1968, Date of Assent: 27 June 1968, last amended on 1 January 2019, Part V, Division 5—Offences and summary proceedings, 132AK - Aggravated offence - work etc. converted to digital form; Part VAA, Division 3—Offences and Part XIA, Division 3—Offences) • Domain Name Registrar (Australia) (Domain Names - Search and Registration) • .auDA Domain Administration LTD(.auDA Domain Administration LTD, .au Domains, last accessed in July 2020) • auDA, .au Licensing Rules (auDA, .au Licensing Rules, issued on 26 February 2020, section 1.3 Australian presence (paragraph 17))
Austria	• Cartel Act 2005(Kartellgesetz 2005 – KartG 2005, BGBl. I Nr. 61/2005, 5 July 2005, last updated on 11 January 2013 (BGBl. I Nr. 13/2013, par. 36.4) • Copyright Law (Urheberrechtsgesetz, par. 91) • Copyright Law (Urheberrechtsgesetz, par. 41 - 56d)
Belgium	• Economic Code - Book XI Intellectual Property (last updated on 31 May 2016, Book XI) • Economic Code - Book IV Protection of Competition (last updated on 31 May 2016, Livre IV, article IV.16 et seq.) • Regulation 733/2002 on the implementation of the .eu Top Level Domain (last amended on 3 April 2016, Article 4(2)(b))
Brazil	• Lei Geral de Proteção de Dados (LGPD) • Law 12529/2011 Structure of the Brazilian System of Competition Defence (Adopted 30/11/2011, Last modification 01/12/2015, Article 47 and Title VI)
Canada	• The Competition Act (R.S.C., 1985, c. C-34), Part IV-36) • Canadian Internet Registration Authority (CIRA) (.CA Domains) • Copyright Act (Copyright Act (R.S.C., 1985, c. C-42), adopted 1985, with latest modification of 17.06.2019, PART IV - Remedies, section 42, 41.1)
Chile	• Law 17.336 on Intellectual Property (Ley de la Propiedad Intelectual, implemented 02/10/1970, last amended 29/05/2014, Articles 19 and 81 to 83) • Decree 211 for the Defence of Free Competition (implemented 07 March 2005, last amended 30 August 2016)
China	• Personal Information Protection Law (PIPL) • PRC Cybersecurity Law., 2017

Country	Act, practice (laws regulating content on digital platforms, intellectual property rights, and other barriers affecting trade in digitally enables services)
	• Personal Information Security Specification (GB/T 35273-2020) • Internet Publishing Services Management Regulations (adopted on 14 February 2016, Article 10) • Anti-monopoly Law of the People's Republic of China (adopted 1 August 2008, article 38) • Administrative Provisions on Internet Audio-Visual Program Service (adopted 31 January 2008, last updated 28 August 2015 article 8 and 17) • Regulations on Broadcasting and Television Administration (adopted 1 September 1997, last updated 7 December 2013, article 41) • Copyright Law of the People's Republic of China (adopted 1 June 1991, last updated 1 April 2010, article 48) • Trademark Law of the People's Republic of China (adopted 1 March 1983, last updated 1 May 2014, article 17) • Regulation on the Implementation of the Trademark Law of the People's Republic of China (adopted 3 August 2002, updated 1 May 2014, article 5)
Colombia	• Law 1340 of 2009 which dictates norms on the protection of competition (last amended 10 January 2012, Chapter III, Articles. 6-8 and 19)
Costa Rica	• Law for the Promotion of Competition and Effective Consumer Protection (20 December 1994, Article 17, 21 and 46) • Civil Procedure Code (on 8 October 2018, Articles 103-109) • Law on Procedures for Enforcement of Intellectual Property Rights (12 October 2000, last amended on 03 May 2010, Articles 42-71) • Law on Copyright and Neighbouring Rights (last amended on 03 May 2010, Articles 121, 123, 125, 67-76) • Law on Procedures for Enforcement of Intellectual Property Rights (last amended on 03 May 2010)
Czech Republic	• Civil code (Act No. 89/2012 Coll., last updated in February 2017) • Copyright Law (Act No. 121/2000 Coll, last updated 15 February 2019, § 40) Act on the Protection of Competition (Act No. 143/2001 Coll., last updated in July 2017, § 20, 20a) • Regulation 733/2002 on the implementation of the .eu Top Level Domain • Copyright Law (Act No. 121/2000 Coll, last updated 15 February 2019, § 40) • Civil Procedure Code (Act No. 99/1963 Coll., last updated on 24 April 2020, § 74 - 77a)
Denmark	• Competition Act (adopted 08/07/2015, last amended in 2016) • Copyright Act (adopted 23/10/2014, last amended 05/04/2016, Chapter 2) • Arbitration act (last changed 26.02.2008) • Regulation 733/2002 on the implementation of the .eu Top Level Domain (Regulation (EC) No 733/2002 of the European Parliament and of the Council on the implementation of the .eu Top Level Domain, OJ L 113, 22 April 2002, last amended on 3 April 2016, Article 4(2)(b)) • Danish Act on Internet Domains (not updated since, Chapter 5) • Copyright Act (adopted 23/10/2014, last amended 05/04/2016, §§ 76-80, 84)
Estonia	• Competition Act (RT I 2001 56 332, 5 June 2001, last amended on 5 June 2017, article 78) Regulation 733/2002 on the implementation of the .eu Top Level • Domain (Regulation (EC) No 733/2002 of the European Parliament and of the Council on the implementation of the .eu Top Level Domain, OJ L 113, 22 April 2002, last amended on 3 April 2016, Article 4(2)(b)) • .EE Domain Regulation (.EE Domain Regulation, Approved by the Estonian Internet Foundation Council on October 24, 2016 and taking effect on May 1, 2017, article 3.1.1 and 4.1.1) • Penal Code (Karistusseadustik, RT I 2001 61 364, adopted on 6 June 2001, last updated on 6 July 2017, Chapter 14) • Code of Civil Procedure (last updated on 6 July 2017, article 378(2))

Country	Act, practice (laws regulating content on digital platforms, intellectual property rights, and other barriers affecting trade in digitally enables services)
	• Copyright Act (Autoriõiguse seadus, RT I 1992 49 615, adopted on 11 November 1992, last amended on 1 July 2017, article 3 and Chapter IV)
Finland	• Act on compensation for antitrust complaints • Competition act (Kilpailulaki (948/2011), adopted 01.11.2011, last amended 01.01.2017, 20 §) • Regulation 733/2002 on the implementation of the .eu Top Level Domain (Regulation (EC) No 733/2002 of the European Parliament and of the Council on the implementation of the .eu Top Level Domain, OJ L 113, 22 April 2002, last amended on 3 April 2016, Article 4(2)(b)) • Viestintävirasto - Finish Communication Regulatory Authority (FICORA) Domain Name Regulation (Domain Name Regulation, FICORA 68/2016m, 15 June 2016, last updated on 30 October 2017) • Copyright Act (404/1961), adopted 01.09.1961) last amended 01.01.2017, Chapter 7 § 56, 60d) • Intellectual Property Code (Code de la propriété intellectuelle, 1 July 1992, consolidated version of 1 August 2017, Legislative Part Book III Title III Chapter V articles L335-1 to L335-9)
France	• Commercial Code (last updated on 15 October 2017, article L45-3) French Network Information Centre (AFNIC) – webpage (Association Française pour le Nommage Internet en Coopération - Nom de Domaine) • Regulation 733/2002 on the implementation of the .eu Top Level Domain (Regulation (EC) No 733/2002 of the European Parliament and of the Council on the implementation of the .eu Top Level Domain, OJ L 113, 22 April 2002, last amended on 3 April 2016, Article 4(2)(b)) • Law on Freedom of Communication (consolidated version of 8 September 2017, articles 43-1-1 to 43-10) • Decree on on-demand audiovisual media services (last updated on 31 October 2015, article 7)
Germany	• Regulation 733/2002 on the implementation of the .eu Top Level Domain (Regulation (EC) No 733/2002 of the European Parliament and of the Council on the implementation of the .eu Top Level Domain, OJ L 113, 22 April 2002, last amended on 3 April 2016, Article 4(2)(b)) DENIC (DENIC Domain Guidelines, section VIII) • Act against Restraints of Competition (Competition Act) (GWB, 26 June 2013 (BGBl. I p. 1750, 3245), last updated on 25 June 2020 (BGBl. I p. 1474)) • Act on Copyright and Related Rights (Copyright Act) (Gesetz über Urheberrecht und verwandte Schutzrechte (Urheberrechtsgesetz) par. 106-111a, 9 September 1965 (BGBl. I p. 1273), last updated on 28 November 2018 (BGBl. I p. 2014)) • Act on Copyright and Related Rights (Copyright Act) (9 September 1965 (BGBl. I p. 1273), last updated on 17 July 2017 (BGBl. I p. 2541))
Greece	• Regulation 733/2002 on the implementation of the .eu Top Level Domain (Regulation (EC) No 733/2002 of the European Parliament and of the Council on the implementation of the .eu Top Level Domain, OJ L 113, 22 April 2002, last amended on 20 June 2019, Article 4(2)(b)) Law 3959/2011 on the Protection of Competition (adopted 2011, Article 36, last amended on 13 November 2017) • EETT Decision 843/2/2018 on the management and assignment of .gr domain names (adopted in 2018, Article 7(4)) • Decision/Circular on the attribution of the VAT Number (Αριθ. 1006/31-12-2013 (adopted on 31.12.2013 with effect from 10.01.2014, Article 1) • Law 2121/1993 on Intellectual Property (adopted 1993, Articles 18-28C, last amended on 30 March 2017) • Law 3057/2002 on the reproduction of the works of the rightholders (adopted 2002, Chapter 4, Article 81)

Country	Act, practice (laws regulating content on digital platforms, intellectual property rights, and other barriers affecting trade in digitally enables services)
Hungary	• Act LVII of 1996 on the Prohibiton of Unfair Trading Practices and Limitation of Competition (last amended in 2016, Article 43/G) • Regulation 733/2002 on the implementation of the .eu Top Level Domain (Regulation (EC) No 733/2002 of the European Parliament and of the Council on the implementation of the .eu Top Level Domain, OJ L 113, 22 April 2002, last amended on 3 April 2016, Article 4(2)(b)) • Domain Registration Rules and Procedures • Act CLXXXV of 2010 on Media Services (last amended in 2016, Article 20(2)) • Act C of 2012 on the Criminal Code (implemented 1 July 2013, last amended in 2016, Article 385)
Iceland	• The competition Act (adopted 19 May 2005, last amended on 30.12.2016, chapters IV and IX) • Act on contractual arbitration (last changed 20.10.2016 (change takes effect 01.01.2018)) • Act on Supervision of Unfair Commercial Practices and Transparency of the Markeadopted 20 May 2005, last amended on 31 December 2013, Articles 5 - 7) • Media Act (Lög um fjölmiðla 2011 nr. 38/2011, adopted 20 April 2011, last amended on 12 April 2013, Articles 23 and 33) • The Copyright Act (Höfundalög 1972 nr. 73/1972, adopted 29 May 1972, last amended 19.10.2016, Article 54)
India	• Information Technology Act, 2000 • Information Technology (Intermediary Guidelines and Digital Media Ethics Code) Rules, 2021 • Cable Television Networks Regulation Act 1995 • Review of policy on Foreign Direct Investment (FDI) in e-commerce (Review of policy on Foreign Direct Investment (FDI) in e-commerce, Press Information Bureau Government of India Ministry of Commerce & Industry, 26 December 2018, 5.2.15.2.4 Other Conditions (point v).) • Government of India, Ministry of Commerce & Industry, Press Note No 3 (2016 Series) (Guidelines for Foreign Direct Investment (FDI) on E-commerce) • The Competition (Amendment) Act, 2007(Amendment) Act, 2007, Chapter VIIIA, COMPETITON APPELLATE TRIBUNAL:) • The Finance Act 2016 (The Finance Act, 2016 no. 28 of 2016, chapter VIII, equalization levy) • The Advertising Standards Council of India (ASCI), Code for Self-Regulation in Advertising, Chapter IV) • The Cinematograph Act, 1952(Act no. 37 of 1952, adopted 10 June 1952, last amended in 1983, Section 4) • The Cable Television Networks (Regulation) Act 1995(Act No. 7 of 1995, last amended in 2011) • Indian Copyright Act 1957(Act No 14 of 1957, enacted on 4 June 1957, last amended on 7 June 2012, Section 63) • The Copyright (Amendment) Act 2012(Act No. 27 of 2012, last amended 7 June 2012) • Indian Copyright Act 1957(Act No 14 of 1957, enacted on 4 June 1957, last amended on 7 June 2012, Article 52) • Copyright Rules 2013 (G.S.R. 172E, enacted 14 March 2013, last amended on 10 August 2016)
Indonesia	• Indonesian Broadcasting Commission (KPI), monitors all broadcasting content • Anti-Monopoly and Unfair Competition Act (Act No. 5/1999, adopted 05.03.1999, Chapter VII) • Limited Liability Company Act (Act No. 40/2007, Article 5) • PANDI (Registration Requirements) • Trade Act (Act No. 7/2014, Article 24) • Limited Liability Company Act (Act No. 40/2007, Article 5) • Telecommunication Act (Act No. 36/1999, adopted 08.09.1999)

Country	Act, practice (laws regulating content on digital platforms, intellectual property rights, and other barriers affecting trade in digitally enables services)
	• Regulation of the Minister of Communication and Information No. 19 of 2014(Ministry Regulation No. 19/2014, adopted 07.07.2014)
Ireland	• Competition Act 2002(Act No. 14 of 2002, implemented 10 April 2002, last amended 19 June 2017, Part 2, Article 14) Regulation 733/2002 on the implementation of the .eu Top Level • Domain (Regulation (EC) No 733/2002 of the European Parliament and of the Council on the implementation of the .eu Top Level Domain, OJ L 113, 22 April 2002, last amended on 3 April 2016, Article 4(2)(b)) • Electronic Commerce Act, 2000(Act No. 27 of 2000, last amended 30 August 2016) • Ireland's Domain Registry (Document Requirements) • Copyright and Related Rights Act, 2000(No. 28 of 2000, implemented 10 July 2000, last amended 10 July 2000, section 140)
Israel	• Restrictive Trade Practices Law (- 1988 adopted 26.7.1988, with latest modifications of 26.01.2017, Section 50.) • Copyrights Law (2007, adopted 25.11.2007, with latest modifications of 28.03.2017, Sections 61-63. Section 47-60) The Criminal Law (1977, adopted 04.08.1977, with latest modifications of 14.03.2017.)
Italy	• Italian Competition Law (Adopted 10/10/1990, Last modification 19/01/2017) • The Italian Civil Code (Adopted 16/03/1942, Last modification 30/03/2017, articles 1223, 1226, 1227) • Regulation 733/2002 on the implementation of the .eu Top Level Domain (Regulation (EC) No 733/2002 of the European Parliament and of the Council on the implementation of the .eu Top Level Domain, OJ L 113, 22 April 2002, last amended on 3 April 2016, Article 4(2)(b)) • NIC (Registering a .IT) • Legislative Decree on the Consolidated Broadcasting Code Act (Adopted 31/07/2005, Last modification 30/12/2016, Article 44(7)) • Resolution on the promotion of the production and distribution of European works by on-demand audio-visual media services (Delibera n. 188/11/CONS, 6 April 2011)
Japan	• Companies Act 2005 • Foreign Exchange and Foreign Trade Act • Act on Prohibition of Private Monopolization and Maintenance of Fair Trade (Law No.54 of April 14, 1947, last amended on December 16, 2016 (Law No. 108 of 2016), article 24 and 25) • Unfair Competition Prevention Act (Law No.47, May 19, 1993, last amended on June 3, 2016 (Law No. 54 of 2016), article 3 and 4) • Telecommunications Business Act (Supplementary Provisions, Act No.26-March 22, 2015 Excerpts, article 2) • Order for Enforcement of the telecommunications Business Act (Posts and Telecommunications Ordinance No.25 of 1985, last amended on April 1, 2018 (MIC ordinance No.6 of 2018), article 59-2) • Japan Registry Services Co., Ltd. (Japan Registry Services Co., Ltd.)
Kazakhstan	• Law On Informatisation • Law On communications 2020 • Law On Informatisation 2019 • Act against Unjustifiable Premiums and Misleading Representations 2014 • Act on Prohibition of Private Monopolization and Maintenance of Fair Trade amended on 2016 • Unfair Competition Prevention Act 2016
Republic of Korea	• Personal Information Protection Act (PIPA), 2011 Released “Guidelines for De-identification of Personal Data.”

Country	Act, practice (laws regulating content on digital platforms, intellectual property rights, and other barriers affecting trade in digitally enables services)
Latvia	• Commercial Law 2000
Lithuania	• Competition law 1999
Luxembourg	• Competition Act 2011
Malaysia	• Communications and Multimedia Act 1998
Mexico	• Federal Law on Economic Competition
Netherlands	• Competition Act 2014
New Zealand	• Inland Revenue - New Zealand, Tax Policy (Inland Revenue - New Zealand, Tax Policy, Consultation on taxing the digital services industry)
Norway	• Law on arbitration
Peru	• Law for the repression of antitrust conducts
Poland	• Regulation 733/2002 on the implementation of the .eu Top Level Domain
Portugal	• Law 19/2012 approving the new competition regime
Russian Federation	• Law On Information, Information Technologies and Protection of Information • On Modification of the Federal Law on Information, Information Technologies and on Protection of Information (adopted 27.07.2006, last amended 01.05.2019, articles 15-3 and 15-8) • Law on Mass Media (adopted 27.12.1991, last update 01.03.2020, article 6 and 25-1.) • Official website of the RF Ministry of Justice (Registry of foreign mass media performing the functions of a foreign agent, last accessed 22.10.2020) • Law On Information, Information Technologies and Protection of Information (adopted 27.07.2006, last amended 08 June 2020, article 10 and 15-9) • On Foreign Investments in the Russian Federation (last amended 31.05.2018, article 10 (5.2)) • The Arbitration Procedural Code of the Russian Federation (last amended 26.07.2019, article 27 (5))
Saudi Arabia	• Saudi Arabia's Anti-Cyber Crime Law (ACCL)
Slovak Rep.	• Act on Protection of Competition
Slovenia	• Prevention of Restriction of Competition Act 2008
South Africa	• Cybercrimes and Cybersecurity Act (Act) 2021 • Protection of Personal Information Act 4 of 2013 ("POPI")
Spain	• Competition Act (adopted on 3 July 2007, last amended on 26 december 2013, Title IV) • Consolidated Intellectual Property Law (adopted on 12 April 1996, last amended on 5 November 2014, Article 143) • Competition Regulation (Real Decreto 261/2008 por el que se aprueba el Reglamento de Defensa de la Competencia, adopted on 22 February 2008, last amended on 31 August 2013) • Regulation 733/2002 on the implementation of the .eu Top Level Domain (Regulation (EC) No 733/2002 of the European Parliament and of the Council on the implementation of the .eu • Top Level Domain, OJ L 113, 22 April 2002, last amended on 3 April 2016, Article 4(2)(b))
Sweden	• The competition act 2008

Country	Act, practice (laws regulating content on digital platforms, intellectual property rights, and other barriers affecting trade in digitally enables services)
Switzerland	• Federal Act on Cartels and other Restraints of Competition (last updated on 1 December 2014, articles 2, 3, 12, 13 and 26) • Ordinance on Domain Names (November 2014, last updated on 1 November 2017, article 24, 25, 50 and articles 53) • Telecommunications Act (last updated on 1 July 2010, articles 28, al. 2 et 2bis, 48a, 59, al. 3, 62 et 64, al. 2,) • Federal Act on Copyright and Related Rights (Loi fédérale sur le droit d'auteur et les droits voisins, RS 231.1, 9 October 1992, last updated on 1 April 2020, Title 5, Chapter 2, Article 65)
Thailand	• The Electronics Transaction Organisation Restructuring Act • Data Protection Act • Cybersecurity Act • Digital Economy and Society Council Act • Digital ID Act • Electronics Transaction Officer Act
Turkey	• Radio and Television Supreme Council (RTUK)
United Kingdom	• Data Protection Act (DPA), 2018 British Broadcasting Corporation (BBC), 2018 regulates the content broadcasted on OTT platform. • Enterprise Act 2002(last updated in May 2004, Section 18) Competition Act 1998(last updated in July 2012) • Regulation 733/2002 on the implementation of the .eu Top Level Domain (Regulation (EC) No 733/2002 of the European Parliament and of the Council on the implementation of the .eu Top Level Domain, OJ L 113, 22 April 2002, last amended on 3 April 2016, Article 4(2)(b)) • NOMINET (Rules for the registration and use of domain names within the .UK domain and its sub-domains, June 2014) • Copyright, Designs and Patents Act 1988(last updated in March 2002) • Copyright, etc. and Trade Marks (Offences and Enforcement) Act 2002 • The Copyright and Related Rights Regulations 2003(last updated in September 2003, Chapter III)
United States	• National Telecommunications and Information Administration • Start with .US (usTLD Nexus Requirements Policy) • Commerce and Trade (15 U.S.C. §15 Suits by persons injured) • California Privacy Rights Act (CPRA) • Copyrights Act (17 U.S.C. §506 (2017)) • Crimes and Criminal Procedure Act (18 U.S.C. §2319 (2017)) • Copyrights Act (17 U.S.C. §107 - §109 (2016))

Source: OECD (DSTRI), Official websites of Government among other sources

Appendix Table 10: Classification of indices for NRI

Index	2020		2016	
	Sub-Index	**Variables**	**Sub-Index**	**Variables**
ICT Readiness /Technology	**Access**	Mobile tariffs	Infrastructure	Electricity production, kWh/capita
				Mobile network coverage, % population

Index	2020		2016	
	Sub-Index	**Variables**	**Sub-Index**	**Variables**
				International Internet bandwidth, kb/s per user
		Handset prices		Secure Internet servers per million population
		Households with internet access		
		mobile network coverage		
		Fixed-broadband subscriptions	Affordability	Prepaid mobile cellular tariffs, PPP $/min.
		International Internet bandwidth		Fixed broadband Internet tariffs, PPP $/month
		Internet access in schools		Internet and telephony sectors competition index, 0–2 (best)
	Content	GitHub commits	Skills	Quality of education system
		Wikipedia edits		Quality of math and science education
		Internet domain registrations		Secondary education gross enrollment rate, %
		Mobile apps development		Adult literacy rate, %
	Future Technologies	Adoption of emerging technologies		
		Investment in emerging technology		
		ICT PCT patent applications		
		Computer software spending		
		Robot density		
ICT Usage /People pillar	**Individuals**	Internet users	Individual usage	Mobile phone subscriptions per 100 population

Index	2020		2016	
	Sub-Index	**Variables**	**Sub-Index**	**Variables**
				Percentage of individuals using the Internet
		Active mobile-broadband subscriptions		Percentage of households with computer
		Use of virtual social networks		Households with Internet access, %
		Tertiary enrollment		Fixed broadband Internet subscriptions per 100 population
		Adult literacy rate		Mobile broadband Internet subscriptions per 100 population
		ICT skills		Use of virtual social networks
	Businesses	Firms with website	Business usage	Firm-level technology absorption
		Ease of doing business		Capacity for innovation
		Professionals		PCT patent applications per million population
		Technicians and associate professionals		ICT use for business-to-business transactions
		Business use of digital tools		Business-to-consumer Internet use
		R&D expenditure by businesses		Extent of staff training
	Governments	Government online services	Government usage	Importance of ICTs to government vision*
		Publication and use of open data		Government Online Service Index, 0–1 (best)
		Government promotion of investment in		Government success in ICT promotion*

Index	2020		2016	
	Sub-Index	Variables	Sub-Index	Variables
		emerging technologies		
		R&D expenditure by governments and higher education		
ICT Environment /Governance pillar	Trust		Political and regulatory environment	Effectiveness of law-making bodies
		Secure Internet servers		Laws relating to ICTs
		Cybersecurity		Judicial independence
		Online access to financial account		Efficiency of legal system in settling disputes
		Internet shopping		Efficiency of legal system in challenging regulations
	Regulation	Regulatory quality		Intellectual property protection
				Software piracy rate, % software installed
		ICT regulatory environment		Number of procedures to enforce a contract
		Legal framework's adaptability to emerging technologies		Number of days to enforce a contract
		E-commerce legislation	Business and innovation environment	Availability of latest technologies
		Privacy protection by law content		
				Venture capital availability
	Inclusion	E-participation		Total tax rate, % profits
		Socioeconomic gap in use of digital payments		Number of days to start a business

Index	2020		2016	
	Sub-Index	**Variables**	**Sub-Index**	**Variables**
		Availability of local online content		Number of procedures to start a business
		Gender gap in internet use		Intensity of local competition
		Rural gap in use of digital payments		Tertiary education gross enrollment rate, %
				Quality of management schools
				Government procurement of advanced technology products
ICT Impact/ Impact pillar	**Economy**	Medium and high-tech industry	Economic impacts	Impact of ICTs on business models
				ICT PCT patent applications per million population
		High-tech exports		Impact of ICTs on organizational models
		PCT patent applications		Knowledge intensive jobs, % workforce
		Labour productivity per employee	Social impacts	Impact of ICTs on access to basic services
		Prevalence of gig economy		
	Quality of Life			Internet access in schools
		Happiness		ICT use and government efficiency
		Freedom to make life choices		E-Participation Index, 0–1 (best)
		Income inequality		
		Healthy life expectancy at birth		

Index	2020		2016	
	Sub-Index	**Variables**	**Sub-Index**	**Variables**
	SDG Contribution 274	SDG 3: Good Health and Well-Being		
		SDG 4: Quality Education		
		SDG 5: Gender Equality		
		SDG 7: Affordable and Clean Energy		
		SDG 11: Sustainable Cities and Communities		

Source: NRI Report 2020 and GITR Report 2016

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