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Achieving economic and social sustainability through hyperconnectivity

A cross-country comparison

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Abstract

Purpose – The purpose of this paper is to identify cross-country differences in socio-economic sustainability, which are operationalized as relative efficiency of economic and social impacts of hyperconnectivity (usage intensity of information and communication technologies (ICT) devices). The authors have a particular interest in the emerging economies because they enjoy outstanding growth rates and prospects for market expansion, and have undertaken significant economic reforms and, thus, should be expected to lead other two groups in the efficiency of transforming hyperconnectivity into sustainable growth.

Design/methodology/approach – The authors use canonical correlation analysis (CCA) to confirm the existence of a strong and significant relationship between hyperconnectivity drivers and socio-economic outcomes on a country level. The authors test the difference in efficiency of transforming hyperconnectivity into socio-economic sustainability among three groups of countries: advanced, emerging and developing nations using data envelopment analysis (DEA).

Findings – The findings indicate that indeed emerging economies were the most effective ones to use infrastructure and digital content followed by developing and advanced countries, respectively. However, relatively better affordability of technologies in the emerging countries did not produce as much socio-economic impact as compared with developing nations. Favorable legislative conditions and high individual ICT usage in advanced economies did not contribute much to socio-economic sustainability either.

Research limitations/implications – One of the limitations of this study stems from the classification of the countries. World Economy Forum and International Monetary Fund resources are utilized for the economy categories, but their basis for classification of counties is rather subjective. Lack of existing comparative efficiency studies on a country level prevents effective benchmarking of the results.

Practical implications – Since the key vehicles of transforming technology into socio-economic impact are organizations, they should design and implement an appropriate organizational architecture which would facilitate this transformation in the emerging markets more effectively.

Social implications – In a climate of increasing public accountability, governments have been increasingly urged to introduce good administrative practices and performance standards to enable efficient utilization of their resources and enhance social implications within and across countries.

Originality/value – Although the impact of ICT on macro-economic development has been previously studied, the efficiency of this impact was not. Using CCA as a complementary tool for DEA approach in this study constitutes a methodological contribution to existing DEA research, mostly done in the area of operations management. Using DEA on a country level is a novel approach which contributes to the realm of application of this methodology.

Keywords Emerging markets, DEA, Economic and social sustainability, Hyperconnectivity, Information and knowledge management, NRI

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1. Introduction

Through rapid developments in information and communication technologies (ICT), the way how we live, work, study, communicate and entertain has changed dramatically. Mobile technologies, the Internet of Things, smart cities and knowledge societies become highly popular discussion topics. Nowadays, it is so difficult to think of a life without ICTs from education, health and security to manufacturing. ICTs facilitate the access to information and educational resources making them readily available (Bonk, 2009). It improves our lives through increasing efficiency and effectiveness in our activities, defining new communication channels and creating new relationships and business models (Levy and Wong, 2014).

ICTs are the key enablers for super-fast mobile connectivity anywhere, anytime, via any device (Biggs *et al.*, 2012). According to United Nations International Telecommunication Union, there were 2.9b internet users and 2.3b mobile broadband subscriptions worldwide at the end of 2014, while 43.6 percent of household globally have internet access (Levy and Wong, 2014). In this hyperconnected world, access to the internet is considered as one of the fundamental human rights (Brian *et al.*, 2010).

ICT role in socio-economic sustainability was studied by several scholars. For example, Lee *et al.* (2005) tested ICT's impact on the economy and found that ICT investments have a positive effect on the productivity levels in the developed and emerging nations, but not in the developing countries. Jin and Cho (2015) found that ICT supply, demand and policy have a strong positive impact on country's GDP. However, there seems to be no study investigating cross-country differences in the efficiency of converting ICT usage into socio-economic sustainability.

We decided to focus specifically on the emerging countries because they enjoy outstanding growth rates and prospects for market expansion, and have undertaken significant economic reforms (Cavusgil, 1997). Therefore, our research question was formulated as follows:

RQ1. Do emerging markets differ significantly from the advanced and developing nations in their efficiency of transforming ICT drivers in socio-economic sustainability?

In this study, we benchmarked these three groups of countries based on their ability to achieve socio-economic sustainability on the basis of ICT usage intensity (called "hyperconnectivity") drivers. Network readiness index (NRI) developed by The World Economic Forum in collaboration with INSEAD was used as a metric to measure the drives and impacts of hyperconnectivity. Eight drivers and two impacts of an NRI were selected in the efficiency comparison as inputs and outputs, respectively. To this end, two analytical approaches, named canonical correlation analysis (CCA) and data envelopment analysis (DEA) are utilized to complement each other. Both methods allow the use of multiple inputs and outputs. Although these two complementary approaches have been extensively used as methodologies in their own right and applied to a various range of industrial and organizational contexts, we use CCA to verify the relationships between input and output variables in conjunction with DEA to measure the efficiency on the country level, which represents a novelty in the methodological realm. In the first stage of the study, CCA is applied to assess the significance of the relationships between input and output measures. Once the associations between input and output variables are confirmed by the significance of input parameters through CCA, we then apply DEA to measure the relative efficiency of countries in hyperconnectivity.

The remainder of the paper is organized as follows. The next section offers a systematic literature review of the relationship between ICT and socio-economic factors. Then, we discuss the notion of hyperconnectivity and outline the conceptual model by establishing the link between the drivers of hyperconnectivity and its economic and social impacts. The following section presents the research methods. Results are presented in the pen-ultimate section followed by a discussion and implications.

2. Literature review

We have conducted a systematic literature review on the connection between ICT and socio-economic factors using the Scopus database. Systematic reviews are used to assess the current state of knowledge surrounding a certain topic. They use replicable and transparent techniques to appraise and screen the data (Gaur and Kumar, 2017). In total, 270 papers were extracted using three separate search phrases: "ICT and Economy," "ICT and Society," and "ICT and Impact." The papers were divided into two groups. The first group contained highly cited papers. Any paper above the average of 11.6 citations was included. The second group consisted of newer papers, published in the high ranking journals after 2014. The abstracts of these papers were then read and evaluated to make sure that they matched the research topic. After applying all selection criteria, 29 papers were selected for the literature review.

Among those papers, seven articles studied the impact of ICT on the firm level and 22 papers investigated the relationships on the country level.

2.1 Firm level effects

Several researchers tested the link between ICT and innovation. Gago and Rubalcaba (2007) found that the ICT plays the role of an agent that enables and facilitate innovation. ICT was also found to complement other functions, such as R&D and HRM, to facilitate innovation (Hall *et al.*, 2013; Bourke and Crowley, 2015). Higón (2012), in a study to evaluate the role of ICT and its effect on innovation at the firm level, found that ICT primarily enhance efficiency. These finding fall in line with other researchers' conclusions. ICT-based innovation was also found to positively impact organizational performance (Yunis *et al.*, 2017). However, the researchers note that the positive performance depends on the individuals within the organization and their capability to make use of new innovations. Others have also noted that different factors such as family ownership, group affiliation and institutional ownership can affect R&D intensity and thus innovation (Singh and Gaur, 2013).

Innovation is not the only domain that ICT has been found to impact. Rao (2001) tackled ICT's impact on global marketing. Rao argues that ICT would have the strongest impact on product development in multinational enterprises. The trend of creating modular products, as well as creating products with common cores and different variations for different segments will likely accelerate. The author also argues that ICT can reduce the effect of country-specific risks by increasing the rate and volume of information. ICT usage was also linked to new product success, quality and time performance (Silva *et al.*, 2016). Silva *et al.* focused on the utility that ICT provides when collaborating with others to create products. Gaur *et al.* (2014) suggested that having more technological resources can mean that firms are more likely to transition into foreign direct investments and thus internationalize. One of the benefits often attributed to ICT is the ease of transfer of knowledge. Thus, ICT can indirectly affect offshoring success since knowledge was found to be one of the major factors affecting offshoring success (Mukherjee *et al.*, 2013, 2017).

2.2 Country level effects

Scholars studied the impact of ICT on various country-level variables, such as economy, equality, education, social impact and democracy.

Economy. Samoilenko and Osei-Bryson (2017) created a framework to explore ICT capabilities and their impact on microeconomic outcomes. The capabilities impact specific targets that later aggregate into macro-economic outcomes. This framework was tested to determine its appropriateness. The authors extracted five economy groups from the International Monetary Fund (IMF) and their corresponding World Development Indicators from the World Bank. An NRI was used as a metric to measure ICT capability. The researchers found that on average market environment, infrastructure environment, and political and regulatory environment need work to improve their efficiency. Samoilenko and Osei-Bryson were able to determine the strengths and weaknesses of each economy. For instance, one of Central and Eastern Europe's strengths is their ability to significantly improve their productivity in converting ICT investments in the different environments into a positive impact on the labor market.

While some researchers chose to examine ICT from a microeconomic point of view, others focused more on the aggregate effects. Huarng (2011) focused on clustering countries based on their ICT development. Using GDP and the number of internet subscribers, Huarng clustered 121 economies into three separate groups. These groups represented low, medium and high ICT development. The author found that around 50 percent of the economies studied fall under the low category. GDP was also used as a variable to measure ICT outcomes. Researchers that utilized this approach found that ICT has a positive impact on GDP (Jin and Cho, 2015). Researchers have also tested the relationship between ICT and productivity on the national level and across countries. ICT investments were found to have a positive effect on the productivity levels in developed and newly industrialized nations, but not in developing countries (Lee *et al.*, 2005). One of ICT's most touted benefits is its ability to reduce geographic distances. Malhotra and Gaur (2014) indicated that geographic distance is a significant factor that affects a firm's choice of control in cross border acquisitions. Additionally, researchers indicated that institutional distance can affect subsidiary survival (Gaur and Lu, 2007; Gaur Delios and Singh, 2007).

Equality. ICT's impact is not limited to the economy. Scholars studied ICT's impact from a societal point of view. Gender was one of the topics discussed. Gillard *et al.* (2008) undertook a literature review to provide insights on gender issues. The authors argued that the ICT development has not been able to reduce inequality between males and females. They noted that the IT/ICT workforce is dominated by males. They also contend that as women enter this domain, working conditions, salaries and status start to drop. One benefit of ICT, distance working, was criticized for allowing organizations to provide lower pay and no benefits for employees working from home. This is a particular issue for women as the global number of females employed in this sector exceeds the corresponding number of males.

Not all research into the societal impacts of ICT had negative results. Some researchers found uses for ICT that promote equality. Government and non-governmental programs in India exist to help poor Indians get better information, get fast and easy access to governmental services and get reasonable loans (Mathur and Ambani, 2005; Bisht and Mishra, 2016). Achieving this equality requires the individuals to be familiar with the technology they are using. This is evident in a study conducted by Huang *et al.* (2017) on the use of ICTs by African-American students. Their goal was to investigate the potential influence of emotional costs and PC self-efficacy on students' computer use. The researchers found that a lack of access to computers at home could result in increased emotional cost and lower levels of computer self-efficacy.

Education. In the field of education, various studies have been conducted to evaluate the impact of ICT on the field. Eng (2005) conducted a systematic review of the literature on the subject. Eng noted that the different methods used to test the link between ICT and education. In the USA, meta-analysis is widely used, while in the UK, a combination of quantitative and qualitative methods had been employed in recent large-scale research. The conclusion from the review was that ICT has a small positive effect on educational outcomes. However, the author noted that there is a need for further research. Webb *et al.* (2017) reviewed the literature on the impact of ICT on learning outcomes in the field of nursing. ICTs were found to positively improve teaching and learning efficiencies, in addition to the learning environment. However, the authors noted that the support is needed to achieve these benefits. Webb *et al.* (2017) also emphasized the importance of addressing human and environmental barriers.

Separate studies were found that provided more insight into ICT's impact on education. Van Brakel and Chisenga (2003) argued that ICT facilitated distance learning initiatives in sub-Saharan Africa. The initiative allowed for 23,000 students to register in its semester courses, in addition to more than 3,000 h of teaching programs to be delivered to students. Research also indicated that ICT implementation in schools promoted learning and teaching efficiencies (Zain *et al.*, 2004; Aristovnik, 2012). In addition, some scholars found that learning outcomes were positively influenced by ICT (Erdogdu and Erdogdu, 2015; Bai *et al.*, 2016). While the aforementioned research focused on the performance impacts of ICT, others discussed the impact on the experience of students and teachers. Teachers who undertook ICT professional development reported having improved their attitudes and skills (Karagiorgi and Charalambous, 2006). Sahlin *et al.* (2016) studied the effects of introducing ICT into classrooms and integrating them with the lessons delivered. They found that ICT had a positive impact on the learning experience. Students were more interested, engaged and amused. This made the lesson more interesting.

Social impact. Societal benefits from ICT are not limited to education and equality. Health and the environment can be affected by ICT adoption and implementation. Lindsay *et al.* (2002), for instance, found that facilitated access could influence behavioral change and strengthen social support to sufferers from heart disease. Ollo-López and Aramendía-Muneta (2012) explored the relationship between ICT adoption and the environment. The researchers were able to conclude that the use of energy efficiency promoting ICT leads to a positive impact on the environment and vice versa.

Democracy. Governance and democracy have been studied in light of ICT. Gatautis (2008) discussed some of the literature related to ICT. In the domain of governance, the author dismissed the notion that ICT can save money. Gatautis argued that ICT should be treated as supplementary to existing services. Thus, the author regarded ICTs on the national level as tools that can improve efficiency. In Tanzania, NGOs receive ICT as donations in the hopes of improving the democratic process (Mercer, 2004). Mercer found that the ICTs being donated to NGOs in the country were not being used as the donors intended. The author contends that only the elite NGOs were able to utilize the ICT to facilitate lobbying and other activities. Economic freedom is another topic that arose in the literature. Shirazi *et al.* (2009) evaluated ICT's role as a promoter of economic freedom and found a positive link between the two. However, as Shirazi *et al.* noted, correlation does not necessarily mean causation.

2.3 Focus on emerging economies

Academic research on different types of economies suggests that emerging economies as an interesting group to focus on. Research on emerging market firms has indicated that foreign ownership, product diversification and association with a particular business group significantly affect international diversification and, thus, performance (Kumar *et al.*, 2012; Gaur and Delios, 2015; Gaur and Kumar, 2009). Foreign ownership and business group affiliations are known to be enabled by ICT. Additionally, the performance of exporting firms seems to be enabled by R&D expenditure as well (Singh, 2009). When comparing the efficacy of managerial mechanisms of diversified firms, socio-cultural mechanisms seem to have a significant effect on performance (Lee and Gaur, 2013). Emerging market firms, however, require different strategies compared to developed economy firms (Lee and Gaur, 2013). Therefore, emerging economies can be a fruitful area to explore in research.

2.4 Studying efficiency at the national level

Although several studies in our sample studied the impact of ICT on various macro-economic and social factors, none of the identified studies were concerned with the efficiency of this use. In fact, efficiency studies are usually conducted on the firm level, in the area of operations management. Thus, the novelty of our research lies in both conceptual undertaking of investigating efficiency on the country level and using DEA methods for such level of analysis.

3. Conceptual development

3.1 Hyperconnectivity and NRI

In order to conduct our comparative efficiency study, we have selected one of the ICT country-level aggregated indicators, hyperconnectivity, as our main independent variable. Hyperconnectivity is the use of many communication means simultaneously. Recent developments in telecommunication industry facilitate the inclusion of the following attributes to hyperconnectivity (Fredette *et al.*, 2012): always on, readily accessible, information rich, interactive, not just about people, always recording. Therefore, hyperconnectivity does not only involve people to people communications, but also machine to machine communication. As a result, individuals, enterprises and governments are just a few of its stakeholders. Recently, highly discussed issues such as big data, social media and growing mobile technologies are important enablers of hyperconnectivity. However, it has also some drawbacks such as violating personal privacy, cyber crimes and security problems. Then, we should not consider hyperconnectivity as a way of communication and interaction improving standards of living only, but also focus on its behavioral and organization sides as well.

In order to measure hyperconnectivity, NRI was created in 2012 by World Economic Forum with the collaboration of INSEAD to help the decision makers develop strategies on ICT. NRI comprises four sub-indexes, 10 pillars and 54 individual indicators as follows (Bilbao-Osorio *et al.*, 2014):

(1) Environment sub-index:
- political and regulatory environment; and
- business and innovation environment.

(2) Readiness sub-index:
- infrastructure and digital content;
- affordability; and
- skills.

(3) Usage sub-index:
- individual usage;
- business usage; and
- government usage.

(4) Impact sub-index
- economic impacts; and
- social impacts.

Details of an NRI and corresponding components, as well as their measurements and calculations, may be accessed from The Global Technology Report (www.weforum.org).

3.2 Hypotheses development

Given significant structural differences between countries, first we propose several hypotheses related to specific hyperconnectivity drivers. Samoilenko *et al.* (2017) argued in their paper that the effects of ICT capabilities aggregate into macro-economic outcomes. As such, elements in the political and business environments can be expected to impact socio-economic variables. Therefore, we propose the following hypothesis:

H1a. Environmental drivers have a positive relationship with socio-economic outcomes.

The readiness sub-index gauges the readiness of society to make use of an affordable infrastructure. Availability of digital content and infrastructure can facilitate the adoption and use of ICT, thus impacting innovation, education and the economy as was found in the literature review. Another element in the readiness sub index, affordability, is critical for ICT adoption. Van Brakel *et al.* (2003) found that cost was the main factor preventing widespread ICT adoption in sub-Saharan Africa. The skills pillar measures the ability for society to properly utilize the available ICT. Therefore, the readiness sub index with all its pillars can be expected to impact socio-economic outcomes:

H1b. Readiness drivers have a positive relationship with socio-economic outcomes.

Individual use, business use and government use represent de-facto ICT adoption. Increasing the number of individual users would mean increasing the general public's access to information and services. This access was shown to aid in education (Webb *et al.*, 2017; Van Brakel and Chisenga, 2003), equality (Mathur and Ambani, 2005; Bisht and Mishra, 2016) and health (Lindsay *et al.*, 2007). Similarly, an increase in business use can benefit innovation activities (Hall *et al.*, 2013; Bourke and Crowley, 2015) and new product development (Rao, 2001; Silva *et al.*, 2016). Government use is directly related to the services provided. An increase in this metric can result in equal access to governmental services (Gatautis, 2008). Therefore, usage sub-index can be expected to impact society and the economy:

H1c. Usage drivers have a positive relationship with socio-economic outcomes.

Emerging countries' success in conducting significant economic reform and achieving economic sustainability, as evidenced by their high-growth rate, makes them attractive for both selling and sourcing and for market expansion (Cavusgil, 1997). In addition, research has shown that ICT investments have a positive effect on the productivity levels in developed and newly industrialized nations, but not in developing countries. Thus, we reasoned that this group of countries will be more efficient in their use of ICT toward socio-economic sustainability:

H2. Emerging countries will be more efficient in converting drivers into outcomes than advanced or developing economies.

3.3 Conceptual model tested

We tested these hypotheses using the following conceptual model. The first three sub-indexes in NRI, namely, environment, readiness and usage, are regarded as drivers, which establish the conditions for the results of the last one, impacts (Bilbao-Osorio *et al.*, 2014). This conceptual model is shown in Figure 1.

The study here focuses on how efficiently the countries linking the drivers of hyperconnectivity to its impacts. Therefore, DEA in conjunction with CCA will be discussed and applied in the next sections.

4. Research methods

In this section, we present the data and research methods used in this study.

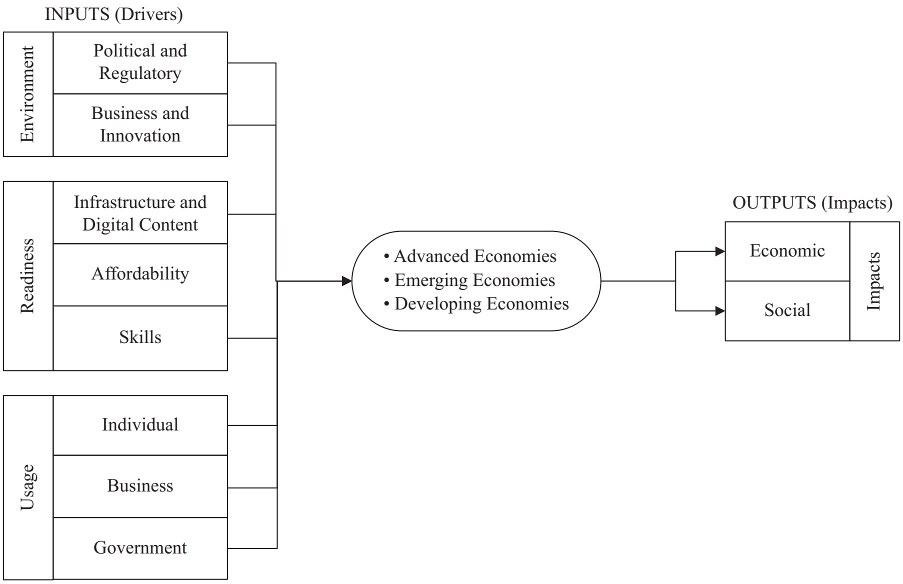

Figure 1.
The conceptual input-output framework

4.1 Sample data

In the analysis, data for NRI and its comprising ten pillars are gathered from The Global Information Technology Report 2014 (Bilbao-Osorio *et al.*, 2014). In 2014, data are collected from 148 countries, but two of them have some missing elements. Therefore, they are eliminated from the analysis.

In the classification of the countries listed in NRI, the world is divided into three groups: advanced economies, emerging economies and developing economies. These groups are formed based on the country classifications of World Economic Situation and Prospects of United Nations and World Economic Outlook of IMF.

4.2 The canonical correlation analysis

As a multivariate statistical model, CCA examines the linear interrelationships between two sets of variables, so called canonical variates (Hair *et al.*, 2010). The strength of this relationship between two canonical variates is also represented by the canonical correlation coefficient. Compared to multiple regression, discriminant analysis and MANOVA, CCA is more general and may consider multiple dependent variables that can be metric or non-metric. CCA is also the most appropriate and powerful multivariate technique to measure the level of association between the variables involving multiple independent and dependent variates (Hair *et al.*, 2010; Tabachnick and Fidell, 2007). Since CCA assess the relationship between two sets of variables in a single model rather than multiple models (one for each dependent variable), it limits the probability of Type I errors. However, CCA itself does not provide a support for the existence of a causal relationship between the canonical variates. It may only justify this association mathematically if the theory has enough support for such a relationship (Tabachnick and Fidell, 2007).

4.3 The DEA model

DEA is a linear programming based approach for measuring the relative efficiency of DMUs. It was first proposed by Charnes *et al.* (1978) based on the seminal work of

Farrell (1957). Due to its advantages over traditional methods, DEA has received significant attention in recent years. First of all, DEA produces a single score for each DMU to make the comparison easy among many similar DMUs. It is based on peer group comparison in which efficient DMUs will form the efficiency frontier and inefficient DMUs will be enveloped by this frontier. Unlike ratios, DEA is a powerful aggregate method to assess the productivity of organizations with multiple incomparable inputs and outputs, which can be expressed in different units of measurement. Since a best-practice function is empirically built from observed inputs and outputs, there is no need for any assumption about the form of the production function (Cooper *et al.*, 2000).

Another advantage of DEA that attracts analysts and management is its ability to identify the potential improvement possibilities for inefficient DMUs while spotting the benchmarking DMUs. The indicated targets, which are shown to the inefficient DMUs, are their actual peer units, therefore the results are more likely to be accepted by the managers of these DMUs. For the inefficient DMUs enveloped by the frontier, DEA compares the DMU with a convex combination of DMUs located on the frontier and enables the analyst to indicate the sources and the level of inefficiency for each of its inputs and outputs.

In contrast to regression methods which state only average relationships between multiple inputs or outputs, but not both, DEA focuses on individual observations and optimizes the performance measure of each DMU. A *priori* knowledge of weights or prices for inputs and outputs is not required in DEA (Cooper *et al.*, 2000); however, managerial judgment can be accommodated when desired.

An output-oriented DEA model initially developed by Charnes *et al.* (1978), and known as CCR in the literature, can be expressed below for m outputs, n inputs and k DMUs:

$$\text{Max } \varphi_o + \varepsilon\left(\sum_{i=1}^{n} e_{io} + \sum_{j=1}^{m} d_{jo}\right), \tag{1}$$

s.t.:

$$\sum_{r=1}^{k} \lambda_r x_{ir} + e_{io} = x_{io} \quad i = 1,\ldots,n, \tag{2}$$

$$\sum_{r=1}^{k} \lambda_r y_{jr} - d_{jo} = \varphi_o y_{jo} \quad j = 1,2,\ldots,m, \tag{3}$$

$$e_{io}, d_{jo}, \lambda_r \geqslant 0 \quad \text{for all } i,\ j,\ r. \tag{4}$$

In this model, each country is represented as a DMU to assess how efficiently it utilizes its current level of drivers for hyperconnectivity to create economic and social impacts in contrast to the other countries. φ_o is the efficiency score of a country o, where x_{io} and y_{jo} are values of input i and output j realized, respectively, e_{io} and d_{jo} are the amounts of excess input i and deficit output j for the country; $\varepsilon > 0$ is a pre-defined non-Archimedean element; λ_r's are the dual variables employed to construct a composite ideal country to dominate the country o.

The objective function above assesses the efficiency score (φ_o) of each country o. Within the same objective function in case the country is efficient ($\varphi_o = 1$), all-zero slack values (output deficits and input excesses) are also enforced for full-efficiency. Constraint (2) ensures that the level of input i for a country o is a linear combination of the inputs for each country and the excess input of i. Similarly, Constraint (3) states that the optimal output of j

for a country o is a linear combination of the outputs for each country minus its slacks. In the optimal solution of the model (1–4), the country o is efficient, if $\varphi_o = 1$ and $e_{io} = d_{jo} = 0$ for all i and j (Cooper *et al.*, 2000). If $\varphi_o = 1$ but either e_{io} or d_{jo} is non-zero, the country o is called weakly efficient. The countries found efficient in the solution of the model (1–4) form the efficiency frontier reference set for countries.

The efficiency frontier defined by the above CCR model reveals constant returns to scale (CRS) (Cook and Zhu, 2005). As an extension of CCR DEA model, Banker *et al.* (1984), known as BCC model, adds the constraint, $\Sigma \lambda_r = 1$, to the model (1–4) for variable returns to scale. In addition, the traditional DEA models can be analyzed in two ways: an input-orientation or an output-orientation (Cooper *et al.*, 2000). An input-oriented projection provides information on the proportional reduction of inputs necessary while maintaining the current level of output for an inefficient country to become DEA efficient. In contrast, an output-oriented analysis provides information on how much augmentation of the output of an inefficient country is necessary while maintaining the current level of inputs.

In this study, output-oriented BCC model is adopted in the assessment of technical efficiencies of the countries based on economic and social impacts of hyperconnectivity. Assuming that current level of the drivers for hyperconnectivity should be at least maintained, the study seeks a possible potential to increase the outputs of inefficient countries relative to the efficient ones. In this model, there are 146 countries acting as DMUs (k), which is sufficiently a large sample for our DEA model including eight inputs (n) and two outputs (m) and satisfies the following inequality, $k \geqslant \max\{m \times n, 2(m + n)\}$, as suggested by Cooper *et al.* (2000). While this has been generally accepted as a benchmark criterion, it should also be noted that DEA can be subjected to even smaller sample sizes (Ramanathan, 2003).

DEA has received significant attention in recent years due to its advantages over traditional methods and have been immensely applied in various problem settings as well for not-for-profit organizations and service firms (Sarrico and Dyson, 2000; Forker and Mendez, 2001; Zhu, 2003; Cook, 2004; Lin *et al.*, 2004; Johnes, 2006; Korpela *et al.*, 2007; Liu and Wang, 2008; Demirbag *et al.*, 2010; Bayraktar *et al.*, 2012, 2013). DEA models are assumed to have multiple incompatible input and output variables that are of quantitative and qualitative nature.

5. Results

5.1 Descriptive analysis

Table I presents the descriptive statistics concerning drivers (input) and impacts (output) of hyperconnectivity along with F-test scores for advanced, emerging and developing economies. According to F-test results, there are statistically significant differences among the different groups of economies in each dimension of NRI. Other than affordability, advanced economies have better scores than emerging and developing economies in every aspect of NRI. Emerging economies also dominate developing economies in terms of overall NRI scores as well as its drivers and impacts. It is worthwhile to note that the average affordability score of emerging economies is slightly better than advanced economies, and it is also the highest score among the all drivers and impacts of an NRI for emerging and developing countries. This clearly indicates how strongly it is emphasized by the emerging countries in order to spread out hyperconnectivity. These findings are not particularly surprising and quite fit the common expectations.

5.2 Canonical correlation analysis (CCA)

CCA is used to investigate the degree of relationships existed between eight input and two output variables which are calculated for 146 countries. Figure 1 illustrates this canonical model. The 146 cases for eight input variables exceed the threshold value of 10 observations

	Economies								
	Advanced		Emerging		Developing		Total		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	F-test
Network readiness index (NRI)	5.26	0.52	4.29	0.69	3.61	0.70	4.02	0.90	60.72
Inputs (drivers)									
Political and regulatory environment	5.02	0.76	3.85	0.78	3.52	0.63	3.84	0.87	45.92
Business and innovation environment	5.05	0.36	4.40	0.69	3.99	0.60	4.25	0.70	31.89
Infrastructure and digital content	6.24	0.60	4.42	1.06	3.43	1.22	4.10	1.51	62.63
Affordability	5.57	0.76	5.69	0.77	4.64	1.41	5.00	1.30	11.59
Skills	5.86	0.32	4.98	0.78	4.16	1.21	4.61	1.21	28.44
Individual usage	5.83	0.57	4.08	1.10	3.04	1.25	3.72	1.53	59.03
Business usage	5.03	0.80	3.94	0.73	3.36	0.42	3.76	0.83	84.82
Government usage	4.87	0.60	4.29	0.80	3.82	0.78	4.09	0.85	19.78
Outputs (impacts)									
Economic impacts	4.76	0.75	3.61	0.84	2.99	0.50	3.41	0.90	79.14
Social impacts	4.95	0.69	4.18	0.92	3.41	0.86	3.82	1.03	34.83
Output-oriented BCC DEA efficiency scores	0.971	0.029	0.976	0.046	0.966	0.045	0.969	0.043	
Total number of countries	24		30		92		146		

Note: All of the F-test values are significant at $p < 0.01$

Table I. Descriptive statistics for NRI, its drivers and impacts along with efficiency scores

per independent variables (Hair *et al.*, 2010). Therefore, the sample size is sufficiently large to conduct a CCA.

After examining data and assumptions of canonical correlation model, as many canonical functions as the number of variables in the smallest set (two for outputs) are derived. The first canonical function which also extracts the maximum amount of variance in the variable set is satisfied all the fitness tests below. Hence, it is selected to consider further. In fact, the second canonical function has also successfully passed all the fitness criteria other than the redundancy test. Therefore, we are not going to consider it anymore.

CCA in Figure 2 reveals that canonical correlation coefficient is 0.98 and statistically significant ($F = 137.02$, p-value < 0.0001). In addition to overall model fit for CCA,

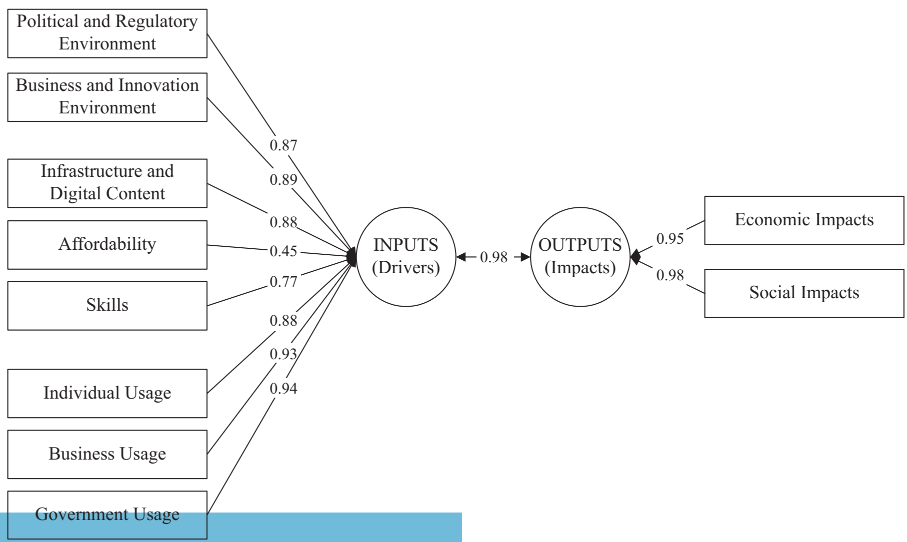

Figure 2. Canonical correlation and loadings

multivariate significance tests are also employed including Wilks' λ ($F = 137.02$), Pillai's trace ($F = 68.43$), Hotelling-Lawley trace ($F = 260.81$) and Roy's Greatest Root (498.90). The results of all these tests show that canonical correlation found earlier is also significant with p-value < 0.01. The squared canonical correlation which estimates the shared variance between canonical variates (inputs and outputs in the study) is calculated as 0.97. However, this may be misleading because it uses shared variance (calculated by the linear composites of the sets of input and output variables), but not the extracted variance (from the sets of variables) (Hair *et al.*, 2010). To overcome this bias and uncertainty in using squared canonical correlation, a redundancy index is developed to measure the ability of the input variables to explain variation in the output variables. The redundancy index for canonical variate of inputs (outputs) explaining the outputs (inputs) is found as 0.91 (0.68). Therefore, canonical relationship, as well as canonical correlation coefficient, is statistically significant, and degree of squared canonical correlation and the redundancy index are acceptable.

In order to interpret the results further and comment on the importance of each variable, canonical loadings and cross-loadings may be examined. Canonical loadings represent the correlations between a variable and its respective canonical variate. For canonical variate of inputs, six variables have loadings exceeding 0.85 and only affordability and skills have values 0.45 and 0.77, respectively, as shown in Figure 2. This indicates a very high inter-correlation among the first six variables, suggesting that any one of the variables will be enough to include in the canonical variate of inputs. Similarly, canonical variate of outputs has also highly inter-correlated two variables. Hence, any one of them may represent canonical variate of outputs. Moreover, canonical cross-loadings denote the correlations between a variable and an opposite canonical variate and listed in Table II. Other than affordability, high correlation values between the input variables and the opposite canonical variate of outputs are notable.

As a result, CCA confirms that there are strong and significant relationships between input and output measures of the study. The CCA findings imply that the inputs to the model tend to adequately explain the model's outputs. Accompanied by the CCA approach, DEA enables the use of multiple inputs and outputs simultaneously. Moreover, DEA imposes neither a specific functional relationship between outputs and inputs nor any assumptions on the specific statistical distribution of the error terms. Hence, all of the inputs that are shown to be statistically significant in any CCA validate the role of inputs mathematically over the outputs in this study. They can now be used with more confidence in the second stage of our analysis to determine the relative efficiency of countries based on DEA in the following section.

Table II. Cross-loadings

Variables	Canonical variates Outputs	 Inputs
Inputs (drivers)		
Political and regulatory environment	0.85	
Business and innovation environment	0.87	
Infrastructure and digital content	0.87	
Affordability	0.44	
Skills	0.76	
Individual usage	0.87	
Business usage	0.91	
Government usage	0.92	
Outputs (impacts)		
Economic Impacts		0.94
Social Impacts		0.97

5.3 Efficiency scores of the countries

An output-oriented BCC DEA model is developed to compute the efficiency scores of the countries to measure how efficiently they yield economic and social impacts from hyperconnectivity. The results are summarized according to the groups of economies in Table II. Overall average efficiency score is calculated as 0.97, and it does not vary much among the groups of economies. In order to compare the efficiency scores of different economies statistically, Kruskal–Walles rank test is applied, and no significant difference among them is also found (KW $=1.764$, p-value $=0.414$). However, this is a fairly surprising result, since it is anticipated that advanced economies should be efficiently utilizing their capabilities to yield much better economic and social impacts out of hyperconnectivity. This clearly indicates that having better scores on drivers (favorable situation for advanced economies) of hyperconnectivity does not really mean that the country may achieve higher efficiency in the process of converting them into economic and social impacts. There might be many reasons for this result such as problems associated with immature technologies, their high early-stage prices and their acceptance by the societies.

In the analysis of efficiency, returns to scale are another facet of evaluation. Banker *et al.* (1984) classify the scale efficiency of DMUs into three categories: increasing returns to scale (IRS); CRS; and decreasing returns to scale (DRS). IRS means that an increase in the input will result in a greater than proportionate increase in output, whereas DRS is the case where the result is less than the proportionate increase in output. CRS is exhibited where the result is the proportionate increase in output. Then, the countries based on their types of economies are classified into these three categories by their returns to scale. The numbers and distributions of the countries within these three categories of the returns to scale are shown in Table III.

Table III indicates that 52.74 percent of the countries are listed under IRS category. Therefore, the majority of the countries improving their drivers for hyperconnectivity yield more than proportionate increase in economic and social impacts indicators. Including, 31.51 percent of the countries categorized under CRS, the number of countries listed as IRS or CRS reaches a total of 84 percent of them. Therefore, the majority of the countries have a potential to increment the impacts of hyperconnectivity either proportionally or over proportionally with their increment on drivers. This also supports the claim that hyperconnectivity is rather an emerging concept and further efforts to enhance its applicability will produce more impact economically and socially.

It should be noted that emerging economies fallen in DRS category are the highest with 23.33 percent, and the lowest in IRS category with 43.34 percent. However, there is no statistically significant difference among the different groups of economies in terms of their returns to scale characteristics ($\chi^2=2.174$, p-value $=0.704$).

5.4 Comparison of structural differences among the different economies

DEA study in the previous section has focused on the overall efficiencies where there are no significant administrative and structural differences among the different economies. However, the administrative systems and associated capabilities may vary in each group of

	DRS		CRS		IRS		
	Number	Percent	Number	Percent	Number	Percent	Total
Advanced economies	3	12.50	7	29.17	14	58.33	24
Emerging economies	7	23.33	10	33.33	13	43.34	30
Developing economies	13	14.13	29	31.52	50	54.35	92
Total	23	15.75	46	31.51	77	52.74	146

Table III. Categories of returns to scale countries, and structural differences among the groups may not be identified clearly due to administrative efficiency differences. Brockett and Golany (1996) suggest a methodology to determine categorically inherent efficiency differences in DEA, where Sueyoshi and Aoki (2001) extend their study later to handle many categories instead of only two.

In fact, there are some obvious structural differences among different groups of economies with regard to their view of technology. Openness to the technological innovations, cultures, the percentage of the young population in the country, income levels, political and economic infrastructures and stabilities, institutional governance are some of the dimensions of these differences.

In order to eliminate administrative efficiency differences and identify structural discrepancies in our study, each group of economies is evaluated separately in line with the procedure suggested by Brockett and Golany (1996) and Sueyoshi and Aoki (2001). In each group, inefficient countries are projected into their efficiency frontier and a new pooled DEA (with output-oriented BCC approach) is run including all countries at their adjusted efficiency levels. Efficiency scores of all economies, as well as their comparisons through Kruskal–Wallis rank test, are shown in Table IV.

Eliminating the effect of administrative efficiency differences in all groups of countries lets us focus more on the structural discrepancies among them. In fact, Kruskal–Wallis rank test results in Table IV shows that there are some differences among the countries based on their status of economies ($p < 0.01$). Indeed, developing economies are the most efficient ones followed by the emerging economies. It is remarkable that advanced economies are the least efficient ones. The pairwise comparisons depicted in Table V indicate that the efficiency difference between developing and emerging economies is not statistically significant either, while there are some significant differences between advanced economies and both emerging ($p < 0.1$) and developing ones ($p < 0.01$).

It should, however, be noted that these findings tend to contradict with those of our earlier analysis which did not find any significant efficiency variation, where we did not consider any administrative and structural differences among the different economies. The contradictory findings may be explained from the several viewpoints. First, emerging and especially developing countries have some significant administrative inefficiency compared to their peer countries in their categories. Dealing with this administrative deficiencies makes emerging and developing countries more efficient in the creation of impacts. Second, structural differences in terms of hyperconnectivity in favor of emerging and developing

Table IV. Kruskal–Wallis rank test results for structural differences

	Efficiency scores			
	Mean	SD	KW	p-value
Advanced economies	0.977	0.025	11.212	0.004
Emerging economies	0.986	0.041		
Developing economies	0.993	0.012		

Table V. Rank sum test results for pairwise comparisons

Comparison of economies				
Economy 1	Mean rank	Economy 2	Mean Rank	KW
Developing	79.361	Advanced	49.628	3.344**
Emerging	74.636	Advanced	49.628	2.354*
Developing	79.361	Emerging	74.636	0.579

Notes: *$p < 0.1$; **$p < 0.01$

countries help them achieve better efficiency scores and yield more impacts. On the other side, advanced countries align the deficiencies raised by the structural differences through better administrative management and governance.

For further analysis of the results, it is necessary to study the technical inefficiencies in terms of the input excesses and the output deficits, which are summarized in Tables VI and VII. The average slacks for variables considered in DEA model derived from each economy group individually are presented in Table VI. As the slacks are so close to 0, a *t*-test is conducted to verify that they are significant. In advanced economies, only two of the drivers of hyperconnectivity, namely, infrastructure and digital content and affordability, are found as drivers excessively emphasized and yield no impacts at all, while developing economies should focus on the all dimensions of hyperconnectivity to improve their administrative efficiency gaps. Emerging countries should also watch closely their excessive practices on political and regulatory and business and innovation environments, affordability, skills and business usage, which does not produce any impact.

	Average improvement potential of economies		
	Advanced	Emerging	Developing
Input (drivers) excesses			
Political and regulatory environment	0.029	0.070**	0.085***
Business and innovation environment	0.008	0.066**	0.103***
Infrastructure and digital content	0.076*	0.075	0.166***
Affordability	0.080*	0.037*	0.250***
Skills	0.014	0.209**	0.180***
Individual usage	0.034	0.048	0.108***
Business usage	0.045	0.030*	0.039***
Government usage	0.001	0.000	0.017**
Output (impacts) deficits			
Economic impacts	0.003	0.022	0.019**
Social impacts	0.029	0.007	0.004*

Notes: $*p < 0.1$; $**p < 0.05$; $***p < 0.01$

Table VI. The source of administrative inefficiencies

	Average improvement potential of economies			
	Advanced	Emerging	Developing	*F*-test
Input (drivers) excesses				
Political and regulatory environment	0.110***	0.066*	0.008**	8.582***
Business and innovation environment	0.109**	0.134***	0.085***	0.768
Infrastructure and digital content	0.365***	0.041**	0.147***	6.280***
Affordability	0.054	0.155***	0.016*	7.760***
Skills	0.309***	0.173***	0.239***	0.600
Individual usage	0.226***	0.049*	0.071***	4.579**
Business usage	0.061	0.009	0.007***	5.045
Government usage	0.012	0.004	0.009**	0.358
Output (impacts) deficits				
Economic impacts	0.002	0.012	0.006*	0.530
Social impacts	0.004	0.005	0.007*	0.082

Notes: $*p < 0.1$; $**p < 0.05$; $***p < 0.01$

Table VII. The source of structural inefficiencies

Table VII depicts the average slacks for variables (similar to Table VI) derived from the DEA model to measure the structural differences among the economy groups. In order to confirm the significance of the slacks, a *t*-test is applied to every entry in Table VII, and all impact deficits along with some driver excesses for advanced and emerging economies are found insignificant. Although developing economies are found as the most efficient ones, they have potential improvement areas in all aspects of hyperconnectivity, which is in line with the finding as shown earlier in Table VI.

Among the different groups of economies, the main structural differences found statistically significant are listed in Table VII as follows: political and regulatory environment ($p < 0.01$), infrastructure and digital content ($p < 0.01$), affordability ($p < 0.01$) and individual usage ($p < 0.05$). In order to identify the pairs showing significant differences, multiple pairwise comparisons are conducted with *post hoc* tests, and the results are shown in Table VIII. It should be noted that the drivers referenced above are excessively emphasized, and do not contribute to any impact generation at all. A significant difference between advanced and developing countries on political and regulatory environment underlines the fact that relatively favorable legislative conditions in advanced economies do not contribute much to produce economic and social impacts. Emerging economies are the most effective ones to use infrastructure and digital content followed by developing and advanced countries respectively. It is doubtful that the investments on information and communication infrastructures in advanced economies may be justified by their return on the economy. There is a slight difference between emerging and developing economies in terms of affordability. In this driver, emerging economies are assessed relatively higher in Table I, but they have also the largest slack value in Table VII. For emerging economies, relatively affordable access cost to technologies is not fully appreciated by its impacts on economy and society. Individual usage is also assessed as the highest one for advanced economies. Similar to affordability, the high usage of the technologies by individuals is not sufficient for impact generation.

6. Discussion and implications

Sustainability is an important aspect of the development of the twenty-first-century world. Countries fare differently in their ability to achieve socio-economic sustainability, and organizations in those countries play an important role toward this end. Although emergent markets have shown tremendous growth in the past decades, their record of converting ICT into socio-economic outcomes has proven to be less spectacular. Our study investigated this particular issue.

Using DEA in conjunction with CCA, the aim of this study was to measure differences in the relative efficiency of economic and social impacts of hyperconnectivity with regard to its drivers. A set of eight drivers and two impacts of an NRI were identified as input and output measures, respectively. Next, CCA was employed to verify the relationships between input and output variables mathematically. CCA confirmed the existence of strong and significant relationships between input and output measures of the study. Then, an output-oriented

Table VIII. Pairwise comparisons of some significant structural differences

Drivers	Multiple pairwise comparisons for economies$^{\xi}$ Advanced emerging	Advanced developing	Emerging developing
Political and Regulatory Environment	0.435	0.102**	0.059
Infrastructure and Digital Content	0.324***	0.218*	−0.107**
Affordability	−0.101	0.038	0.139*
Individual usage	0.176**	0.155**	−0.021

Notes: ξ, the not-equal variance assumption. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

DEA was developed to measure the efficiency of countries on the economic and social impacts of hyperconnectivity. The initial DEA findings indicated that there was no significant difference among the groups of economies. However, this was fairly surprising since it was anticipated that advanced economies should be more efficient than the other countries. In terms of returns to scales, 84 percent of the countries were classified either CRS or IRS. So, this might indicate that hyperconnectivity was quite immature and has potential to spread out. Finally, as suggested by Brockett and Golany (1996), the structural efficiency differences among the different economies were also measured by eliminating the administrative differences in each group. A significant structural difference was found among the different economies. Developing economies were measured as the most efficient ones followed by the emerging economies. It was also found that advanced economies were the least efficient ones. The main structural differences found statistically significant among the different economies were listed as follows: political and regulatory environment, infrastructure and digital content, affordability and individual usage. Multiple pairwise comparisons were shown that there was a significant difference between advanced and developing countries on political and regulatory environment, underlying that relatively favorable legislative conditions in advanced economies do not contribute much to produce economic and social impacts. Emerging economies were the most effective ones to use infrastructure and digital content followed by developing and advanced countries, respectively. For emerging economies, relatively better affordability for technologies did not produce much the economic and social impacts. Even though individual usage was highly assessed for advanced economies, this did not generate sufficient impact.

This study makes important conceptual and methodological contributions. Although the impact of ICT on macro-economic development has been previously studied, the efficiency of this impact was not. Moreover, previous studies only looked into the efficiency of the impact of ICT investments on productivity (Lee *et al.*, 2005). Using CCA as a complementary tool for DEA approach in this study constitutes a methodological contribution to existing DEA research, mostly done in the area of operations management. Using DEA on a country level is a novel approach which contributes to the realm of application of this methodology. In addition, focusing on the efficiency of the impact on macro-economic development allows us to expand on previous research.

This study has several important policy and managerial implications. In a climate of increasing public accountability, governments have been increasingly urged to introduce good administrative practices and performance standards to enable efficient utilization of their resources and enhance their reputation within and across countries. On the other hand, organization's success in the emerging markets depends on how well it designs and implements organizational architecture which is seamlessly aligned with the socio-politico-cultural realities existing in the emerging markets. Given that organizations are the main vehicles that transform hyperconnectivity into socio-economic outcomes; their aim should be to work on improving the efficiency of this transformation. Based on the results obtained, managers now have yet another tool to evaluate countries for strategic purposes. Gaining an understanding of how and to what degree ICT investments are going to impact the country is critical for strategic planning.

This study has several limitations. While it provides an initial attempt to examine the efficiency differences among countries, the findings should be interpreted with caution. One of the limitations of this study stems from the classification of the countries. World Economy Forum and IMF resources are utilized for the economy categories, but their basis for classification of counties is rather subjective. The lack of existing comparative efficiency studies on a country level prevents effective benchmarking of our results.

Future research can develop this new conceptual and methodological stream further. For example, one of the most interesting avenues may be conducting longitudinal studies.

Moreover, DEA can be used in such a study to assess changes in efficiency over time. It would also be useful to estimate technical efficiency using deterministic cross-sectional and stochastic panel data regression models that allow multiple outputs and inputs. Finally, further research into organizational structures and employee training are needed to identify the ideal setup to efficiently take advantage of ICT.

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