20th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2016, Mediterranean Sea Cruising, 24th September - 1st October, 2016

MEASURING ECONOMIC AND SOCIAL IMPACTS OF HYPERCONNECTIVITY: A CROSS-COUNTRY EFFICIENCY COMPARISON

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ABSTRACT

Using data envelopment analysis (DEA), the aim of this study is to measure cross-country 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 network readiness index (NRI) are identified as input and output measures respectively. After eliminating the administrative differences among countries, DEA findings indicate that developing economies are the most efficient ones followed by the emerging and advanced economies.

Keywords: Hyperconnectivity, DEA, Network Readiness Index

1. INTRODUCTION

Information and Communication Technologies (ICTs) are the key enablers for super-fast mobile connectivity anywhere and anytime via any device. According to United Nations International Telecommunication Union, there will be 2.9 billion internet users and 2.3 billion mobile broadband subscriptions worldwide by the end of 2014, while 43.6% of household globally will have internet access (Levy and Wong, 2014). In this hyperconnected world, access to internet is considered as one of the fundamental human rights (Brain et al., 2010).

In this study, the countries are benchmarked for their efforts to drive hyperconnectivity to create economic and social impacts by using data envelopment analysis (DEA). Network readiness index (NRI) developed by The World Economic Forum in collaboration with INSEAD is used as a metric to measure the drivers and impacts of hyperconnectivity. Eight drivers and two impacts of NRI are selected to measure the relative efficiency of countries in hyperconnectivity as inputs and outputs respectively.

The remainder of the study is organized as follows. The next section discusses the hyperconnectivity and outlines the conceptual model by establishing the link between the drivers of hyperconnectivity and its economic and social impacts. Section 3 presents the research methods. Results and discussion are in Section 4. Conclusions and implications are provided in the final section.

2. HYPERCONNECTIVITY AND NETWORK READINESS INDEX

Hyperconnectivity is a term to explain 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. 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, cybercrimes, and security problems. Then, we should not consider hyperconnectivity only as a way of communication and interaction improving standards of living, but also focus on its behavioral and organization sides as well.

Based on the importance of the topic, network readiness index was created in 2012 by World economic Forum with the collaboration of INSEAD to help the decision makers develop strategies on ICT. NRI comprises 10 pillars and 54 individual indicators under the following four subindexes (Bilbao-Osorio et al., 2014):

- *Environment:* Political and regulatory environment, Business and innovation environment
- *Readiness:* Infrastructure and digital content, Affordability, and Skills
- *Usage:* Individual usage, Business usage, and Government usage
- *Impact:* Economic impacts and Social impacts

Details of the NRI and corresponding components as well as their measurements and calculations may be accessed from The Global Technology Report (www.weforum.org). First three subindexes above, namely environment, readiness, and usage, are regarded as drivers, which lead to the last one, namely impacts (Bilbao-Osorio et al., 2014). This conceptual model is shown in Figure 1.

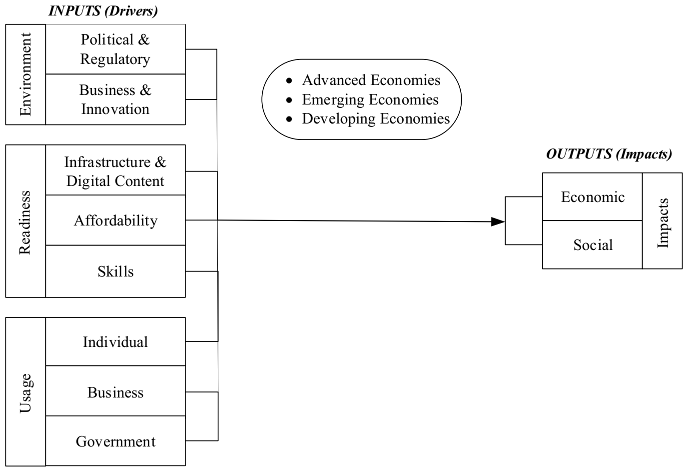

Figure 1. The Conceptual Input-Output Framework

3. RESEARCH METHODS

3.1. Sample data

In the analysis, data for NRI and its comprising 10 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. The countries listed in NRI are also divided into three catagories based on the country classifications of World Economic Situation and Prospects (WESP) of United Nations and World Economic Outlook of International Monetary Fund (IMF): Advanced economies, emerging economies, and developing economies.

3.2. The DEA model

DEA is a linear programming based approach for measuring the relative efficiency of DMUs. 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. 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:

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

Subject to

$$\sum_{r=1}^{k} \lambda_r x_{ir} + e_{io} = x_{io} \qquad i = 1, ..., n \qquad (2)$$

$$\sum_{r=1}^{k} \lambda_r y_{jr} - d_{jo} = \varphi_o y_{jo} \qquad j = 1, 2, ..., m \qquad (3)$$

$$e_{io}, d_{jo}, \lambda_r \geq 0 \qquad \text{For all i, j, r} \qquad (4)$$

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 predefined 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. 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.

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.

4. RESULTS AND DISCUSSION

4.1. Descriptive analysis

Table 1 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 aspects of NRI. Emerging economies also dominate developing economies in terms of overall NRI scores as well as its drivers and impacts.

4.2. 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 1. Overall average efficiency score is calculated as 0.97, and it does not variant 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). 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.

4.3. Comparison of structural differences among the different economies

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 advanced, emerging and developing economies are calculated as 0.977, 0.986 and 0.993 respectively. In fact, Kruskal-Wallis Rank test result shows that there are some differences among the countries based on their status of economies (KW=11.212 and $p < 0.01$). Indeed, developing economies are the most efficient ones followed by the emerging economies. It is remarkable that advanced economies are the least efficient ones.

Table 1. Descriptive Statistics for NRI, Its Drivers and Impacts along with Efficiency Scores

		Economies								**F-test***
		Advanced		**Emerging**		**Developing**		**Total**		
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	
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 & Regulatory Env.	5.02	0.76	3.85	0.78	3.52	0.63	3.84	0.87	45.92
	Business & Innovation Env.	5.05	0.36	4.40	0.69	3.99	0.60	4.25	0.70	31.89
	Infrastructure & 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**		

Notes:
** All of the F-test values are significant at p<0.01*
S.D. = Standard deviation.

5. CONCLUSION AND IMPLICATIONS

Using DEA, 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 NRI were identified as input and output measures respectively. Then, an output-oriented 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. Finally, by eliminating the administrative differences in each group of economies, a significant structural difference was found, and developing economies were measured as the most efficient ones followed by the emerging economies

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