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The Role of ICT Ecosystem for Sustainable Innovation: Evidence from the Gaming Industry of China

Sadaf Hafeez[a*], Noreen Izza Arshad[b], Lukman Bin AB Rahim[c], Mazeyanti M. Ariffin[d], Mohamed Imran Mohamed Ariff[e], Muhammad Farooq Shabbir[f], [a,b,c]Department of Computer and Information Science, Universiti Teknologi PETRONAS, Malaysia, [d]Positive Computing Research Cluster, Institute of Autonomous Systems, Universiti Teknologi PETRONAS, Perak, Malaysia, [e]Faculty of Computer & Mathematical Sciences, Universiti Teknologi MARA (UiTM) Perak Branch, Tapah Campus, Malaysia, [f]Department of Management Science, The Islamia University of Bahawalpur, Pakistan, Email: [a*]sadaf.hafeez85@yahoo.com

Increased digital participation adds new momentum to the economy and changes the nature of business. The gaming industry has become a large industry in China, and this industry has not developed independently. The development and innovation in the ICT ecosystem influences the development and innovation of the gaming industry. This investigation follows the ICT layer model by using Meta-frontier analysis to estimate and analyse the innovation in the gaming industry of China. The change in the technology gap ratio (TGR) is utilised to measure innovation in the gaming industry. The decrease in technical efficiency brings an increase in the technology gap ratio which alludes that some companies have shifted the production function upward due to technological innovation. Similarly, an increase in technical efficiency can be understood as the diffusion of innovation by imitation of competitors. The steady increase in meta-frontier efficiency explains that the gaming industry of China is growing by innovation. This study has significant position in frontier studies by explaining the production process in a distinctive way which has previously been ignored.

Key words: *ICT Ecosystem, Gaming Industry, Innovation, Data Envelopment Analysis, Meta-frontier Analysis.*

Introduction

The enormous changes in information and communication technology (ICT) has altered business dynamics. The tremendous growth in the gaming industry has been witnessed with the emergence of the internet. Increased digital participation will not only add new momentum to the economy, but will also change the nature of growth. The gaming industry has become a big industry, and this industry has not developed independently. As a member of the information and communication technology ecosystem, the gaming industry does not develop and innovate on its own (Anchordoguy, 2000). The widespread use of the Internet has transformed the ICT ecosystem into a four-tier, evolving innovation system of ICT network providers, network operators, platform and content provider, and end users. Innovation is generated by symbiotic interaction between the four layers in this environment (Bauer, 2012; Amitrano, Tregua, Spena, & Bifulco, 2018; Fransman, 2007; Dedehayir, Mäkinen, & Ortt, 2016). It is therefore essential to have a balanced ICT ecosystem at the national level, to promote open innovation and cooperation among enterprises (Evangelista, 2006; Hollenstein, 2003; Hipp & Grupp, 2005).

The ICT ecosystem is an emerging and evolving concept that has been the point of focus since the researchers introduced the term. The ICT Ecosystem is the Application, Usefulness, and future of an Evolving Concept (Diga & May, 2016). The first definition of the ICT ecosystem was provided by the Open ePolicy Group: "An ICT ecosystem system envelops the methodologies, process, data, technologies, applications, and stakeholders that together make up a technology atmosphere. In particular, an ICT ecosystem incorporates individuals who make, purchase, sale and use technology" (Kaplan et al., 2005). The conceptualisation of ICT ecosystems sought to be seen as the worldwide, national, and local setting in which ICT is performed. This stimulates the idea to understand the ICT world in more detailed and thoughtful ways. Building upon the notions of (Diga & May, 2016; Nguyen, Nielsen, & Sæbø, 2017) this study conceptualises the ICT ecosystem as a framework that incorporates the strategies, processes, information and other ICTs, that together make up the socio specialised condition and the surroundings where an ICT performs (Kaplan et al., 2005).

The ICT industry has been evolving speedily. Therefore, ICT's capability to efficiently manage its resources with its ecosystem characterises its future. The esteem changes in ICT organisations demonstrate this pattern clearly. In fact, as human-driven innovation turns out to be progressively essential, understanding clients by communicating with them consistently through a variety of connected devices is increasingly critical. As the interest for more smart devices expands, the software is getting progressively incorporated into hardware. Therefore, the association between ICT sectors is expanding, co-developing through cooperative communication and technologies (Kim, Shin, & Lee, 2015; Fransman, 2010). Hence, it is worth understanding the inter-industry relationships to evaluate the overall ICT industry and its performance.

Therefore, this study proposes to analyse the evolution of the gaming industry within the National ICT ecosystem perspective as the national ecosystem affects the efficiency of individual firms. This investigation aims to estimate the efficiency of the gaming industry to analyse its evolution process and the effect of information and communication technology ecosystem on internet firms. The results of this investigation will lead to determining whether the production function was affected by enterprise led innovation, or it was affected by external factors such as broadband internet and smartphones.

Literature Review

The ICT sector has an important role in the 21st century. The ICT Sector consists of hardware, software, consumer electronics, and telecommunications and Internet-based services. From the past, it clarifies that the cluster of new technologies evolved with social and economic growth and change. New technologies create new opportunities for investment and consumption through growth and change. During the Second World War, ICT technologies emerged and from then they have been the most crucial driver of global economic and social growth and change. An earlier cluster was dependent on the textile industry in the late 17th century, the steam engine at the beginning of the 18th century, electricity and steel in the late 18th century, the inner ignition engine, petrochemicals in the 19th century. In the current technological landscape, the ICT sector is the largest in the economy in most industrialised countries, holding around 10 percent of GDP. Although, its influence is even more important in economic growth. As per OECD, up to 20 percent of all economic growth is contributed by the ICT sector. The ICT sector also plays a crucial role in one-third of all business research and development. So, in modern technology and society, the ICT sector provides the most important infrastructure.

This study assumes the ICT sector as an ecosystem, where a common environment cooperates with different market players. The concept of the new ICT ecosystem and Layer model approach was first introduced by Lombard (2008) to study the changes in the ecosystem and its effect on the ecosystem organisms. This layer model approach was further described by Fransman (2007), to illustrate the symbiotic associations that occur within ICT players. Arlandis and Ciriani (2011) further explain this model in an economic context where firms are distributed into groups on the basis of their core business and activities. Four groups of players are classified: network elements (Layer 1), network providers (Layer 2), platform and content providers (Layer 3) and end users (Layer 4), to analyse how to achieve high efficiency on composed development of the four layers.

The first layer consists of networked elements. Telecommunication switches and transmission systems are included in this layer which are produced by firms like Cisco, Huawei, and Ericson. Apple, Nokia, Samsung or LG manufacture mobile devices which are associated to networks such as PCs manufactured by Apple, Dell, Acer, and Toshiba, or TV, Digital cameras and MP3 player are widely manufactured by Sharp, Sony, and Panasonic. In the second layer, some of these elements are looped by network operators. The second layer consists of network operators which include telecommunication operators like BT Group, France Telecom, Telecom Italia, China Telecom, Airtel, AT&T and mobile operators such as Vodafone. TV cable operators such as Ono, Time Warner Cable and satellite operators such as Direct TV and BSkyB.

Search engines like Yahoo, Google, and internet companies like Alibaba, eBay, and Amazon, and social networking software's Twitter, Facebook, and Weibo are the platforms which lie on the third layer. These firms are involved in two sides of business which collaborate with firms in the second layer to achieve their own services. For instance, search engines earn their revenues from the advertiser by providing a relationship between consumers and advertiser. Content depends upon the material which is viewed, downloaded and uploaded by consumers, such as music, movies, or any text information. Antenna 3 CBS, TF1 is the national broadcasting channel that produces content. Similarly, entertainment channels like Time Warner and Walt Disney are also included in this layer.

There is a dearth of literature on the ecosystem and structure impact on each layer's performance of the ecosystem in the ICT industry. Previous researchers have focused on measuring the performance of the ICT industry as a whole and to measure the effect of ecosystem structure (Lee, Park, & Lee, 2016). However, the impact of the ICT ecosystem on the performance at the layer level of the ecosystem, has not been given attention. As asserted by (Arlandis & Ciriani, 2010) the impact of the ICT ecosystem structure on layers might be different. Hence, this study investigates the impact of ecosystem structure, on the innovation of gaming industry in China by relating the external events in the industry.

Materials and Methods

In this study, we measure the effect of the ICT ecosystem on the innovation of the gaming industry using the frontier analysis approach. In the first step Data Envelopment Analysis (DEA) was applied to measure the technical efficiency of the gaming industry for each year. In the second step meta-frontier analysis (MFA) has been carried out using the same data set of all the years at once, to analyse the innovation level, by estimating the technology gap ratio. Financial information was utilised to measure the efficiency of internet companies, with the inputs to measure efficiency being 1) no. of employees (I), 2) cost of production (M), and 3) total asset (K). The *no. of employees* was chosen because it is an essential element of production; whereas, the *cost of production* represents the cost of the revenue and *total assets* represent the resources of the business that determines success and failure. The selected outputs are revenues which were measured through total sales (Y).

The selected companies in this study are the companies that publish their financial data. Companies that do not publish their financial information to the public, are excluded from the data set. It is noted that the gaming industry is dominated by global giant companies. Hence, the exclusion of companies that do not publish financial information are considered as small companies and may not affect the significance of the study. The data was extracted from the Wind database which provides authentic financial data for companies. We extract data for 173 gaming companies from 2005 to 2017. The reason for selecting this time period is that this era is dominated by intensive growth of the gaming industry.

Efficiency Estimation

Efficiency measurement is crucial in reducing resource waste and improving performance (Yang, Shi, & Yan, 2016). DEA is an extremely valuable non-parametric instrument to measure the efficiency of homogeneous units. The proficiency of organisations can be assessed under the presumption that organisations have identical production functions. However, in reality, this assumption cannot be argued, as organisations have dissimilar production functions even in a similar industry. Hence, keeping in view the distinctive production function for each organisation, we adopt variable return to scale technology to measure the technical efficiency.

Previously, many researchers have utilised this technique to measure comparative efficiency, particularly in the agriculture industry (Battese, Prasada Rao, & O'Donnell, 2004; O'Donnell, Rao, & Battese, 2008). Similarly, a study has been conducted to measure and compare the efficiency of the agriculture industry of different regions on the basis of DEA (Chen & Song, 2008). Afterward, the DEA approach has been utilised in diverse industries, for instance, the Banking industry (Bos & Schmiedel, 2007), the Dairy Farming industry (Moreira & Bravo-Ureta, 2010) and Pharmaceutical Industry (Mazumdar & Rajeev, 2010). Recently, Meta frontier analysis based on DEA has been utilised in the ICT industry to compare efficiencies of software and hardware companies (Lee et al., 2016; Lee, Park, & Lee, 2018). Thus, to compare the efficiencies of ICT companies in different layers with different production functions, this study followed a DEA approach. Further, to estimate the efficiency of the ICT companies the DEA based approach is more valuable for the homogeneous group. The following equation (1) is utilised to measure the technical efficiency.

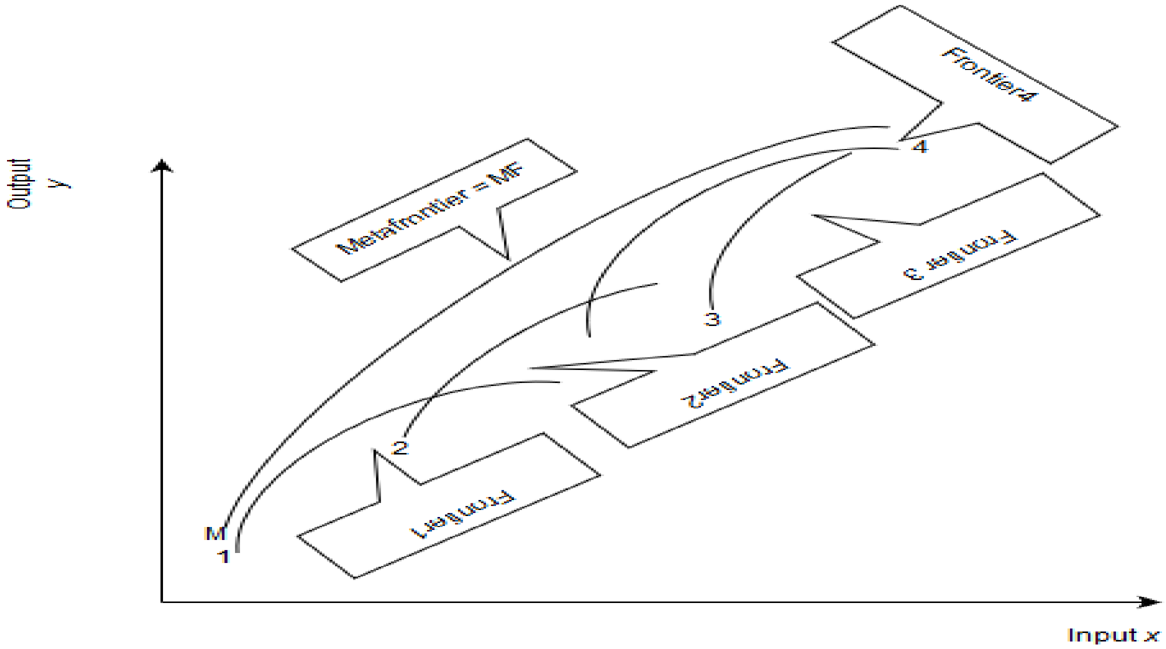
$$\begin{aligned} &\min_{\lambda_{ji},\Phi_{ji}} \Phi_{ji} \\ &s.t.\ Y\lambda_{it} - y_{it} \geq 0, \\ &\Phi_{it}x_{it} - X\lambda_{it} \geq 0, \qquad \text{Eq (1)} \\ &j'\lambda_{it} = 1 \ \text{ and} \\ &\lambda_{it} \geq 0 \end{aligned}$$

The output is denoted by Y_{it} where "i" represent company and t is time period.
Φ_{ji} is understood as a scaler.

$\boldsymbol{\lambda_{it}}$is a parameter.
x_{it} *and* y_{it} are vectors of inputs and outputs respectively.

Further, to measure the innovation in the Chinese gaming industry we estimate the technology gap ratio. The technology gap ratio is the bi-product of meta frontier analysis. Meta-frontier analysis is a very useful technique to estimate and compare the different production functions, or efficiency of different groups. It estimates the technology gap which is used as a proxy of productivity potential in different sectors, regions or groups. MFA enveloped the production function obtained through group frontier analysis, using the same input and output variables (Battese et al., 2004; Battese & Rao, 2002). We applied meta-frontier by applying the same equation eq (1) with the same data set for all the time periods. The DMU's would be more efficient in group efficiency is contrasted with Meta-frontier efficiency due to the reason that meta-frontier envelops all the group frontiers (O'Donnell et al., 2008). The meta-frontier efficiency for all periods can be estimated by applying a similar DEA model to the whole data source. Figure 1 explains the meta-frontier function where 1, 2, 3 and 4 represent the group frontiers, or in other words are yearly production frontierd. Meta-frontier is denoted with MF which has values that are no less than the deterministic functions associated with the DEA frontiers.

Figure 1. Meta Frontier Function Diagram



The meta-frontier technical efficiency (TE*) is the product of technical efficiency (TE) and technology gap ratio (TGR). Henceforth equation (2) is used to express the calculation of TE*.

$$\text{TE}^{*}_{\text{it}} = \text{TE}_{\text{it}} \times \text{TGR}_{\text{it}} \qquad \text{Eq (2)}$$

From equation (2) the technical efficiency form meta-frontier (TE*) is calculated by multiplying the technological gap ratio with technical efficiency (TE). The technology gap ratio is estimated by solving equation (2) as presented below;

$$\text{TGR}_{\text{it}} = \frac{\text{TE}^{*}_{\text{it}}(x,y)}{\text{TE}_{\text{it}}(x,y)} \qquad \text{Eq (3)}$$

Data Analysis

Descriptive statistics for the gaming industry are presented in Table 1. The statistics in Table 1 illustrate that the gaming industry has an aggressive growth pattern. Therefore, it is worth examining the pattern of growth and estimate whether this growth is innovation led.

Table 1: Descriptive Statistics

			Gaming Industry (millions $)
2000	Y[1]	Mean	92.12
		st.dev	82.82
	K[2]	Mean	126.60
		st.dev	108.14
	I[3]	Mean	1950.23
		st.dev	1364.04
	M[4]	Mean	96.25
		st.dev	79.60
2017	Y	Mean	986.12
		st.dev	715.10
	K	Mean	692.91
		st.dev	1037.23
	I	Mean	4619
		st.dev	3180.21
	M	Mean	492.88
		st.dev	766.21

Table 2 presents the production function for the gaming companies in China. The values of technical efficiency measured by DEA estimation have been presented in table 2. It is further

[1] Sales
[2] Cost of production
[3] Number of employees
[4] Assets

noted that the production frontier has a declining trend from 2007 to 2009. However, the frontier starts raising from 2010 to 2015. The TE values show that in 2016 and 2017 the production frontier again has a decreasing trend. However, overall production function has an increasing trend which illustrates that the gaming industry is in a growing trend.

Table 2: Technical Efficiency of Gaming Companies

Years	TE	S.D	Maximum	Minimum
2005	0.9233	0.135	1	0.366
2006	0.9346	0.162	1	0.256
2007	0.9107	0.238	1	0.134
2008	0.8967	0.251	1	0.573
2009	0.8714	0.273	1	0.347
2010	0.9335	0.246	1	0.354
2011	0.9427	0.193	1	0.256
2012	0.9435	0.372	1	0.185
2013	0.9583	0.242	1	0.479
2014	0.9517	0.347	1	0.369
2015	0.9509	0.318	1	0.213
2016	0.9451	0.257	1	0.123
2017	0.9445	0.212	1	0.128

Table 3 presents the results for meta-frontier efficiency. It can be seen that the TE* values from 2005 to 2017 has a steadily increasing trajectory. This corresponds with the potential of the gaming industry and presents that the overall production of the gaming industry is increasing over the period of time.

Table 3: Meta-frontier Efficiency of Gaming Companies

Years	TE*	S.D	Maximum	Minimum
2005	0.8217	0.235	0.9451	0.7434
2006	0.8283	0.134	0.9571	0.7665
2007	0.8274	0.181	0.9121	0.7198
2008	0.8384	0.144	1	0.7191
2009	0.8425	0.227	0.9651	0.7620
2010	0.8412	0.418	0.9662	0.8558
2011	0.8428	0.367	0.9699	0.7418
2012	0.8403	0.415	0.9793	0.8562
2013	0.8401	0.483	1	0.8624
2014	0.8457	0.236	0.9528	0.7420
2015	0.8465	0.412	1	0.7922
2016	0.8469	0.389	0.9823	0.8183
2017	0.8478	0.472	0.9746	0.7268

Table 4 illustrates the technology gap ratio for the gaming industry of China. The technology gap ratio (TGR) is calculated as the ratio of estimated TE of DEA by TE* of MFA. Results show that when Chinese gaming companies are more efficient, it has less of a technology gap and when technical efficiency is low, the technology gap ratio is higher.

Table 4: Technology Gap Ratio of Gaming Companies

Years	TGR	S.D	Maximum	Minimum
2005	0.88996	0.0367	0.9321	0.6253
2006	0.886262	0.0438	0.9468	0.7831
2007	0.908532	0.0245	0.9263	0.7610
2008	0.934984	0.0146	1	0.7284
2009	0.966835	0.0424	0.9326	0.8813
2010	0.901125	0.0487	0.9764	0.7251
2011	0.894028	0.0327	0.9567	0.7392
2012	0.89062	0.0342	0.9432	0.6881
2013	0.876657	0.0307	1	0.6853
2014	0.88862	0.0438	0.9468	0.6922
2015	0.890209	0.0581	1	0.7152
2016	0.896096	0.0228	0.9793	0.7012
2017	0.897618	0.0392	0.9664	0.7262

The increase in TGR illustrates that the gaming industry production function shifts upward due to the innovation of companies and a difference between TE and TE* increased. Similarly, a decrease in TE values represents the rise of production function, which shows that innovation has been copied and the advantage of innovation has been eradicated. This process is continued throughout the observation period. Furthermore, if we look at the pattern of change in the TGR values, it described a sudden increase in TGR values from 2007 to 2009 and 2014 to 2017. These changes show that the gaming industry has utilised the advantages of new technologies in the ICT industry, for instance introduction of smartphones in 2007 and online payment and the use of artificial intelligence in 2014 and 2016 respectively. This proves the hypothesis that the gaming industry is innovation-led. However, this innovation is not only organisation led but also industry-led that is due to the symbiotic relationship of ICT ecosystem layers. As mentioned in the results the shift in production function of the gaming industry in 2006-07 and 2014-16, which corresponds with the innovation of some gaming companies, correlates the innovation by other ICT ecosystem layers. The ICT ecosystem is interconnected and interdependent; innovation takes place at different layers of the ICT industry and affects the overall ICT ecosystem (Xing, Ye, & Kui, 2011). The ICT sector including hardware, software, networks, services, and equipment, is the focal point of continuous innovation. Innovation in gaming depends upon broadband networks which act as a platform. Platform innovation plays a crucial role in technical infrastructure that helps other processes and services innovation (Bauer, 2012). Primary communication technologies such as telephone and telegraph also act as a crucial infrastructure, internet broadband such as fibre optical networks are general-purpose technologies in the new era (Basole, Park, & Barnett, 2015). An even larger range of literature points to the significant innovation potential in other industries that are the source of the advance communication platforms (Bauer, 2012).

Conclusion

The massive development of the digital economy is opening doors by potential market development in the overwhelming global competition in the ICT industry. Consequently, it is important to build up a well-balanced and interactive ICT ecosystem. To understand and analyse the ICT ecosystem structure and interactive mechanism, this study utilised a multilayer model approach.

The technology gap ratio value obtained by Meta-frontier analysis provides empirical evidence to compare the efficiency of ICT ecosystem layers. These results provide a comparative analysis of the production function, and a deeper analysis of the ICT ecosystem's effect over firms' efficiency, will help to understand the ICT ecosystem structure in a particular region and country.

Hence, results will provide guidelines to grasp opportunities by promoting a balanced ICT ecosystem to strengthen the gaming industry in the regions, where the efficiency of the gaming industry is at the bottom. Therefore, policymakers will comprehend the attributes of their ICT ecosystems to exploit their own strengths.

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