Telecommunications Policy 42 (2018) 107–115

Contents lists available at ScienceDirect

Telecommunications Policy

journal homepage: www.elsevier.com/locate/telpol

Measuring efficiency and ICT ecosystem impact: Hardware vs. software industry

Kyoungsun Lee [a], Yuri Park [a,*], Daeho Lee [b]

[a] Department of ICT Strategy Research, Korea Information Society Development Institute, 18 Jeongtong-ro, Deoksan-myeon, Jincheon-gun, Chungchengbuk-do, 27872, South Korea
[b] Department of Interaction Science, Sungkyunkwan University, 25-2 Sungkyunwan-ro, Jongno-gu, Seoul, South Korea

ARTICLE INFO

Keywords:
Stochastic frontier analysis
Meta frontier analysis
Efficiency comparison
ICT ecosystem
Hardware
Software

ABSTRACT

The ICT industry is reshaping itself through convergence and coopetition across the ecosystem. In particular, many ICT companies have been trying to achieve both hardware and software capabilities to accelerate innovation. To understand the changes in the ICT industry, we empirically study the hardware and software industries using the ecosystem framework. We estimate the efficiency levels of the hardware and software industries in China, Japan, South Korea, and the United States (US) using stochastic frontier analysis and meta frontier analysis, and we examine the effects of the ICT ecosystem structure on efficiency levels using a Tobit regression. We find that the US, which is the global ICT leader, performs significantly better than other countries, with the biggest technology gap ratios in both hardware and software, and South Korea, which has the most hardware-centric industrial structure among the four countries, has the biggest efficiency gap between the hardware and software industries. Tobit results further reveal that a well-balanced ecosystem is important in achieving high efficiency in both hardware and software, and the effect is much higher in the software industry than in the hardware industry.

1. Introduction

The landscape of the information and communications technology (ICT) industry has been changing rapidly. As the ICT paradigm shifts towards a human-centric system, software is eating everything; a company's software capability now defines its future. The value changes in ICT companies show this trend clearly. In the 90's, the top 20 ICT companies were mostly network companies, such as NTT, BT Group, and Verizon, and hardware companies, such as IBM, Sony, and Toshiba. However, in recent years, companies with software capabilities, such as Apple, Google, Microsoft, and Facebook, have grown beyond those network and hardware giants.

The increasing value of software, however, does not necessarily undermine the importance of other ICT sectors. In fact, as the human-centric innovation becomes more crucial, understanding users by interacting with them seamlessly through a variety of connected devices becomes more important, and as demand for smarter devices increases, software is getting more integrated into hardware. That is, the interdependence between ICT sectors is increasing, co-evolving through symbiotic interaction (Fransman, 2007, 2010).

Certainly, ICT firms have been trying to expand their core competencies across the ICT ecosystem to accelerate innovation. Apple classifies itself as a hardware company, but it is renowned for its excellence in both software and hardware. Samsung is one of the largest

* Corresponding author.
E-mail addresses: leeks@kisdi.re.kr (K. Lee), yrpark@kisdi.re.kr (Y. Park), daeho.lee@skku.edu (D. Lee).

http://dx.doi.org/10.1016/j.telpol.2017.08.007
Received 22 June 2017; Received in revised form 24 August 2017; Accepted 24 August 2017
Available online 9 September 2017
0308-5961/

ICT manufacturing companies, but it has been developing its own operating system, Tizen, and Tizen-based hardware, while keeping business alliances with Google, Facebook, etc. Xiaomi, which has grown into one of the dominant smartphone makers based on its low prices, is now releasing smartphones with its own firmware, the MI user interface. Likewise, software companies have been investing to obtain the ability to control hardware as well as software. Google, a dominating leader with its search engine and mobile operating system, acquired Motorola, which builds mobile devices (later sold to Lenovo), and has been expanding its integrated device line-up. Facebook, one of the largest online social media and social networking service companies, bought Oculus, which makes virtual reality headsets, to secure hardware competitiveness. To extend its reach, Amazon, a giant electronic commerce and cloud computing company, developed an electronic book reader, the Kindle. These examples show that the current ICT ecosystem is reshaping itself through convergence and coopetition across the ecosystem (Basole, Park, & Barnett, 2015).

To better understand the changes that the current ICT industry is experiencing, we empirically study the performance of the ICT industry and the impact of an ICT ecosystem on its performance. For our study, we assume that the ICT ecosystem is composed of four layers—content, hardware, software, and telecommunications—and analyze how important the balanced development of the four layers is in achieving high efficiency at a layer level. In particular, our analysis is focused on hardware and software industries because hardware, software, and their convergence are driving the ICT paradigm shift (e.g., in the smartphone market, there are Android (Google) vs. iOS (Apple) with everything else that goes along with it; the companies that are transforming the world are mostly software companies such as Uber and Airbnb), and because content and communications industries have either data limitation or disparate industrial characteristics. For the content industry, a substantial amount of firm-level data could be missing in that it has many small-sized firms which do not release their financial data to the public, and thus the results of the content industry would be unreliable. The telecommunications industry, which provides the national infrastructure, may be inappropriate to examine the effect of the private-led changes because it tends to consist of the small number of giant companies that have grown in response to government-led initiatives and plans. Nevertheless, given that hardware and software are the major players in the ICT ecosystem, an analysis focused on the hardware and software industries would be able to convey meaningful messages.

Our work is related to literature that has incorporated the ecosystem approach. In Fransman (2007, 2010), the new ecosystem has four layers—1) networked elements, 2) networks, 3) platforms/content/applications, and 4) consumption—and those layers have a co-evolutionary relationship. Suh and Kim (2015) define an ecological index based on productivity, size, spillover effect, and coverage and identify commodity, landlord, controller, keystone, facilitator, and dominator as the six roles in the ICT industry in a mobile ecosystem. Koslowski, Longstaff, Vidal, and Grob (2012) use an adaptive cycle model to reflect the complexity and uncertainty of the ICT ecosystem and claim that the performance of the ecosystem should be optimized collaboratively to achieve resilience. Clark and Claffy (2015) argue that in the ICT ecosystem, regulatory changes fail to keep up with changes in industrial structures and technologies and suggest that an adaptive regulatory system is necessary to reduce those gaps. Arlandis and Ciriani (2010) define an ICT ecosystem with four layers—technology providers (layer 1), network operators (layer 2), platform operators (layer 3), and content providers (layer 4)—and measure the performance of ICT firms in the four layers based on revenue, profitability, and return on capital investment. They identify network operators as an important contributor to the ecosystem and platform operators as the most profitable layer. Basole et al. (2015) attempt to visualize convergence and coopetition in the ICT ecosystem, claiming that as the ecosystem becomes mature, the importance of formal interfirm relationships could decrease because convergence occurs mostly in the early stage, whereas coopetition increases over time.

Studies analyzing the ICT industry in the ecosystem perspective are limited, and to the best of our knowledge, no previous work has empirically studied the effects of an ecosystem structure on the layer level. Our work is closely related to that of Lee, Park, and Lee (2016) in that they measure the efficiency of the ICT industry and further investigate how it is affected by an ICT ecosystem structure. However, the effects of the ICT ecosystem might differ by layer, as Arlandis and Ciriani (2010) and Fransman (2010) considered. Thus in this paper, we evaluate the effects of ecosystem structure at the layer level. Another closely related work is Arlandis and Ciriani (2010), in which they compare layer-level performance. However, they focus on the contribution of each layer to an ecosystem, whereas we estimate the effects of the ecosystem structure on the performance at the layer level.

Our study contributes to the literature by providing empirical evidence that the hardware and software industries co-evolve. We first estimate the efficiency levels of the hardware and software industries in China, Japan, South Korea and the US and show that countries with high efficiency in the software industry tend to have high efficiency in the hardware industry and vice versa. Then, we perform a Tobit regression to examine the effects of ICT ecosystem structure on efficiency, and we find that a well-balanced ecosystem is important in achieving high efficiency in both the hardware and software industries, with a much higher effect in the software industry than in the hardware industry. In addition, we discuss the policy implications of our results.

The rest of this paper is organized as follows. Sections 2 and 3 describe the methodology and data used for this study. In Section 4, we present our main results. Our conclusions are summarized in Section 5.

2. Methodology

For our study, we first measure the efficiencies of hardware and software companies in China, Japan, South Korea, and the US based on stochastic frontier analysis (SFA) and meta frontier analysis (MFA), and we then analyze the effects of an ICT ecosystem on those companies using a Tobit regression.

2.1. Measuring efficiency

The efficiencies of the companies are estimated based on SFA and MFA. Specifically, the results from SFA are used for comparison