한국 가상 이동통신망 사업자의 시장 경쟁력 강화를 위한 전략
Strategies to Enhance Market Competitiveness of Korea's Mobile Virtual Network Operators*

노한남(주저자) · 양홍석(공저자) · 김창희(교신저자)
Hannam Ro(First Author) · Hongsuk Yang(Co-Author) · Changhee Kim(Corresponding Author)

서울대학교 경영대학 Seoul National University Business School(*hannamro@gmail.com*)
서울대학교 경영대학 Seoul National University Business School(*hongsuk@snu.ac.kr*)
인천대학교 경영대학 Incheon National University Business School(*ckim@inu.ac.kr*)

This study explores the dynamics of the Korean Mobile Virtual Network Operator (MVNO) industry, focusing on the strategic decisions small and medium-sized enterprises (SMEs) face between efficient management and technological advancement. In a sector dominated by subsidiaries of Mobile Network Operators (MNOs), SMEs encounter unique challenges in competing effectively. Using Data Envelopment Analysis (DEA), Malmquist Productivity Index (MPI), and Importance-Performance Analysis (IPA), this study evaluates the efficiencies and productivity changes of nine MVNO companies. The results indicate that while operational efficiency does not directly correlate with increased market revenue, advanced technology offers a significant advantage, boosting both productivity and customer satisfaction. Notably, technological advancements were found to have a more substantial impact on market competitiveness than efficient management. Our study suggests that SME MVNOs should prioritize technological innovations, such as data speed and service quality, to strengthen their market position. Our research also provides valuable insights into enhancing the competitiveness of Korean MVNOs and offers practical guidance for business strategies within the telecommunications sector.

Keyword: Mobile Virtual Network Operator (MVNO), Technological Advancement, Efficient Management, Competitive Strategy

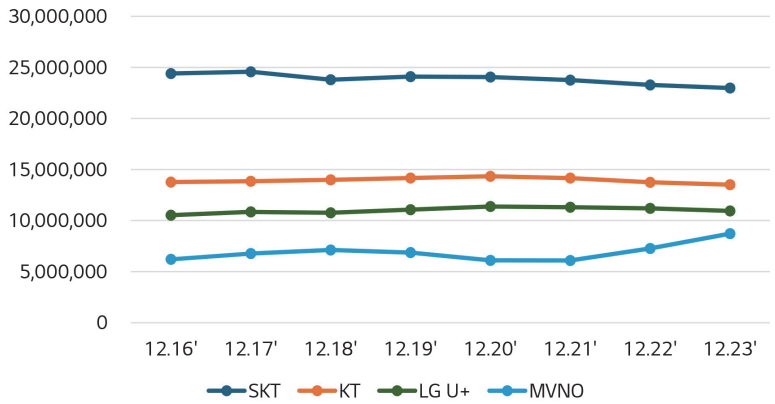
Ⅰ. Introduction

A Mobile Virtual Network Operator (MVNO) stands as a service provider that operates without owning the network infrastructure it utilizes to serve its clientele. Unlike Mobile Network Operators (MNOs) that have their network setups, MVNOs rent capacity from network owners and provide these services to

Submission Date: 08. 24. 2024 Revised Date: (1st: 10. 09. 2024) Accepted Date: 10. 11. 2024
* This study was supported by the Institute of Management Research at Seoul National University, Research Fund in 2024.

their customers. MVNOs procure voice, text and data services from MNOs at wholesale rates and sell them at retail prices to earn a profit through the margin (Shin, 2010). Before the emergence of MVNOs in Korea, the telecommunications market was largely controlled by three firms: 'SK Telecom', 'KT', and 'LG U+'. This dominance in the market resulted in high pricing levels within the industry. Consequently, scholars in the 2000s proposed introducing a MVNO as a means to boost competition in the telecommunications sector and reduce prices. As a result of this advocacy, the Korean government amended the Telecommunications Business Act by adding Paragraph 2 to Article 38 mandating that telecommunication service providers must offer their services or allow usage of their facilities upon request (Shin, 2015). With regards to pricing matters, it is up to the government to assess costs and determine wholesale prices. For example, the government reviews the pricing strategies of MNOs by excluding costs, like advertising and distribution expenses. This approach encourages both MNOs and MVNOs to optimize their advertising expenditure and other expenses to stay competitive resulting in price cuts that benefit consumers. The government expected that the introduction of MVNOs would enhance market competition and eventually lead to lower prices for consumers. Since their launch, MVNOs have steadily increased their market share. By December 2023, MVNOs held a 15% market share closely following 'LG U+' with a 20% share. This establishes MVNOs as players in the telecommunications industry as shown in Figure 1.

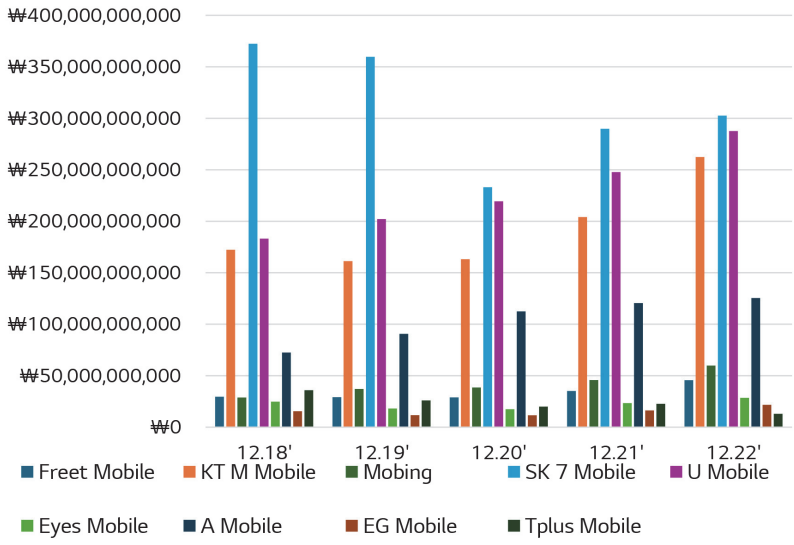
The fact that MVNOs now hold a 15% market share highlights the success of government initiatives aimed at diversifying the telecommunications sector in Korea by ex-



〈Figure 1〉 Number of Mobile Phone Lines in Korea

panding competition from three players to four. However, within the MVNO sector itself, there exists an oligopoly dominated by four companies. As of April 2023, there are 53 MVNO companies in South Korea including four firms—'SK 7 Mobile', 'KT M Mobile', 'U Mobile', and 'Hello Mobile'—operating as MNO subsidiaries and only 19 MVNOs have over 100,000 subscribers. Even though the Korean government aimed to promote competition in the MVNO market, it is evident that subsidiaries of telecommunication companies dominate the industry while SMEs have significantly lowered revenue shares as illustrated in Figure 2. Figure 2 features MVNOs with substantial subscriber bases of over 100,000 and consistent public disclosures over the past five years. 'Hello Mobile', one of the four subsidiaries, is excluded from Figure 2 due to the lack of specific public disclosures for its MVNO sector. Despite attempts to break up the oligopoly, the MVNO sector has essentially turned into an oligopoly within the telecommunications landscape.

Before suggesting remedies for this issue, it is crucial to grasp the root causes behind the oligopolistic conditions in the MVNO market. By examining the factors contributing to these market dynamics, valuable insights can be gained to develop strategies that boost competition and reduce market dominance. There are five primary factors that contribute to the oligopoly in general: collusion (Fershtman and Pakes, 1999; Harrington, 1987; Stenbacka, 1990), market entry barriers (Abbring and Campbell, 2006; Fujita, 1996; Hajiyev et al.,



〈Figure 2〉 Revenues of the MVNOs in KRW

2021; Saha et al., 2019), government policies and regulations (Hajiyev et al., 2021; Schwartz, 1960; Stern, 1986; Yang and Zentefis, 2023), technological advancements and capital requirements (Aiginger and Pfaffermayr, 1999; Baldani and Michl, 1998; Hajiyev et al., 2021; Tishler and Milstein, 2008), and inefficient management (Bös and Peters, 1995; Dixon, 1994; Pinto and Goerke, 2019). For SME MVNOs, possessing significantly lower revenue shares compared to MNO subsidiaries, it is vital to identify the causes of the oligopoly and make necessary adjustments to become more competitive. While some factors like 'collusion', 'market entry barriers', and 'government policies and regulations' are influenced by forces beyond the firm's control, factors such as 'technological advancements and capital requirements' and 'inefficient management' can be addressed by the companies themselves. It is essential for SME MVNOs to focus on improving these aspects to enhance their edge. Given the typical constraints faced by SMEs, such as limited capital, it may be more practical to prioritize improvements in either technological advancements or efficient management rather than trying to develop both simultaneously. This study delves into the question of whether SMEs in the MVNO market should focus on efficient management or technological advancement to boost their competitiveness and explores the actions that can be taken to improve in the chosen area. The goal of this research is to support the growth of the MVNO market and its businesses offering guidance for companies to enhance their edge and practical insights for developing business strategies within the telecommunications sector.

II. Literature Review

Research on MVNOs and their market dynamics is extensive, encompassing various aspects such as the causes of failure in different regions (Shin and Bartolacci, 2007), economic impacts (Kim and Seol, 2007), policy implications (Shin, 2010; Shin, 2015), market structure and penetration (Shin, 2008), and future prospects (Shin and Chung, 2012). Moreover, research on strategies that MVNOs can employ to enhance their competitiveness has identified several approaches: cost leadership (Lee et al., 2008), differentiation in services (Corrocher and Lasio, 2013; Domazet and Saric, 2009; Lee et al., 2008), innovative value-added services (Lee et al., 2008), inventive pricing strategies (Corrocher and Lasio, 2013), strategic partnerships (Corrocher and Lasio, 2013; Domazet and Saric, 2009; Lee et al., 2008), targeted customer segmentation (Corrocher and Lasio, 2013), and market development strategies (Domazet and Saric, 2009). These strategies encompass aspects of

both efficient management and technological advancement and are not dependent on the size of the firms. However, it is important to note that smaller firms, particularly SME MVNOs, may face challenges in implementing some of these strategies due to limited capital resources. Additionally, there is a gap in research regarding whether MVNOs should prioritize improving operational efficiency or investing in technological advancement. Addressing this research gap could provide clearer guidance for MVNOs on optimizing their competitive strategies within the telecommunications market. Despite this breadth of study, there is a notable paucity of research specifically addressing the reasons behind the oligopoly within the MVNO market. Kamiyama and Nakao suggest that zero-rating strategies employed by MVNOs could lead to market monopolization and increased user fees (Kamiyama and Nakao, 2019). Zero-rating refers to the practice wherein internet service providers and mobile operators do not charge end users for data used by specific internet content and applications, effectively making those services free of data charges (Asghari et al., 2017; Lorenzon, 2022; Preta and Peng, 2016). An instance of zero-rating in Korea involves SK Telecom's 'T Map', a smartphone navigation service launched in 2002 and later monetized in 2021 after considerations of potential violations of the Fair Trade Act. However, according to the Korea Information Society Development Institute (KISDI), the proportion of data dedicated to zero-rated services within overall data caps remains minimal, suggesting that zero-rating does not significantly influence user choices regarding content and is unlikely to hinder competition in the content market (Hwang, 2022). In addition, MVNOs also provide zero-rating services as offered by their host MNOs. Although MNO subsidiaries exclusively utilize their MNOs' networks while SME MVNOs offer a broader range of network options, the subsidiaries possess significantly higher market shares, as shown in Figure 2 and Table 1. It appears that zero-rating does not contribute distinctly to the oligopoly in Korea's MVNO market. Rather, it may be inferred that the oligopoly in the Korean MVNO market is attributable to the same factors that influence other industries such as collusion (Fershtman and Pakes, 1999; Harrington, 1987; Stenbacka, 1990), market entry barriers (Abbring and Campbell, 2006; Fujita, 1996; Hajiyev et al., 2021; Saha et al., 2019), government policies and regulations (Hajiyev et al., 2021; Schwartz, 1960; Stern, 1986; Yang and Zentefis, 2023), technological advancements and capital requirements (Aiginger and Pfaffermayr, 1999; Baldani and Michl, 1998; Hajiyev et al., 2021; Tishler and Milstein, 2008), and inefficient management (Bös and Peters, 1995; Dixon, 1994; Pinto and Goerke, 2019). In the MVNO market, especially in regions dominated by a

〈Table 1〉 Networks offered by MVNOs

MVNO	SKT	KT	LG U+
SK 7 Mobile	○		
KT M Mobile		○	
U Mobile			○
Freet Mobile	○	○	○
Mobing	○	○	○
Eyes Mobile	○	○	○
Tplus Mobile	○	○	○
A Mobile		○	○
EG Mobile		○	○

few players, larger MVNOs that are backed by their MNOs may engage in indirect collusion by aligning their pricing strategies to avoid aggressive price competition. This behavior is similar to what has been observed in other industries such as airlines or oil (Zhang and Round, 2011; García, 2010), where firms often act in parallel to maintain profitability without formal agreements. High market entry barriers significantly limit competition across various industries, reinforcing the dominance of a few large firms. This is particularly evident in sectors like banking, where substantial capital investment is required for infrastructure, licensing, and compliance (Hannan and Prager, 1998). Similarly, the MVNO market faces significant barriers. While MVNOs do not build their own networks, they must negotiate favorable terms with MNOs for network access, often at costs that are prohibitive for smaller players. Regulatory compliance, alongside the need for robust marketing and customer service infrastructure, further complicates matters. Moreover, government policies and regulations play a crucial role in shaping market dynamics, often unintentionally fostering oligopolistic structures. In the pharmaceutical industry, strict patent laws and lengthy approval processes limit competition and grant substantial control to larger firms (Atella et al., 2008). A comparable situation exists in the MVNO market, where regulatory policies concerning spectrum allocation, data privacy, and licensing often favor larger players, particularly those backed by MNOs, which possess the resources to navigate complex regulations. While factors such as 'collusion', 'market entry barriers', and 'government policies and regulations' are influenced by forces beyond a firm's control, aspects like 'technological advancements and capital requirements' and 'inefficient management' can be actively addressed by companies themselves. For SME MVNOs, focusing

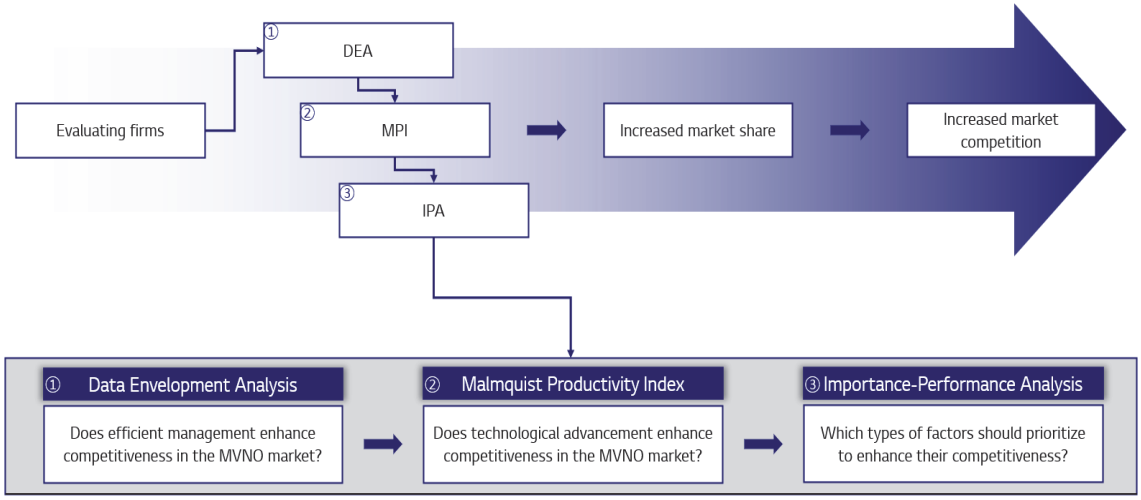
on enhancing these areas is vital for improving their competitive edge. Given the typical constraints faced by SMEs, such as limited capital, it may be more pragmatic to prioritize either technological advancements or management efficiency rather than attempting to develop both simultaneously.

Ⅲ. Research Methodologies

To decide whether SMEs in the MVNO market should focus on managing efficiently or gaining a technological edge to stay ahead of competitors and improve competitiveness, it is important to start by looking at how they allocate their costs. Cost allocation plays a role in management (Kaplan and Wettstein, 1999; Osadi, 2010; Ray and Goldmanis, 2012; Sengupta, 1998) and is a significant factor in measuring a company's effectiveness (Hisali and Yawe, 2011; Liao and Gonzalez, 2009; Liao and Lien, 2012; Sousa et al., 2020; Yang and Chang, 2009). Furthermore, as the wholesale service price is determined by subtracting costs from the plan price set by MNOs, properly managing cost allocation is crucial. In this research, we utilize Data Envelopment Analysis (DEA) to evaluate cost allocation and assess the efficiency of companies. By comparing these efficiencies with their market revenue share, we can understand how management influences market performance and assess its suitability as a competitive strategy. Additionally, based on the DEA findings, we analyze the productivity trend in the MVNO market to determine whether emphasizing on efficiency change (EC) or technical change (TC) would lead to improved productivity using the Malmquist Productivity Index (MPI). This analysis will help determine whether efficient management or technological advancement has a greater impact on enhancing firms' productivity and their competitiveness. Finally, we investigate consumer preferences and their desired improvements using Importance- Performance Analysis (IPA). This method aims to identify the factors that could significantly boost customer satisfaction and determine which aspects firms should prioritize for improvement (Figure 3).

3.1 Data Envelopment Analysis

DEA was initially introduced by Charnes et al. (1978) and has since been widely applied across various fields to extract insights pertinent to the implementation of enhanced management strategies. This analytical tool enables the measurement of the relative efficiency of decision-making units (DMUs). It also facilitates the assessment of inefficiencies among the input and output factors employed in the analysis and aids in establishing benchmarks for performance improvement (Jeon et



〈Figure 3〉 Study Flow Chart

al., 2011; Kim et al., 2016). In the realm of DEA, two primary models are prominent: the Charnes-Cooper-Rhodes (CCR) model (Charnes et al., 1978) and the Banker-Charnes-Cooper (BCC) model (Banker et al., 1984). The fundamental distinction between these models lies in their assumptions about returns to scale. The CCR model assumes constant returns to scale, implying that changes in input lead to proportional changes in output across all DMUs. Conversely, the BCC model allows for variable returns to scale, accommodating non-proportional changes in output relative to input changes. Both the CCR and BCC models can be further categorized into two orientations: input-oriented and output-oriented. The input-oriented model prioritizes minimizing inputs while maintaining consistent output levels, which is particularly useful for analyzing efficiency in resource utilization. On the other hand, the output-oriented model aims to maximize outputs given a fixed level of inputs, which is suitable for scenarios focusing on productivity enhancement. For this study, the input-oriented CCR model, shown below, was selected due to its relevance in scenarios where DMUs are assumed to be homogeneous and the primary goal is to minimize input usage. This choice aligns with the objective of enhancing operational efficiency by reducing resource consumption while sustaining output levels.

In this analysis of the Korean MVNO market, nine DMUs have been selected: 'Freet Mobile', 'KT M Mobile', 'Mobing', 'SK 7 Mobile', 'U Mobile', 'Eyes Mobile', 'A Mobile', 'EG Mobile', and 'Tplus Mobile'. These firms were chosen based on their significant subscriber base of

over 100,000 and their consistent public disclosures over the past five years. The study utilizes two inputs—salary cost (Banker and Morey, 1986; Reynolds, 2014) and advertising cost (Rahman et al., 2020; Wu et al., 2014)—and one output, which is revenue (Li et al., 2009; Liao and Lien, 2012; Kim and Chung, 2022), to evaluate the relative efficiency of these firms. These inputs are chosen because the wholesale price of the service is determined by subtracting costs from the MNOs' plan price. Since MVNOs are non-contact service providers, advertisement and salary costs play a significant role in their overall expenses. This selection of DMUs and variables meets the requisite analytical criteria that the total number of inputs and outputs, multiplied by three, must not exceed the number of DMUs (Dyson et al., 2001; Pedraja-Chaparro et al., 2017; Khezrimotlagh, 2015).

$$Maximize\ \theta = \frac{u_1 y_{1k} + u_2 y_{2k} + \cdots + u_s y_{sk}}{v_1 x_{1k} + v_2 x_{2k} + \cdots + v_m x_{mk}}$$

$$subject\ to\ \frac{u_1 y_{1j} + \cdots + u_s y_{sj}}{v_1 x_{1j} + \cdots + v_m x_{mj}} \leq 1$$

$$(j = 1, 2, 2, .., n)$$

$$v_1, v_2, ..., v_m \geq 0,\ u_1, u_2, ..., u_s \geq 0$$

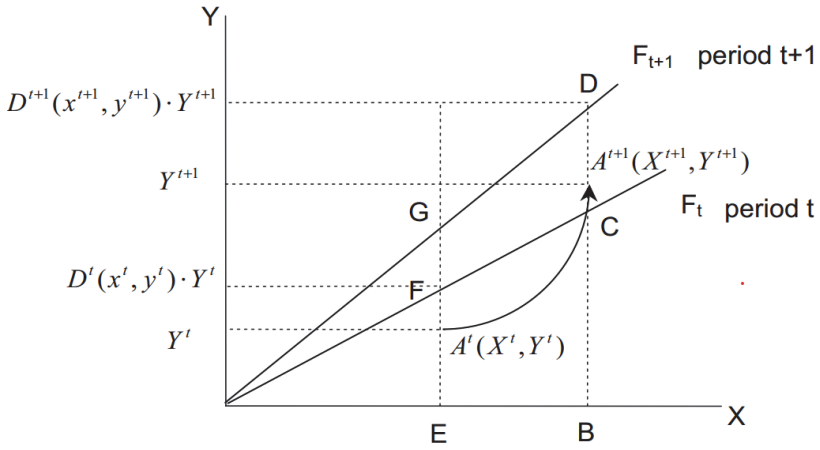
v_i : *the weight assigned to the i th input* $(i = 1, 2, .., m)$

u_r : *the weight assigned to the r th output* $(r = 1, 2, .., s)$

3.2 Malmquist Productivity Index

MPI is employed to measure the productivity changes of DMUs over time, facilitating dynamic analysis, such as evaluating productivity shifts across an entire industry (Malmquist, 1953). MPI assesses productivity variations by comparing the efficiency of a period t with that of the subsequent period $t+1$ as well as by comparing the technology levels at these two points (Färe et al., 1997). An MPI value of 1 denotes no change in productivity, values greater than 1 indicate an increase and values less than 1 suggest a decrease in productivity (Ammons, 2012; Vedung, 2017). Leveraging the results from the DEA, MPI quantifies changes in market productivity (Caves et al., 1982; Hwang and Chang, 2003), as illustrated in Figure 4.

In this framework, F_t and F_{t+1} represent the efficient frontiers for periods t and $t+1$, respectively. The term $D^{t+1}(x^t, y^t)$ denotes the efficiency distance functions, where x represents inputs and y denotes outputs. Efficiency Change (EC) is calculated by observing the degree of change between two specific A points and these points represent the efficiency scores of DMUs at consecutive time periods, thereby indicating any shifts in how resources are utilized without considering changes in technology. Technical Change (TC), on the other hand, is assessed by examining the change in the slopes of F lines. These lines describe the technology



〈Figure 4〉 MPI Measurement of Efficiency Change, (Hwang and Chang, 2003)

frontier at different time intervals and shifts of the lines explain the technological advancements or innovations that affect the production capabilities of DMUs.

For distance function at time t,

$$Maximize\ \lambda\ such\ that,$$
$$\Sigma_{j=1}^{n} \lambda_j x_{ij}^{t} \leq x_i^{t+1} \quad for\ all\ i$$
$$\Sigma_{j=1}^{n} \lambda_j y_{rj}^{t} \geq y_r^{t+1} \quad for\ all\ r$$
$$\lambda_j \geq 0 \quad for\ all\ j$$

For distance function at time $t+1$,

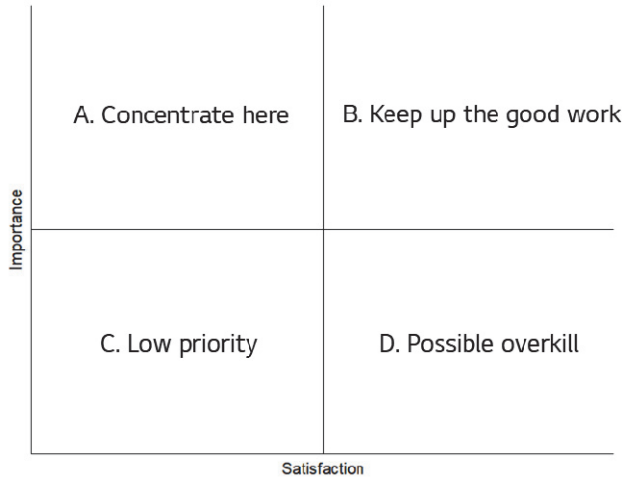
$$Maximize\ \lambda\ such\ that,$$
$$\Sigma_{j=1}^{n} \lambda_j x_{ij}^{t+1} \leq x_i^{t} \quad for\ all\ i$$
$$\Sigma_{j=1}^{n} \lambda_j y_{rj}^{t+1} \geq y_r^{t} \quad for\ all\ r$$
$$\lambda_j \geq 0 \quad for\ all\ j$$

where,

$$MPI = \sqrt{\left(\frac{D_{t+1}(x_{t+1}, y_{t+1})}{D_t(x_{t+1}, y_{t+1})}\right) \times \left(\frac{D_{t+1}(x_t, y_t)}{D_t(x_t, y_t)}\right)}$$

3.3 Importance—Performance Analysis

IPA is an invaluable tool for evaluating the significance and effectiveness of service attributes, particularly when optimizing operations with limited resources and capabilities (Martilla and James, 1977; Kim et al., 2016). The methodology employed involves conducting a survey to ascertain the importance and satisfaction levels of specific factors using a 1-5 Likert scale. The mean values for each factor are then calculated and plotted on a graph (Figure 5). This graph features a horizontal line representing the average importance across all factors and a vertical line representing the average satisfaction for all factors. The intersection of these lines divides the graph into four quadrants. The positioning of the factors within these quadrants enables a nuanced analysis of consumer preferences and identifies areas



〈Figure 5〉 Importance-Performance Analysis Graph

where businesses may be underperforming. This quadrant-based visualization serves as a strategic tool for assessing discrepancies between consumer expectations and their corresponding satisfaction levels, thereby guiding business strategies to address these gaps effectively.

Ⅳ. Results

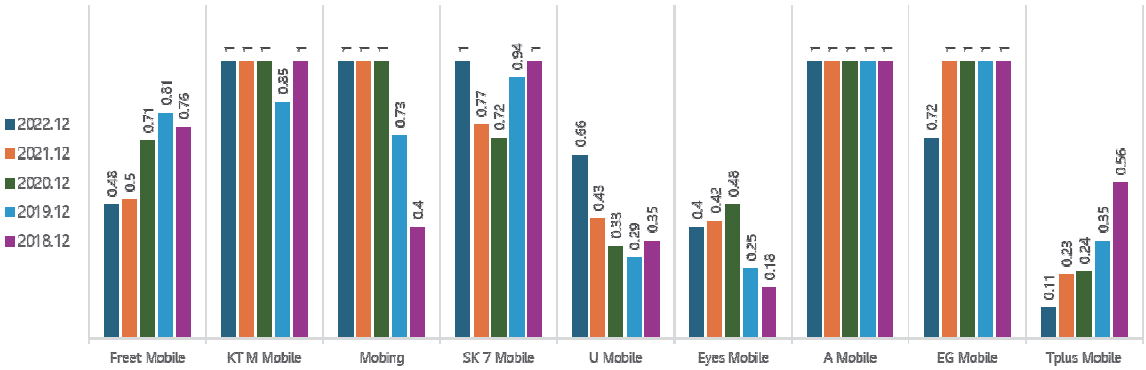
4.1 Data Envelopment Analysis Result

Before interpreting the DEA results, it is important to remember that DEA evaluates relative efficiency. Even if a firm improves its efficiency compared to the previous year, its DEA score may decline if competitors grow at a faster rate. Nonetheless, a high DEA score indicates superior efficiency relative to competitors within the same period. Data for the input and output factors of the nine MVNO firms were extracted from the financial corporate disclosures registered on the Data Analysis, Retrieval and Transfer System (DART) from 2018 to 2022. All figures are presented in South Korean Won (KRW). Descriptive statistics of the study are summarized in Table 2, and the results of the DEA are illustrated in Figure 6.

The analysis reveals that 'A Mobile' consistently maintained the highest relative efficiency scores over the five-year period, despite having lower revenue shares than 'KT M Mobile', 'SK 7 Mobile', and 'U Mobile', which are subsidiaries of the major MNOs. Conversely, 'U Mobile', despite being second in sales ranking

〈Table 2〉 Descriptive Statistics of the Study

	Mean	Median	SD	Max	Min
Salary Cost	9,194,176,366	5,874,684,000	8,466,963,819	28,378,750,000	1,154,017,000
Advertising Cost	1,850,995,091	769,212,000	2,330,431,266	8,971,419,000	21,152,000
Revenue	108,189,089,586	45,661,853,211	106,380,034,539	372,382,524,616	11,614,638,757

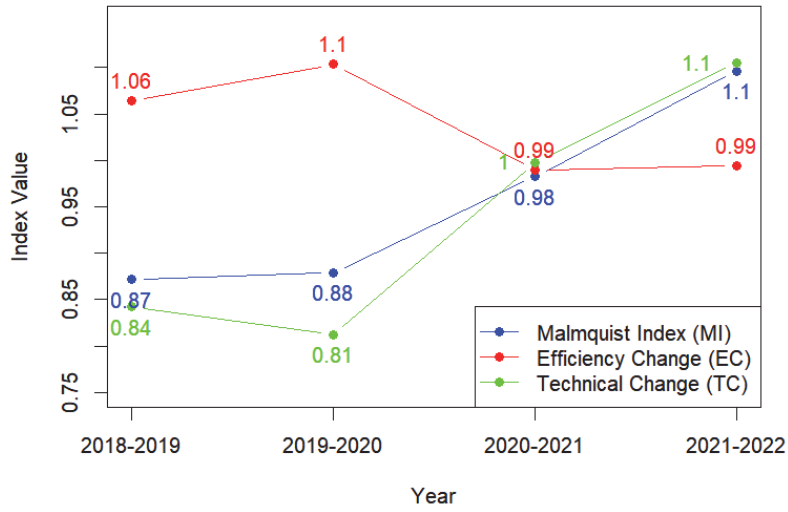


〈Figure 6〉 Results of the DEA

among the nine DMUs for five consecutive years, exhibits relatively low efficiency scores. 'EG Mobile' also achieved highest relative efficiency scores for four years, although it reported the lowest revenue shares for the same duration among the DMUs. These findings indicate that there is no clear correlation between relative efficiency and sales ranking among Korean MVNO firms, suggesting that efficient management does not necessarily enhance competitiveness in the oligopolistic MVNO market in Korea.

4.2 Malmquist Productivity Index Result

The MPI results, as illustrated in Figure 7, reveal that despite a decline in EC following the period 2019-2020, Malmquist Index (MI) experienced an increase, attributable primarily to a significant rise in TC. For the relationship $MI = TC \times EC$, taking the logarithm of both sides facilitates a transformation of this multiplicative relationship into an additive one. Specifically, the equation becomes $log(MI) = log(TC) + log(EC)$. This transformation is crucial for employing multiple regression analysis, which examines the elasticity of the MI with respect to EC and TC. The regression analysis allows us to quantify how the MI responds to changes in the underlying factors. It specifically measures the percentage change in MI resulting from a one percent change in either



〈Figure 7〉 Aggregated Malmquist Index Components Over Time

〈Table 3〉 Results of the Multiple Regression Analysis

Independent Variables	Estimate	Std. Error	t value	p value
Constant	-0.0084	0.006	-1.397	0.396
log(EC)	1.0188	0.268	3.808	0.164
log(TC)	1.0826	0.098	11.011	0.058

Dependent variable is Malmquist Index (MI).

EC or TC, shown in Table 3. The analysis of the regression coefficients reveals that the coefficient of $log(TC)$ is larger than that of $log(EC)$. This indicates that a one percent increase in TC results in a greater positive change in the MI compared to a one percent increase in EC. These findings suggest that technical advancements are more influential in driving productivity improvements than mere efficiency enhancements. Consequently, this analysis indicates that investing in research and development (R&D) is more effective for enhancing competitiveness than focusing on efficient management within the Korean MVNO market.

4.3 Importance–Performance Analysis Result

The survey questionnaire comprised six questions regarding the general characteristics of respondents, eighteen questions about the importance and satisfaction levels of various attributes, and one question about overall satisfaction with MVNOs in Korea. Out of 1,141

collected responses, 467 were analyzed, focusing on respondents currently or previously using MVNO services.

General characteristics queried included gender, age, marital status, household type, occupation, and area of residence (Table 4). The demographic breakdown showed 51.2% male and 48.8% female respondents. Age distribution was as follows: 36.6% were in their twenties, 33.2% were in their thirties, 21.6% were in their forties, 7.1% were in their fifties, and 1.5% were aged over sixty. Marital status revealed 38.8% married and 61.2% single. Household composition indicated 30.4% living alone and 69.6% with family. Employment data showed 13.9% in production, sales, or services, 48.2% in office or professional roles, 30.6% unemployed, and 7.3% in other occupations. Geographically, 66.2% resided in the Seoul, Incheon, or Gyeonggi-do areas, with the re-

〈Table 4〉 General Characteristics of the Respondents

Variable	Value
Gender	
Male	239 (51.2)
Female	228 (48.8)
Age (yrs)	
20-29	171 (36.6)
30-39	155 (33.2)
40-49	101 (21.6)
50-59	33 (7.1)
60-	7 (1.5)
Marital Status	
Married	181 (38.8)
Single	286 (61.2)
Household Type	
Single-person household	142 (30.4)
With family	325 (69.6)
Occupation	
Production, sales, service	65 (13.9)
Office and professionals	225 (48.2)
Unemployed (student, housewife, etc.)	143 (30.6)
Others	34 (7.3)
Area of Residence	
Seoul/Incheon/Gyeonggi-do	309 (66.2)
Other	158 (33.8)
Total	467 (100.0)

Values are expressed as frequency percentages (%).

maining 33.8% from other parts of the country. Respondents evaluated the importance and satisfaction of eighteen MVNO attributes on a 5-point Likert scale (1: very low, 5: very high) (Table 5).

The average importance score was 3.22, with the highest scores for 'Plan Rates' (4.00), 'Data Speed' (3.77), and 'Variety of Plans' (3.69), among others. The average satisfaction score was 3.13, with 'Plan Rates' (3.72) and 'Variety of Plans' (3.53) ranking highest. The lowest importance and satisfaction scores were related to 'Prepaid/Postpaid Options' and 'Insurance' (Table 6).

The IPA graphed in Figure 8 categorizes attributes into four sections based on average scores. Section A includes attributes with higher importance but lower satisfaction, such as 'Data Speed' and 'Customer Service Quality'. Section B lists attributes high in both dimensions like, 'Voice Call Quality' and 'Plan Rates'. Section C shows attributes low in both dimensions and Section D features an attribute with low importance but high satisfaction, 'Variety of Networks'.

Factor analysis divided the attributes into five factors, revealing a Cronbach's alpha of 0.929 and explaining 58.833% of the variance (Table 7).

The correlation analysis showed all five

〈Table 5〉 MVNO Selection Attributes

Evaluation Items	
Voice Call Quality	**Babu and Sundar (2018), Yu and Lee (2022), Taghizadeh and Meskarian (2013), Chakraborty and Sengupta (2014), Liang et al., (2013), Gautam (2011), Gunjan et al., (2011), Santouridis and Trivellas (2010), Rahhal (2015), Nimako (2012), Mpwanya and Letsoalo (2019), Hossain and Suchy (2013), Hosseini et al., (2013), Mathiraj et al., (2019)**
Data Speed	Babu and Sundar (2018), Yu and Lee (2022), Nimako (2012), Mpwanya and Letsoalo (2019), Chakraborty and Sengupta (2014), Dharmadasa and Gunawardane (2017), Chee and Husin (2020)
Data Stability	**Babu and Sundar (2018), Nimako (2012), Mpwanya and Letsoalo (2019), Chakraborty and Sengupta (2014), Dharmadasa and Gunawardane (2017), Chee and Husin (2020)**
International Roaming Speed	Gerpott and Jakopin (2006)
International Roaming Stability	**Gerpott and Jakopin (2006)**
Service Coverage	Babu and Sundar (2018), Taghizadeh and Meskarian (2013), Chakraborty and Sengupta (2014), Rahhal (2015), Palladan and Ahmad (2019), Wen and Hilmi (2011), Nimako (2012), Mpwanya and Letsoalo (2019), Hossain and Suchy (2013), Dharmadasa and Gunawardane (2017)
Variety of Networks	**Kimiloglu et al. (2011)**
Variety of Plans	Gunjan et al., (2011), Hossain and Suchy (2013), Hosseini et al., (2013)
Additional Services	**Babu and Sundar (2018), Yu and Lee (2022)**
Insurance	Yu and Lee (2022)
Customer Service Quality	**Babu and Sundar (2018), Yu and Lee (2022), Rahhal (2015), Ojo (2010), Loke et al., (2011), Nimako (2012), Hassan et al., (2013), Dharmadasa and Gunawardane (2017)**
Availability of Device Sales	Yu and Lee (2022)
Easy Signup/Cancellation	**Babu and Sundar (2018)**
Plan Rates	Babu and Sundar (2018), Yu and Lee (2022)
Various Payment Methods	**Babu and Sundar (2018)**
Events/Promotions/Partnerships	Babu and Sundar (2018), Yu and Lee (2022)
Subsidies	**Babu and Sundar (2018)**
Prepaid/Postpaid Options	Babu and Sundar (2018)

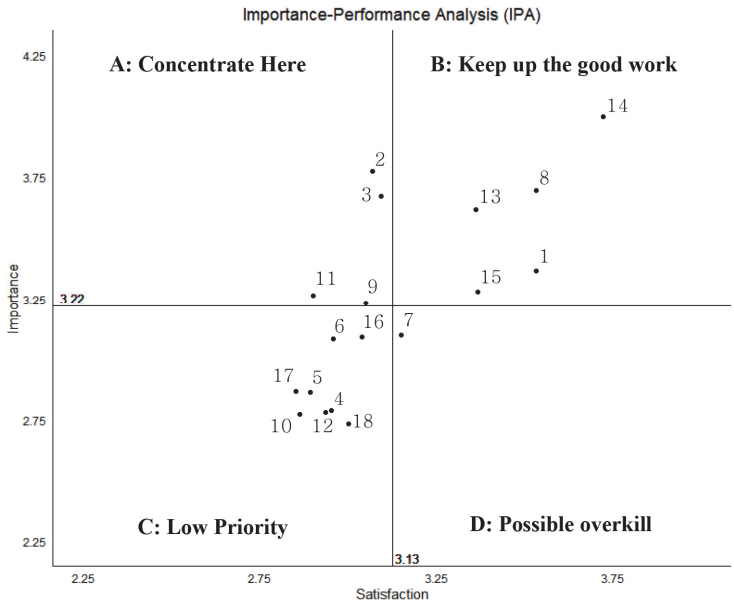
〈Table 6〉 Comparative Analysis of the Importance and Satisfaction with MVNO Selection Attributes

Evaluation Items	Importance[1)]	Satisfaction[2)]	t-value
Voice Call Quality	3.36 ± 1.07	3.53 ± 1.01	-2.855*
Data Speed	3.77 ± 1.00	3.07 ± 0.99	12.614***
Data Stability	3.67 ± 1.01	3.09 ± 0.99	10.523***
International Roaming Speed	2.79 ± 1.18	2.95 ± 0.99	-2.695
International Roaming Stability	2.86 ± 1.21	2.89 ± 0.98	-0.504
Service Coverage	3.08 ± 1.08	2.96 ± 1.04	2.219*
Variety of Networks	3.10 ± 1.07	3.15 ± 0.99	-0.968
Variety of Plans	3.69 ± 1.09	3.53 ± 1.10	3.043**
Additional Services	3.23 ± 1.05	3.05 ± 1.00	3.206**
Insurance	2.77 ± 1.15	2.86 ± 1.00	-1.533
Customer Service Quality	3.27 ± 1.05	2.90 ± 1.10	5.820***
Availability of Device Sales	2.78 ± 1.20	2.94 ± 1.06	-2.646**
Easy Signup/Cancellation	3.62 ± 1.08	3.36 ± 1.10	5.026***
Plan Rates	4.00 ± 1.03	3.72 ± 1.14	5.869***
Various Payment Methods	3.28 ± 1.11	3.37 ± 1.06	-1.593
Events/Promotions/Partnerships	3.09 ± 1.20	3.04 ± 1.10	0.975
Subsidies	2.87 ± 1.21	2.85 ± 1.05	0.309
Prepaid/Postpaid Options	2.73 ± 1.16	3.00 ± 1.03	-5.170***
Average Score	3.22 ± 1.11	3.13 ± 1.04	

Values are presented as mean ± standard deviation.
1) Importance scores were derived from mean values obtained using a 5-point Likert scale, where 1 indicates strongly disagree, 3 indicates neutral, and 5 indicates strongly agree.
2) Satisfaction scores were derived from mean values obtained using the same 5-point Likert scale.
*p < 0.05; **p < 0.01; ***p < 0.001.

factors—'Flexibility', 'Customer Experience', 'Technology', 'Roaming Performance', and 'Incentives'—had a statistically significant positive correlation with overall satisfaction (Table 8), with 'Technology' showing the strongest correlation.

Multiple regression analysis determined the influence of these factors on overall satisfaction (Table 9). The 'Technology' factor had the highest positive coefficient, indicating that advancements in technology are most likely to increase overall satisfaction among MVNO users. The second-highest positive coefficient was for 'Flexibility', which includes attributes such as 'Plan Rates', 'Variety of Plans', 'Various Payment Methods', and 'Easy Signup/Cancellation'. These attributes are all plotted in B section of the IPA graph, indicating that they are already meeting customer expectations, as customers consider them important.



〈Figure 8〉 Results of Importance-Performance Analysis of MVNO Selection Attributes

A: Concentrate here	2. Data Speed 3. Data Stability 9. Additional Services 11. Customer Service Quality
B: Keep up the good work	1. Voice Call Quality 8. Variety of Plans 13. Easy Signup/Cancellation 14. Plan Rates 15. Various Payment Methods
C: Low priority	4. International Roaming Speed 5. International Roaming Stability 6. Service Coverage 10. Insurance 12. Availability of Device Sales 16. Events/Promotions/Partnerships 17. Subsidies 18. Prepaid/Postpaid Options
D: Possible overkill	7. Variety of Networks

〈Table 7〉 Results of Factor Analysis of MVNO Selection Attributes

Factor and Variables (Cronbach's α)	Factor Loadings	Eigen Values	Cumulative (%)
Factor 1: Flexibility (0.829)		2.511	13.952
Plan Rates	0.778		
Variety of Plans	0.706		
Various Payment Methods	0.585		
Easy Signup/Cancellation	0.534		
Factor 2: Customer Experience (0.820)		2.472	27.684
Insurance	0.633		
Customer Service Quality	0.621		
Availability of Device Sales	0.602		
Additional Services	0.502		
Service Coverage	0.416		
Factor 3: Technology (0.802)		1.920	38.352
Data Speed	0.711		
Data Stability	0.579		
Voice Call Quality	0.569		
Variety of Networks	0.397		
Factor 4: Roaming Performance (0.915)		1.851	48.634
International Roaming Stability	0.851		
International Roaming Speed	0.777		
Factor 5: Incentives (0.786)		1.836	58.833
Subsidies	0.700		
Prepaid/Postpaid Options	0.633		
Events/Promotions/Partnerships	0.574		

The five factors in the data set explained 58.833% of the variance; Cronbach's α = 0.929

〈Table 8〉 Results of Inteorrelation of all Measures

Variables	Flexibility	Customer Experience	Technology	Roaming Performance	Incentives
Overall Satisfaction	0.362**	0.339**	0.457**	0.308**	0.268**

**p < 0.01

〈Table 9〉 Results of the Multiple Regression Analysis

Independent Variables	Unstandardized Coefficients		Standardized Coefficients	t-value	VIF
	B	SE	Beta		
Constant	4.013	0.037		108.777***	
Flexibility	0.091	0.052	0.102	1.764	1.966
Customer Experience	0.023	0.059	0.026	0.396	2.554
Technology	0.298	0.055	0.333	5.441***	2.200
Roaming Performance	0.069	0.049	0.077	1.400	1.775
Incentives	0.003	0.049	0.003	0.062	1.775

Dependent variable is overall satisfaction, R^2 = 0.222, adjusted R^2 = 0.214, F = 26.191 (p < 0.001).
*p < 0.05, **p < 0.01, ***p < 0.001

Therefore, focusing more on 'Technology' factor is likely to further enhance customer satisfaction, as demonstrated by the multiple regression analysis results.

Ⅴ. Conclusion & Discussion

5.1 Managerial Insights

In oligopolistic markets such as the Korean MVNO sector, where three subsidiary firms of major MNOs dominate, SME MVNOs face significant challenges due to limited capital and lower market shares. Despite these challenges, it is essential for these small businesses to pinpoint areas for enhancement to boost their competitiveness individually. This study delves into the effectiveness in management versus technological advancement in bolstering the competitive edge of SME MVNOs in Korea.

The Data Envelopment Analysis indicates that higher efficiency does not always translate to increased market revenue. For instance, 'U Mobile', a subsidiary of 'LG U+', despite its high sales ranking, shows low relative efficiency. Similarly, 'A Mobile' and 'EG Mobile' rank lower in sales despite their high efficiency. These results indicate that relying on efficient management may not significantly influence competitiveness. Further analysis using the Malmquist Productivity Index reveals that technological changes have a more substantial positive impact on the market index than efficiency changes. Specifically, a one percent increase in Technical Change (TC) results in a more significant increase in productivity than an equivalent increase in Efficiency Change (EC). This underscores the importance of technological advancement over efficient management for enhancing competitiveness. The Importance-Performance Analysis highlights areas where consumers desire improvements, including data speed, data stability, additional services, and customer service quality. Intercorrelation and multiple regression analyses reinforce that enhancing technology-related factors significantly boosts customer satisfaction. Therefore, SME MVNOs in Korea should focus on securing a technological advantage, especially, data speed, data stability, voice call quality, and variety of networks, to gain an edge over competitors, rather than efficient management, to become more competitive in the market.

To capitalize on these insights, SME MVNOs should consider adopting the 'Always Best Connected' (ABC) strategy. This strategy ensures that users stay connected to the network based on their location network conditions and preferences (Copeland and Crespi, 2011; De Leon and Adhikari, 2010). Studies show that implementing ABC technology enhances user experience and service quality (Passas

et al., 2005). By utilizing services from all three MNOs, SME MVNOs can provide optimal network solutions to their customers, potentially increasing customer satisfaction and competitiveness in the market. This suggestion not only provides a strategic direction for SME MVNOs in the Korean market to bolster their competitive edge but also contributes to the broader development of the MVNO market and the companies operating within it. Given the findings of this paper, which conclude that focusing on technological advancement better enhances MVNOs' competitiveness than efficient management, adopting ABC technology presents an encouraging opportunity for firms to consider exploring.

5.2 Limitations & Future Research

One limitation of this research is the constrained number of decision-making units analyzed, which narrowly meets the minimum requirement. As of April 2023, there are 53 MVNO companies in Korea, of which 19 have secured over 100,000 subscribers. However, only nine of these companies have five years' worth of publicly available data, which is needed for a thorough analysis and meeting the minimum threshold of DMUs required for a robust analysis. This constraint could impact the breadth and depth of the study's conclusions. To improve the robustness of research findings, it would be beneficial to include a variety of MVNOs for a more comprehensive comparison and analysis in the future. Another notable limitation of the study is the absence of a calculated correlation between DEA results and market revenue share. Given the inherent nature of DEA scores as indicators of relative efficiency, it is imperative to acknowledge that fluctuations in these scores can occur, even when a particular DMU consistently performs well. This variability may stem from the comparative performance of other DMUs within the analyzed dataset. Furthermore, the low significance of the MPI results, particularly regarding the higher coefficient associated with TC compared to EC, underscores the influence of limited variables, data points, and the duration of the observed time frame. Even though it can still accept the p-value at a slightly less strict significance level, future research can benefit from a larger dataset involving more MVNOs over an extended period of time. This expansion would yield heightened precision, enhanced statistical power, and higher significance in p values ultimately contributing to an understanding of market dynamics and operational efficiencies in the telecommunications industry. Additionally, the survey component of this study did not include questions about the specific MVNO that respondents currently use or have used in the past. The primary focus was on understanding the types of advancements that interest customers and evaluating the

importance and performance of service quality attributes broadly. Including a question about respondents' specific MVNO affiliations in future surveys could enable a more detailed analysis of IPA matrices and offer deeper insights into customer preferences and experiences unique to each MVNO. Addressing these limitations in future studies would not only strengthen the findings but also provide more detailed guidance for enhancing competitiveness in the MVNO market in Korea.

References

Abbring, J. H., and Campbell, J. R.(2006), "Oligopoly dynamics with barriers to entry," *FRB of Chicago*, Working Paper No.2006-29.

Aiginger, K., and Pfaffermayr, M.(1999), "Product quality, cost asymmetry and the welfare loss of oligopoly," *International Journal of the Economics of Business*, 6(2), pp.165-180.

Ammons, D.(2012), "Municipal benchmarks: assessing local performance and establishing community standards," *Armonk, NY: ME Sharpe*.

Asghari, M., Yousefi, S., and Niyato, D.(2017), "A mobile network operator's decision for partnership with zero-rating Internet platforms," In *GLOBECOM 2017-2017 IEEE Global Communications Conference* (pp.1-6). IEEE.

Atella, V., Bhattacharya, J., and Carbonari, L.(2008), "Pharmaceutical industry, drug quality and regulation: evidence from US and Italy," *National Bureau of Economic Research*, No. w14567.

Baldani, J., and Michl, T. R.(2000), "Technical change and profits: The prisoner's dilemma," *Review of Radical Political Economics*, 32(1), pp. 104-118.

Banker, R. D., and Morey, R. C.(1986), "Efficiency analysis for exogenously fixed inputs and outputs," *Operations Research*, 34(4), pp. 513-521.

Banker, R. D., Charnes, A., and Cooper, W. W.(1984), "Some models for estimating technical and scale inefficiencies in data envelopment analysis," *Management Science*, 30(9), pp. 1078-1092.

Bös, D., and Peters, W.(1995), "Double inefficiency in optimally organized firms," *Journal of Public Economics*, 56(3), pp.355-375.

Caves, D. W., Christensen, L. R., and Diewert, W. E.(1982), "The economic theory of index numbers and the measurement of input, output, and productivity," *Econometrica: Journal of the Econometric Society*, pp. 1393-1414

Charnes, A., Cooper, W. W., and Rhodes, E.(1978), "Measuring the efficiency of decision making units," *European Journal of Operational Research*, 2(6), pp.429-444.

Copeland, R., and Crespi, N.(2011), "Modelling multi-MNO business for MVNOs in their evolution to LTE, VoLTE & advanced policy," *15th International Conference on Intelligence in Next Generation Networks* (pp.295-300). IEEE.

Corrocher, N., and Lasio, L.(2013), "Diversification strategies in network-based services: The case of mobile virtual network operators," *Telecommunications Policy,* 37(11), pp.1110-

1123.

De Leon, M. P., and Adhikari, A.(2010), "A user centric always best connected service business model for mvnos," *14th International Conference on Intelligence in Next Generation Networks* (pp. 1-8). IEEE.

Dixon, H. D.(1994), "Inefficient diversification in multi-market oligopoly with diseconomies of scope," *Economica*, pp.213-219.

Domazet, A., and Sarić, N.(2009), "Strategies of mobile virtual network operators in the southeast Europe region," *Interdisciplinary Management Research*, 5, pp.123-135.

Donthu, N., Hershberger, E. K., and Osmonbekov, T.(2005)," Benchmarking marketing productivity using data envelopment analysis. *Journal of Business Research*, 58(11), pp.1474-1482.

Dyson, R. G., Allen, R., Camanho, A. S., Podinovski, V. V., Sarrico, C. S., and Shale, E. A.(2001), "Pitfalls and protocols in DEA," *European Journal of Operational Research*, 132(2), pp.245-259.

Färe, R., Grifell Tatjé, E., Grosskopf, S., and Knox Lovell, C. A.(1997), "Biased technical change and the Malmquist productivity index," *Scandinavian Journal of Economics*, 99(1), 119-127.

Fershtman, C., and Pakes, A.(1999), "A dynamic oligopoly with collusion and price wars," *National Bureau of Economic Research*.

Fujita Y.(1997), "The effect of entry barriers in a "mixture" market," *Keio Economic Studies*, 34(2), pp.81-88.

García, J. P.(2010), "Dynamic pricing in the Spanish gasoline market: A tacit collusion equilibrium," *Energy Policy*, 38(4), pp.1931-1937.

Hajiyev, N., Mansura, M., Sverdlikova, E., Safronov, R., and Vityutina, T.(2021), "Oligopoly trends in energy markets: Causes, crisis of competition, and sectoral development strategies," *International Journal of Energy Economics and Policy*, 11(6), pp.392-400.

Hannan, T. H., and Prager, R. A.(1998), "The relaxation of entry barriers in the banking industry: An empirical investigation," *Journal of Financial Services Research*, 14(3), pp.171-188.

Harrington, J. E.(1987), "Collusion in multiproduct oligopoly games under a finite horizon," *International Economic Review*, pp.1-14.

Hisali, E., and Yawe, B.(2011), "Total factor productivity growth in Uganda's telecommunications industry," *Telecommunications Policy*, 35(1), pp.12-19.

Hwang, S. N., and Chang, T. Y.(2003), "Using data envelopment analysis to measure hotel managerial efficiency change in Taiwan," *Tourism Management*, 24(4), pp.357-369.

Hwnag H.(2022), "Zero-rating the Need for Data and Regulation: The Case of Austria," *KISDI Perspectives*

Jeon, J., Kim, C., and Lee, H.(2011), "Measuring efficiency of total productive maintenance (TPM): a three-stage data envelopment analysis (DEA) approach," *Total Quality Management & Business Excellence*, 22(8), 911-924.

Kamiyama, N., and Nakao, A.(2019), "Analyzing Dynamics of MVNO Market Using Evolutionary Game Theory," *IEICE Technical Report; IEICE Tech. Rep.*, 119(29), pp.45-50.

Kaplan, T. R., and Wettstein, D.(1999), "Cost sharing: efficiency and implementation," *Journal of Mathematical Economics*, 32(4), pp.489-502.

Khezrimotlagh, D.(2015), "How to deal with numbers

of decision making units and variables in data envelopment analysis," *arXiv preprint arXiv:1503.02306*.

Kim, B. W., and Seol, S. H.(2007), "Economic analysis of the introduction of the MVNO system and its major implications for optimal policy decisions in Korea," *Telecommunications Policy*, 31(5), pp.290-304.

Kim, C., and Chung, K.(2022), "Measuring customer satisfaction and hotel efficiency analysis: An approach based on data envelopment analysis," *Cornell Hospitality Quarterly*, 63 (2), pp.257-266.

Kim, C., Lee, S., and Kim, S. W.(2016), "Surviving in the Red Ocean: measuring factors for business excellence among coffee franchises in Korea," *Total Quality Management & Business Excellence*, 27(7-8), pp.761-774.

Lee, S., Chan-Olmsted, S. M., and Ho, H. H.(2008), "The emergence of mobile virtual network operators (MVNOs): An examination of the business strategy in the global MVNO market," *The International Journal on Media Management,* 10(1), pp.10-21.

Li, Y., Yang, F., Liang, L., and Hua, Z.(2009), "Allocating the fixed cost as a complement of other cost inputs: A DEA approach," *European Journal of Operational Research*, 197(1), 389-401.

Liao, C. H., and González, D. B.(2009), "Comparing operational efficiency of mobile operators in Brazil, Russia, India and China," *China & World Economy*, 17(5), pp.104-120.

Liao, C. H., and Lien, C. Y.(2012), "Measuring the technology gap of APEC integrated telecommunications operators," *Telecommunications Policy*, 36(10-11), pp.989-996.

Lorenzon, E.(2022), "Zero-rating, content quality, and network capacity," *Information Economics and Policy*, 58, p.100965.

Malmquist, S.(1953), "Index numbers and indifference surfaces," *Trabajos de Estadística*, 4(2), pp. 209-242.

Martilla, J. A., and James, J. C.(1977), "Importance-performance analysis," *Journal of Marketing*, 41(1), pp.77-79.

Osadi, B. E., and Okpako, E. O.(2010), "Cost management strategy: A tool for improving efficiency in business performance," *International Journal of Economic Development Research and Investment*, 1(2), pp.191-197.

Park, M. S., and Bae, H, J.(2020), "Analysis of the factors influencing customer satisfaction of delivery food," *Journal of Nutrition and Health,* 53(6), pp.688-701.

Passas, N., Paskalis, S., Kaloxylos, A., Bader, F., Narcisi, R., Tsontsis, E., ... and Aghvami, H.(2005), "Enabling technologies for the 'always best connected' concept," *Wireless Communications & Mobile Computing,* 5(2).

Pedraja-Chaparro, F., Salinas-Jiménez, J., and Smith, P.(1999), "On the quality of the data envelopment analysis model," *Journal of the Operational Research Society*, 50(6), pp.636-644.

Pinto, M. D., and Goerke, L.(2019), "Efficiency Wages in Cournot-Oligopoly," *IAAEU Discussion Paper Series in Economics,* No. 07/2018

Preta, A., and Peng, P.(2016), "Openings for Zero Rating," *InterMEDIA*, 44(2)

Rahman, M., Rodríguez-Serrano, M. Á., and Lambkin, M.(2020), "Advertising efficiency and profitability: evidence from the pharmaceutical industry," *Industrial Marketing Management*,

89, pp.619-629.

Ray, K., and Goldmanis, M.(2012), "Efficient cost allocation," *Management Science*, 58(7), pp. 1341-1356.

Reynolds, D.(2014), "An exploratory investigation of multiunit restaurant productivity assessment using data envelopment analysis," In *Management Science Applications in Tourism and Hospitality (pp. 19-26). Routledge.*

Saha, A., Havenner, A., and Rauschenbach, S.(2019), "The Rise of Dominant Firms: The Role of Chance," *Open Economics*, 2(1), pp.76-91.

Schwartz, L. B.(1970), "New Approaches to the Control of Oligopoly," *J. Reprints Antitrust L. & Econ.*, 2, 335.

Sengupta, J. K.(1998), "The efficiency distribution in a production cost model," *Applied Economics*, 30(1), pp.125-132.

Shin, D. H., and Bartolacci, M.(2007), "A study of MVNO diffusion and market structure in the EU, US, Hong Kong, and Singapore," *Telematics and Informatics*, 24(2), 86-100.

Shin, D. H.(2008), "Overlay networks in the West and the East: a techno-economic analysis of mobile virtual network operators," *Telecommunication Systems*, 37, pp.157-168.

Shin, D. H.(2010), "MVNO services: Policy implications for promoting MVNO diffusion," *Telecommunications Policy*, 34(10), pp.616-632.

Shin, D., and Chung, S.(2012), "Will mobile virtual network operators succeed in Korea?," *info*, 14(3), pp.48-67.

Shin, J.(2015), "Korea MVNO policy and adequacy study," *Journal of the Korea Institute of Information and Communication Engineering*, 19(12), pp.2765-2772.

Sousa, K. M. D., Pinhanez, M. D. M. S. F., Monte, P. A. D., and Diniz, J. A.(2020), "Salary, financial autonomy and efficiency of healthcare systems in local governments," *Applied Economics Letters*, 27(2), pp.122-126.

Stenbacka, L. R.(1990), "Collusion in dynamic oligopolies in the presence of entry threats," *The Journal of Industrial Economics*, pp.147-154.

Stern, N.(1987), "The effects of taxation, price control and government contracts in oligopoly and monopolistic competition," *Journal of Public Economics*, 32(2), pp.133-158.

Tishler, A., and Milstein, I.(2009), "R&D wars and the effects of innovation on the success and survivability of firms in oligopoly markets," *International Journal of Industrial Organization*, 27(4), pp.519-531.

Vedung, E.(2017), "Public policy and program evaluation," 1st ed., Routledge.

Wu, H. Q., Liu, Y. X., Zhuang, D. L., and Zhu, W. D.(2014), "A DEA-based measurement of effectiveness of provincial image advertisement for local tourism destination: evidence from China," *International Journal of Management and Decision Making*, 13(2), pp.192-206.

Yang, H. H., and Chang, C. Y.(2009), "Using DEA window analysis to measure efficiencies of Taiwan's integrated telecommunication firms," *Telecommunications Policy*, 33(1-2), pp.98-108.

Yang, K. H., and Zentefis, A. K.(2023), "Regulating oligopolistic competition," *Journal of Economic Theory*, 212, 105709.

Zhang, Y., and Round, D. K.(2011), "Price wars and price collusion in China's airline markets," *International Journal of Industrial Organization*, 29(4), pp.361-372.

- The author Hannam Ro earned his M.S. in Operations Management from Seoul National University Business School and a B.S. in Management Science from the University of California, San Diego. He has worked as a management consultant since earning his master's degree. His main research areas are optimization and business strategy.

- The author Hongsuk Yang is a Professor of Operations Management at Seoul National University Business School. He holds a B.A. from Seoul National University, a M.S. in Industrial Engineering from Stanford University, and a Ph.D. from the University of Chicago Booth School of Business. His research areas include inventory management, supply chain management, and service operations.

- The Corresponding author Changhee Kim is an Associate Professor of Management Science and Data Science at Incheon National University Business School. He earnd a B.B.A. from Sungkyunkwan University, a M.S. and Ph.D. in Operations Management from Seoul National University. His research interests include service operations management, optimization, and efficiency measurement.