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Demand forecasting for the 5G service market considering consumer preference and purchase delay behavior

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A R T I C L E I N F O

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A B S T R A C T

Unlike previous mobile communications technologies that centered on service subscribers, 5G mobile communication (5G) is expected to converge with various industry fields such as transportation, manufacturing, and construction, thereby stimulating innovation and generating significant ripple effects. At a time when 5G commercialization is incipient, it is necessary to understand mobile communication service users who are likely to be important initial users for the creation and diffusion of 5G services. The current study analyzed consumer preference for 5G services based on conjoint survey data and a mixed logit model, and we conducted a market simulation based on the estimation results to determine the impact of 5G technology development on the 5G market, specifically regarding the mobile communication fields. In addition, this study derived consumer purchase delay factors for 5G services using an ordered logit model. The results show that consumers delay the adoption of 5G services mainly because of the cost and lack of need. By considering the consumer purchase delay, it is estimated that the acceptance rate of 5G services by consumers will decrease by more than 50%; this is because it is hard to conclude a purchase delay of more than one year leads to an actual purchase. The results of this study suggest important strategic implications that are likely to reduce the purchase delay of consumers, improve the actual adoption rate, and increase the diffusion of 5G services.

1. Introduction

Mobile communication has introduced personal conveniences in daily life, changed our society, and developed new markets and industries, with 10-year-cycle generation after the first launch in 1978 (Dunnewijk and Hultén, 2007; Jehadessan, 2005; Rappaport, 1996). The 2nd generation of mobile communication (2G) popularized voice communication among people, and the 3rd generation of mobile communication (3G) introduced wireless internet (Korhonen, 2003; Siau and Shen, 2003). The 4th generation of mobile communication (4G) provided various mobile services, including applications in finance, shopping, and entertainment through high-speed wireless Internet (Arshad et al., 2010; Govil and Govil, 2007). In particular, with the spread of smartphones, smart devices, and the Internet of Things (IoT), wireless data traffic in 4G networks is increasing exponentially and concerns over the early saturation of

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bandwidth are increasing.[1] Additionally, since the ubiquitous and mobile nature of the internet has gained attention as the major push factor of the 4th industrial revolution (Klaus, 2016), there is a steady demand for next-generation communication technology that can process massive amounts of data in real time.

With the transformative history of mobile communication in mind, the 5th generation of mobile communication (5G) is expected to expand the mobile communication market as both an essential infrastructure and an innovative platform (Osseiran et al., 2016; Xiang et al., 2016). 5G, also known as IMT-2020, debuts significant technological improvements, with a 20 times faster maximum transfer rate, 10 times shorter latency time, 10 times larger maximum number of connections, and 3 times better frequency efficiency than 4G (International Telecommunication Union, 2015). With these technical specifications, 5G is expected to bring about changes and new opportunities for businesses and industries not confined to telecommunication (Mavromoustakis et al., 2016). For example, high-speed enables the use of large amounts of data-based content such as ultra-high-definition (UHD), virtual reality, and augmented reality (Agiwal et al., 2016). Ultra-low latency can also support real-time services that require immediate response without delays such as telemedicine and connected vehicles. Furthermore, hyper-connectivity, which increases the number of terminals and sensors connected through the Internet, allows 5G to be utilized as the underlying technology of Internet of Things (IoT), Internet of Everything (IoE), smart homes and smart cities. Knowing this, most governments have made substantial efforts to build information and communications technology (ICT) infrastructure and create new services to develop cross-industry and ecosystem applications and secure national competitiveness in the future 5G market (Cave, 2018; Frias and Pérez Martínez, 2018; Kabalci, 2019; Sgora, 2019).

However, despite the affirmative atmosphere for 5G, there is concern about the successful diffusion of 5G (Osseiran et al., 2016; Xiang et al., 2016). One matter of concern is the question of whether the initial demand for 5G is sufficient. 2G and 4G, which are considered successful, provided differentiated services such as wireless communication and high-speed wireless internet from the previous generation. On the other hand, 5G in the early stages has not offered services different from those of 4G yet, except for the faster transmission rate. Of course, consumers will prefer faster and more stable services than before, but their preferences may change if communications charges increase. In particular, the fast data transmission rate of 5G allows consumers to use more data, so consumers may have to pay as much for their data usage as they did under previous generations. This can be a major obstacle for consumers' initial acceptance of 5G. Another concern is the technological time lag between 5G technology and various 5G services. On 3 April 2019, 5G services went live for Korean consumers and will be commercialized worldwide around 2020, but Business to Business (B2B) applications using 5G would need more time before being introduced to consumers. Gartner (2018) anticipated that commercialization of autonomous vehicles will need more than 10 years, and smart robot and smart factory technologies will require 5–10 years. Hence, companies will likely take conservative approaches to 5G applications due to their vague economic validity. These concerns can increase consumer fear, uncertainty, and doubt (FUD), and it may influence consumer acceptance of 5G in the form of purchase delay.

The potential for consumer adoption delay is a critical issue of the 5G market. Mobile communication technology has a relatively short technology life cycle, so consumer purchase delay might lead to non-adoption. Future demand can be overestimated if those non-adoptions are considered in the demand forecast process. The misleading estimates of future demand may not only impede the spread of 5G, but also cause market failure and distortion of the entire 5G industry, while industrial and national resources are expected to be extensively used in 5G-based industry. Despite the criticality of consumer purchase delay behavior, to the best of our knowledge, a 5G diffusion study considering the purchase deferral has not yet been conducted. Therefore, the current study analyzes consumer preference and acceptance for 5G services. To make this possible, this study estimates consumer preference for technical attributes and application services of 5G by using a mixed logit model and conducting simulations to forecast the future 5G market based on the estimation results. Additionally, this paper analyzes the consumer delay factor for 5G service adoption by using an ordered logit model.

The remainder of the current study is organized as follows. Section 2 offers a literature review of the 5G market and consumer purchase delay behavior. Section 3 presents the modeling methods employed in the current paper and a description of the survey data set. Section 4 shows the estimation results and the market simulation under assumed future 5G markets, and additionally explains the purchase delay behavior of potential 5G service consumers. Section 5 presents the conclusions and directions for future study.

2. Literature review

The diffusion of ICT has been investigated from several different perspectives, particularly the application of modeling and forecasting (Fildes and Kumar, 2002; Meade and Islam, 2015). However, most studies deal with the spread of hardware like television, cellular phones, computer, and network equipment, and only a few studies handle the diffusion of mobile communications. Most studies have focused on the impacts of market competition, technology standardization, price, infrastructure cost, and so forth on the number of subscribers. They also concentrated on 2G as an object of study, because it led to a dramatic increase in the number of new subscribers where mobile communication subscribers were originally absent, resulting in a significant change in market structure and economic feasibility (Bohlin et al., 2010; Gruber and Verboven, 2001; Koski and Kretschmer, 2005; Li and Lyons, 2012; Rouvinen, 2006).

Gruber and Verboven (2001) analyzed the spread of 1G and 2G in 140 countries over the period from 1981 to 1997, including licenses, consumer switching costs, and the technological standard. They found that diffusion between countries converged slowly

[1] Worldwide wireless data transmission traffic is anticipated to grow at a CAGR of 23.7% for the next 16 – 21 years (Cisco). Mobile data traffic of South Korea is expected to increase by about 10 times over the next six years from 2018 to 2023 (ETRI, 2018).

and consumer switching costs affect the diffusion process. They also suggested that setting a single technological standard accelerates the diffusion of digital technologies. Koski and Kretschmer (2005) analyzed the impact of standardization and price on the diffusion of 2G, using 2G subscriber data from 32 countries during the 1990s. They suggested that standardization accelerates 2G diffusion and penetration pricing is effective in monopolistic markets. Rouvinen (2006) analyzed the effects of competition between multiple standards and market competition on 2G diffusion for 165 countries from 1993 to 2000. They found that standard competition hinders and market competition promotes 2G diffusion in both developing and developed countries, while the speed of diffusion is not significantly different between them. They also suggested that a large potential user base and network effect played a more important role in developing countries. Bohlin et al. (2010) analyzed the spread of 2G and 3G in 177 countries from 1991 to 2007, and considered market and technology competition with the speed of diffusion. They identified that per capita income, urbanization and Internet penetration rates have a positive influence on diffusion. They also found that first-generation technologies boosted diffusion of the second generation, but that second-generation technology had a negative impact on diffusion of the third generation. Li and Lyons (2012) used mobile subscriber data from 30 countries to analyze mobile telecommunication diffusion factors, including the number of enterprises, standardization, and service price. They thought that both the number of networks and the history of market structures affected the speed of mobile diffusion. They insisted that digital technology, standardization, privatization, and independent regulation are also important positive factors. Most previous studies have empirically investigated the diffusion of 2G and 3G, but they did not consider subsequent generations and have failed to explain other factors beyond standardization and market competition.

While B2C businesses such as mobile data services had a decisive role in the diffusion of previous generations, in the case of 5G, various B2B applications are expected to play an important role (Frias and Pérez Martínez, 2018). However, these changes will be gradual and consumers will still be crucial to secure the initial demand for 5G (LGERI, 2018). In this respect, investigating consumer preference and behavior is important and purchase delays have been studied as a way of understanding consumer behavior. Consumers often delay the purchase of a product or service to gain more time and energy to search for information and make better decisions, but at the same time they will have fewer opportunities or more costs. Consumer purchase delay often pose a major threat to the sales of businesses. Therefore, factors affecting the consumer's purchase delay behavior have become a subject of interest to scholars (Anderson, 2003; Cho et al., 2006; Greenleaf and Lehmann, 2002; Inman and Zeelenberg, 2002; Loewenstein, 1988; Tversky and Shafir, 2016).

Loewenstein (1988) and Tversky and Shafir, 2016 demonstrated the applicability of behavioral economic approaches for explaining consumers intertemporal choice behavior. Their experimental evidence showed that consumer purchase delays have a significant impact on their purchasing decisions. Additionally, they revealed that the tendency of deferring a decision can increase when the offered choice set is enlarged or improved. Greenleaf and Lehmann (2002) classified the reasons why consumers might delay their important decisions. They suggested that time pressure, the need for information, unaffordability, uncertain need, social and psychological risks, product and financial risks, and finding shopping unpleasant are the main factors that lead to postponing purchases. Inman and Zeelenberg (2002) examined the consequences of maintaining the status quo versus switching via psychological experiments. They found that the more consumers expect to regret buying something, the more likely they are to postpone a purchase. Anderson (2003) presented a rational-emotional model that considers the key factors such as negative emotions, decision-making strategies, and preference uncertainty for consumer purchase avoidance. They determined four decision avoidance effects: choice deferral, status quo bias, omission bias, and inaction inertia. Cho et al. (2006) investigated the various factors that delayed purchases in online shopping and divided the purchase delay into overall hesitation, shopping cart abandonment, and hesitation to click the final payment button. They observed that overall hesitation appeared when a consumer has an unfavorable attitude toward online shopping or wants to avoid regret after making a wrong decision. They also found evidence of the shopping cart abandonment effect, which is when a decision is delayed because there are too many alternatives or the website is unreliable.

Although previous studies empirically analyzed the diffusion of former generations of mobile communications and identified the factors affecting consumer purchase delay, to the best of our knowledge, there has not yet been a paper investigating consumer preference and behavior in terms of 5G services. Identifying the consumer preference on 5G technology and applications is essential for both telecommunication company and policymakers. This paper focuses on the specific attributes of 5G technology and applications with the consumer purchase delay.

3. Methodology

3.1. Model specification

This study analyzes consumer preference for 5G services and consumer behavior regarding purchase delay. To investigate these topics, we use discrete choice models based on random utility theory. The discrete choice model assumes the utility function that consumer i chooses a product or service j (McFadden, 1974; Train, 2009), and it can be written as follows:

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \sum_k \beta'_{ik} \cdot X_{kj} + \varepsilon_{ij} \tag{1}$$

In Eq. (1), the utility can be divided into the deterministic part V_{ij} and stochastic part ε_{ij}. The deterministic part consists of the preference parameter for each attribute k of the service j (β_{ij}) and the observable attributes for alternative j (X_{ij}). Depending on the assumptions about β and ε, discrete choice models are classified into various models, and the current study employs two models: one is a mixed multinomial logit model to estimate the consumer preference for 5G service, and another is an ordered logit model to analyze the purchase delay behavior of potential 5G consumers.

The first part of the current study uses the mixed logit model to derive the consumer preference, marginal willingness to pay (MWTP), and the relative importance of 5G services. The multinomial logit model is extensively employed and enables an easy estimation, but it has a few demerits, such as the homogeneous-preference assumption and an independence of irrelevant alternatives (IIA) property (Train, 2009). To overcome these problems, the mixed logit model, which reflects consumer heterogeneity and has a looser IIA assumption, might be considered. For this reason, the mixed logit model has been widely used in analyzing differentiated products, market segmentation, targeted marketing, and forecasting for new products (Koo et al., 2013; Lee et al., 2011; Shin et al., 2014; Shin et al., 2016; Train and Sonnier, 2005; Train, 2009). In this study, we employed the mixed logit model and assumed that the vector of coefficients to be estimated follows either a normal or lognormal distribution with mean b and variance covariance matrix W, while $f(\beta)$ is the assumed continuous distribution function of β. The choice probability of the ith consumer choosing alternative j, P_{ij}, can be expressed as follows (Train, 2009).

$$P_{ij} = \int \left(\frac{e^{\sum_k \beta'_{ik} x_{kj}}}{\sum_{l=1}^{J} e^{\sum_k \beta'_{ik} x_{lj}}} \right) f(\beta) d\beta \tag{2}$$

To derive the economic value of each attribute, we calculate the MWTP of each attribute k, as given in Eq. (3). The MWTP represents the monetary units of payment needed to compensate for the change of attribute k by a unit. We can also calculate the relative importance (RI) of each attribute k, as given in Eq. (4). The RI indicates the degree to which each attribute affects consumer choice.

$$\text{Median } MWTP_k = \text{Median}_i\left[-\frac{\partial U_i/\partial x_i}{\partial U_i/\partial x_{price}} \right] = \text{Median}_i\left[-\frac{\beta_{ik}}{\beta_{i(price)}} \right] \tag{3}$$

$$RI_k = \frac{1}{N}\sum_{n=1}^{N}\left(\frac{partworth_{nk}}{\sum_k partworth_{nk}} \times 100 \right) \tag{4}$$

The second part of the current study uses an ordered logit model to analyze the delay factors influencing the purchase of 5G services. Unlike the multinomial logit model, the ordered logit model is an appropriate method for analyzing an ordinal choice situation. Individual consumers' 5G service purchase timing is expected to vary depending on the 5G service type, so the current study employs an ordered logit model that categorizes 5G service purchase time as ordinal data. The ordered logit model explains the relationship between the purchase time and purchase delay factor by using a latent continuous variable (y*), which is characterized by threshold points μ_i, as described in equation (5):

$$\begin{aligned} y_i^* &= \beta x + \varepsilon \\ y_i &= \begin{cases} 0 & \text{if } y_i^* < \mu_0 \\ 1 & \text{if } \mu_0 < y_i^* \leqslant \mu_1 \\ \vdots & \vdots \\ n & \text{if } \mu_{n-1} < y_i^* \leqslant \mu_n \end{cases} \end{aligned} \tag{5}$$

where μ_i represents thresholds to be estimated, along with parameter β.

Using a transformation function, the model creates a linear index of the probabilities with a cumulative standard normal distribution. Given the classification, the study derives the probability of belonging to each class as follows:

$$P(y_i = n) = P(\mu_{n-1} < y_i^* \leqslant \mu_n) = \Phi(\mu_n - \beta x) - \Phi(\mu_{n-1} - \beta x) \tag{6}$$

where Φ is the logistic cumulative distribution function.

Meanwhile, the current study uses the Bayesian inference technique to overcome problems that involve complex calculations. Bayesian estimation methods have been used to avoid the complicated integral calculation of a multivariate density function and to overcoming the initial value problem and global optimal solution problem (Allenby and Rossi, 1998; Edwards and Allenby, 2003; Huber and Train, 2001). In addition, the results from the Bayesian inference estimation can be interpreted as the classical estimation results (Train and Sonnier, 2005).

3.2. Choice experiment and data

Due to the diversity of 5G services and their prospective customers, it is not appropriate to discuss the overall 5G diffusion with a specific service or consumer. In addition, 5G service is a worldwide emerging state-of-the-art technology, so it is infeasible to obtain comprehensive market data at such an early stage. To resolve this issue, we use conjoint analysis to collect the stated preference data from potential 5G service users. In conjoint analysis, individual respondents make choices to maximize their utility in a hypothesis choice situation, comprised of virtual alternatives with combinations of core attributes, similar to a real choice situation (Green and Srinivasan, 1978, 1990). Further, conjoint analysis can provide the part-worth and marginal willingness to pay for each attribute

Table 1
Characteristics of survey respondents.

		Observations within sample (ratio, %)
Total		528 (100%)
Gender	Male	279 (52.8%)
	Female	249 (47.2%)
Age	20–29	111 (21.0%)
	30–39	133 (25.2%)
	40–49	161 (30.5%)
	50–59	123 (23.3%)
Monthly household income (millions of KRW[a])	Under 3	123 (23.3%)
	3–4	89 (16.9%)
	4–5	95 (18.0%)
	Over 5	221 (41.9%)

[a] According to the Bank of Korea (www.bok.or.kr), USD 1.00 was worth KRW 1109.3 on September 2018.

(Gustafsson et al., 2013). Data were collected by Gallup Korea, which is a professional survey company. Prior to the main survey, an online pilot test was conducted with 118 participants to test the validity of the experiment design. Reflecting the modifications from the pilot test, the main survey was conducted in September 2018. Table 1 summarizes the demographic characteristics of the 528 survey respondents.

To incorporate representative 5G characteristics in our study, we chose the attributes used in the survey from 5G mobile services and 5G application services. We considered the “data transmission rate” and “monthly data offer” as core attributes of 5G mobile services. “Connected vehicles” and “IoT for family use” are considered as 5G application services that represent ultra-low latency and hyper-connectivity applications, respectively. These application services are currently available and well-known in the media, so we believe that they can provide fruitful information on the consumer decision-making process. Finally, an additional monthly payment amount was considered in our 5G subscription model with the above attributes. Table 2 shows the attributes and their levels used in the conjoint survey.

The number of all possible alternatives is 1024, but we reduce the number of alternatives to 16 through a fractional factorial design to lessen the respondent burden and maintain the orthogonality among attributes. We composed each choice set (Fig. 1), including three 5G services and one no-choice option, and provided the three choice sets to each group.

Table 2
5G service attributes and their levels.

Attribute	Levels	Description
Data transmission rate	No use 2 Gbps 5 Gbps 10 Gbps	Maximum data download speed (The actual speed decreases when the number of users increases): 2, 5 and 10 Gbps can download a UHD movie at least 20, 8, and 4 s, respectively.
Monthly data offer	10 GB 50 GB 100 GB 150 GB	The amount of data offered from the 5G service plan in a month.
Connected vehicle	No use	
	Provide basic information	Connected vehicle provides basic information (traffic information, hazardous road section, vehicle diagnosis and so on) when people drive.
	Driving assistant	Connected vehicle partially intervenes to assist drivers when driving (avoid a vehicle pedestrian collision, emergency braking).
	Advanced autonomous driving support	Connected vehicle drives autonomously (vehicle platooning, cooperative lane changes and collision avoidance, remote driving, and so on).
Internet of Things	No use	
	Low level	The user can directly check the information measured and provided by the Internet device and manually control the individual device.
	Middle level	Easy control of all devices connected directly to the user through various Internet services.
	High level	Minimize user involvement with automated customized services.
Additional charge (KRW/month)	0 10,000 30,000 50,000	Additional payment amount compared to the current service level.

There are four types of 5G services (three 5G services and one no service). If you actually purchase the below services:

1) Please, answer the preference ranking for three 5G service types from Types A to C.

2) Please, select your most preferred 5G service. If there is no preferred 5G service, choose no choice.

Attribute	Type A	Type B	Type C	No choice
Data transmission rate	5Gbps	No use	10 Gbps	
Monthly data offer	10 GB	100 GB	100 GB	
Connected vehicle	Driving assistant	Advanced autonomous driving support	Advanced autonomous driving support	There are no preferred 5G service
Internet of Things	High level	Low level	No use	
Additional charge (KRW)	10,000	0	10,000	
Preference ranking of 5G service	No.__	No.__	No.__	
The most preferred 5G service (choose only one service)				

Fig. 1. Questions posed in the conjoint survey.

4. Empirical analysis

The current study aims to provide competent diffusion strategies for 5G services in the Korean market considering the purchase delay of consumers. For this, we carried out three different analyses. First, we analyzed the consumer preference for 5G services by using the mixed logit model and stated preference data from the conjoint analysis in Section 4.1. We considered representative attributes of 5G services and analyzed consumer preferences and their MWTP for each attribute. Second, in Section 4.2, we forecasted the 5G services market share, based on the estimation results from the first analysis. This means that Section 4.2 deals with the application of forecasting techniques based on stated-preference data that does not consider consumer purchase delay behavior. However, the forecasted market share will be further reduced if consumer delay in purchasing 5G application services is accurately reflected in the model. Thus, finally, in Section 4.3, we investigated the relationship between the adoption time of 5G services and potential purchase delay factors.

4.1. Consumer preference for 5G services

In the first part, we used a mixed logit model to analyze the consumer preference for 5G service, which consisted of five attributes. When consumer i chooses the 5G service j, the utility function for a mixed logit model can be expressed as follows:

$$
\begin{aligned}
U_{ij}= & \ \beta_{i1}\cdot \mathrm{speed}_j + \beta_{i2}\cdot \mathrm{data}_j + \beta_{i3}\cdot \mathrm{connected1}_j + \beta_{i4}\cdot \mathrm{connected2}_j + \beta_{i5}\cdot \mathrm{connected3}_j \\
& + \beta_{i6}\cdot \mathrm{IoT1}_j + \beta_{i7}\cdot \mathrm{IoT2}_j + \beta_{i8}\cdot \mathrm{IoT3}_j + \beta_{i9}\cdot \mathrm{price}_j + \varepsilon_{nj}
\end{aligned} \tag{7}
$$

where speed_j is the data transmission rate and data_j is the monthly data offer in a 5G service plan. $\mathrm{connected1}_j$, $\mathrm{connected2}_j$, and $\mathrm{connected3}_j$ denote the dummy variable for the level of connected vehicle in increasing order, and no use of connected vehicle service is set as the reference. $\mathrm{IoT1}_j$, $\mathrm{IoT2}_j$, and $\mathrm{IoT3}_j$ are also dummy variables for the level of IoT in increasing order, and no use of IoT service is set as the reference. price_j is the additional payment for using a 5G service against the current service. We assumed a lognormal distribution for the coefficient of $price_j$ and normal distribution for the others.[2] For the continuous variables, we used a unit of 10 Gbps for $speed_j$, 100 GB for $data_j$, and 10,000 KRW for $price_j$. The estimation results, including the MWTP and RI[3] for each attribute, are shown in Table 3.

Table 3 shows that the standard deviations of all parameter estimates are statistically significant, and it implies that consumer preference for the attributes of 5G technology and new services are heterogeneous. Therefore, we confirm that the mixed logit model is appropriate for our purposes. The results show that consumers significantly prefer a faster speed, large data offer, and lower 5G service fees. In terms of connected vehicles, consumers prefer 'provide basic information' over 'driving assistant' and 'high level of autonomous driving.' Moreover, mean difference between 'driving assistant' and 'high level of autonomous driving' is not statistically significant based on the *t*-test.[4] It means that consumers did not have additional utility when companies provided the 'Connected 2′ option after launching 'Connected 1.' In IoT services, the consumer prefers, in descending order, mid-level, high-level, and low-level. However, the mean difference between mid and high level is not statistically significant based on the *t*-test results. This means that consumers may feel that providing mid-level IoT services is sufficient. The highest median MWTP is for 'provide basic information' of the connected vehicles level (9319 KRW; 8.4 USD), followed by 'high level of autonomous driving' (8580 KRW; 7.7 USD) 'driving assistant' (8272 KRW; 7.5 USD), and mid-level IoT (6505 KRW; 5.9 USD). Additionally, if the download speed of 5G services is twenty times faster, consumers' MWTP will be 23,820 KRW (21.5 USD). The RI of price (33.3%) is the highest, followed by connected vehicles (28.1%), IoT (20.2%), speed (10.2%), and data (8.2%). Based on this, 5G service providers can establish market strategies and reasonable pricing policies considering 5G service attributes.

4.2. 5G market simulations

Based on the estimation results from the first part of this chapter, we conducted market simulations to predict consumer acceptance of 5G services in South Korea. For market simulations, we assumed a few scenarios considering 5G technology improvements and investigated the changes in choice probability for 5G services in each scenario. The number of Korean 4G subscribers in April 2019 was 56,338,826, which is account for 85.7% of total mobile communication users; this indicates that as the matter stands, 5G may compete with 4G in the mobile communication market. To derive rational results, we assume scenarios where new 5G service compete with existing 4G service. 4G service for analysis is assumed to reflect the current level of 4G technology as follows: 1 Gbps data transmission rate with 100 GB of data provided per month[5], but not providing connected vehicles or IoT service, with no additional usage fee. The assumed base scenario for 5G is as follows: 10 Gbps data transmission rate with 150 GB of data provided per month, providing driving assistant level services for connected vehicles, mid-level IoT services, and an additional usage fee of 30,000 KRW.

Scenario 1 assumes that the data transmission rate increases from 4 Gbps to 20 Gbps, while maintaining the other 5G service levels the same as the base scenario. Fig. 2 shows the impact of speed improvements on the 5G market, and consumer acceptance increased from 41.1% to 55.3%. The results show that the 5G service acceptance increased by 2.9% to 4.2% for every 4 Gbps increase in the data transmission rate.

Scenario 2 assumes that the amount of monthly data offered increases from 30 GB to 300 GB, while maintaining the other 5G service levels the same as the base scenario. According to the analysis of scenario 2, the acceptance of consumers increased from 42.1% to 51.5%. The results show that consumer acceptance of 5G services increased sharply from the moment when the monthly data offer exceeded 240 GB (See Fig. 3).

Scenario 3 assumes that additional charges for service use decreased from 60 thousand KRW to 0 KRW, while maintaining the other 5G service levels the same as the base scenario. The results show that consumer acceptance of 5G service increased from 31.6% to 80.3%. The acceptance rate of 5G service increased by 4.0–14.1% for depreciations in additional fees of 10,000 KRW (See Fig. 4).

4.3. Delay in purchasing 5G services

In this section, an ordered logit model was used to analyze consumer purchase delay behavior, especially for connected vehicles

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[2] In general, a rational economic person does not prefer the higher price, ceteris paribus, so the researcher assumes a log-normal distribution for the price coefficient. On the other hand, if the researcher cannot decide the preference direction of preference on attributes, the coefficients for them are assumed to be normal distributions (Train, 2009; Train and Sonnier, 2005). In this study, we assumed that consumers have heterogeneity regarding the preference of non-price attributes.

[3] In the current analysis, the MWTP and RI of each attribute are calculated by Equations (3) and (4) using 2000 draws of the estimation results.

[4] We enumerated the preferences for each level based on the mean of the estimated coefficients, but their variances seem to be relatively much larger than mean differences. To identify the differences of overall preference among coefficients of Connected 1–3 and IoT 1–3, we performed t-tests. The test results showed that the differences in overall preference between them were not statistically significant. However, the mean differences among Connected 1–3 and IoT 1–3 were still partially valid.

[5] Since the launch of 4G mobile services in Korea, LTE data traffic has been steadily increasing, which in turn has increased consumer's financial burdens for telecommunication charges. To alleviate these communication costs, the Korean government proposed a low-cost system by reforming the related policies twice. Under this revamped policy, major Korean carriers divided their mobile data plans into lower-cost plans and higher-cost plans; lower-cost plans offer 1 to 4 GB data monthly and higher-cost plans offer 100 GB to unlimited data monthly. In this situation, consumers who use 8.4 GB data per month on average (www.mist.go.kr) may consider the 100 GB plan as the most affordable data plan. To reflect this situation, we assumed the level of data offers to be set as 100 GB in the 4G baseline scenario.

Table 3
Estimation results for 5G service.

Coefficients	Assumed distribution	Mean, b		Standarddeviation, $\sqrt{W}$		Median MWTP	RI
Speed	Normal	1.5086	*	1.6864	*	1191 (KRW/Gbps)	10.2%
Data	Normal	0.4874	*	0.9693	*	33 (KRW/Gb)	8.2%
Connected1	Normal	1.3158	*	1.5627	*	9319 (KRW)	9.2%
Connected2	Normal	1.1408	*	1.5655	*	8272 (KRW)	9.4%
Connected3	Normal	1.1714	*	1.5433	*	8580 (KRW)	9.5%
IoT1	Normal	0.6789	*	1.0794	*	5158 (KRW)	6.3%
IoT2	Normal	0.7787	*	1.1018	*	6505 (KRW)	7.0%
IoT3	Normal	0.7591	*	0.9611	*	5936 (KRW)	6.9%
Price	Lognormal	−2.0732	*	4.1921	*		33.3%

*e coefficients based on the on.
Note: * denotes significance at the 1% levels.

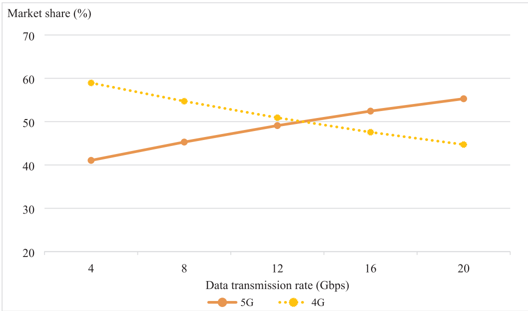

Fig. 2. Market share when the data transmission rate changes.

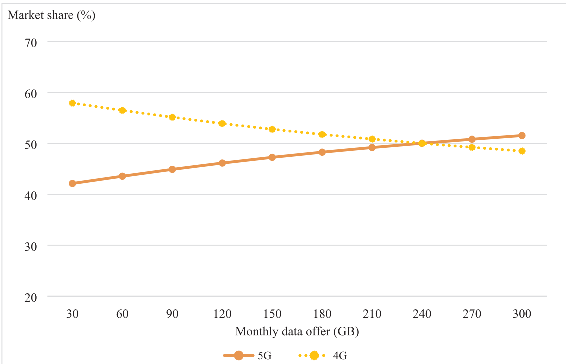

Fig. 3. Market share when the monthly data offer changes.

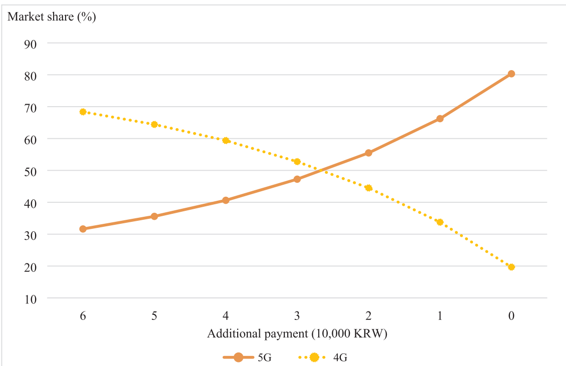

Fig. 4. Market share when the 5G service fee changes.

Table 4
Information about the intention to use and purchase time of 5G services.

Respondents		5G service		Connected vehicle		Internet of Things	
		Number	Ratio	Number	Ratio	Number	Ratio
Intention to use		491	100%	438	100.0%	459	100.0%
Time to purchase	Immediately upon release	48	9.8%	31	7.1%	36	7.8%
	Within a year	175	35.6%	105	24.0%	160	34.9%
	Within 2 years	133	27.1%	99	22.6%	123	26.8%
	Within 3 years	82	16.7%	92	21.0%	79	17.2%
	Within 5 years	27	5.5%	60	13.7%	29	6.3%
	Over 5 years	26	5.3%	51	11.6%	32	7.0%

and IoT services. Prior to the analysis, we surveyed the willingness of adoption for the entire 5G service. Of the total 528 respondents, 491 respondents answered that they would like to use 5G service in the future. Specifically, only 45.4% of respondents responded that they intended to use 5G service within a year since the launch of the service. Generally, demand forecasting studies using the stated preference data of the consumer assume that the consumer willingness to use or purchase becomes future demand regardless of the purchase timing. However, more than half of the respondents in our study are planning to purchase 5G service one year after its launch. Therefore, we considered the purchase timing of 5G services to resolve the overestimation problem of future demand. Table 4 summarizes the statistics of 491 respondents regarding the intention to use 5G services and purchase timing.

83.0% of total respondents were willing to use a connected vehicle in the future, and 31.1% of them answered that they have intention to use a connected vehicle within a year after launch. In the case of IoT, 86.9% of the total respondents intended to use the service in the future. Among them, 42.8% answered they intended to use an IoT service a year after launch.

Based on data regarding future intentions to use a connected vehicle and IoT service, the relationship between the purchase time and delay factor is analyzed using an ordered logit model. For empirical analysis, we consider the explanatory variables differently according to the properties of each service. For instance, the variable ‘low compatibility with other devices’ is not included in the empirical model for a connected vehicle, because the inter-vehicle communication system already presumes compatibility with other vehicles or infrastructure. The variables used in the ordered logit model are described in Table 5, and the estimation results are shown in Table 6.

According to the estimation results of the ordered logit model, all explanatory variables of the connected vehicle are statistically significant delay factors. ‘Burden of expenses’ is the most influential factor when consumers delay their decision for the purchase of a

Table 5
Description of variables used in the ordered logit model.

Variables		Connected vehicle	Internet of things	Remarks
Dependent variable	Service purchase timing	Shortly after release: 0 Within a year: 1 Within two years: 2 Within three years: 3 Within five years: 4 5 years later: 5		
Explanatory variable	Not necessary	O	O	Dummy
	Mistrust	O	O	
	Low compatibility with other devices		O	
	Burden of expenses	O	O	
	Limited service area	O	O	
	Insufficiency of functionality and performance	O	O	
	Inconvenience of use	O	O	
	Waiting for a certain number of users	O	O	
	Waiting for a technology and service development	O	O	
Control variable	Gender			Male: 1 Female: 0
	Age			
	Monthly cost			
	Daily internet use time			
	Service awareness			Five-point scale
	Service preference			Five-point scale
	Service use experience			Dummy
	Personality propensity to use new technology			Five-point scale
	Education level			
	Size of family			
	Monthly income			

*e coefficients based on the on.

Table 6
Estimation results for a 5G service purchase delay.

	Connected vehicle		IoT	
Coefficient	Mean	Standard deviation	Mean	Standard deviation
Not necessary	2.6065**	0.0001	2.9869**	0.0321
Mistrust	3.0110**	0.0002	2.2306**	0.0249
Low compatibility with other devices			2.8005**	0.0420
Burden of expenses	3.2120**	0.0001	2.8844**	0.0342
Limited service area	2.4619**	0.0001	1.7709**	0.0343
Insufficiency of functionality and performance	2.2127**	0.0001	3.2768**	0.0425
Inconvenience of use	1.1271**	0.0001	2.6954**	0.0983
Waiting for a certain number of users	1.5000**	0.0002	2.3359**	0.0279
Waiting for a technology and service development	1.9655**	0.0001	2.4907**	0.0564
Gender	−0.1611**	0.0002	0.1077**	0.0327
Age	0.0063**	0.0001	−0.0326**	0.0069
Monthly cost	0.0000**	0.0000	0	0.0000
Daily internet use time	−0.0434**	0.0001	−0.4818	0.0388
Service awareness	−0.1402**	0.0001	−0.3071**	0.0215
Service preference	−0.1489**	0.0001	−0.4950**	0.0417
Service use experience	−0.6840**	0.0001	1.0670**	0.0309
Personality propensity to use new technology	−0.1811**	0.0001	−1.1950**	0.0209
Education level	−0.0349**	0.0002	−0.0607**	0.0245
Size of family	−0.0140**	0.0001	−0.1067**	0.0125
Monthly income	−0.0004**	0.0001	−0.0001**	0.0002

*e coefficients based on the on.
Note: ** denotes significance at the 5% levels.

connected vehicle, and 'mistrust' and 'not necessary' are also important delay factors after considering the 'burden of expenses.' In terms of IoT services, all explanatory variables are statistically significant, and the major reasons for the purchase delay are 'insufficiency of functionality and performance,' 'not necessary,' and 'burden of expenses.'

5. Conclusion

5G mobile service was commercialized in South Korea on April 2019, potentially facilitating the development and integration of new application services (such as connected vehicles and IoT services) through convergence with various fields. For the successful integration of 5G technologies and services, it is necessary to understand the potential consumers' preferences and purchase behavior. In this context, this study analyzed consumer preference for 5G services based on data from a conjoint survey. Furthermore, we also analyzed consumers purchase delay behavior to mitigate inaccuracies in demand forecasting that existing diffusion studies based on stated preference data have overlooked.

From the results of the mixed logit model in Section 4.1, we verified that consumers preferred a 5G service with faster speed, large data offers, and a lower service fee. In terms of the relative importance (RI), the service price was the highest (33.3%), followed by connected vehicles (28.1%), IoT (20.2%), speed (10.2%) and data (8.2%). In Section 4.2, we conducted 5G market simulations in which 4G and 5G competed with one another to investigate the impacts of the data transmission rate, monthly data offer, and charge on potential 5G consumers. Our results demonstrated that the 5G adoption rate increased as the data transmission rate and data offer increased, while the service price decreased. In Section 4.3, to adjust the overestimated 5G market share in the previous section, we analyzed the consumer purchase delay factor for a connected vehicle and IoT service. The results showed that only 31.1% of respondents who answered they were going to purchase a connected vehicle in the future will use it within a year after launch. The main reasons for the delayed purchase of a connected vehicle were the cost burden, distrust, and a lack of need. In terms of IoT, the adopter within a year after launch is 42.8% and the main reasons for delayed purchase were the lack of functionality, poor performance, the sentiment that 5G for IoT devices is unnecessary, and cost burden.

Based on the results of our empirical analyses, we suggest the following implications. Firstly, in terms of innovation theory, consumers identified 5G technology as a continuous innovation that simply improves the technical capabilities of the previous generation. On the other hand, practitioners constantly insisted that 5G technology is a discontinuous innovation that will change consumer usage patterns and industry paradigms (Bauer and Bohlin, 2018). This discrepancy between the perceptions of consumers and producers of 5G is not desirable for facilitating diffusion and activate consumer demand in the 5G market. Thus, corporations and governments should focus on altering consumer perceptions of 5G technology and promoting innovative aspects of 5G services and applications. Secondly, we have empirically analyzed the existence value-action gap in the ICT industry under consideration of consumer purchase delays. Generally, the value-action gap, i.e., the difference between what people say and what people do, has been largely studied in environmental fields of study (Blake,1999; Gifford et al., 2011; Kollmuss and Agyeman, 2002; Rogers, 2010; Shim et al., 2018; Shin et al., 2018), whereas such studies are scarce in the ICT fields. Considering the technology life cycle in the ICT industry, it is not sure that a purchase delay of more than one year will lead to an actual purchase (Chang and Fan, 2016; Shahmarichatghieh et al., 2016; Coccia, 2017). Under the scenarios that take into account the mid-level attributes considered in our analysis[6], consumers' acceptance rate of IoT services was 47.7%, but decreased to 20.4% when considering consumer purchase delay. This empirical evidence can remind ICT practitioners to take into account consumer delays when they need accurate and punctual demand forecasting without overestimation. Finally, our findings regarding 5G purchase delay factors are helpful to scholars in behavioral economics and marketing sciences. Particularly, our research provides a different point of view from previous literature in that it deals with 5G services that are not yet in the market. For marketers and policymakers, our findings also suggest that it is important to establish an appropriate pricing policy and promote the usefulness of 5G services to reduce consumer purchase delays.

This study has limitations arising from the hypothetical nature of the stated preference approaches. We used stated preference data to analyze consumers preferences for 5G and application services that were not yet released into the market during the survey period. Hence, respondents were in unfamiliar situations in which complete information was not available. Although we tried to minimize bias from respondent's incomplete understanding in various ways, some bias remains because the participants' understanding of the 5G market differs. Furthermore, we are aware that the number of research subjects of this study was limited. 5G services are expected to have a greater impact on the market and affect new application services as time goes on. Therefore, it is necessary to consider new services or new mobile ecosystems in future studies. Specifically, we did not ask the respondents if they owned a connected vehicle in our questionnaire. Therefore, further research needs to incorporate connected vehicle usage to determine more accurate predictions. Additionally, our scenarios did not reflect all changes in the 5G environment or people's lives resulting from gradual advances in 5G technologies. Despite these limitations, this paper is useful as an early study of consumer preferences for 5G technology. With the commercialization of 5G just beginning, proactive pricing, bundling, and marketing strategies are necessary to successfully foster its use and adoption.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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