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The Value of Wi-Fi as Entertainment: An Application to Free Wi-Fi in City Buses of Korea

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ABSTRACT

As the usage of mobile data is significantly increasing, the demand for free public Wi-Fi also continues to grow. The ministry of science & ICT(MSIT) and some municipalities in Korea have been constructing free Wi-Fi networks on mass transportation for the benefit of users. In this study, we estimate the economic value of Wi-Fi for leisure based on demand function, which considers the time cost of using the internet. By using the 2016-2019 Korean Media Panel(KMP) data, we estimated the yearly consumer surplus of Wi-Fi and that of Wi-Fi in city buses. In this way, we showed the cost-benefit analysis could be carried out in public Wi-Fi projects.

1. Introduction

Recently, with the popularity of video streaming services in smartphones, individual demand for data traffic is rapidly increasing. Cisco(2019) reports global IP(Internet Protocol) traffic was 1.5ZB per year in 2017, and forecast that it will reach 4.8ZB per year in 2022. Wireless communication service traffic in Korea also increased from 30PB in January 2012 to 595PB in December 2019, which result in a twentyfold increase(MSIT 2012, 2020). As the data usage increases, demand for Wi-Fi is also expected to increase. Cisco(2019) forecasts that Wi-Fi will account for 51% of global IP traffic in 2022, up from 43% in 2017. In response to increasing Wi-Fi traffic demand, Cisco(2020) expects that the number of public Wi-Fi hotspots in the world will reach 628 million in 2023, compared to 169 million in 2018.

As is known, Wi-Fi is a complimentary service to cellular mobile service provided in the unlicensed spectrum band. Wi-Fi enables consumers to save money to those who are sensitive to cellular data expenses. Because the speed of Wi-Fi is comparable to that of the mobile cellular network, Wi-Fi is more useful when we consume data for massive downloads. Therefore, many municipalities in the world construct free public Wi-Fi hotspots. (Wikipedia)

Korea has also promoted public Wi-Fi networks since the mid-2010s. In Korea, consumers can use an open Wi-Fi network provided by telecommunications carriers and public Wi-Fi networks by the government. The government has urged the carriers to open a great portion of their Wi-Fi network to the public since 2012. The number of open Wi-Fi

provided by three big carriers in Korea amounts to 257 thousand in 2017, which is 65% of total access points (AP). Open Wi-Fi provides good quality with download (upload) speed of 374Mbps(336Mbps) in 2019, which is over the average LTE download(upload) speed of 159Mbps(43Mbps) (MSIT,2019). Besides, Wi-Fi also provides the benefit to mobile carriers by off-loading the data, which alleviates the congestion of the network.

Considering the benefits of Wi-Fi, the ministry of Science & ICT(MSIT) and some municipalities in Korea have expanded the free Wi-Fi network. According to the report of the National Assembly Research Service, since the government constructs and opens the Wi-Fi to the public in 2012, public Wi-Fi is now available in 13,369 public places in 2017. In late 2018 and 2019, the government expanded the Wi-Fi coverage by initiating the new construction in city buses in addition to stationary public places. Over 70 municipalities, including the Seoul metropolitan government, which began the project in 2011, also have constructed the public Wi-Fi with their budget(NARS,2019).

Although the provision of public Wi-Fi by the government and municipalities give some benefits to consumers, for the public expenditure to be justified, these projects should be evaluated by precise cost-benefit analysis. As the benefits of Wi-Fi, governments usually mention the amount saved phone bill on the part of consumers. However, since there are so many assumptions involved with this calculation, we may need more precise estimation based both on some economic model and on actual usage patterns from extensive survey data.

This study aims to estimate the economic value of Wi-Fi to evaluate the Korean government's expenditure projects for the expansion of public Wi-Fi. In the estimation, we employ the economic model by Goolsbee and Klenow(2006), which considers the time cost of using the internet to estimate its value. With the model, we can estimate the consumer surplus of internet usage through the Wi-Fi network, which is assumed to be equal to the value Wi-Fi.

To estimate the model, we use the Korean Media Panel(KMP) data during 2016-2019, which contains 9,000-11,000 respondent's digital activity records and characteristics each year. Also, using specific place data where individuals engaged in digital activity based on the KMP survey, we estimate the consumer surplus of Wi-Fi in public transportation. By disaggregating the benefit into specific transit like bus and subway, we estimate the consumer surplus of Wi-Fi in the city buses and compare it with its cost incurred in building Wi-Fi in all city buses in Korea.

The remainder of the paper is structured as follows. Section 2 reviews the previous literature estimating consumer surplus of Wi-Fi and internet service, and we primarily focus on studies using GK(2006) model. Section 3 explains the GK(2006) model and data generating process using the Korean Media Panel survey. Section 4 presents the result of panel analysis and estimate the annual consumer surplus of Wi-Fi for leisure. We then disaggregate the value by location and calculate the consumer surplus of Wi-Fi in city buses recently constructed by the Korean government to apply in cost-benefit analysis. Section 5 summarizes the paper and conclude with a discussion of policy implications and limitation of the study.

2. Literature Review

Most of the studies aiming to measure consumer surplus is based on the estimation of the demand function. However, the demand for Wi-Fi is difficult to estimate since it is provided free of charge. Because of this characteristic, most of the previous studies compute the cost-saving from using Wi-Fi either by calculation of saved data or by calculation of willingness-to-pay to derive the consumer surplus. We review some literature in this context first, and then we review

researches that applied GK(2006) model.

1) Estimating Value of Wi-Fi services

As the usage of unlicensed spectrum band increased, there have been some research attempts to measure the economic value of the services which uses the spectrum band, such as Wi-Fi. Since Wi-Fi service has similar characteristics to the internet, these studies have estimated its value by (referring other researches on) willingness-to-pay for broadband, the estimated value of mobile 3G networks, and the profits of related businesses(Thanki(2009); Milgrom et al.(2011); Cooper(2012)). Katz(2014) calculated consumer surplus as the willingness-to-pay, which is regarded as the price to be paid if traffic is transported through the cellular network.

In Korea, Kim et al.(2016) and Kim et al.(2017) computed the economic value of Wi-Fi. Kim et al.(2016) calculated that Korea's public Wi-Fi services are worth between \$126.8M-\$239.2M annually from 2012 to 2014. Kim et al.(2017) estimated the value of cellular off-loading by Wi-Fi as \$704M to \$1,407M per year in 2016. and the value of residential Wi-Fi as \$703M to \$1,406M per year in 2015. These studies derived consumer surplus from the perspective of cost savings, and this method is also used when the Korean government derives the benefits of public Wi-Fi. In addition to these studies, Hong et al.(2016) estimated the willingness to pay of super Wi-Fi utilized by TVWS(TV White Space) by using conjoint analysis. Estimation result shows that consumers are willing to pay \$4.6 per month when super Wi-Fi service are introduced in Korea.

<Table 1> below summarizes the results of studies that estimated the overall economic value of Wi-Fi.

Table 1
Summary of Recent studies of valuing Wi-Fi (in \$ billions)
Sources: Katz(2014), Kim et al.(2017)

		Thanki (2009)	Milgrom et al. (2011)	Cooper (2012)	Katz (2014)	Kim et al. (2017)
Cellular Offloading Wi-Fi	Consumer Surplus	N.A.	25	20.0	1.9	0.7-1.4
	Producer Surplus	N.A.	N.A.	26.0	10.7	0.6-1.2
	Benefit from High Speed	N.A.	12	N.A.	2.8	N.A.
	New Business Revenue	N.A.	N.A.	N.A.	0.3	N.A.
	SUBTOTAL	N.A.	37	46.0	15.7	1.3-2.6
Residential WiFi		4.3-12.6	>12.6	38.0	36.1	0.7-1.4

2) Estimating Value of Internet

Since the economic value of Wi-Fi comes from the use of the internet, it is also needed to review studies estimating the economic value of the internet itself. Because internet service also has a minimal marginal cost and the price is almost the same for all users, estimating consumer surplus from the demand for the internet is quite difficult. Previous researches that estimate consumer surplus of the internet have used various methods to overcome this difficulty. As mentioned earlier,

WTP of the internet was often assessed through conditional valuation method(CVM) and conjoint analysis method (Savage & Waldman (2005,2009); Rosston et al. (2010); Liu et al. (2018)). However, it is known that CVM and conjoint analysis involves some bias since these methodologies are based on surveys. To minimize any bias involved with these methodologies, Brynjolfsson et al.(2019) conducted choice experiments like single-binary discrete choice(SBDC) experiment and Best Worst Scaling(BWS) in various activities during 2016 and 2017 to measure the WTA(Willingness to Accept) of various activities. By using an incentive-compatible process, they decreased the bias that occurred during the survey and measured the WTA of accessing internet service. Some studies estimated WTP of internet service by using transaction data, which includes the characteristics of the internet used by consumers(Dutz et al. (2009); Lee & Whitacre (2017)). Greenstein & Mcdevitt(2011) measured consumer surplus from broadband by using the net cost incurred when consumers switch the service from dial-up to broadband.

In addition to the literature estimating WTP or WTA, there are other streams of research to derive the value of the internet. GK(2006) estimate the demand curve and compute the consumer surplus by relating the time consumers spend on a good to the opportunity cost of their time. In GK(2006) model, utility depends on purchased internet service and the fraction of time devoted to enjoying the internet. In the budget constraint, consumer's income refers 'full income' that can be earned when an individual works during all non-sleeping hours. Therefore the time cost is set as the forgone income. When the time spent on goods and services is considered as a factor of the utility function, it is possible to overcome the difficulty in estimating the demand function of time-intensive services like the internet due to its minuscule marginal cost and price variation. That is, GK(2006) model does not need the price and quantity of the internet to estimate the demand function. They applied this model to internet service to estimate the consumer surplus of the internet for the leisure of US in 2005. Nevo et al.(2016) overcame the difficulty of estimating the demand function of broadband service by finding variations from shadow price in a three-part tariff plan and derived the consumer surplus of the domestic broadband from the demand function. Since Wi-Fi is provided with almost free of charge in most public places,¹ Nevo et al.'s approach cannot be adopted.

As mentioned earlier, since there may be some limitations in the conjoint analysis or WTP analysis, we are going to adopt GK(2006) model in this paper.

3) Studies using Goolsbee & Klenow(2006) Method

Table 2
Summary of Recent studies using GK(2006) model

	Service	Country	Period	Consumer Surplus Estimated (Hausman Linear)
Goolsbee & Klenow(2006)	Internet	US	2005	2-3% of full income

¹ Because cost of Wi-Fi is also supported by communication cost or tax, we can't assume it as free. However we use term "almost free" because there's no marginal cost of using Wi-Fi.

Loomis(2011)	Urban Recreation Area	US	N/A	0.39% of full income
Brynjolfsson & Oh(2012)	Internet, TV	US	2007~2011	Internet: 5.83% of GDP TV: 10.17% of GDP
		Germany		0.8% of full income 1.78% of GDP
		Spain		1.01% of full income 2.04% of GDP
		France		0.55% of full income 1.24% of GDP
Pantea & Martens(2016)	Internet	Italy	2011	0.8% of full income 1.14% of GDP
		UK		0.81% of full income 2.09% of GDP
		Korea		3.4% of monthly household income
Byun(2018)	Public Radio	Korea	2016	0.4% of GDP

Full income first presented in Becker(1965), which can be earned when an individual works during all non-sleeping hours

GK(2006) estimated the consumer surplus of internet use in the US in 2005 as 2-3% of full income. By using GK(2006) model, Pantea & Martens(2016) derived consumer surplus of the internet for leisure of five European countries (France, Germany, Italy, Spain, and the UK) in 2011 between 0.5% to 1.0% of full income. Using GK(2006) model to recreational activity, Loomis(2011) estimated the consumer surplus of recreational sites in Jackson, Wyoming as 0.39% of full income using survey data. In Korea, Byun(2018) estimated the consumer surplus of terrestrial radio as \$5,833M per year using the model in 2016 using Korean Media Panel data. Brynjolfsson & Oh(2012) included watching TV and using the internet in addition to other goods and services in the utility function. They estimated that consumer surplus of the internet in the United States had increased from \$562B in 2007 to \$1,196B in 2011, and the consumer surplus of watching TV lies between \$1,080B and \$1,715B during the same period.

4) The originality of this Study

In this paper, we aimed to estimate the consumer surplus from Wi-Fi service based on GK (2006) model. While most of the studies on the economic value of Wi-Fi estimated the cost savings by calculating off-loading from cellular services or by estimating willingness-to-pay from conjoint analysis, we estimated equivalent variation derived from the consumer utility maximization problem. By estimating the elasticity of substitution by year, we can find the change of consumer surplus.

In addition, by using the Korea Media Panel data specifying the Wi-Fi usage pattern in various sites, including public transportation, we can derive the consumer surplus of Wi-Fi enabled by the public investment from the government. The consumer surplus can be compared to the amount of investment, allows us to conduct a cost-benefit analysis.

3. Model and Data

This section explains the model and the data used in this study. The model is GK(2006) model, and the data is Korea Media Panel data, which has detailed information regarding the sample's behavior on data usage, location the data is used, connection method, and the device used.

1) Model

GK(2006) model has the quantity of and time spent on goods and services as the components of the utility function. The utility function of the consumer takes the form of Constant Elasticity of Substitution(CES) function of the nested Cobb Douglas function, which includes purchased quantity(C) for each good or services and the fraction of time spent on these (L) during the non-sleep time (Equation (1)). We assume consumers consume both Wi-Fi(W) for leisure and a composite, which means all other purchased goods and services (O). The multipliers of the Cobb Douglas function(α_W, α_O) are the money intensity parameters of Wi-Fi and other goods.² The elasticity of substitution between Wi-Fi service and the composite is captured by σ , and θ reflects the preference for Wi-Fi relative to the composite.

$$U(W, O) = \theta(C_W^{\alpha_W} L_W^{1-\alpha_W})^{1-1/\sigma} + (1 - \theta)(C_O^{\alpha_O} L_O^{1-\alpha_O})^{1-1/\sigma} \quad (1)$$

Equation (2) is a budget constraint where P_i refers to the price of Wi-Fi and the composite, and F_W refers to the fixed cost of Wi-Fi. In the case of Wi-Fi, the cost of installing an AP and the cost of using the internet at home can be included in fixed costs(F_W). I represents full income, which is wage income plus the value of leisure time. That is, the use of Wi-Fi and consumption of the other goods incurs costs in the form of the value of leisure time during consumption.

$$P_W C_W + F_W + P_O C_O = I(1 - L_W - L_O) \quad (2)$$

From the utility maximization under the budget constraint, demand functions and expenditure function can be derived. To measure the consumer surplus of the Wi-Fi, we use the Equivalent Variation(EV). Equivalent Variation(EV) of Wi-Fi for leisure is the expenses to be compensated to the consumer, who no longer can use the Wi-Fi in case the Wi-Fi became unavailable. Equation (3) shows the ratio of EV to full income, and all variables except for elasticity of substitution(σ) can be obtained from data.

$$EV/I = \left(1 - \frac{L_W}{1 - F_W/I}\right)^{-1/(\sigma-1)}(1 - F_W/I) - 1 \quad (3)$$

² Money intensity of Wi-Fi and the composite can be defined as share of money expenditure compare to total expenditure which includes both money and time expenditure: $\alpha_W = \frac{P_W C_W}{P_W C_W + I L_W}$, $\alpha_O = \frac{P_O C_O}{P_O C_O + I L_O}$.

In the derivation of EV, GK (2006) utilized the Hausman linear approximation to prevent the overestimation of the consumer surplus from the log demand. We also adopt the linear approximation of demand for leisure, and the equivalent variation equation becomes equation (4).

$$EV/I = 0.5L_W/(\sigma(1 - L_W(1 - F_W/I))) \quad (4)$$

To estimate the elasticity of substitution, we use the following regression equation as shown in equation (5). The equation is derived from the optimal allocation of quantity and time for the Wi-Fi and the composite good. Here, $\ln A$ is a constant term and $\sigma \ln((1 - \theta)/\theta)$ means an error term. Money intensity parameters (α_o, α_w) are included in the coefficient of $\ln I$, and we assume that α_w is equal to 0, implying monetary cost (P_w) is equal to zero. Consequently, the coefficient of $\ln I$ includes the elasticity of substitution (σ) between Wi-Fi for leisure and composite goods, and money intensity of other goods (α_o), which reflects the change in utility for time-intensive service as full income increases.

$$\ln\left(\frac{1 - L_W}{L_W}\right) \approx \ln A + (\alpha_o - \alpha_w)(\sigma - 1) \ln I + \sigma \ln\left(\frac{1 - \theta}{\theta}\right) \quad (5)$$

GK(2006) derives a range of elasticity of substitution between the internet and other goods by sequentially adding related variables such as demographic variables for checking robustness. On the other hand, Pantea and Martens(2016) assume that preferences for internet services compared to other goods (θ) depends on users' demographic characteristics, and estimate the estimation of substitution elasticity. We also assume that additional demographic variables affect preference (θ). In addition, we also control the effect to the preference parameter (θ) of the difference of leisure time caused by the characteristic of surveyed day. We add the number of observed years to test the selection bias of the unbalanced panel data used in this study. Lastly, to estimate the yearly variation to equivalent variation, we added an interaction term between year dummy ($D_{2017,it}, D_{2018,it}, D_{2019,it}$) and the full income variable (I_{it}). Equation (6) represents the regression model used in this study. All of the additional variables which we introduced briefly are included in X_{it} . Since we are using panel data, we estimate the model with the assumption of fixed effect and random effect. In case of random effect, we assume the error term has individual effect, α_i with conventional error term, u_{it} .

$$\ln\left(\frac{1 - L_W}{L_W}\right)_{it} = \beta_0 + \beta_1 \ln(I_{it}) + \beta_2 \ln(I_{it}) * D_{2017,it} + \beta_3 \ln(I_{it}) * D_{2018,it} + \beta_3 \ln(I_{it}) * D_{2019,it} + X_{it}\beta + \alpha_i + u_{it} \quad (6)$$

2) Data

The data for this study include time spent on Wi-Fi, time spent on the composite, working hours, sleeping hours, and various demographic characteristics. The data used is the 2016-2019 Korea Media Panel data constructed by KISDI. The KMP data provided all the variables for the estimation. The KMP data has been constructed to find out the media usage activity of individuals and households. KMP has three parts, which are personal survey, household survey, and media diary survey. Among them, the media diary survey provides the details of individual's media usage activity in 15 minutes interval for 3 days. In every 15 minutes, respondents record place, connection method (Wi-Fi, cable, Bluetooth, etc.), device, and kinds of activity they were engaged in. From this dataset, data such as time spent for Wi-Fi as entertainment, working hours, sleeping hours, and time for other activities could be obtained. Since the location information was provided, data for the duration of time using Wi-Fi on public transportation was available.

We regarded hours spent at the workplace during non-sleeping hours as working hours. Hours of using Wi-Fi for leisure was considered as the hours of using Wi-Fi outside the workplace. Time spent on the composite good was calculated as the difference between non-sleeping hours and the sum of time for Wi-Fi for leisure and time for work. Besides, individuals without income and without the usage of Wi-Fi were excluded from the data. <Table 3> shows the number of observations from 2016 to 2019. Out of 39,503 observations, we selected 7,545 observations.

Table 3
Observation selection

	2016	2017	2018	2019	Total
Total Observations	9,788	9,425	9,426	10,864	39,503
Observations who have income	5,536	5,460	5,613	6,793	23,402
Observations who use Wi-Fi for leisure among with income	1,294	1,589	1,983	2,679	7,545

<Table 4> shows descriptive statistics on average minutes spent on each activity per day and other characteristics. The activity data were constructed by averaging the data for 3 days recorded in media diary, and the socio-demographic variable was constructed from the individual data in the KMP. The low average work minutes of 364.8 seem to be related with the special days (such as vacation), which are included in the survey. The average time spent on Wi-Fi for leisure turned out for about 1 hour, and the average time spent on other goods and services is about 9 hours. The average time for sleep was about 8 hours, which is similar to the data from OECD statistics. As socio-demographic characteristics, average monthly income, gender, age, marital status, number of house members, schooling, and region are used. Since the average monthly income was provided in categories, the median value for each category was adopted, and it was used to construct I_{it} (full income).

The survey is based on 3 days for each individual, and since the 3 days may include special day, we controlled this by including dummy for this. The selection of samples with income and with the usage of Wi-Fi for leisure inevitably yielded the unbalanced panel. We tested the possible sample selectivity by introducing the number of the observed years.

Table 4
Variable Summary

	Variable	Mean	S.D	Min	Max
Time Variables (Day average)	Work hours (min)	364.8	199.8	0	930
	Hours for use of leisure Wi-Fi (min)	62.49	68.58	5	925
	Hours for consuming the composite (min)	535.8	180.7	0	1125
	Sleeping hours (min)	477.0	65.24	235	960
Demographic Characteristics	Income (\$/month)	2,157	1,217	220	8791
	Gender (Men=1)	0.57	0.50	0	1
	Age	43.28	11.85	13	83
	Spouse (Yes=1)	0.67	0.47	0	1
	Number of House Members (more than 3 = 3)	2.82	0.47	1	3
	Schooling (below elementary school=1, below middle school=2, below high school=3 below college graduate=4, upper than graduate school=5)	3.62	0.62	1	5
Other variables	Working day (yes=1)	0.90	0.30	0	1
	Special day (yes=1)	0.08	0.27	0	1
	Observed Years	2.29	1.08	1	4

Note: Number of observations is 7,545.

Although the KMP data contains rich information regarding the usage of various media by individual and household, we did not use these as control variables since we assumed these as a component of the composite good.

4. Result

1) Estimation Result

The estimation result is summarized in <Table 5>. According to the Hausman test, the random effect model turned

out to be appropriate, and the result from the random effect model was presented. Coefficient of $\ln(I_{it})$ is positive and significant. Although the coefficients of interaction terms seem insignificant, if we calculate the standard error of each year's coefficient of $\ln(I_{it})$, each coefficient turns out significant, as is reported in <Table 6>. All coefficients for 2016-2019 are similar in sign to the results of Goolsbee & Klenow(2006), Loomis(2011), Pantea & Martens(2016), and Byun(2018). Each year's positive coefficients indicate that individuals with higher full income spend less time on Wi-Fi for leisure. However, compared to previous studies using GK(2006) model, our result has a smaller coefficient of $\ln(I_{it})$ meaning a relatively smaller change in the decrease of time spent on Wi-Fi as the opportunity cost of time increases.

For the socio-demographic characteristics, older people and males turn out to spend less time on Wi-Fi for leisure, and individuals with higher education spend more time on Wi-Fi. During working days, people tend to use less Wi-Fi for leisure. These results seem reasonable. The coefficient of observed years is also significant, indicating the existence of selection bias. This indicates we should regard the estimated consumer surplus from the time-varying coefficient pertinent only to Wi-Fi users who have income in each year.

Table 5
Estimation Results (Random Effect Model)

Dependent Variable: $\ln\left(\frac{1-LW}{LW}\right)_{it}$		Coefficient (Standard Error)
	$\ln(I_{it})$	0.086** (0.040)
	$\ln(I_{it}) * D_{2017}$	0.020 (0.051)
	$\ln(I_{it}) * D_{2018}$	-0.013 (0.050)
	$\ln(I_{it}) * D_{2019}$	-0.005 (0.047)
Demographic Characteristics	Household Size	-0.002 (0.029)
	Male	0.070** (0.028)
	Age	0.021*** (0.002)
	Schooling	-0.11*** (0.023)
	Married	0.012 (0.036)
	Working day	0.532*** (0.042)
Other Variables	Special day	0.042 (0.042)
	Observed years	-0.130*** (0.013)
	Constant	2.077*** (0.275)
	Hausman Test (P-value)	30.29 (0.086)
	Observations	7,545
	R-squared	0.247

I_{it} means full income of individuals, and D_{2017} , D_{2018} , D_{2019} mean dummy variables for each year. We also controlled year and area by dummy variables. We use usual standard error because heteroskedasticity is not present. (***) $p < 0.01$, (**) $p < 0.05$, (*) $p < 0.1$)

Table 6

Estimation Results

Year	Coefficient	Standard Error	t value	p value
2016	0.086**	0.040	2.155	0.031
2017	0.106***	0.038	2.769	0.006
2018	0.073*	0.037	1.940	0.053
2019	0.091***	0.032	2.823	0.005

(*** p<0.01, ** p<0.05, * p<0.1)

2) Estimating Equivalent Variation

To derive the elasticity of substitution, α_o and α_w should be computed. Using the concept of money intensity and Equation (2) α_o can be calculated under the assumption of zero monetary cost of Wi-Fi (P_w) as in equation (7).

$$\alpha_o = \frac{P_o C_o}{P_o C_o + I L_o} = \frac{I - (P_w C_w + I L_w + I L_o)}{I - (P_w C_w + I L_w)} = \frac{I - (I L_w + I L_o)}{I - I L_w} = \frac{1 - L_w - L_o}{1 - L_w} \quad (7)$$

Median values of $(\alpha_o - \alpha_w)$ for each year were calculated as 0.4482, 0.4248, 0.4252, and 0.4436. Computed money intensities of the other goods (α_o) are higher than those in Pantea and Martens(2016). This indicates that Korea relatively spends more money than time on other goods compare to five countries in Europe covered in Pantea and Martens(2016). The elasticity of substitution between Wi-Fi for leisure and other goods is estimated as 1.16 - 1.25 for each year, which means Wi-Fi is more complementary than other time-intensive services, such as the internet. GK(2006) and Pantea and Martens(2016) estimated the elasticity of substitution between the internet for leisure and other goods as 1.3 - 2.12. Byun(2018) estimated the elasticity of substitution between radio and other goods between 1.3 - 1.6. Because the fixed cost (F_w) is small relative to full income, we assume $F_w/I = 0$ in equation (4) and estimate the equivalent variation by using the median value of L_w and the median value of the full income of each year.³

Table 7

Estimated Equivalent Variation(Consumer Surplus)

Year	Share of Using Wi-Fi for Leisure (L_w)	Coefficient	Substitution Elasticity (σ)	Equivalent Variation (\$ per month)	Percentage to Full Income
2016	0.0349	0.0857	1.19	79.29	1.52%
2017	0.0390	0.1056	1.25	84.91	1.63%
2018	0.0471	0.0726	1.17	110.29	2.11%
2019	0.0451	0.0911	1.16	106.22	2.03%

Estimated equivalent variations in <Table 7> means the average consumer surplus of the Wi-Fi for leisure for Wi-Fi users with income. The benefits of using Wi-Fi for leisure has increased from \$79.29 to \$110.29 per month until 2018. Although the estimate in 2019 is a bit less than that in 2018, but it's still much higher than those in 2016 and 2017. Since

³ We also estimated the equivalent variation of Wi-Fi for leisure using the mean of the fixed cost of internet per household, which means $F_w/I \neq 0$. Since the results were almost identical, we only reported the result with the assumption, $F_w/I = 0$.

the estimated consumer surplus of Wi-Fi for leisure may look bigger than expected, we compare the estimates with the price of unlimited data plan without deterioration of speed, which is a close substitute for Wi-Fi. Prices of that unlimited data plan of a carrier range from \$68.6 to \$92.3 as of May 2020, which shows a similar figure with the consumer surplus.

A big increase in EV occurred from 2017 to 2018. It seems that the increase is due to the explosive growth of online video usage. In Korea, YouTube and Netflix became very popular during that period. Especially, Netflix subscribers dramatically increased since 2018.

Fig. 1 illustrates the time spent on various activities using Wi-Fi from 2016 to 2019 from KMP data. All the average time spent on various activities per day are measured for the Wi-Fi users. The services in which people spend a lot of time are messenger, searching, playing game, and streaming videos. Video streaming service shows a sudden increase from 2017 to 2018, which is consistent with the variation of consumer surplus of Wi-Fi for leisure. While time spent on video streaming increased in 2019, time spent on search has decreased a lot, leading to the offset of the total time spent on Wi-Fi, and explaining the decrease of consumer surplus.

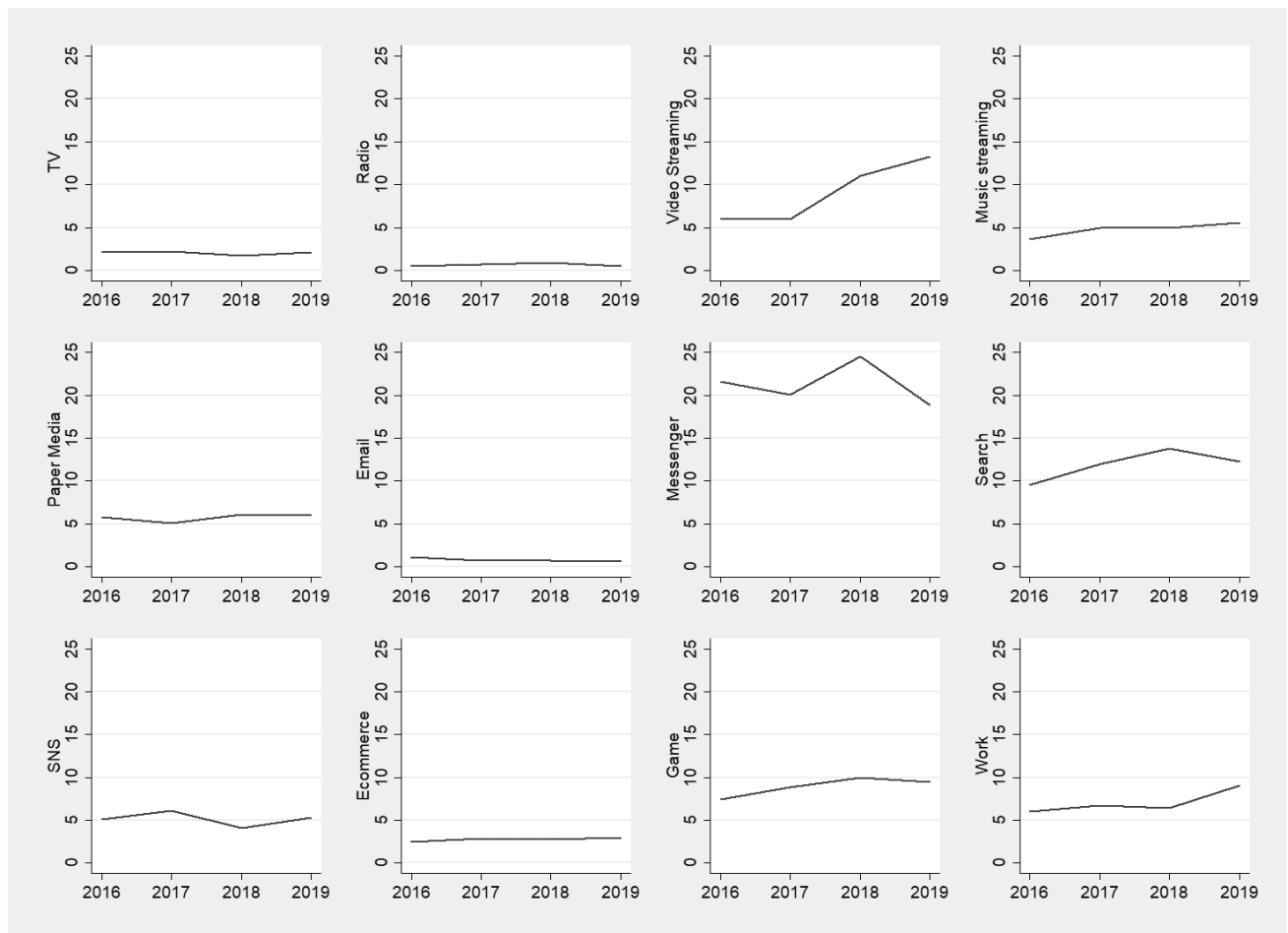


Fig. 1. Changes in time spent on activities using Wi-Fi (min per day)

GK (2006) estimates that the benefit of leisure online in the US is between 1.9% to 2.9% of a full income, while Pantea & Martens (2016) reports the consumer surplus from the internet for leisure for five European countries to be 0.55% to 1.01% of full income. In our study, the value of Wi-Fi for leisure in Korea was estimated as 1.52%-2.11% of a full

income, which lies between the result for the European countries and the US.

3) Applying to the City Bus Wi-Fi Policy

The Korean government has built and opened 13,369 public Wi-Fi in public facilities and subways during 2012-2017 in cooperation with municipalities and mobile carriers. In addition, from late 2018, the government started to build free Wi-Fi in 4,200 city buses nationwide and started service in May 2019. In 2019, the second city bus Wi-Fi construction project was implemented, and 23,047 more city buses nationwide were installed the free Wi-Fi. In addition to the government's policy, in 2019, some municipalities installed public Wi-Fi in 3,200 local district buses nationwide. Seoul metropolitan city built free Wi-Fi in about 1,500 local district buses in 2019. In the first and second city bus Wi-Fi construction projects, the government and municipalities bore the cost of renting carrier's equipment and data usage charge, which accounts for most of the costs involved in Wi-Fi. It is advised that some kind of cost-benefit analysis should be carried out in advance since these projects are public in nature. We believe that the economic value of free Wi-Fi in city buses can be derived through the methodology of this study.

If the utility from each time spent on Wi-Fi is the same, the consumer surplus of Wi-Fi in specific places can be calculated by using the proportion of time used in each place of KMP data. <Table 8> reports the consumer surplus of Wi-Fi in each place. Since Wi-Fi service in public transportation and at home are used mostly for leisure purpose, GK(2006) model, which estimate the benefit occurred in leisure time, can be used to estimate the total consumer surplus of each service. As is shown in <Table 8>, most of the Wi-Fi service as entertainment is used in home, and the proportion used in public transportation is the smallest. As most people spend their leisure time mainly at home, the share of consumer surplus of residential Wi-Fi is higher than the others.

Table 8
Consumer Surplus of Wi-Fi for leisure by location

Year	Equivalent Variation (\$ per month)	Public Transportation		Home		Other Places	
		Percentage	Benefits (\$)	Percentage	Benefits (\$)	Percentage	Benefits (\$)
2016	79.29	4.5%	3.56	82.2%	65.21	13.3%	10.51
2017	84.91	4.2%	3.54	83.4%	70.79	12.5%	10.58
2018	110.29	3.7%	4.09	84.8%	93.53	11.5%	12.67
2019	106.22	4.6%	4.91	83.8%	89.04	11.6%	12.27

Note: Other Places includes restaurants, cafés, and other amenities.

As mentioned above, due to the selection bias problem, the results in <Table 8> can be applied only to Wi-Fi users with income. Therefore, this figure can be regarded as the lower limit of the consumer surplus of Wi-Fi. Using the figures in <Table 8>, we plan to calculate the consumer surplus from using free Wi-Fi in city buses by individuals with income and compare it with the cost of installing free Wi-Fi in all city buses each year.

The procedure for the calculation of the benefit of Wi-Fi in city buses is as follows. Consumer surplus for public transportation users in <Table 8> is multiplied by the proportion of people using city buses, which are about 57% nationwide and 26% ~ 33% in Seoul metropolitan city, to derive the benefit of Wi-Fi in city buses. Then we multiply the

benefit by the proportion of wireless internet users among public transportation users with income to calculate the benefit of Wi-Fi of city buses, as shown in <Table 9>. The cost of Wi-Fi construction in city buses was calculated based on the equipment rental cost and on the data usage charge by telecommunications operators in the first and second city bus Wi-Fi construction projects in 2019.

Table 9
Cost and Benefit of Wi-Fi Provision in City Buses (2016~2019)
 Sources: KTSA, KOSIS, KISA(2016;2017;2018;2019)

Year	Benefit of Wi-Fi in City Buses (Nationwide)	Cost of Wi-Fi (Nationwide)	Benefit of Wi-Fi in City Buses (Seoul metropolitan city)	Cost of Wi-Fi (Seoul metropolitan city)
2016	\$68.3M	\$33.7M	\$5.0M	\$7.5M
2017	\$69.6M	\$33.8M	\$8.9M	\$7.4M
2018	\$83.6M	\$34.6M	\$10.7M	\$7.4M
2019	\$102.7M	\$34.8M	\$12.8M	\$7.4M

Note: Each estimate reflects the benefits of city bus Wi-Fi for people who earn income and use Wi-Fi.

<Table 9> shows the cost and benefit of Wi-Fi provision to city buses in the country and in the Seoul metropolitan city. According to the result, the cost was less than the benefit in each year except the case for Seoul metropolitan in 2016. In particular, the consumer surplus of Wi-Fi service in city buses in 2019 has surged, which may be attributed by the increase of the proportion of Wi-Fi use in public transportation and by the increase of the overall wireless Internet users.

The model only estimates the consumer surplus of time-intensive service used in leisure time, and there is a tendency of overestimation since the model values leisure time at the wage. However, the result is expected to be used as a reference value in a cost-benefit analysis for the public Wi-Fi project. For example, Seoul metropolitan city recently estimated the benefit of public Wi-Fi in Seoul based on the cost saving effect. With the assumption of data usage from the public Wi-Fi per person as 8GB and the price per Gigabyte, they announced the benefit of public Wi-Fi as \$46.41 per person per month in Seoul. If we use our figures in <Table 8>, the estimated consumer surplus of public Wi-Fi is about \$17.18 per month per person. In this way, we can use our results to check the validity of calculations from municipalities.

One noteworthy thing in the cost-benefit analysis for public Wi-Fi project is the social cost of public Wi-Fi. In some cases, the public Wi-Fi may be initiated to appeal to voters. And public investment in communication networks may crowd out private investment (Hudson(2010)). In this sense, the cost of public investment may be higher than just the budget, considering the social cost of investment (Ahn & Lee(2010)).

5. Conclusion

In this paper, we estimated consumer surplus of time-intensive Wi-Fi service for leisure by considering the time cost. We also figured out the consumer surplus of Wi-Fi in city buses by disaggregating the total value of Wi-Fi for leisure, and carried out the cost-benefit analysis in constructing Wi-Fi in city buses, which Korean government recently proceed. We used the 2016-2019 Korea Media Panel personal survey and media diary data. Under the random effect model, the

coefficient of all years was estimated as positive with significance. This means that as income increase, the percentage of time spent on Wi-Fi decreases, considering the opportunity cost of time. The estimated consumer surplus of Wi-Fi for leisure has increased from \$79.3 in 2016 to \$106.2 per month until 2018.

With locational information of Wi-Fi usage from the panel data, and with some statistics regarding the usage pattern of city buses, we could figure out the benefit of Wi-Fi in city buses. With the cost data, the cost-benefit analysis for public Wi-Fi in the buses could be performed. It turned out the benefits are greater than the cost of public Wi-Fi in city buses.

This research may be used in carrying out a cost-benefit analysis for a project where the service is time intensive and also free. Since the model is based on a microeconomics foundation, and it was estimated with actual panel data, we can figure out the consumer surplus by year and by location. The result can be utilized as another reference in a public project.

Although our study showed the consumer surplus of time-intensive service, there are some limitations. First, it is true that the opportunity cost of leisure time can be quite lower than income. In this sense, the estimated consumer surplus may be overstated (Shaw, 1992). Secondly, there is only one time-intensive service (Wi-Fi) in our model. As is already mentioned in GK (2006) paper, it is better to introduce substitutes for the Wi-Fi in the model. Overcoming these limitations will be left as a future research task.

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