Old People's Fear of COVID-19 Infection and Public Transportation Avoidance : Korean Subway Evidence

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Research

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Abstract

Background: With the spread of the coronavirus worldwide, a principal policy implemented by nations was restrictions on movement of people. The effect of governments' mobility restriction measures has been analyzed after the COVID-19 outbreak. However, there is lack of studies on the impact of voluntary restriction that significantly affects the decrease of the mobility. This research aims to analyze mass transportation use after the COVID-19 outbreak by age group to explore how the fear of infection affected the public transit system.

Methods: Mass transportation big data of Seoul Metro transportation use in the capital city of South Korea was employed for a panel analysis. To control the environmental characteristics of each district of Seoul Metropolitan City, the fixed-effect model was employed.

Results: The analysis results showed that in both the period of the highest infections and the period of the lowest infection of COVID-19, users aged 65 and over reduced subway use more than people aged between 20 and 64. The decrease of subway use caused by the sharp increase of COVID-19 cases was the most prominent among people aged 65 and over. The elasticity of change of subway use demand to change in cases in Seoul was about 0.08 for people aged 65 and over, higher than 0.06 for people aged between 20 and 64.

Conclusion: The voluntary restrictions driven by fear of the COVID-19 infection have led to the decrease of public transit demand in Seoul. Although the subway use demand decreased both in the age group of 20 to 64 and the age group of people 65 and older, the elderly responded more sensitively to COVID-19. The results suggest that the fear of COVID-19 pandemic varies with age. It seems that the elderly's higher death rate from COVID-19 has significantly impacted their behavioral change. This study imply that the elder's fear of infection has affected their daily lives, consumption, and production activities and their mobility using public transportation.

Background

Since the World Health Organization (WHO) declared the COVID-19 pandemic, the spread of infections around the world has not abated. The global total number of COVID-19 cases was 0.7 million in March when the WHO announced the COVID-19 outbreak a global pandemic but exceeded 79.2 million in December [1, 2]. With the incessant outbreak of community transmission, clusters of cases, and sporadic infections, coronavirus is still spreading across the world.

The spread of COVID-19 infections was inevitable even in Korea. In the early phase of the pandemic, the rate of increase of cases was relatively low. However, in Daegu, the southern city of South Korea, massive cluster infections occurred at *Shincheonji* Church of Jesus on February 18, and then cases sharply jumped and spread out from the city. The pandemic moved north to reach Seoul in mid-August and the spread accelerated rapidly with many cases detected in Sarang Jeil Church in Seoul. Figure 1 shows the progress of COVID-19 cases in Seoul between February and September. As of December 24, the number of COVID-19 cases in South Korea reached 53,533 with 756 deaths [3].

With the spread of the coronavirus worldwide, nations implemented a principal policy restricting the movement of people to minimize contact between people as WHO reported that the COVID-19 is rapidly transmitted through human contact and respiratory organs [4]. Asymptomatic "silent spreaders" were found, making it difficult to track the routes of transmission [5]. Wuhan, the Chinese city where the pandemic is believed to have started was effectively sealed off from the rest of the country immediately, and movement between regions in China was strictly banned [6]. In Europe, strict restrictions such as lockdowns, curfews, and permits for movement were imposed by governments [7]. In the United States—with most the coronavirus cases worldwide—heightened mobility restrictions such as stay home order, ban on gathering, and travel restrictions were implemented, depending on the status of each state [8].

The Korean government is implementing social distancing measures instead of strong restrictions on movement to curb the contagion of the COVID-19. Lockdowns and other forms of restrictions on mobility are enforced mandatorily for all residents in a region. However, social distancing is a sort of a campaign, guidance, or recommendation of the Korean government to achieve regulated mobility through citizens' voluntary cooperation and compliance. From March 22 to April 19, the period of the first wave of the pandemic, "enforced social distancing" was first implemented, and during the second wave, August 16 to September 20—depending on the case severity—phase 2 and phase 2.5 of social distancing were enforced. From late November, social distancing in the phase 2 or higher was imposed to stem the spread of the third wave of the pandemic [9].

Mobility restriction policies of countries and voluntary restrictions—driven by fear of the coronavirus infection—have led to the decrease of transit demand. In France, during the national lockdown, consumer mobility estimated based on the use of payment cards has decreased by 75% compared to 2019 [10]. According to Google Trend data, mass transit demand in ten countries including Italy, Brazil, and the United Kingdom has fallen sharply since the COVID-19 outbreak [11]. In Mexico, the use of automobiles has decreased by 10 to 25 % since the outbreak [12].

Seoul has also witnessed a drastic reduction of transit demand amid the pandemic, which can be measured based on the changes in mass transit system use in Seoul—among the top ten in the world in terms of efficiency and user satisfaction [13]. The population of Seoul was 9,668,465 as of December 2020, and the use of buses and subways surpasses 100 million a month for each. Figure 2 shows the number of bus and subway rides in 2018, 2019, and 2020. As cases of COVID-19 began to rise in late January 2020, mass transit demand fell dramatically and rebounded after March, but still well below the demand recorded in the same periods of 2018 and 2019. Besides, in August, mass transportation demand declined again after the outbreak of cluster infections in Seoul, showing that mass transportation is significantly affected by the pandemic.

Most studies on the decrease of mass transit demand are focused on the effect of governments' mobility restriction measures. However, there is a lack of studies on the impact of voluntary restriction that significantly affects the decrease of transit demand. That may be attributed to the fact that, as many countries are implementing restrictions on mobility, it is difficult to isolate the effect of citizens' voluntary restraint of movement.

Data on subway transit demand in Seoul is useful in studying the voluntary mobility reduction during the pandemic as it has three characteristics that are not found in other cities. First, it is a type of mass transit that carries a high probability of infection. Mass transportation involves very high risks of infection because of the high density, diversity of contacts, and potential presence of patients [14]. Hence, when traveling in the subway, passengers are aware of the risk of infection. Second, government did not issue any restrictions on subway use. Without enforced mobility regulation, subway use reflects the voluntary mobility of people. Third, people aged 65 and over can ride a subway for free—following Article 19 of the Welfare of Senior Citizens Act, in Seoul, the elderly aged 65 and over can ride on a subway for free [15]. For the elderly without income earned through economic activity participation, the subway is an essential and most common means of mass transit for leisure. However, after the COVID-19 outbreak, subways were classified as facilities that carry the highest infection risk, and the age group most prone to fatality because of the COVID-19 infection is the elderly group. Therefore, though they have free access to the subway, the most efficient means of movement, the aged cannot ride on a subway train without concern over the COVID-19 impact. As such, the change in the subway ride patterns by the elderly most effectively reflects the risk of the COVID-19 infection.

This study aims to empirically analyze changes in the subway use pattern by older people and the economically active population, amid the risk of COVID-19 infection. First, the period when cases spiked sharply, and other periods were separated for analysis. The Korean government is controlling the social distancing level according to the number of cases. The rise of the social distancing level imposed by the government is intended to heighten citizens' awareness against the pandemic and cause behavioral change. As such, by focusing on the social distancing level imposed by period, changes in the behavior of each age group associated with changes in social distancing level can be identified. Next, the elasticity of the demand for subway use to the number of COVID-19 cases was measured, determining whether the elderly most vulnerable to the coronavirus are more sensitive to infection than young people. Lastly, through analysis based on the number of subway stations by period, this study attempted to determine whether changes in subway ride decisions are related to fear of COVID-19 infection. In areas near stations for transfer[1] and multiple stations, there is more transit demand because of easy access to the subway. That is, such areas carry a higher risk of infection from more human contacts. Accordingly, if areas with a greater number of stations are found to experience a higher decrease of passengers than areas with a smaller number of stations, that can be interpreted as a behavioral change to avoid COVID-19 infection.

Change in the Pattern of Subway Use Demand Amid the Pandemic in Seoul

The number of deaths because of the COVID-19 infection rises as the age of patients climbs. According to the Center for Disease Control and Prevention data, 80% of death from the coronavirus is associated with people over 65 years old [16]. Reports on case-fatality rate (CFR) in China and Italy found that CFR for people aged under 60 was less than 2% while CFR for the aged over 60 years old rises to 20% [17]. In the United States, the CFR of the aged 65 or older was 3% to 27%, higher than that of younger people [18]. In Korea, COVID-19-related CFR for the older people was like other countries. Figure 3 shows the share of Korean coronavirus cases and CFR by age group. Over 70% of people infected with COVID-19 are aged under 50, whereas people aged over 60 showed a non-linear rapid rise of CFR.

The Seoul Metropolitan Subway with a potentially higher rate of COVID-19 cluster infection has seen users declining significantly since the outbreak of the pandemic. Figure 4 shows changes in the number of rides for passengers aged between 20 and 64 and those aged 65 and older. During 2018 and 2019 before the pandemic, those aged between 20 and 64 recorded 94,130,730 subway rides a month on average, and those aged 65 and older 14,278,200 rides. After the COVID-19 outbreak, people between 20 and 64 used the subway 72,398,975 times a month while those aged 65 and older 10,815,514 times a month, showing a dramatic decrease.

The COVID-19 pandemic has led to changes in hours for the use of the subway and the number of rides. Figure 5 shows a change in the share of the number of subway rides by the hour in 2020 and 2019. Compared with 2019, the subway ride of passengers aged 20 to 64 in 2020 rose by 0.2% to 1% during six to nine O'clock (commute to work), and also rose by 0.5% to 0.9% during five to six O'clock in the afternoon (commute from work). In hours other than those, the use of the subway transit dropped. This is likely to be attributed to the reduction of operating hours of stores owing to social distancing rule and a decrease in the number of permitted persons for meetings and dinners. The subway use for passengers aged 65 and over rose by 0.5% during five to seven O'clock, and the use of subway decreased during hours other than this. Such changes in time for the use of the subway for the aged people who are not constrained by time for their social activities seem to be meant to reduce human contacts and restrict external activities voluntarily to avoid COVID-19 infection.

[1] The number of transfer stations was counted in terms of the number of subway lines available for the station. For instance, for a subway station on three subway lines, the number of stations was counted as three.

Method

Data

This study collected data from Seoul Bigdata Campus and Seoul Open Data Plaza of Seoul Metropolitan government. The period for this analysis runs from January to September 2018, 2019, and 2020. Data for cases of COVID-19 in Seoul relied on data from the Seoul Metropolitan government, and data for the Korean cases came from data from the Center for Systems Science and Engineering of Johns Hopkins University.

Seoul Bigdata Campus

Seoul Bigdata Campus collects big data provided by organizations of the Seoul Metropolitan government and provides it to public institutions, academics, and private companies to help research and solve social issues. As collected data contains personal information, sources of that data needed to be visited to get the pre-processing and approval for exporting that data before it can be used. Figure 6 shows the procedure of using raw data obtained from the Seoul Bigdata Campus.

Data on subway use in Seoul is the raw data provided by Tmoney Co., Ltd. to Seoul that cannot be used without pre-processing and approval for exporting it. In Seoul, passengers must use smart cards equipped with transportation card function to use the subway, and thus data of Tmoney Co., Ltd. listing details of transportation card transactions is highly reliable. This data includes the date and time for subway use, the station for departure and arrival, the type of users[2], and the number of passengers.

This research focuses on changes in demand for the subway for residents in Seoul. While Seoul Metro also covers subway stations in both Seoul Metropolitan City and Gyeonggi-do province, this study conducted analysis only for subway stations located in 25 districts of Seoul Metropolitan City and collected data of Korea Smart Card Co on the number of rides by the district at departure stations.

Seoul Open Data Plaza

Like Seoul Bigdata Campus, Seoul Open Data Plaza collects data provided by organizations of the Seoul Metropolitan government. However, unlike Seoul Bigdata Campus, it makes public data open to all citizens and does not require visits to organizations providing such data. Seoul Open Data Plaza provides links to providers of a vast amount of data so that the latest data can be obtained from the links. Data for independent variables used under this study is based on the data of Seoul Open Data Plaza, the Ministry of Land, Infrastructure, and Transport, and the Transport Operation & Information Service of Seoul.

Empirical Model

This study used panel data of 25 districts of Seoul. Using the fixed-effects model, changes in the pattern of subway use by passengers aged 20 to 64 and passengers aged 65 and older amid the COVID-19 pandemic were analyzed. The fixed-effects model is effective in controlling for omitted variable bias because of unobserved heterogeneity [19]. Hence, a model is suitable to control the environmental characteristics of each district of Seoul Metropolitan City.

The Korean government adjusts social distancing levels based on variations of the number of confirmed cases. In phase 2 or higher of social distancing, there are significantly more restrictions on the economically active population than below phase 2. Hence, it is necessary to distinguish the period according to the social distancing level. The formula is as follows:

$$y_{it} = \beta_1 SDLv1 + \beta_2 SDLv2 + \beta_3 Carspeed_{it} + \beta_4 pop_{it} + \beta_5 ownCar_{it} + \beta_6 wealth_{it} + \alpha_i + \varepsilon_{it} \quad (1)$$

In the formula (1) above, subscript i means districts of Seoul, and t is monthly data. y_{it} is the logarithm of the number of subway rides per month in each district. $SDLv1$ is a dummy variable taking 1 for January, February, May, June, and July 2020 when social distancing was in phase 1 to 1.5 and 0 for other periods. $SDLv2$ is a dummy variable taking 1 for March, April, August, and September of 2020 when social distancing was phase 2 or higher. $Carspeed$ is the average speed of automobiles measured by each district. pop refers to the population registered in each district office. $ownCar$ refers to the share of a privately-owned car out of total registered vehicles in each district. $Wealth$ is the average price per square meter of an apartment house in each district. α_i is time-invariant location fixed-effects.

Next, the elasticity of subway use to the number of COVID-19 cases was measured. The elasticity indicates the sensitivity of the number of subway use in response to an increase in cases, and also reveals the differing sensitivity to the number of cases among age groups. The formula is as follows:

$$y_{it} = \beta_1 Covid_t + \beta_2 Carspeed_{it} + \beta_3 pop_{it} + \beta_4 ownCar_{it} + \beta_5 wealth_{it} + \alpha_i + \varepsilon_{it} \quad (2)$$

Additionally, concerning the *Covid* variable, the number of cases in Seoul and the number of cases in Korea were used respectively to see the difference between residents' responses to infection in local communities and nationwide.

Last, if passengers' decision to use the subway reflects COVID-19 infection risk, areas with more subway use would experience a larger decrease in subway use. Accordingly, analysis by period was made separately for areas with 16 or more stations including transfer stations and areas with less than 16 stations.

[2] Type of users of subway refers to senior citizens, persons of national merit, children, foreign senior citizens, general citizens, disabled persons, and youth. About 80% of subway users are general citizens aged between 20 and 64, and the elderly aged 65 and older account for 12 to 13% of users and the rest 6 to 7%.

Results

Table 1 shows the change in the number of subway rides in each age group. Under stronger social distancing levels, subway use of the two groups decreased. People aged 20 to 64 saw their subway ride fall by 13% in phase 1 and phase 1.5 of social distancing level, and by 30% as social distancing level rose to phase 2 or higher. Likewise, the elderly aged 65 and older reduced subway use by 19% in phase 1 and phase 1.5 and by 43% in the phase 2 or higher. This suggests changes in users' behavioral patterns to avoid cluster infection risk by reducing subway use during the periods when cases of the coronavirus increased, and thus social distancing level was heightened.

Although subway use demand decreased both in the age group of 20 to 64 and the age group of people 65 and older, the subway use of the elderly fell more prominently regardless of the social distancing phase. For the economically active population of Seoul, the subway is the essential transportation means to commute to work. Accordingly, this study expected that in phase 1 of social distancing, the decrease in subway use demand by people aged 20 to

64 would be smaller than that for the elderly aged 65 and older, and this expectation was consistent with analysis results. But when the social distancing level is lifted to phase 2 or higher, subway use demand by the economically active population would decrease by a larger margin than people aged 65 and older because of remote work and ban on non-essential meetings and events. Nevertheless, in phase 2 or higher of social distancing, subway use demand by people aged 65 and older dropped by a significantly larger margin than the economically active population. For the elderly, the strengthening of social distancing does not change much in daily life, but the increase in the possibility of COVID-19 infection causes decision making changes. Therefore, the result implies that subway use demand by people aged 65 and older was affected more by voluntary restraint of mobility to avoid coronavirus infection than the social distancing policy.

Table 2 shows the change in subway use in tandem with the increase in the number of coronavirus cases. Both in Seoul and Korea, the increase of coronavirus cases is negatively related to subway use. However, subway use is more sensitive to the number of cases in Seoul than to the number of cases nationwide. For subway users aged 20 to 64, a 1% increase of Seoul cases leads to a decrease of subway use by 0.06%, but a 1% increase of cases nationwide reduces subway use by 0.03%. As for the elderly aged 65 and older, the elasticity of subway use was higher for the number of cases in both Seoul and the whole nation than for people aged 20 to 64. A 1 % increase of Seoul cases reduced subway use by 0.08%, while a 1% increase of cases nationwide led to a decrease of subway rides by 0.06%. This finding suggests that despite differing elasticities of subway use to the number of cases in a given region and the nation as a whole, the fear of COVID-19 infection was stronger for the aged people than for the younger people.

The results of the analysis above confirm that subway use demand decreased because of the coronavirus and that the aged were more sensitive to the virus than the other age groups. Table 3 illustrates the analysis results by area based on the number of subway stations including transfer stations. Findings reveal that change of subway use pattern to avoid infection risk was similar in all areas. Passengers aged 65 and older reduced more subway rides than those aged 20 to 64 regardless of the number of subway stations. Moreover, the elderly reduced subway rides by a larger margin in areas with 16 or more stations including transfer stations than in areas with less than 16 stations. In summary, such a strong reduction of subway use in areas more likely to cause infection suggests that behavioral change of passengers reflects the impact of the COVID-19 pandemic.

Conclusion

As the COVID-19 pandemic is protracted for an extended period, cases of COVID-19 are found in all age groups. However, the death rate because of coronavirus infection is significantly higher among the aged than other age groups, and this rate is consistent across nations.

The results of this research showed that the mobility of the aged is more seriously affected by fear of the COVID-19 infection than that of younger people. When cases were not spiking, younger age groups reduced subway rides by 13%, but the aged decreased by 20%. Moreover, during the period when cases soared sharply, younger age groups reduced subway rides by 30%, and the aged people by 42%, indicating a significantly more drastic change in subway use demand among the elderly than among the other age groups. Furthermore, the elderly group showed higher sensitivity of subway use to the change of the number of cases. For a 1% rise of cases in Seoul, subway use decreased by 0.06% for younger people and 0.08% for the aged. Although the elderly can move easily by riding the subway for free, they are giving up subway use to escape the fear of infection. This suggests that because of the higher fatality rate from the coronavirus among the elderly, the elderly's fear of the pandemic is stronger, leading to a change of mobility.

This study analyzed a voluntary change of mobility by people because of fear of the COVID-19 infection. Mobility encompasses various types of movement for living, leisure, consumption, and production. Before the pandemic, the Korean government, like other countries, allowed people aged 65 and older to use the subway for free to reduce their cost of public transit and provided various national assistance programs such as public employment to help support their income. After the COVID-19 outbreak, the government further expanded the national assistance program for the aged people whose employment rate has outstripped that of other age groups, preventing the fall of the total employment rate for all age groups. The increase of economic activity seems to have increased the mobility of the elderly. Still, despite this government policy, the older population tried to avoid COVID-19 infection which is more fatal to the elderly, resulting in reduced mobility and more severe contraction in living, consumption, and production than other age groups. This voluntary mobility reduction may have been effective in reducing infections among the aged people in the short-term but may cause deterioration of their health status in the long-term.

Discussion

With the advent of the super-aged society, the employment of the older population to participate in economic activity has been rising. In Korea, because of the unsecured pension system for the aged, the elderly rely more on income through economic activity participation [20]. For the elderly with a lower level of education, reliance on income earned through economic activity is even higher, and thus wish to get jobs even after retirement [21]. Against this backdrop, the government has expanded support for the employment of the aged. This government's continued support for the aged has transformed job markets during the Middle East Respiratory Syndrome and the current COVID-19 pandemic. During the MERS epidemic in 2015, it was the aged people who were most affected in the job market [22]. However, during the current COVID-19 pandemic, thanks to various employment programs of the government, the employment rate, and the number of jobs available to the elderly climbed. In Korea, for the elderly who depend more on income from economic activity than on the social safety net [20], a free subway ride is an efficient means of transit for their economic activity. Hence, the increase of re-employment of the aged people results in the rise of demand for subway use. Still, to identify changes of mobility in sub-sectors such as consumption, production, and living, in-depth analysis of the use of other means of mass transportation such as buses other than the subway by age group and by time is necessary. Through this added analysis, more precise implications regarding mobility by age group can be derived.

Declarations

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Authors' contributions

BJ contributed to the data collection, statistical analyses, and the literature search strategy. JM contributed to the conceptual framework and paper writing. All authors contributed to interpretation of data, revised the article, and approved the final version of the manuscript.

Availability of data and materials

The datasets used and/or analysed in the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

Competing interests

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Ethics approval and consent to participate

Not applicable.

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Tables

Table 1. Panel Results: Change in subway demand by age and period

Independent variable	Dependent variable	
	Log (the number of subway use cases)	
	Aged 20 to 64 years old	Over 65 years old
Social Distancing Lv1 period	-0.1301*** (0.0143)	-0.1973*** (0.0109)
Social Distancing Lv2 period	-0.3092*** (0.0208)	-0.4212*** (0.0158)
Average speed of a car	-0.0309*** (0.0061)	-0.0437*** (0.0045)
Population	0.0016 (0.0011)	-0.0009 (0.0013)
Percentage of one's own car	-0.0314** (0.0146)	-0.0006 (0.0079)
Average apartment price per	-0.0001* (0.0000)	0.0002*** (0.0000)
Cons	18.0675*** (1.3860)	14.3751*** (0.7550)
R-squared	0.7674	0.7782
Observations	675	675
Location FE	Yes	Yes

Note: Cluster robust standard errors in parenthesis.
* $p < .1$. ** $p < .05$. *** $p < .01$.

Table 2. Panel Results: Elasticity of subway use demand by age to COVID-19 cases

Independent variable	Dependent variable			
	Log (the number of subway use cases)			
	Aged 20 to 64 years old		Over 65 years old	
Log (the number of case in Seoul)	-0.0600*** (0.0051)	-	-0.0810*** (0.0048)	-
Log (the number of case in Korea)	-	-0.0357*** (0.0022)	-	-0.0627*** (0.0022)
Average speed of a car	-0.0252*** (0.0044)	-0.0315*** (0.0046)	-0.0501*** (0.0034)	-0.0410*** (0.0029)
Population	-0.0002 (0.0029)	0.0016 (0.0020)	-0.0057* (0.0033)	-0.0028 (0.0020)
Percentage of one's own car	0.0284 (0.0344)	-0.0323 (0.0430)	0.1656*** (0.0395)	0.0871** (0.0410)
Average apartment price per	0.0001 (0.0001)	-0.0008*** (0.0001)	0.0008*** (0.0002)	-0.0000 (0.0001)
Cons	12.8778*** (3.1716)	18.9296*** (3.7799)	0.4762 (3.4244)	7.2712* (3.5412)
R-squared	0.5893	0.6058	0.5671	0.7323
Observations	225	225	225	225
Location FE	Yes	Yes	Yes	Yes

Note: Cluster robust standard errors in parenthesis.

* $p < .1$. ** $p < .05$. *** $p < .01$.

Table 3. *Panel Results: Change in subway use demand for the number of subway stations*

Independent variable	Dependent variable			
	Log (the number of subway use cases)			
	Less than 16 stations		More than 16 stations	
	Aged 20-64	Over 65	Aged 20-64	Over 65
Social Distancing Lv1	-0.1211*** (0.0185)	-0.1751*** (0.0109)	-0.1462*** (0.0155)	-0.2193*** (0.0146)
Social Distancing Lv2	-0.2928*** (0.0301)	-0.3877*** (0.0164)	-0.3349*** (0.0227)	-0.4538*** (0.0197)
Average speed of a car	-0.0287*** (0.0069)	-0.0500*** (0.0081)	-0.0304*** (0.0085)	-0.0386*** (0.0059)
Population	0.0009 (0.0015)	-0.0017** (0.0007)	0.0016 (0.0020)	-0.0006 (0.0032)
Percentage of one's own car	0.0335 (0.0358)	-0.0072 (0.0223)	-0.0462*** (0.0131)	-0.0021 (0.0112)
Average apartment price per	-0.0002** (0.0000)	0.0001** (0.0000)	-0.0000 (0.0000)	0.0002*** (0.0000)
Cons	11.9597*** (3.0686)	15.2013*** (2.0075)	19.7357*** (1.3862)	14.4994*** (1.1523)
R-squared	0.7617	0.7740	0.7833	0.7861
Observations	351	351	324	324
Location FE	Yes	Yes	Yes	Yes

Note: Cluster robust standard errors in parenthesis.

* $p < .1$. ** $p < .05$. *** $p < .01$.

Figures

Figure 1

Number of cumulative confirmed cases in Seoul, 2020. The above and below figures show the infection in February and September respectively.

Figure 2

Number of uses of mass transit during 2018–2020

Figure 3

COVID-19 status in South Korea as of Dec 23, 2020

Figure 4

Number of subway use during 2018–2020

Figure 5

Change in the share of subway use hours

Figure 6

Data collection procedure of Seoul Bigdata Campus