SPECIAL ISSUE

COVID-19 Impacts on Public Transportation



The Impact of an Epidemic on Transit Ridership

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Abstract

This paper explores how an epidemic impacts ridership on public transportation. The scanner panel data on credit and debit card transactions provide an important opportunity for researchers to gather empirical evidence on how the outbreak of a disease can substantially affect public transit ridership in relation to the socioeconomic heterogeneity of the commuters. For example, the transit mode decisions of consumers in the highest and lowest income classes remained largely consistent, while consumers in the middle-income class demonstrated a reduction in public transit ridership and instead switched to private transport use by a considerable margin. The findings presented here add important empirical knowledge about individual decisions between public transit and private vehicle use during an epidemic. Such estimated effect is qualitatively different from those of other macroeconomic factors and provides important guidance for policy interventions and practical decisions aimed at sustaining economic growth.

Keywords: Epidemic, outbreak, sustainable growth, transit ridership, consumer behaviors

Introduction

Infectious diseases have devastating effects on economies. The direct and indirect medical costs of treating patients account for a considerable share of healthcare expenditures in industrialized nations (Lee et al. 2013; Rubin et al. 1999). A significant disruption in production and trade is caused by restrictions on the transportation of people and goods, undercutting future growth. Apart from the aforementioned costs levied on governments and firms, an epidemic imposes considerable negative impacts on consumer behaviors, and the subsequent reduction in consumption extensively impacts the economies (Bloom and Mahal 1997; Gubler 2002; Kalia 2002).

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It is noteworthy that the influences of an epidemic on consumer behaviors arise from the fear of contagion. For example, consumers avoid travel and shun public places in an attempt to reduce the risk of infection. Such indirect effects are qualitatively different from those by macroeconomic factors, such as business cycles and gasoline prices, because the impact of an epidemic is primarily due to a disruption on the willingness to buy rather than from a restriction on economic ability. As a result, the reduction on expenditures is not necessarily witnessed in all categories. Instead, consumers often lower expenditures at traditional distributional channels and switch to e-commerce (Jung et al. 2016).

Recognizing the substantial differences in the impact of an epidemic across categories, this paper aims to understand how the outbreak influences public transportation ridership. Such a discussion is particularly important because the commitment to ridership on public transportation may differ based on a number of factors. Therefore, understanding the substantial heterogeneity in individual responses to an epidemic would contribute meaningful implications and effective guidance for practitioners and policy makers.

Surprisingly, however, limited attention has been placed on how consumers alter ridership on public transportation when the risk of infection is high. This absence is primarily because microdata that enables systematic studies on the indirect effects of epidemics is not widely available to academics. Studies on the effects of an epidemic on public transportation ridership heavily rely on aggregated data, leading to restricted implications (Jung, Yu, and Kwon 2016).

This paper explores how an epidemic impacts ridership on public transportation and provides substantial empirical understanding on the individual decisions concerning transit modes. Based on a unique scanner panel data set of credit and debit card transactions, a series of empirical analyses document robust evidence of a statistically and economically significant effect on the decision to use public transit ridership with substantial heterogeneity across individuals. The empirical knowledge presented in this paper yields implications that are particularly valid for policy intervention to control an extreme event.

The remainder of the paper is organized as follows. The next section describes an epidemic, which is followed by a discussion of the related literature, an explanation of the data, and presentation of preliminary analyses. Next, empirical models and their results are provided, and the paper concludes with a discussion of the implication of the findings.

Background – The MERS Outbreak in Korea

An outbreak of the Middle East respiratory syndrome coronavirus (MERS) in South Korea occurred from May 2015 to July 2016. It became the largest outbreak of MERS outside the Middle East with 186 confirmed cases and a death toll of 36. In the early stage of the outbreak, the government withheld details from the public to prevent unnecessary anxiety. However, as the number of infected patients and death toll grew, the government disclosed the names of MERS exposed health institutions. The outbreak also caused the isolation of more than 6,500 people in the country from possible exposure to the disease and the temporary close of more than 2,200 schools (Economist 2015; Newsweek 2015; Kim 2015; Associated Press 2015; Park and Kim 2015). While the MERS outbreak caused fear and anxiety among the population and resulted in an overreaction to both their behaviors (Yang and Cho 2017), closures in other parts of society, travel bans, or quarantines were not enforced by the government.

Literature Review

An extensive line of studies has explored the effects of macroeconomic factors such as business cycles and gasoline prices on consumers' transit mode decisions. Currie and Phung (2007) and Bhat, Sen, and Eluru (2009) showed that, with a focus on the effect of the business cycle, economic conditions affect transit mode decisions. Golub (2010) and Haire and Machemehl (2007) examined the impact of gasoline prices on individual choices between private vehicle use and public transit ridership and revealed that significant heterogeneity was present in the effect of gasoline prices across individuals. The conventional wisdom on the effect of a macroeconomic factor, offered in these studies, is that a key mechanism by which a macroeconomic factor impacts the economy is through disruption on consumption and purchases of goods and services (Hamilton 2009).

Unlike the macroeconomic factors discussed in these studies, an epidemic impacts the economy mainly though a disruption on the psychological willingness to buy, consequently differing its impact qualitatively. As a result, much attention has been paid to address such differences in studying the burden an epidemic indirectly levies on individual consumption behaviors. For example, upon identifying a considerable reduction in expenditures during an outbreak, Jung, Yu, and Kwon (2016) found that consumer responses to the outbreak varied considerably across product categories and that consumers switched from traditional shopping channels to e-commerce. The switch to e-commerce suggests that the fear of contagion strongly influenced shopping behaviors and resulted in a significant disruption on spending at traditional channels that accompanied the risk of infection. Such an implication is especially important for studies on public transportation in that consumers, in an attempt to lower the risk of contagion, may have avoided travel or switched to private transport.

While little attention has been paid to the effect of an extreme event on individuals' transit mode decisions, one of the few exceptions investigated the effect of an epidemic on individual transit mode decisions. Sung (2016) examined the changes in transit ridership during the MERS outbreak in Korea. However, the results are subject to a strong restriction in that the data were aggregated over individuals and the data on consumer behaviors in different fields were not available. Thus, only limited understanding about the impact of an outbreak can be extrapolated. For example, Sung's investigation was restricted to the changes in transit ridership without addressing choices on private transit uses and failed to fully explain how the reduction in transit ridership arose.

The study presented here contributes to these streams of research by exploring how an epidemic influences consumers through the disruption on their psychological willingness to spend in order to understand the economic effect of an extreme event. The unique feature of the data allows investigation of individual expenditures across different categories and provides comprehensive understanding of how such changes in transit choices arise from the fear of contagion. Accordingly, this paper makes explicit and direct implications to policy makers and managers, which cannot be inferred from studies on other macroeconomic factors.

Data

A company that developed a household account-book application in South Korea allowed the data to be used for academic research purposes. The application is available only in Korea and provided free of charge. The application collects the information of credit and debit card transactions using text messages received on the users' mobile phones. The data is anonymized, and the transaction records include the consumer's identifier, date and time of transaction, amount paid, and name of retail store. The company later identifies the retailer's type.

Given the construct, the data include a variety of expenses, ranging from expenditures at restaurants, grocery stores, and cafes to payments for electronics. The data also maintain the records of payment for gas as well as public transit transactions, revealing consumers' individual decisions on transit modes. Since that data is limited

to credit and debit card transactions, it unfortunately lacks the location information of users. However, credit and debit card transactions make up approximately 45% of the total purchases in Korea (Cha 2020), and the application is available across the nation. Thus, the data record a significant share of consumption behaviors and consumers in the sample are representative of the study area.

The data used in this study contain the retail transactions for 15,000 consumers. In Korea, a rechargeable series of smart cards and other smart devices used for paying transportation fares, implemented and operated in part by the government, account for the largest share of public transport payment. Accordingly, the credit or debit card is not the most common payment method for public transit ridership, and the records of both public transit and gasoline purchases appeared at least once for only 3,298 consumers in the sample. Thus, this study focuses on these consumers to examine their decisions concerning transit modes.

This particular sample raises concerns about the robustness of empirical results provided by the data. Nonetheless, given the absence of the microdata that enable investigation of the indirect economic effect resulting from a transitory extreme event, the data used in this analysis reveal consumer purchase and consumption behaviors in considerable detail and provide a comprehensive understanding of how consumers respond. Such discussion may have never been offered by data in other formats. Thus, the implications made by analyzing the record on individual transactions are important for practitioners and policy makers, as this paper provides critical guidance for sustainable growths in different industries.

Table 1 summarizes the shopping behaviors of the 3,298 consumers. An average consumer in this group engaged in 13.19 transactions and spent 212,841 won per week. More specifically, expenditures on groceries were the largest components of the total expenditures, followed by expenditures on food outside the home and e-commerce. Such a pattern is fairly similar to those observed in previous studies (Jung et al. 2016), providing empirical evidence that the data used maintain the comprehensive records of consumption behaviors.

	Number of Transactions (per Week)	Amount of Expenditures in Won (per Week)
Recreation and Culture	1.37	21,675 (10.18%)
Department Stores	0.13	5,204 (2.44%)
Food outside the Home	2.41	43,529 (20.45%)
E-commerce	1.87	31,633 (14.86%)
Grocery Stores	0.93	89,637 (42.11%)
Gasoline	0.17	6,471 (3.04%)
Public Transportation	2.45	3,968 (1.86%)
Others	3.86	10,724 (5.03%)
Sum	13.19	212,841

Number of Transactions and Amount of Expenditures

Table 2 shows the daily public transit ridership. During the sample period, on average, 8,081.24 transactions were made weekly for public transportation by 3,298 consumers. The average number of transactions observed on a weekday was 0.428 (17.46%), and the average number of transactions observed on Saturday and Sunday was 0.166 (6.77%) and 0.144 (5.87%), respectively. Although the data sample does not indicate the purpose

of transit ridership, the significantly large share of daily ridership on weekdays reveals that public transit was mainly used for work/school commute.

TABLE 2.

Number of Transactions for Public Transit

Number of Transactions for Public Transit			
Number of Daily Transactions			
Weekday	0.428 (17.46%)		
Saturday	0.166 (6.77%)		
Sunday	0.144 (5.87%)		

Descriptive Analysis

Figure 1 plots the aggregated monthly volume of public transit transactions in 2014 and 2015, presenting clear time trends in public transit ridership volume throughout the entire data period. More specifically, the weekly volume reached its highest and lowest totals during the summers and winters, respectively, and remained in between during the springs and falls. It is important to note that the pattern summarized in Figure 1 is fairly distinctive from the patterns witnessed in Europe, where the volume of public transit ridership is high during the winter. However, the current pattern is largely similar to the public transit volume reported in previous research (Jung et al. 2016), providing empirical evidence that the data contain comprehensive records of public transit ridership. Thus, this seasonal variability was considered when examining the impact of the MERS outbreak and was explicitly addressed in the empirical analysis.



FIGURE 1.

Average monthly expenditures (in won) on public transportation, 2014–2015

The average monthly transaction volumes of public transit expenditures were computed for the outbreak period (test period), three months before and after the outbreak, and another set of three-month-long periods a year before the outbreak (control periods). Table 3 shows that the average monthly transaction volume during the outbreak period was 25,876 won, which is relatively smaller than the number of transactions in other control periods. However, the difference in the monthly expenditures between test and control periods was less than 1% of its volume. Accordingly, a simple comparison of public transit expenditures fails to descriptively identify the impact of the epidemic on consumer sentiments and behaviors, which may have led to changes in public transit ridership.

TABLE 3.

Average Monthly Expenditures on Public Transportation in Control and Test Periods					
Control Period 1 (Feb–Apr 14)	Control Period 2 (May–Jul 14)	Control Period 3 (Aug–Oct 14)	Control Period 4 (Feb–Apr 15)	Test Period (May–Jul 15)	Control Period 5 (Aug–Oct 15)
25,783	26,196	26,132	25,818	25,876	26,096

Average Monthly Expenditures on Public Transportation in Control and Test Periods

Next, expenditures on gasoline were considered and the weekly gasoline expenditures for the same set of threemonth-long periods were calculated. Table 4 shows that private vehicle use also remained fairly stable during the period of the MERS outbreak, although a generally increasing pattern was observed throughout the year. The gasoline expenditures during the outbreak were approximately the same as those in the five control periods.

TABLE 4.

Monthly Gasoline Expenditures in Control and Test Periods

Monthly Gasoline Expenditures in Control and Test Periods						
Control Period 1 (Feb–Apr 14)	Control Period 2 (May–Jul 14)	Control Period 3 (Aug–Oct 14)	Control Period 4 (Feb–Apr 15)	Test Period (May–Jul 15)	Control Period 5 (Aug–Oct 15)	
6,511	6,571	6,603	6,503	6,587	6,627	

Such patterns in total public transportation and gasoline expenditures pose a question about whether changes were made in individual decisions for transit modes in response to the MERS outbreak. For further empirical analyses, individual expenditures were examined by categories, and formal models were developed to investigate how the fear of infection influenced consumers. This was to control for variability in the transaction volume observed in the data between 2014 and 2015, which may prohibit the precise measurement of the effects in the preliminary analyses.

Empirical Analyses

Expenditures on Public Transportation and Gasoline

Based on the preliminary findings, the study explored how the MERS outbreak influenced transit ridership in Korea using an ordinary least squares regression in the following specification:

$$\log Exp_{it}^c = \alpha^0 + \alpha^1 \log Exp_{i0}^c + \alpha^{2,c} I_{MERS}^t + ZX_{it} + \epsilon_{it}^1$$
(1)

where Exp_{it}^c = consumer *i*'s is the expenditures in category *c* during week *t*, Exp_{i0}^c is the expenditures of consumer *i* in category *c* during the first six weeks of the data, I_{MERS}^t =1 if a new case had been reported in the week *t* and I_{MERS}^t =0 otherwise¹, and X_{it} is a set of controls, including dummies for time trends and the demographic information of consumers.

The above specification formally tested the preliminary findings in greater detail. In particular, consumer expenditures on public transit and gasoline, and how the MERS outbreak influenced transit mode decisions, were examined. Note that the dependent variable is specified in log-linear form.

The model of transit and gasoline expenses employs log-log form, and the estimation results provide coefficients in percentages instead of absolute terms. This is because the numerous expenditures on public transit across individuals demonstrate considerable variations. Log-log linear specification is widely employed by studies exploring the effects of macroeconomic factors on consumer expenditures in different categories (Gicheva, Hastings, and Villas-Boas 2010; Ma et al. 2011).

The explanatory variables can be grouped into three sets. The first set estimates the effect of heterogeneity in preferences across consumers using individual values of the dependent variable during a six-week initialization period along with their demographic information (Ma et al. 2011; Briesch, Chintagunta, and Fox 2009). The second set, the interaction effect between dummies indicating whether the time t is during the outbreak and whether the expenditures are made on category c, measures its effect, which was of central interest to this research. The third group, X_{it} , controls for time trends using time dummies and the holiday effect.

To help interpret the coefficient estimates of the focal interests, the estimates of $\alpha^{2,g}$ and $\alpha^{2,pt}$, denoted by $\alpha^{2,c}$ in Equation 1, are the coefficients of this study's primary interests and measure the outbreak's effect on gasoline and public transit expenditures. Based on the fact that the disruption on consumer sentiment, attitude, and behaviors arise from the fear of contagion during an epidemic (Jung et al. 2016), there are negative and positive effects on public transit and gasoline expenditures, respectively.

Table 5 reports the estimation results. The estimate of $\alpha^{2,pt}$ is statistically significant and negative, implying that the average expenditure on public transit dropped by 2.75%. However, the estimate of $\alpha^{2,g}$ is not statistically significant, illustrating that gasoline expenditures remained fairly unchanged during the outbreak. This is somewhat inconsistent to the prediction that, when the risk of infection is high, consumers would substitute public transport with private transport; and the expenditures on gasoline and public transportation would increase and decrease, respectively.

Except for the second and third weeks and the last three weeks of the test period, a new case had been reported and $I_{MERS}^{t} = 1$.

TABLE 5.

Estimation Results for Model 1

Variable	Coefficient	Estimate	Standard Error
Expenditures during Initialization Period	α^1	0.3386**	(0.0114)
MERS*Gasoline	$\alpha^{2,g}$	0.0125	(0.0114)
MERS*Public Transit	$\alpha^{2,pt}$	-0.0275**	(0.0122)
Year Dummy		0.035	(0.04)
1st Quarter	Z	-0.1135**	(0.0112)
2nd Quarter		-0.0807**	(0.0141)
3rd Quarter		-0.0551**	(0.0108)
Age Group: 30's		0.0634**	(0.0.081)
Age Group: 40's		0.0760**	(0.0084)
Age Group: 50's		0.0672**	(0.0083)
Age Group: 60's		0.1204**	(0.0098)
Gender Group: Male		0.0831**	(0.0211)
Holiday Effect		0.1527**	(0.0487)
Intercept	α ⁰	6.9301**	(0.3044)
N	685,984	Adjusted R-Squared	0.1405

Note: Standard errors are shown in parentheses. **p*<0.05; ***p*<0.01.

Turning to variables controlling for time trends and the holiday effect, the effects are all statistically significant and intuitive. In addition, individual consumers' value of the dependent variable during the six-week initialization period has a statistically significant effect and has the largest predicting power in terms of t-value.

The significant but somewhat unexpected effect of the MERS outbreak on public transit ridership indicates that other measures could be considered. For example, the influences on transit ridership decisions due to the fear of contagion might increase relative to the number of deaths (Jung et al. 2016). In addition, there could be other specifications to better describe the effect of the MERS outbreak than the log-linear specification employed in the previous model. Thus, using the death toll² reported during the week t and a linear model specification, two additional models were developed in the following forms:

$$\log Exp_{it}^{c} = \beta^{0} + \beta^{1,c} \log Exp_{i0}^{c} + \beta^{2,c} Death_{t} + BX_{it} + \epsilon_{it}^{2}$$
(2)

and
$$Exp_{it}^{c} = \gamma^{0} + \gamma^{1,c} Exp_{i0}^{c} + \gamma^{2,c} I_{MERS}^{t} + \Gamma X_{it} + \epsilon_{it}^{3}$$
. (3)

Again, $\beta^{2,c}$ and $\gamma^{2,c}$ are the variables of the key interests and measure the effect of the MERS outbreak on expenditures for private vehicle and public transit usage.

²For the first four weeks and the last two weeks of the test period, no new cases were reported and Death_=1.

Table 6 summarizes the key results. Most importantly, the estimates of $\beta^{2,pt}$ and $\gamma^{2,pt}$ are statistically significant and negative; and the estimates of $\beta^{2,g}$ and $\gamma^{2,g}$ are not statistically significant in all replications. More specifically, the estimation results for Model 2 reveal that consumers, on average, reduced their public transit expenditures by 3.18% for a unit increase in the number of death tolls, and the estimation results for Model 3 indicate that consumers, on average, reduced their public transit expenditures by 123.81 won per week during the outbreak. On the other hand, consumers, on average, maintained relatively stable expenditures on gasoline during the outbreak. Given that estimates of all other variables are also consistent with the previous estimation results and are intuitive, the primary findings in the first model survived the robustness checks, despite the decrease in model fit in terms of adjusted R-squared.

TABLE 6.

		Mod	lel 2	Model 3	
Variable	Coefficient	Estimate (log-log)	Standard Error	Estimate (linear)	Standard Error
Expenditures during Initialization Period	$eta^{ extsf{1,g}}/\Upsilon^{ extsf{1,g}}$	0.3941**	(0.1028)	0.2819**	(0.0893)
MERS*Gasoline	$eta^{2,g}/\Upsilon^{2,g}$	0.0142	(0.0091)	58.63	(36.36)
MERS*Public Transit	$eta^{2,pt}/Y^{2,pt}$	-0.0318**	(0.0084)	-123.81**	(39.32)
N Adjusted R-Squared		865,984 0.1135		865,984 0.1224	

Estimation Results for Models 2 and 3

Note: Standard errors are shown in parentheses. *p<0.05; **p<0.01.

To summarize, after explicitly controlling for time trends and heterogeneity across individual consumers, the empirical evidence suggests that the MERS outbreak impacted individual public transit choices considerably. However, the analyses presented in this subsection found no empirical evidence for the substitution of public transit with private transportation.

Expenditures Across Categories

Given the somewhat unexpected effect of the MERS outbreak on individual transit mode decisions, a more comprehensive understanding about the effect is needed. Such an analysis is important because consumer behaviors are at the root of changes at an aggregate level (Gicheva, Hastings, and Villas-Boas 2010). Also, understanding consumers will provide necessary guidance for effective managerial decisions concerning sustainable growth during the period, and in even more challenging and complex epidemics.

To do so, quantifying changes in expenditures in different categories would further explain the changes in public transit ridership during the outbreak. Therefore, product categories were selected in which individual consumers exhibited diverse shopping behaviors, focusing on the following five expenditure categories: public transit, recreation and leisure, gasoline, groceries, and e-commerce. Quantifying changes in these categories would explain whether the MERS outbreak effect was limited to decisions on transit modes or whether the disruption in the public transit ridership arose from the changes in activities that can accompany the risk of contagion.

The model of expenditures in the five categories was specified as a function of the same explanatory groups, with individual *i*'s expenditures in category *c* for week t, Exp_{it}^c , as the dependent variable. This model was also specified in log-log form:

$$\log Exp_{it}^{c} = \zeta^{0} + \zeta^{1,c} \log Exp_{i0}^{c} + \zeta^{2,c} I_{MERS}^{t} + ZX_{it} + \epsilon_{it}^{4}$$
(4)

This specification identifies mutually exclusive marginal effects of the MERS outbreak on expenditures across categories. For example, $\zeta^{2,c}$ estimates the effect on expenditures in category *c* and reveals the differences in adjustments consumers made across categories. Note that the current model follows the first model's specification and incorporates additional categories.

Table 7 reports the key estimation results with marginal effects of the MERS outbreak by categories. Focusing on the variables of key interests, the marginal effects in Table 7 show the following: during the period of the MERS outbreak, consumers lowered expenditures on public transportation by -2.58%; consumer expenditures on gasoline, on the other hand, remained fairly stable and did not exhibit statistically significant changes; and, finally, consumers reduced expenditures on groceries and recreation and leisure by 1.04% and 4.83%, respectively, and increased expenditures on e-commerce by 2.73%. As the first and current models share the specification, the effect of the MERS outbreak on gasoline and public transit expenditures turns out fairly similar.

Variable	Coefficient	Estimate	Standard Error
MERS*Gasoline	ζ ^{2,g}	0.0127	(0.0101)
MERS*Public Transit	ζ²,pt	-0.0258**	(0.0124)
MERS*Recreation and Leisure	ζ ^{2,rl}	-0.0483**	(0.0095)
MERS*Groceries	ζ ^{2,gr}	-0.0104**	(0.0018)
MERS*E-commerce	ζ ^{2,e}	0.0273**	(0.0097)
N	1,714,960	Adjusted R-Squared	0.1402

TABLE 7.

Estimation Results for Model 4

Note: Standard errors are shown in parentheses. **p*<0.05; ***p*<0.01.

Given the unexpected insignificant effect of the MERS outbreak on gasoline expenditures, one interpretation of the above marginal effects is that, in an effort to avoid possible exposure to the disease, consumers reduced recreation and/or leisure activities and switched from traditional shopping channels to e-commerce. At the same time, consumers, in part, substituted public transit with private transportation for necessary recurrent trips. Such adjustments in behaviors led to decreased expenditures for public transportation, while expenditures on gasoline remained fairly constant as the increase in private vehicle use for the daily commute to work offset the decrease in its uses for unnecessary, nonrecurrent leisure trips. However, it is beyond the scope of this paper to validate the above interpretation, and it is equally plausible that consumers attempted to reduce trips while making expenses for public transit go down without compensation in gasoline purchases. Turning to individual consumers' value of the dependent variable during the six-week initialization period, which controlled for individual heterogeneity, the study revealed its statistically significant effect. In addition, variables controlling for time trends and the holiday effect were again all statistically significant and intuitive.

To summarize, after explicitly controlling for time trends and heterogeneity across individual consumers, the MERS outbreak impacted consumers considerably and resulted in significant adjustments to their behaviors. The results imply that the outbreak disrupted decisions concerning transit modes significantly and that the effect was as large as those witnessed in studies on macroeconomic factors such as business cycle or gasoline prices (Currie and Phung 2007; Bhat, Sen, and Eluru 2009; Golub 2010; Haire and Machemehl 2007). However, the effect of an extreme event is largely different from other effects in how it influences expenditures. The guidance provided in this study for practitioners and managers is, therefore, qualitatively different from studies on other macroeconomic factors.

Having identified the significant effect of an epidemic, there is ample evidence that individual characteristics have a significant impact on price sensitivities in many purchase contexts and, as a result, considerable heterogeneity is observed across individuals (Hoch et al. 1995). For example, marginal costs during periods of rising gasoline prices become particularly significant for low-income households (Golub 2010). As individual decisions concerning transit modes are often closely related to financial constraints (Jung et al. 2016), the next analysis addressed this specific aspect and incorporated the effect of financial constraints. Interactions between income and the outbreak were explored, and whether the effect of an extreme event is similar across individuals in different income classes was examined.

Without a direct measure of income in the data, consumption expenditures approximate the financial constraints (Cutler and Katz 1991; Fisher, Johnson, and Smeeding 2013). Accordingly, a categorical variable was constructed to identify the baseline of individual expenditures. Baseline expenditures were defined as the average weekly expenditures in the six-week-long initialization period, and the 25th, 50th, and 75th percentiles of total expenditures were used as cutoff points.

 $Group_i=1$ if below the 25th percentile $Group_i=2$ if between the 25th and 50th percentiles $Group_i=3$ if below the 50th and 75th percentiles $Group_i=4$ if above the 75th percentile

To address the possible heterogeneity in the effect of an epidemic across individuals in different income classes, interaction effects between the variable indicating the period of the MERS outbreak and the categorical variable identifying the income class were included. The following model specification was developed based on the same explanatory variables:

$$\log Exp_{it}^{m} = \eta^{0} + \eta^{1,m} \log Exp_{i0}^{m} + \eta^{2,m,n} I_{MERS}^{t} + HX_{it} + \epsilon_{it}^{1}$$
(5)

 $I\eta^{2,m,n}$ measures the change in expenditures on category *m* during the outbreak for an individual with $Group_i=n$.

Table 8 reports the coefficient estimates and their standard errors. First, the effect turned out statistically significant and negative for groceries and for recreation and leisure, and positive for e-commerce in all income classes. The result provides strong empirical evidence that consumers commonly attempted to reduce the risk of infection by avoiding recreation and/or leisure activities and switched from traditional shopping channels to e-commerce. The MERS outbreak significantly impacted consumer sentiments and consumption and led consumers to prevent possible exposure to the disease, highly consistent with the behavioral patterns in past studies (Jung et al. 2016).

TABLE 8.

Estimation Results for Model 5

Westerk I.	C G	Estimate and Standard Error			
Variable	Coemclent	Group 1	Group 2	Group 3	Group 4
MERS*Gasoline	$\eta^{^{2,g,n}}$	0.0098 (0.0068)	0.0158** (0.0071)	0.0154** (0.0072)	0.0098 (0.0072)
MERS*Public Transit	$\eta^{\scriptscriptstyle 2,pt,n}$	-0.0194 (0.0113)	-0.0284** (0.0117)	-0.0314** (0.0117)	-0.0194 (0.0118)
MERS*Groceries	$\eta^{\scriptscriptstyle 2, gr, n}$	-0.0112** (0.0021)	-0.0103** (0.0019)	-0.0098** (0.0019)	-0.0099** (0.0017)
MERS*Recreation and Leisure	$\eta^{\scriptscriptstyle 2, rl, n}$	-0.0416** (0.0122)	-0.0437** (0.0125)	-0.0484** (0.0124)	-0.0471** (0.0123)
MERS*E-commerce	$\eta^{^{2,e,n}}$	0.0319** (0.0093)	0.0271** (0.0098)	0.0283** (0.0096)	0.0201** (0.0099)
		N	115,153	Adjusted R-Squared	0.2034

Note: Standard errors are shown in parentheses. *p<0.05; **p<0.01.

Turning to the decisions concerning transit modes, considerable heterogeneity was present in the changes in individual responses to the epidemic. First, the effect of the MERS outbreak was not statistically significant on gasoline and public transit expenditures for consumers with the smallest and largest baseline total consumption. On the other hand, its effect was significant for consumers in the middle-income class: consumers in Groups 2 and 3 lowered expenditures on public transit by 2.84% and 3.14% and increased gasoline expenditures by 1.58% and 1.54%, respectively.

Together with the fact that consumers in the lowest and highest income classes made the largest and smallest expenditures on public transit, respectively, the estimation results suggest the following. In transit mode decisions, consumers commonly attempted to reduce public transit ridership and switched to private transport use. As a result, consumers in the middle-income class increased their gasoline expenditures and lowered spending on public transportation by a considerable margin. Consumers in the highest income class, however, already had the largest/smallest expenditures on gasoline/public transportation and, therefore, their transit mode decisions remained largely consistent. Finally, consumers in the lowest income class failed to reduce public transit ridership during the outbreak and maintained the strongest commitment to public transportation use throughout the entire data period.

The results documented in Table 8 are particularly important in that the effect of an epidemic not only significantly disrupts consumer sentiment, attitude, and behaviors, but also exhibits significant heterogeneity across consumers in different income classes. The findings of this study provide comprehensive understanding

about how the MERS outbreak influenced individual behaviors in different dimensions and explain how the unexpected results in previous analyses arose. The current findings confirm the role of income in how an epidemic affects consumer decisions regarding transit modes.

Discussion

This empirical investigation based on the panel data of consumer expenditures presented evidence that the outbreak of an extreme event had a statistically significant effect on transit mode decisions. Confirming the presence of considerable heterogeneity across individuals, the findings also showed that financial constraints were important in determining commitment to public transportation use when the risk of infection was high.

This research has an important implication for policy makers. In an effort to reduce the negative impact of an epidemic, policy makers attempt to lower the risk of infection. However, as described in the previous section, individuals with financial constraints had an increased tendency to use public transportation, thereby failing to lower possible exposure to disease. Given this notion, alternative means of protection from an epidemic must be provided for individuals in a low-income class. In addition to campaigns urging individuals to avoid public places and reduce possible exposures to disease, providing protective gear to people is prudent. For example, subsidies for the wide adoption of surgical masks and/or hand sanitizers that help protect users against MERS were necessary and helpful. The restricted scope of this paper does not allow analysis and validation of such policy intervention; rather, the primary objective of this discussion is to present a particular implication for practitioners and policy makers.

Conclusion

This study addresses how an epidemic influences consumer decisions concerning transit modes. Using the scanner panel data on individual consumer transactions, strong empirical evidence suggests that the outbreak of an epidemic disease causes a substantial effect on public transit ridership with the presence of significant heterogeneity across individuals. The results show that understanding consumer behaviors in different dimensions is necessary to understand the effect of an extreme event on public and private transportation.

The findings of this paper add important empirical knowledge about individual decisions between public transit and private vehicle use. Extensive studies have been compiled to address transit ridership. However, past studies were typically conducted at an aggregate level and generally focused on the disruption of economic abilities. Less is known about individual responses to an epidemic because the effect of an outbreak arises from fear of contagion, unlike those of other economic factors, and aggregate data often fail to provide a comprehensive understanding of how individuals respond in different categories. As a result, the implications made through this research can help assess the effect of an epidemic and formulate supplementary budgets.

The limited scope of this study does not allow analysis and validation of specific policy interventions. Nevertheless, this paper finds that an epidemic influences transit ridership considerably and that there is significant heterogeneity in the effect across individuals in different income classes. As a result, the authors hope their research stimulates further efforts to investigate their argument.

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References

- Associated Press. 2015. "South Korean Schools Reopen Despite Widespread MERS Fear." *The Oklahoman*. Accessed February 2, 2020.
- BBC. 2015. "S Korea Cuts Interest Rates to Record Low amid Mers Concerns." Accessed February 2, 2020. http://www.bbc.com/news/business-33089930.
- Bhat, C. R., S. Sen, and N. Eluru. 2009. "The Impact of Demographics, Built Environment Attributes, Vehicle Characteristics, and Gasoline Prices on Household Vehicle Holdings and Use." *Transportation Research Part B: Methodological* 43 (1): 1–18.
- Bloom, D. E., and A. S. Mahal. 1997. "Does the AIDS Epidemic Threaten Economic Growth?" *Journal of Econometrics* 77 (1): 105–124. https://doi.org/10.1016/S0304-4076(96)01808-8.
- Briesch, R. A., P. K. Chintagunta, and E. J. Fox. 2009. "How Does Assortment Affect Grocery Store Choice?" *Journal of Marketing Research* 46 (2): 176–189. https://doi.org/10.1509/jmkr.46.2.176.
- Bucklin, R. E., S. Gupta, and S. Han. 1995. "A Brand's Eye View of Response Segmentation in Consumer Brand Choice Behavior." *Journal of Marketing Research* 32 (1): 66–74. https://doi.org/10.2307/3152111.
- Cha, J. 2020. "Accelerating Cashless Society: 44% of Credit Card Usage." *New Daily News*. Accessed July 9, 2020. http://biz.newdaily.co.kr/site/data/html/2020/03/10/2020031000136.html.
- Currie, G., and J. Phung. 2007. "Transit Ridership, Auto Gas Prices, and World Events: New Drivers of Change?" *Transportation Research Record: Journal of the Transportation Research Board* 1992 (1): 3–10. https://doi. org/10.3141/1992-01.
- Cutler, D. M., and L. F. Katz. 1991. "Macroeconomic Performance and the Disadvantaged." *Brookings Papers on Economic Activity* 1991 (2): 1–74.
- Economist. 2015. "South Korea and MERS: Fear in the Air." Accessed February 2, 2020. http://www.economist. com/news/asia/21653731-fear-air.
- Fisher, J. D., D. S. Johnson, and T. M. Smeeding. 2013. "Measuring the Trends in Inequality of Individuals and Families: Income and Consumption." *American Economic Review* 103 (3): 184–88. doi:10.1257/aer.103.3.184.
- Gicheva, D., J. Hastings, and S. Villas-Boas. 2010. "Investigating Income Effects in Scanner Data: Do Gasoline Prices Affect Grocery Purchases?" *American Economic Review* 100 (2): 480-84. doi:10.1257/aer.100.2.480.
- Golub, A. 2010. "Welfare and Equity Impacts of Gasoline Price Changes under Different Public Transportation Service Levels." *Journal of Public Transportation* 13 (3): 1–21. http://doi.org/10.5038/2375-0901.13.3.1.
- Gubler, D. J. 2002. "Epidemic Dengue/Dengue Hemorrhagic Fever as a Public Health, Social and Economic Problem in the 21st Century." *Trends in Microbiology* 10 (2): 100–103. doi:10.1016/s0966-842x(01)02288-0.
- Haire, A. R., and R. B. Machemehl. 2007. "Impact of Rising Fuel Prices on U.S. Transit Ridership." *Transportation Research Record: Journal of the Transportation Research Board* 1992 (1): 11–19. https://doi.org/10.3141/1992-02.
- Hamilton, J. D. 2009. "Causes and Consequences of the Oil Shock of 2007-08." *Brookings Papers on Economic Activity* 40 (1, Spring): 215–283. doi:10.1353/eca.0.0047.
- Hoch, S. J., B-D. Kim, A. L. Montgomery, and P. E. Rossi. 1995. "Determinants of Store-Level Price Elasticity." *Journal of Marketing Research* 32 (1): 17–29.

- Jung, H., M. Park, K. Hong, and E. Hyun. 2016. "The Impact of an Epidemic Outbreak on Consumer Expenditures: An Empirical Assessment for MERS Korea." *Sustainability* 8 (5), 454:1–15. doi:10.3390/su8050454.
- Jung, H., G. J. Yu, and K-M. Kwon. 2016. "Investigating the Effect of Gasoline Prices on Transit Ridership and Unobserved Heterogeneity." *Journal of Public Transportation* 19 (4): 56–74.
- Kalia, M. 2002. "Assessing the Economic Impact of Stress The Modern-Day Hidden Epidemic." *Metabolism* 51 (6): 49–53. doi:10.1053/meta.2002.33193.
- Kim, J. 2015. "South Korea Replaces Health Minister Criticized over MERS Outbreak." *Reuters*. Accessed February 2, 2020. http://www.reuters.com/article/us-health-mers-southkorea-idUSKCN0Q90JJ20150804.
- Lee, B. Y., K. M. Bacon, M. E. Bottazzi, and P. J. Hotez. 2013. "Global Economic Burden of Chagas Disease: A Computational Simulation Model." *The Lancet Infectious Diseases* 13 (4): 342–48. doi:10.1016/S1473-3099(13)70002-1.
- Ma, Y., K. L. Ailawadi, D. K. Gauri, and D. Grewal. 2011. "An Empirical Investigation of the impact of Gasoline Prices on Grocery Shopping Behavior." *Journal of Marketing* 75 (2): 18–35.
- Newsweek. 2015. "MERS Prompts Hong Kong to Declare 'Red Alert' on South Korea Travel." Accessed February 2, 2020. http://www.newsweek.com/mers-prompts-hong-kong-declare-red-alert-south-korea-travel-341093.
- Park, J., and S. Kim. 2015. "Secrecy Surrounding MERS Outbreak Fuels Fear, Confusion in South Korea." *Huffpost.* Accessed February 2, 2020. http://www.huffingtonpost.com/2015/06/02/south-korea-mersoutbreak_n_7492380.html.
- Park, M., K. J. Kwon, and J. Kim. 2015. "WHO Calls MERS Outbreak a 'Wakeup Call." CNN. Accessed February 2, 2020. http://edition.cnn.com/2015/06/15/asia/south-korea-mers-outbreak.
- Rubin, R. J., C. A. Harrington, A. Poon, K. Dietrich, J. A. Greene, and A. Moiduddin. 1999. "The Economic Impact of Staphylococcus Aureus Infection in New York City Hospitals." *Emerging Infectious Diseases* 5 (1): 9–17. doi:10.3201/eid0501.990102.
- Sung, H. 2016. "Impacts of the Outbreak and Proliferation of the Middle East Respiratory Syndrome on Rail Transit Ridership in the Seoul Metropolitan City." *Journal of Korea Planning Association* 51 (3): 163–179. doi:10.17208/jkpa.2016.06.51.3.163.
- Yang, S., and S. Cho. 2017. "Middle East Respiratory Syndrome Risk Perception among Students at a University in South Korea." *American Journal of Infection Control* 45 (6): e53-e60. doi:10.1016/j.ajic.2017.02.013.

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