HHS Public Access
Author manuscript
Travel Med Infect Dis. Author manuscript; available in PMC 2020 July 01.

Published in final edited form as:
Travel Med Infect Dis. 2019 ; 30: 54–66. doi:10.1016/j.tmaid.2019.05.009.

The effects of past SARS experience and proximity on declines in numbers of travelers to the Republic of Korea during the 2015 MERS outbreak: A retrospective study

Heesoo Joo, PhD[1], **Ronald E. Henry, BA**[1], **Yeon-Kyeng Lee, PhD**[2], **Andre D. Berro, MPH**[1], **Brian A. Maskery, PhD**[1]

[1]Division of Global Migration and Quarantine, Centers for Disease Control and Prevention, Atlanta, GA, USA

[2]Korea Centers for Disease Control and Prevention, Cheongju-si, Chungcheongbuk-do, Republic of Korea

Abstract

Background: The experience of previous sizable outbreaks may affect travelers' decisions to travel to an area with an ongoing outbreak.

Methods: We estimated changes in monthly numbers of visitors to the Republic of Korea (ROK) in 2015 compared to projected values by selected areas. We tested whether areas' experience of a previous SARS outbreak of ≥100 cases or distance to the ROK had a significant effect on travel to the ROK during the MERS outbreak using t-tests and regression models.

Results: The percentage changes in visitors from areas with a previous SARS outbreak of ≥100 cases decreased more than the percentage changes in visitors from their counterparts in June (52.4% vs. 23.3%) and July (60.0% vs. 31.4%) during the 2015 MERS outbreak. The percentage changes in visitors from the close and intermediate categories decreased more than the far category. The results from regression models and sensitivity analyses demonstrated that areas with ≥100 SARS cases and closer proximity to the ROK had significantly larger percentage decreases in traveler volumes during the outbreak.

Conclusions: During the 2015 MERS outbreak, areas with a previous sizable SARS outbreak and areas near the ROK showed greater decreases in percentage changes in visitors to the ROK.

1. Background

The 2015 Middle East respiratory syndrome (MERS) outbreak in the Republic of Korea (ROK) was initiated by the arrival of a single infected international traveler who visited the Middle East [1]. The first case was confirmed on May 20, 2015, and the outbreak resulted in 186 cases and 38 deaths before the government of the ROK and the World Health

Corresponding Author: Heesoo Joo, PhD, Division of Global Migration and Quarantine, United States Centers for Disease Control and Prevention, 1600 Clifton Road, MS H16-4, Atlanta, GA 30333, USA, Tel: +1 404 718 1667, Fax: +1 404 471 8864, hjoo@cdc.gov.

The findings and conclusions of this article are those of the authors and do not necessarily represent the official position of the United States Centers for Disease Control and Prevention or the Korea Centers for Disease Control & Prevention.

Organization (WHO) officially announced the end of the outbreak on December 23, 2015 [2].

During the 2015 MERS outbreak, the ROK government conducted entry screening and active monitoring of all travelers from the Middle East region to avoid additional importations of MERS cases [2]. In addition, the ROK government restricted international departures by confirmed or suspected MERS patients or their contacts to prevent the global spread of MERS [2]. Although WHO did not recommend any travel restrictions or entry screening for MERS coronavirus (MERS-CoV) [3], the numbers of international travelers visiting the ROK decreased significantly during the 2015 MERS outbreak [4, 5].

Fear-induced behavioral changes during novel infectious disease outbreaks have been reported to depend on an individual's perception of risk rather than the actual risk [6]. One factor that could affect an individual's perception of the risk of an infectious disease outbreak is the individual's previous experience of a similar infectious disease outbreak. Governments of countries that had a similar sizable outbreak, as well as individuals from those countries, may have responded differently to the ROK MERS outbreak than governments or individuals who had less exposure to a similar sizable outbreak.

This evaluation estimates the changes in numbers of non-citizen short-term visitor arrivals from selected areas to the ROK during the 2015 MERS outbreak and examines the correlation between travel volume declines and previous experience of the most similar sizable outbreak, the 2003 severe acute respiratory syndrome (SARS) outbreak. We also examined the correlation between decrease in travel volume and proximity to the ROK.

2. Methods

We used monthly international traveler statistics from TOURGO, the Korea tourism knowledge and information system, maintained by the Korea Culture and Tourism Institute [7]. The data include numbers of inbound non-citizen short-term visitor arrivals by area following the international guideline from the United Nations World Tourism Organization [7]. The numbers of arrivals reported in this analysis are limited to the numbers of non-citizen short-term visitor arrivals.

Each area includes one country or political unit. Note that area information in the data set is based on travelers' passports rather than the areas from which travelers departed. First, we selected areas comprising more than 0.5% of total non-citizen visitor arrivals, i.e. more than 70 000 visitors to the ROK during 2014. Selected areas in descending order of numbers of arrivals to the ROK during 2014 are China (mainland China excluding Hong Kong Special Administrative Region (SAR), Macau, and Taiwan), Japan, United States (USA), Taiwan–China, Hong Kong SAR–China, Thailand, Philippines, Malaysia, Russia, Indonesia, Singapore, India, Canada, Vietnam, Australia, United Kingdom (UK), Germany, and France. They combined to contribute 94% of the total number of arrivals to the ROK during 2014. Monthly actual numbers of arrivals in 2015 by area from TOURGO are shown in Appendix Table 1.

For each area, we compared monthly numbers of arrivals in 2015 to the monthly average numbers of arrivals in 2013 and 2014. The baseline percentage change in numbers of arrivals (y) of each area to the ROK by month was calculated from the projected values (averages of 2013 and 2014) subtracted from the actual values (2015) and then divided by the projected values as shown in the following equation:

$$y_{ij} = \frac{Actual\ (with\ the\ MERS\ outbreak)_{ij} - Projected\ (if\ there\ was\ no\ MERS\ outbreak)_{ij}}{Projected\ (if\ there\ was\ no\ MERS\ outbreak)_{ij}} \times 100\,\%$$

where "i" stands for each area, while "j" stands for each month during the ROK MERS outbreak from June 2015 to December 2015. If the actual value is smaller than the projected value in a given area-month, i.e. decreasing arrivals associated with the MERS outbreak, the negative value y_{ij} corresponds to the estimated percentage decrease in visitor arrivals. The number of travelers for each area in each month were treated as a single observation. We assumed that any changes of numbers of arrivals caused by the MERS outbreak would be observed starting in June because the first MERS case was confirmed on May 20, 2015.

We chose two main variables that could affect individuals' decisions to travel to an outbreak area. The first variable was whether an area had a sizable outbreak of limited duration of a novel viral respiratory disease before the 2015 MERS outbreak. The 2003 SARS outbreak was chosen because it was sizable including local transmission and its duration was limited [8]. During the 2003 SARS outbreak, more than 8 000 individuals were infected worldwide with a 9.6% average case fatality rate [9]. In addition, SARS and MERS are both viral respiratory infections caused by coronaviruses, although the case fatality rates reported for SARS were lower than for MERS [10]. Community transmission of SARS was more commonly reported, while MERS transmission in the ROK occurred primarily in healthcare settings or through close contact, e.g. caring for or living with an infected person [10, 11]. The 2009 H1N1 influenza pandemic was also caused by viral respiratory infection; however, country-specific H1N1 attack rates were orders of magnitude higher and its case fatality rate was much lower compared to the limited-duration outbreaks of SARS and MERS [10, 12, 13].

Using WHO data for reported numbers of probable SARS cases by area during the 2003 outbreak [9], we hypothesized that individuals from areas with ≥100 SARS cases during the 2003 outbreak may have been significantly more or less likely to visit the ROK during the 2015 MERS outbreak. China, Taiwan–China, Singapore, Canada, and Hong Kong SAR–China each had ≥100 SARS cases during the 2003 outbreak, and all of those areas were included in the current analyses. Although the threshold was set at 100 probable SARS cases, each of the five areas experienced at least 238 probable SARS cases, while the country/area with next highest number of probable SARS cases, Vietnam, had 64 cases (Appendix Figure 3) [9]. Thus, our results would be consistent with any threshold set between 65 cases and 237 WHO-reported probable cases.

The second variable we considered was travel distance to the ROK from each area. Since travel time cost is likely to be correlated to travel distance between two areas, the opportunity cost to change travel plans from a more distant place to the ROK would be expected to be higher. Thus, individuals from more distant areas might be less likely to cancel trips to the ROK during the outbreak period. We subdivided selected areas into three groups based on distance to the ROK: (1) close (China, Japan, Taiwan–China, and Hong Kong SAR–China), (2) intermediate (Thailand, Philippines, Malaysia, Indonesia, Singapore, India, and Vietnam), and (3) far (USA, Russia, Canada, Australia, UK, Germany, and France). More details about how we defined distance categories for analyses are shown in Appendix Tables 2 and 3.

For both variables, we performed Welch's t-tests for two samples with unequal variances [14] to examine whether the monthly average percentage decreases in numbers of arrivals from each category differed significantly. For the SARS variable, the null hypothesis is that the simple average percentage change of arrivals from areas with <100 SARS cases (reference) was the same as the percentage change of arrivals for areas with ≥100 SARS cases. The alternative hypothesis is that the percentage decreases for arrivals from areas with ≥100 SARS cases were larger than for areas with <100 SARS cases. For the distance categories, the null hypothesis is that the simple average percentage change of arrivals from the far category (reference) was the same as the percentage change of arrivals from the intermediate or the close category. The alternative hypothesis is that the percentage decreases for arrivals from areas in the far category were smaller than for arrivals from the areas in the intermediate or the close categories. When p-values from Welch's t-tests are <0.05, we reject the null hypotheses in favor of the alternative hypotheses.

We used ordinary least squares (OLS) regression models to examine the impact of each factor on percentage changes in numbers of visitor arrivals for each month during the ROK MERS outbreak (June–December 2015). The following equation was used in an OLS regression model.

$$y_{ij} = \alpha SARS_i + \beta_1 close_i + \beta_2 Intermediate_i + \beta_0$$

"y_{ij}" is a dependent variable that shows percentage changes in numbers of arrivals by area-month. "$SARS_i$" is a dummy variable, which is one when an area "i" reported ≥100 SARS cases during the 2003 outbreak, otherwise zero. "$Close_i$" is a dummy variable, which is one when an area "i" is in the "Close" category, otherwise zero. "$Intermediate_i$" is an additional distance dummy variable. When an area "i" is in the "Intermediate" category, the variable is one, otherwise zero. In summary, the OLS model included two independent variables: 1) a binary variable to identify areas with ≥100 SARS cases during the 2003 outbreak (reference category: <100 SARS cases during the 2003 outbreak), and 2) a categorical variable summarizing the distance between an area and the ROK that was transformed into two binary variables (reference category: "far").

We conducted sensitivity analyses using alternative projected values. The baseline model used the average numbers of arrivals in 2013 and 2014 by area to project the expected numbers of arrivals to the ROK in the absence of the outbreak. The baseline model, however, may not account for year-to-year increasing or decreasing trends in the numbers of arrivals to the ROK. That omission could result in underestimated or overestimated projected values in the absence of the MERS outbreak, causing biased estimates from regression models. Thus, we examined two alternative models.

Alternative 1 used projected value based on the monthly average numbers of arrivals from each area in 2014 and 2016; i.e. the predicted value in June 2015 is the average number of arrivals in June 2014 and June 2016. This alternative assumes that neither 2014 nor 2016 travel volumes were affected by the MERS outbreak and that the expected monthly travel volumes in 2015 in the absence of the outbreak could have approximated the average volumes of 2014 and 2016.

For Alternative 2, we again started with the monthly average numbers of arrivals in 2013 and 2014. Since the ROK MERS outbreak was not expected to affect travel volumes during the pre-outbreak period in 2015, we compared the arrivals from January to May 2015 to the average number of arrivals from January to May in 2013 and 2014 to calculate an area-specific adjustment to the projected numbers of arrivals from June to December 2015 in the absence of the outbreak. Alternative 2 used the same method that was used to compare projected and actual numbers of arrivals in Mexico during the 2009 H1N1 pandemic [15].

To avoid bias, we conducted additional sensitivity analyses by excluding outliers. Potential outliers were flagged if any area-month (y_{ij}) observation was ≥100% or ≤−100%. We only identified one observation that met these outlier criteria. We excluded the observation for India in August 2015, when an exceptional increase in the number of crewmembers arriving at seaports [16] resulted in an increase of 106.4% relative to the average of arrivals for India in August 2013 and 2014.

3. Results

Decreases in numbers of arrivals to the ROK were observed during June and July 2015 across all examined areas compared to the average numbers of arrivals in 2013 and 2014 (Table 1). In June, the number of arrivals decreased by 7.5% from the least affected area and 74.2% from the most affected area. The simple average decrease across 17 areas was 31.4%. In July, the simple average decrease in numbers of arrivals was 39.3% (range 4.8% to 82.0% across areas). Although travel volumes declined across all areas during June and July, actual traveler volumes for some areas exceeded projected values starting in August and continuing through December 2015 (Appendix Figures 1 and 2).

Table 2 shows that the percentage decrease in numbers of arrivals from areas with ≥100 SARS cases during the 2003 SARS outbreak was significantly greater than the decrease from areas with <100 SARS cases in June (52.4% vs. 23.3%), July (60.0% vs. 31.4%), and August 2015 (28.5% vs. 3.8%). In comparison, during the pre-outbreak January to May period, the simple averages from both groups showed higher numbers of arrivals than the averages for 2013 and 2014 (Figure 1). The numbers of arrivals from areas with a previous SARS outbreak with ≥100 cases were 21.7% to 38.5% higher in January –May 2015 than in January –May averages for 2013 and 2014, while the simple averages from areas with <100 SARS cases were only1.7% to 15.4% higher in January –May 2015 (Table 2).

The percentage changes in arrivals from areas in the close category decreased more than the percentage changes in arrivals in the far category in June (56.1% vs. 19.5%), July (69.9% vs. 17.1%), and August (35.6% vs. 2.9%) (Figure 2 and Table 3). In addition, the percentage changes in arrivals in the intermediate category decreased more than the percentage changes in arrivals in the far category in July (44.0% vs. 17.1%). Changes in all other months did not show significant differences across distance categories.

The results from baseline OLS regression models also identified statistically significant correlations between the percentage decrease of numbers of arrivals and previous SARS outbreak of ≥100 cases (Table 4). Areas with a previous SARS outbreak of ≥100 cases showed significant correlations in June (p-value = 0.032). Also, the correlation between the percentage decrease of numbers of arrivals and distance from the ROK was statistically significant. The significant percentage decreases in numbers of visitor arrivals occurred in areas in the close category in June (p-value=0.012) and July (p-value≤ 0.001), and in the intermediate category in July (p-value≤ 0.001).

Results from sensitivity analyses were consistent with the baseline analysis. For Baseline and Alternatives 1, the percentage changes of arrivals from areas with a previous SARS outbreak of ≥100 cases showed greater decreases than the percentage changes in arrivals from their counterparts in June, July, and August 2015 (Appendix Table 4). For Alternative 2, the differences between areas with and without a SARS outbreak of ≥100 cases were significant in every month from June through December 2015, except for September.

For both Alternatives, declines in numbers of arrivals from areas in the close category were larger than for areas in the far category from June to August 2015 (Appendix Table 5). For Alternative 1, the declines in arrivals in the intermediate category were significantly larger than the declines in arrivals from the far category from April through December 2015, except for August. However, if we instead used Alternative 2, the decline in numbers of arrivals from the intermediate distance category was statistically significantly greater than the far category only in April, June and July 2015.

The results from sensitivity analyses of regression models were also consistent with the results from baseline models. Using all three projected values, the percentage decrease of arrivals in June and July showed some significant correlations with proximity and previous SARS outbreaks of ≥100 cases (Appendix Table 6). When excluding outliers, the observation for India in August 2015, the difference in the percentage changes in arrivals between the intermediate and far categories was significant; however, when the India, August 2015 observation was included in the analysis (i.e. not excluded), the difference between the intermediate and far categories was no longer significant (Appendix Table 7).

4. Discussion

Results from the baseline and sensitivity analyses found that the 2015 MERS outbreak in the ROK appeared to have a greater effect on travel volumes from areas with ≥100 SARS cases in 2003, especially in June and July 2015. Most of the ROK MERS cases were confirmed during those 2 months, and the ROK government declared a de facto end to the outbreak on

July 28, 2015 by which time no individuals were quarantined because of MERS, nor were there any newly confirmed cases [2]. The decrease of arrivals during the 2015 MERS outbreak is underscored when we compare the trends of numbers of arrivals before and during the 2015 MERS outbreak. Positive values in Tables 1–3 (i.e. increases in arrivals) before the 2015 MERS outbreak reflect the general trend that the number of arrivals to the ROK would be increasing without the outbreak.

Visitors from areas with a previous SARS outbreak of ≥100 cases may have been more likely to change their travel plans because of similarities between SARS and MERS, which are both caused by coronaviruses and capable of causing serious respiratory impairment. In addition, the governments in areas that experienced previous SARS outbreaks may have had stronger restrictions or recommendations about travel to the ROK during the MERS outbreak period. Although WHO did not recommend any travel restrictions to the ROK during the 2015 MERS outbreak [17], WHO noted that raising awareness about MERS among those traveling to affected areas was good public health practice [18]. Some areas issued travel notices to inform travelers about the potential risks and risk mitigation strategies. Although the intent of notices was not to restrict travel, such notices may have raised additional concern among travelers, who may then have decided to cancel their travel plans.

For instance, Hong Kong SAR, which showed the biggest percentage difference between projected and actual arrivals to the ROK, had experienced a sizable SARS outbreak in 2003 with 1 755 cases [9]. Hong Kong SAR issued a Red Outbound Travel Alert (OTA) for the ROK on June 9, 2015 [19]. Hong Kong's Red OTA recommends to adjust travel plans or avoid non-essential travel and is the second highest level travel notice [20]. The alert was lifted on August 1, 2015 [21]. In addition, the Travel Industry Council of Hong Kong canceled all tours, excluding cruises, to the ROK that were scheduled to depart from June 9 to the end of June in 2015 [22]. Since only about 2% of travelers from Hong Kong SAR to the ROK arrive via cruise [7], most tourists from Hong Kong SAR were affected by the cancellation. In addition, some local governments in mainland China (Sichuan and Shandong provinces, and Guangzhou, the capital of Guangdong province) issued travel notices to the ROK because of the 2015 MERS outbreak [23]. Also, some flights between China and Jeju international airport in the ROK were cancelled [24].

Taiwan also experienced a sizable SARS outbreak in 2003, and the Taiwan Centers for Disease Control (CDC) issued a level 2 travel notice (Alert) for Seoul and a level 1 travel notice (Watch) for all other areas in the ROK on June 2, 2015 [25]. The level 2 travel notice was extended to the entire ROK on June 9, 2015 [26]. The notice included a recommendation that travelers avoid unnecessary hospital visits in the ROK [26]. The Taiwan CDC lowered its travel notice to level 1 on July 7, 2015 [27], then removed the notice on July 28, 2015 [28]. The Taiwan Ministry of Foreign Affairs also issued a travel alert for MERS to the ROK [29].

The experience with SARS outbreaks in 2003 is only one potential reason that governments with previous SARS outbreak experiences may have issued stronger restrictions or recommendations about travel to the ROK during the MERS outbreak than governments without previous SARS outbreak experiences. For example, a Korean traveler who was experiencing symptoms consistent with MERS pushed ahead with his plan to travel to Guangdong, China with a layover in Hong Kong SAR [17]. When this traveler was diagnosed with MERS after arrival in China, a public health response was required in China [2]. Although there was no further MERS transmission in China or Hong Kong SAR, public awareness of this imported case may have exacerbated fear among individuals in Hong Kong SAR and Guangdong as well as their local governments. In Taiwan, a patient with suspected MERS was reported on May 30, 2015, although this patient was later confirmed to have influenza B virus infection [30]. This suspected case was one of 17 suspected MERS cases reported in Taiwan between September 2012 and May 2015 [30]. The 17th suspected case was in a person who was neither a ROK citizen nor had visited the ROK [30]. However, the patient could have increased public awareness of MERS in Taiwan. Although countries issued varied levels of travel notices, no countries enforced travel bans or strict quarantine requirements for travelers from the ROK as some did for travelers from countries with Ebola during the West African epidemic [31].

Since the 2015 MERS outbreak ended, the ROK government has continuously made efforts to prevent future MERS outbreaks in the ROK. The Korea Centers for Disease Control & Prevention updated its national prevention and control guidelines for MERS in April 2016 [32]. These guidelines include response plans at airports, hospitals, and local health departments to expedite the identification of individuals suspected of MERS-CoV infection after arriving from MERS-affected areas [32]. Following the guidelines, virological testing for MERS-CoV and other respiratory viruses has been implemented to confirm whether individuals with recent travel to MERS-affected areas and symptoms consistent with MERS are infected with MERS-CoV or not [32, 33]. Also, the ROK's amended quarantine act specifies MERS as a quarantinable infectious disease [34]. These efforts may decrease the risk of future MERS outbreaks in the ROK.

This analysis has some limitations. First, we assumed that the nationality of an individual was a proxy for the area of departure for that individual. For instance, a Japanese national may live in the United States before visiting the ROK but would be counted as if traveling from Japan (close category) for our analysis. Such discrepancies between citizenship and residency might cause some bias in examining the effect of distance on travel volumes to the ROK during the MERS outbreak.

Next, we were limited in our ability to assess the mechanism by which a previous sizable outbreak experience would affect travel to the ROK. As we discussed, issuance of travel notices may correlate with past outbreak experience in that governments in countries or localities that previously experienced outbreaks may be more likely to issue stronger notices. In addition, stronger travel notices in some countries may have correlated with greater decreases in travel volumes during the MERS outbreak in the ROK. However, we were unable to create categorical variables for issuance of travel notices because each country has its own process and terminology for travel notices. Although many countries have similar structures for level of travel notices, they are not easily comparable. In addition to level, each travel notice contains outbreak-specific recommendations. Recommendations, such as avoiding unnecessary hospital visits while in the ROK, further complicate comparisons of the intensity of travel health notices among countries. Thus, we were unable to quantify differences between stronger and weaker travel notices across countries. Also, there could be other country- or area-specific factors, which could affect travel volumes during a disease outbreak, but were not considered in the current analyses.

Last, we chose only one previous outbreak, the 2003 SARS outbreak as an indicator for previous outbreak experiences. While SARS was also caused by a novel coronavirus resulting in respiratory disease similar to MERS, exposure to other sizable outbreaks, such as the 2009 H1N1 pandemic or the 2013–2015 Ebola epidemic, may also have affected governments' and individuals' perceptions of risk from the 2015 MERS outbreak. Although there was a large difference between the top five areas with at least 238 probable SARS cases for each and the next highest country with 63 probable SARS cases during the 2013 outbreak (Appendix Figure 3), a single threshold of ≥100 SARS cases were used. Also, a threshold of ≥100 SARS cases was used without considering other potentially critical factors, such as population size, the extent of geographic area, the time duration of the SARS outbreak, or extent of unlinked community transmission. For instance, both Canada and Singapore had ≥100 SARS cases in 2003. However, more than 95% of probable SARS cases in Canada (n=247) were observed in the greater Toronto area [35], a small part of Canada, while the SARS outbreak in Singapore (n=238) was over the entire country [9]. Thus, Canadian governments' and individuals' perceptions of risk from the 2015 MERS outbreak associated with their SARS outbreak experience could be different from the perception of risk from the 2015 MERS outbreak in Singapore.

5. Conclusions

During the 2015 MERS outbreak, the numbers of arrivals to the ROK from around the world decreased. Countries with a previous sizable SARS outbreak and countries closer to the ROK had the greatest percentage decreases in travel volumes to the ROK. This is the first analysis that has examined area-specific impacts on travel volume to an outbreak area as we know. Future research using different outbreak situations may improve our understanding of the effects of outbreaks on travel volume.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

References

1. Korea Centers for Disease Control and Prevention. Middle East Respiratory Syndrome Coronavirus Outbreak in the Republic of Korea, 2015. Osong Public Health Res Perspect 2015; 6(4): 269–278. [PubMed: 26473095]

2. Korean Ministry of Health and Welfare. The 2015 MERS outbreak in the Republic of Korea: Learning from MERS. 2016; Available from: http://www.mohw.go.kr/react/gm/sgm0601vw.jsp?PAR_MENU_ID=13&MENU_ID=1304021002&CONT_SEQ=337684.

3. World Health Organization. Middle East respiratory syndrome coronavirus (MERS-CoV) Fact Sheet. 2015 6 2015 [cited 2017 Feb. 27]; Available from: http://www.who.int/mediacentre/factsheets/mers-cov/en/.

4. Korea Tourism Organization. Trends in non-resident arrivals, citizen departure, and tourism revenue and expenditure in December 2015. 2016 [cited 2019 April 18]; Available from: http://kto.visitkorea.or.kr/kor/notice/data/statis/profit/board/view.kto?id=426160&isNotice=false&instanceId=294&rnum=117.
5. Joo H, Maskery BA, Berro AD, Rotz LD, Lee YK, Brown CM. Economic impact of the 2015 MERS outbreak on the Republic of Korea's tourism-related industries. Health Security 2019; 17(2): 100–108. [PubMed: 30969152]
6. Smith RD. Responding to global infectious disease outbreaks: lessons from SARS on the role of risk perception, communication and management. Soc Sci Med 2006; 63(12): 3113–3123. [PubMed: 16978751]
7. TOURGO (Tourism Knowledge and Information System). Tourism arrival statistics. [cited 2019 May 15]; Available from: https://know.tour.go.kr/stat/tourStatSearchDis.do
8. World Health Organization. Summary table of areas that experienced local transmission of SARS during the outbreak period from 1 November 2002 to 31 July 2003. 2003 [cited 2019 April 22]; Available from: https://www.who.int/csr/sars/areas/areas2003_11_21/en/.
9. World Health Organization. Summary of probable SARS cases with onset of illness from 1 November 2002 to 31 July 2003. 2004 [cited 2017 November 1]; Available from: http://www.who.int/csr/sars/country/table2004_04_21/en/.
10. Hui DS, Memish ZA, Zumla A. Severe acute respiratory syndrome vs. the Middle East respiratory syndrome. Curr Opin Pulm Med 2014; 20(3): 233–241. [PubMed: 24626235]
11. Chowell G, Abdirizak F, Lee S, Lee J, Jung E, Nishiura H, Viboud C. Transmission characteristics of MERS and SARS in the healthcare setting: a comparative study. BMC Med 2015; 13: 210. [PubMed: 26336062]
12. Van Kerkhove MD, Hirve S, Koukounari A, Mounts AW, H1N1pdm serology working group. Estimating age-specific cumulative incidence for the 2009 influenza pandemic: a meta-analysis of A(H1N1)pdm09 serological studies from 19 countries. Influenza Other Respir Viruses 2013; 7(5): 872–886. [PubMed: 23331969]
13. Dawood FS, Iuliano AD, Reed C, Meltzer MI, Shay DK, Cheng PY, Bandaranayake D, Breiman RF, Brooks WA, Buchy P, Feikin DR, Fowler KB, Gordon A, Hien NT, Horby P, Huang QS, Katz MA, Krishnan A, Lal R, Montgomery JM, Molbak K, Pebody R, Presanis AM, Razuri H, Steens A, Tinoco YO, Wallinga J, Yu H, Vong S, Bresee J, Widdowson MA. Estimated global mortality associated with the first 12 months of 2009 pandemic influenza A H1N1 virus circulation: a modelling study. Lancet Infect Dis 2012; 12(9): 687–695. [PubMed: 22738893]
14. Welch BL. The generalisation of student's problems when several different population variances are involved. Biometrika 1947; 34(1-2): 28–35. [PubMed: 20287819]
15. Rassy D, Smith RD. The economic impact of H1N1 on Mexico's tourist and pork sectors. Health Econ 2013; 22(7): 824–834. [PubMed: 23744805]
16. Korea Tourism Organization. Trends in non-resident arrivals, citizen departure, and tourism revenue and expenditure in August 2015. 2015 [cited 2019 April 19]; Available from: http://kto.visitkorea.or.kr/kor/notice/data/statis/profit/board/view.kto?id=425332&isNotice=false&instanceId=294&rnum=130.
17. World Health Organization. Summary and risk assessment of current situation in Republic of Korea and China. 2015 [cited 2016 August 29]; Available from: http://www.who.int/csr/disease/coronavirus_infections/risk-assessment-3june2015/en/.
18. World Health Organization. WHO statement on the ninth meeting on the IHR Emergency Committee regarding MERS-CoV. 2015 [cited 2018 Feb. 28]; Available from: http://www.who.int/mediacentre/news/statements/2015/ihr-ec-mers/en/.
19. The Government of the Hong Kong Special Administrative Region. Press Releases: Government issues Red Outbound Travel Alert on Korea. 2015 [cited 2016 August 29]; Available from: http://www.info.gov.hk/gia/general/201506/09/P201506090449.htm.
20. The Government of the Hong Kong Special Administrative Region Security Bureau. Outbound Travel Alert. 2016 [cited 2016 August 29]; Available from: http://www.sb.gov.hk/eng/ota/.

21. The Government of the Hong Kong Special Administrative Region. Press Releases: Government removes Red Outbound Travel Alert for Korea. 2015 August 1, 2015; Available from: http://www.info.gov.hk/gia/general/201508/01/P201508010296.htm.

22. Park J, Pomfret J. Hong Kong issues 'red alert' against South Korea travel due to MERS. 2015 [cited 2016 August 29]; Available from: http://www.reuters.com/article/us-health-mers-southkorea-idUSKBN0OO2KE20150609.

23. Korea Ministry of Foreign Affairs. Travel warnings to the Republic of Korea due to the MERS outbreak from all foreign countries are lifted: response activities, achievements, and future plans for the MERS outbreak from Ministry of Foreign Affairs 2015 July 28, 2015 [cited 2019 April 18]; Available from: http://www.mofa.go.kr/www/brd/m_4080/view.do?seq=355787&srchFr=&srchTo=&srchWord=메르스&srchTp=0&multi_itm_seq=0&itm_seq_1=0&itm_seq_2=0&company_cd=&company_nm=&page=1.

24. Xinhua. Airlines cut flights to South Korea as China steps up MERS alert. 2015 [cited 2019 April 25]; Available from: http://www.chinadaily.com.cn/china/2015-06/15/content_21002206_2.htm.

25. Centers for Disease Control, Republic of China (Taiwan). In light of current MERS-CoV outbreak in South Korea, Taiwan CDC issues travel notice level for Seoul to Level 2: Alert for MERS-CoV and plans five major response strategies 2015 June 2, 2015 [cited 2019 April 25]; Available from: https://www.cdc.gov.tw/En/Bulletin/Detail/dsSZdKQDMw8MGW7-5rl6Wg?typeid=158.

26. Centers for Disease Control, Republic of China (Taiwan). Travel notice of Level 2: Alert for MERS-CoV to entire South Korea issued in response to growing MERS outbreak in South Korea; Public urged to avoid unnecessary hospital visits in South Korea. 2015 June 10, 2015; Available from: https://www.cdc.gov.tw/En/Bulletin/Detail/8OCnVfwFn5HMgX22NluyEw?typeid=158.

27. Centers for Disease Control, Republic of China (Taiwan). Taiwan CDC lowers travel notice level for South Korea to Level 1: Watch for MERS and advises travelers visiting China to take precautions against tick bites. 2015 July 7, 2015 [cited 2019 April 25]; Available from: https://www.cdc.gov.tw/En/Bulletin/Detail/F7fh3ojgoiDI6r1oLGToAA?typeid=158.

28. Centers for Disease Control, Republic of China (Taiwan). Taiwan CDC removes MERS travel notice for South Korea and Bhrain as outbreak in South Korea brought under control 2015 July 28, 2015; Available from: https://www.cdc.gov.tw/En/Bulletin/Detail/P6FM9BjmWwPvshoDEEbxGg?typeid=158.

29. Tang P, Esme J, Lilian W. Foreign ministry raises travel advisory for Seoul. 2015 [cited 2017 March 2]; Available from: http://focustaiwan.tw/news/asoc/201506030016.aspx.

30. Centers for Disease Control, Republic of China (Taiwan). Test results of Taipei suspected MERS-CoV case came back negative. 2015 [cited 2019 April 25]; Available from: https://www.cdc.gov.tw/En/Bulletin/Detail/xaSrgpzc2I7RPq3jeIkGrQ?typeid=158.

31. Rhymer W, Speare R. Countries' response to WHO's travel recommendations during the 2013-2016 Ebola outbreak. Bull World Health Organ 2017; 95(1): 10–17. [PubMed: 28053360]

32. Korea Centers for Disease Control and Prevention, Prevention and control guideline for Middle East respiratory synderome coronavirus. 4th ed. Osong: KCDC; 2016 Available from: http://www.cdc.go.kr/CDC/cms/content/mobile/08/67908_view.html.

33. Ryu S, Kim JJ, Cowling BJ, Kim C. Surveillance and public health response for travelers returning from MERS-CoV affected countries to Gyeonggi Province, Korea, 2016-2017. Travel Med Infect Dis 2018 11 9 pii: S1477-8939(18)30405-8 DOI: 10.1016/j.tmaid.2018.11.006.

34. Korea Ministry for Health, Welfare and Family Affairs. Statutes of the Republic of Korea, Quarantine Act, Chapter I General provisions, Article 2 (Definition), 2016 Available from: https://elaw.klri.re.kr/kor_service/lawView.do?hseq=46420&lang=ENG.

35. Skowronski DM, Petric M, Daly P, Parker RA, Bryce E, Doyle PW, Noble MA, Roscoe DL, Tomblin J, Yang TC, Krajden M, Patrick DM, Pourbohloul B, Goh SH, Bowie WR, Booth TF, Tweed SA, Perry TL, McGeer A, Brunham RC. Coordinated response to SARS, Vancouver, Canada. Emerg Infect Dis 2006; 12(1): 155–158. [PubMed: 16494736]

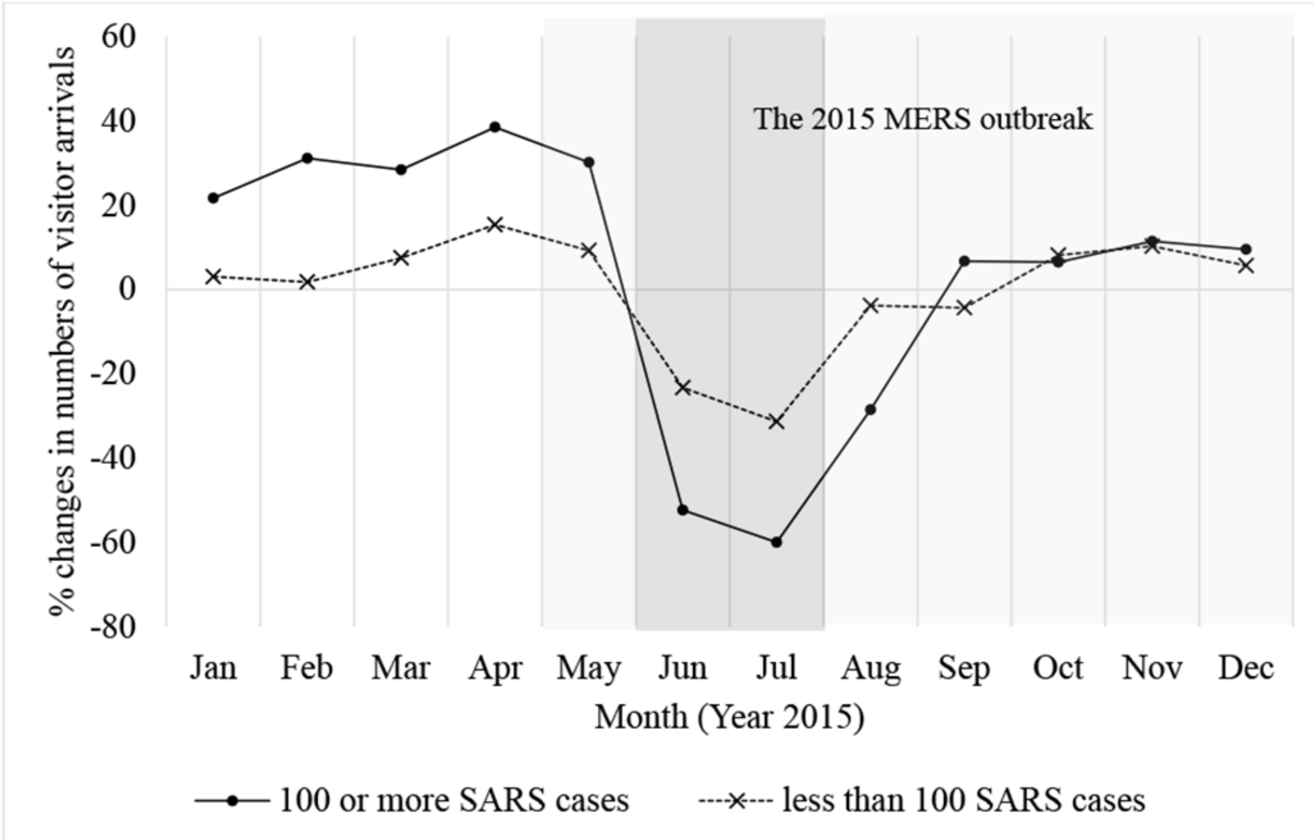

Fig. 1.

Monthly percentage changes of non-citizen arrivals to the Republic of Korea (ROK) in 2015 compared with the average of monthly non-citizen arrivals in 2013 and 2014; areas are subdivided by whether each had 100 or more severe acute respiratory syndrome (SARS) cases during the 2003 SARS outbreak

Notes: Non-citizen arrivals are limited to non-citizen short-term visitor arrivals. The solid line shows the average percentage changes in monthly numbers of arrivals among areas with ≥100 SARS cases, while the dotted line is the average percentage changes in numbers of arrivals among areas with <100 SARS cases. The shaded area indicates the period between the confirmation of the first Middle East respiratory syndrome (MERS) case in the ROK (May 20, 2015) and the declaration of the end of the outbreak by the government of the ROK and the World Health Organization (December 23, 2015). The shaded dark gray area indicates the peak period of the MERS outbreak, and the shaded light gray area indicates the non-peak period. Note that increases in arrivals (i.e. positive values) before the outbreak reflect the general trend of increasing numbers of arrivals to the ROK.

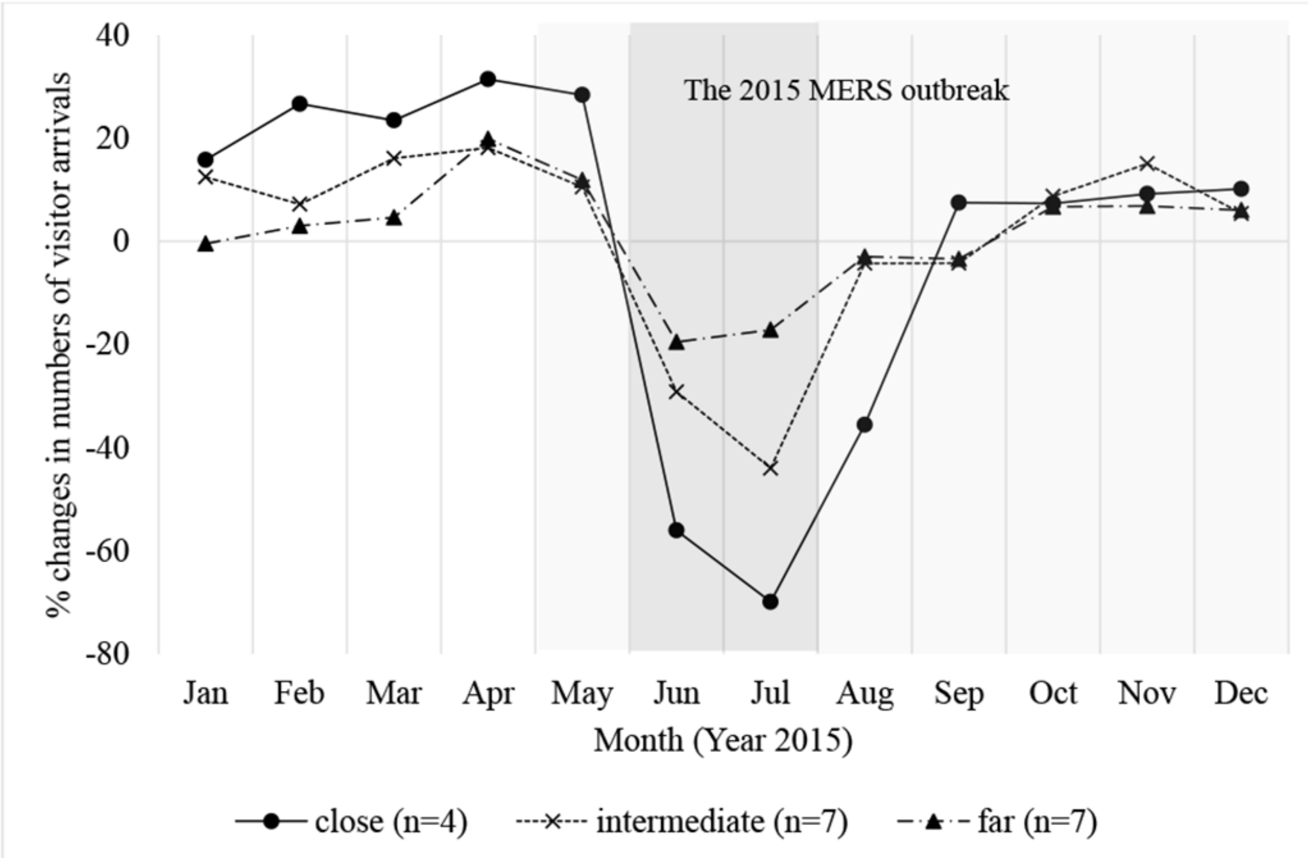

Fig. 2.

Monthly average percentage changes between actual and projected non-citizen arrivals to the Republic of Korea (ROK) during 2015 grouped by distance to the ROK

Notes: Non-citizen arrivals are limited to non-citizen short-term visitor arrivals. The solid line with circles shows the average monthly percentage changes in numbers of arrivals from areas in the close category, while the dotted line with x is the average percentage changes in numbers of arrivals from areas in the intermediate category. The dotted line with triangles shows the average percentage changes in numbers of visitor arrivals from areas in the far category. The shaded area indicates the period between the confirmation of the first Middle East respiratory syndrome (MERS) case in the ROK (May 20, 2015) and the declaration of the end of the outbreak by the government of the ROK and the World Health Organization (December 23, 2015). The shaded dark gray area indicates the peak period of the MERS outbreak, and the shaded light gray area indicates the non-peak period. Note that increases in arrivals (i.e. positive values) before the outbreak reflect the general trend of increasing numbers of arrivals to the ROK.

Table 1.

Percentage changes between 2015 actual and projected (average of 2013 and 2014) monthly non-citizen arrivals to the Republic of Korea (ROK) by area (%)

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Before the Middle East respiratory syndrome (MERS) outbreak				First MERS case reported May 20, 2015	Peak months of the MERS outbreak		Non-peak months of the MERS outbreak				
China	60.0	79.4	47.1	48.0	55.3	−35.2	−59.5	−26.7	12.9	43.6	37.7	33.5
Japan	−26.2	−29.9	−18.3	−19.2	−11.2	−45.9	−57.0	−37.9	−29.0	−17.1	−18.1	−17.1
USA	2.4	4.1	4.1	18.3	6.5	−13.8	−4.8	3.0	−3.6	3.8	10.6	6.8
Taiwan-China	10.1	16.6	17.3	40.5	16.4	−74.2	−82.0	−54.0	−7.1	−9.5	3.4	6.3
Hong Kong SAR-China	19.4	40.6	47.8	56.5	53.1	−68.9	−81.1	−23.6	53.3	12.5	13.8	18.0
Thailand	19.9	3.9	8.2	0.2	−1.6	−32.0	−55.3	−43.1	−42.1	−21.7	−16.4	4.2
Philippines	−3.2	4.9	2.2	12.0	2.2	−26.9	−42.8	−20.1	7.5	13.8	16.2	13.1
Malaysia	11.1	6.0	20.9	23.2	3.4	−29.1	−42.8	−23.0	−8.7	−7.7	6.8	−3.3
Russia	−9.5	−11.1	−1.4	−2.1	6.4	−18.2	−21.9	−7.0	5.7	3.0	8.0	8.4
Indonesia	8.0	30.0	4.8	13.2	8.4	−26.7	−44.3	−23.6	6.2	15.2	13.0	−4.0
Singapore	11.7	1.9	13.6	15.5	11.1	−59.7	−55.8	−32.5	−19.2	−17.3	−7.9	−19.0
India	−6.1	14.7	−4.1	6.5	22.0	−22.2	−40.6	106.4	5.6	29.3	28.3	11.2
Canada	7.1	17.1	16.2	31.9	14.9	−23.8	−21.6	−5.9	−6.4	3.0	10.1	8.7
Vietnam	46.0	−11.0	67.2	56.5	28.4	−7.5	−26.3	6.2	21.2	49.7	65.6	35.7
Australia	10.9	2.9	−14.8	28.6	30.6	−28.3	−19.0	−5.7	−11.6	11.7	−1.9	9.0
UK	−4.4	1.7	6.6	31.9	2.5	−28.9	−26.9	−8.4	−12.4	4.5	7.4	1.9
Germany	−13.3	−12.6	10.8	6.5	1.1	−13.8	−15.3	0.3	−0.4	13.4	4.8	3.0
France	3.7	19.1	11.0	24.0	21.4	−9.7	−10.5	3.1	4.9	7.7	9.0	4.6
Average	8.2	9.9	13.3	21.8	15.1	−31.4	−39.3	−10.7	−1.3	7.7	10.6	6.7

Notes: Non-citizen arrivals are limited to non-citizen short-term visitor arrivals. All numbers are from the following equation:

$$\frac{Actual\ (with\ the\ MERS\ outbreak) - Projected(if\ there\ was\ no\ MERS\ outbreak)}{Projected\ (if\ there\ was\ no\ MERS\ outbreak)} \times 100\,\%$$

Table 2.

Average monthly percentage changes between 2015 actual and projected (average of 2013 and 2014) non-citizen arrivals to the Republic of Korea (ROK) by whether the country had 100 or more severe acute respiratory syndrome (SARS) cases during the 2003 outbreak

Months	The 2015 Middle East respiratory syndrome (MERS) outbreak status	SARS ≥100 cases (n=5)		SARS <100 cases (n=13)		*p-value*
		%	SE	%	SE	
Jan	Before the MERS outbreak	21.7	9.8	3.0	4.9	0.934
Feb		31.1	13.6	1.7	4.3	0.954
Mar		28.4	7.8	7.5	5.8	0.973
Apr		38.5	7.0	15.4	5.2	0.988
May	First MERS case reported May 20, 2015	30.2	9.9	9.2	3.5	0.952
Jun	Peak months of the MERS outbreak	−52.4	9.8	−23.3	2.9	**0.018**
Jul		−60.0	11.0	−31.4	4.7	**0.026**
Aug	Non-peak months of the MERS outbreak	−28.5	7.8	−3.8	10.2	**0.035**
Sep		6.7	12.7	−4.4	4.7	0.776
Oct		6.5	10.6	8.1	5.1	0.446
Nov		11.4	7.5	10.3	5.7	0.548
Dec		9.5	8.6	5.7	3.3	0.655

Notes: Non-citizen arrivals are limited to non-citizen short-term visitor arrivals. Monthly percentage changes were calculated by the following equation.

$$\frac{Actual\ (with\ the\ MERS\ outbreak) - Projected(if\ there\ was\ no\ MERS\ outbreak)}{Projected\ (if\ there\ was\ no\ MERS\ outbreak)} \times 100\,\%$$

SE stands for standard error. Boldface indicates statistical significance ($p < 0.05$). Areas in the ≥100 SARS cases category are China, Taiwan–China, Hong Kong SAR–China, Singapore, and Canada.

Table 3.

Average monthly percentage changes between actual (2015) and baseline projected (average of 2013 and 2014) non-citizen arrivals to the Republic of Korea (ROK) by distance from the ROK

Months	The 2015 Middle East respiratory syndrome (MERS) outbreak status	Far (n=7)		Intermediate (n=7)			Close (n=4)		
		%	SE	%	SE	*p-value*	%	SE	*p-value*
Jan	Before the MERS outbreak	−0.4	3.4	12.5	6.5	0.946	15.8	17.7	0.787
Feb		3.0	4.6	7.2	4.8	0.730	26.7	22.9	0.811
Mar		4.6	3.9	16.1	9.0	0.863	23.5	15.6	0.843
Apr		19.9	5.0	18.2	6.9	0.422	31.5	17.2	0. 723
May	First MERS case reported May 20, 2015	11.9	4.1	10.6	4.1	0.410	28.4	15.9	0.811
Jun	Peak months of the MERS outbreak	−19.5	2.9	−29.2	5.9	0.087	−56.1	9.3	**0.010**
Jul		−17.1	2.8	−44.0	3.9	**<0.001**	−69.9	6.7	**<0.001**
Aug	Non-peak months of the MERS outbreak	−2.9	1.9	−4.2	19.3	0.474	−35.6	6.9	**0.006**
Sep		−3.4	2.8	−4.2	8.0	0.463	7.5	17.5	0.711
Oct		6.7	1.6	8.8	9.8	0.578	7.4	13.6	0.517
Nov		6.9	1.6	15.1	10.1	0.774	9.2	11.6	0.573
Dec		6.1	1.1	5.4	6.5	0.463	10.2	10.7	0. 637

Notes: Non-citizen arrivals are limited to non-citizen short-term visitor arrivals. SE stands for standard error. Boldface indicates statistical significance (*p-values* < 0.05). The *p-values* are from Welch's t-tests for two samples with unequal variances. The reference group is far. The *p-values* in the intermediate column shows *p-values* to evaluate whether differences between the far and intermediate groups are significant, while *p-values* in the close column shows *p-values* to evaluate whether differences between the far and close groups are significant.

Close: China, Japan, Taiwan–China, and Hong Kong Special Administrative Region (SAR)–China

Intermediate: Thailand, Philippines, Malaysia, Indonesia, Singapore, India, and Vietnam
Far: USA, Russia, Canada, Australia, UK, Germany, and France

Table 4.

Monthly marginal percentage change between actual (2015) and baseline projected (average of 2013 and 2014) non-citizen arrivals to the Republic of Korea (ROK) associated with areas that experienced ≥100 probable severe acute respiratory syndrome (SARS) cases and distance to the Republic of Korea

Months	Independent variables		Coef.	*p-value*	R-squared
Jun	2003 SARS outbreak size (cases)	SARS ≥100	−18.3	**0.032**	0.68
	Distance	Close Intermediate	−25.5 −9.7	**0.012** 0.155	
Jul	2003 SARS outbreak size (cases)	SARS ≥100	−11.8	0.058	0.87
	Distance	Close Intermediate	−45.6 −26.8	**<0.001** **<0.001**	
Aug	2003 SARS outbreak size (cases)	SARS ≥100	−11.7	0.595	0.41
	Distance	Close Intermediate	−25.5 −1.3	0.323 0.944	
Sep	2003 SARS outbreak size (cases)	SARS ≥100	7.5	0.593	0.08
	Distance	Close Intermediate	6.4 −0.8	0.695 0.945	
Oct	2003 SARS outbreak size (cases)	SARS ≥100	−2.2	0.876	<0.01
	Distance	Close Intermediate	2.0 2.0	0.903 0.861	
Nov	2003 SARS outbreak size (cases)	SARS ≥100	3.1	0.820	0.04
	Distance	Close Intermediate	0.5 8.2	0.975 0.470	
Dec	2003 SARS outbreak size (cases)	SARS ≥100	2.2	0.819	0.02
	Distance	Close Intermediate	2.8 −0.6	0.807 0.937	

Notes: Non-citizen arrivals are limited to non-citizen short-term visitor arrivals. Boldface indicates statistical significance ($p < 0.05$). The results were from baseline ordinary least squares (OLS) regression models using percentage changes between 2015 actual and the average of 2013 and 2014 monthly arrivals as dependent variables. The reference category for the 2003 SARS outbreak areas with <100 probable SARS cases, and the reference for distance is the far category.