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Non-Pharmaceutical Interventions for COVID-19: Evidence from Large-Scale Mobility Data in Tokyo

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Key Points

- Governments must decide how to balance mobility restrictions while ensuring economic recovery so that losses can be minimized.
- Analysis of Japan reveals a strong association between social contact reduction and a decrease in the effective reproduction number.
- Travel decreased significantly even before the emergency declaration, but the benefits of restricting mobility beyond 60% in Tokyo could be marginal.
- Higher-income households are more likely than lower-income households to be able to reduce their social contact via reducing mobility.
- Future policies should be city-specific and based on the distribution of business types and the needs of the local community, health considerations, and infection rates.
- Each city should determine the optimal mobility restrictions based on data analytics, local conditions that include the spatial distribution of high-risk groups, the type of mobility patterns, city structure, social norms, and the built environment.

Different countries have imposed either partial or full restrictions on people's movement to contain the spread of the coronavirus disease (COVID-19) outbreak. The People's Republic of China (PRC) was the first country to impose strict lockdowns, restricting the mobility of more than 60 million people (Griffiths and Woodyatt 2020). This was followed by countries such as Italy and Spain imposing "red zones" to restrict the movement of people. The US has imposed lockdowns in various states starting with Washington State, followed by California (Calfas, Stancati, and Yap 2020). Japan is one of the few countries that did not restrict people's movements. The effect of these various measures—including strict lockdowns, remote work, school closures, and business closures—is that they act as a multiplier, since both demand and supply shocks happen at the same time, sending the economy into a tailspin. Global estimates from the International Monetary Fund (IMF) show that annual gross domestic product (GDP) is going to contract by as much as 4.9% worldwide, and 5.8% in Japan (IMF 2020). In the context of these significant social and economic consequences, national and regional governments are left asking how to balance economic recovery with mobility restrictions to minimize losses.

In other words, governments currently want to know *how to take a more targeted approach to lockdowns and mobility restrictions that will balance containing the pandemic and running the economy*. This policy brief explores this central question using data from Tokyo to understand the potential impact of various mobility restrictions when non-compulsory measures were in place, and estimates the impacts on social contact and COVID-19 infections. Using big data mobility analytics, the brief will focus on the following issues: (1) the relationship between mobility restrictions and the COVID-19 spread; (2) the inequalities in terms of the mobility restrictions; and (3) the optimal level of mobility restrictions to contain the COVID-19 spread.

Our analysis is based on the location data of more than 200,000 mobile phone app users in the Tokyo metropolitan area provided by Yahoo Japan Corporation. Such data, which typically record the location information of individual users every 10 minutes, are used to estimate the number of social contacts (how many individuals each user came in contact with), and also how much and how far each user traveled on each day. By the end of the first week of the emergency, human mobility decreased by 50% due to people working from home, school closures,

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Box 1: National Responses to COVID-19

As of 22 July 2020, coronavirus disease (COVID-19) cases have exceeded 14.9 million in 188 countries and territories, resulting in more than 616,000 deaths. While Japan has employed only non-compulsory lockdowns, more than 90 countries from all continents have imposed strict lockdown orders on their citizens. The United States (US) has implemented a range of measures, including travel restrictions, social distancing, declaration of states of emergency, closures of schools and non-essential businesses, and increased testing. The People's Republic of China (PRC) imposed strict containment measures, including the extension of the national Lunar New Year holiday, the lockdown of Hubei province, large-scale mobility restrictions at the national level, and social distancing. Germany responded with border closures, closures of schools and non-essential businesses, social-distancing requirements, and a ban on public gatherings. India went under lockdown in March, in addition to containment measures including travel restrictions, business closures, and bans on mass gatherings. Brazil announced a temporary ban on foreign air travelers, and most state governors have imposed quarantines to prevent the spread of the virus (IMF 2020).

Box 2: Literature on Mobility Analysis during COVID-19

During the current COVID-19 crisis, researchers from academia, industry, and government agencies have started to utilize large-scale mobility datasets to estimate the effectiveness of control measures in various countries, including the PRC, Germany, France, Italy, Spain, Sweden, the United Kingdom and the US (Gao et al. 2020; Kraemer et al. 2020; Lai et al. 2020; Bonato et al. 2020; Pullano et al. 2020; Dahlberg et al. 2020). However, we lack studies that analyze the mobility behavioral changes in Japan to further understand their correlation with the spread of COVID-19.

Box 3: COVID-19 Pandemic-Related Definitions

R(t): The effective reproduction number R(t) is commonly used to quantify the transmissibility of an infectious disease, which is defined as the average number of secondary cases generated by a single infectious case (Held et al. 2019). The effects of nonpharmaceutical interventions, such as social distancing, can be measured by the effective reproduction number. The R(t) of COVID-19 in Tokyo was estimated using the time series data of daily confirmed local cases reported by the metropolitan government.

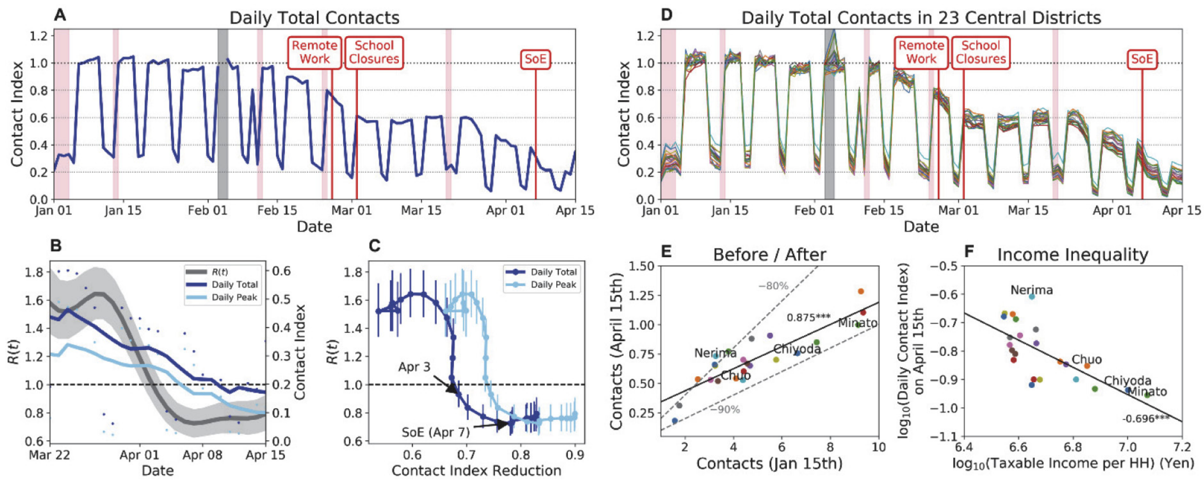
Social contact index: A measure that quantifies how much contact has been made in a city during a given timeframe compared to pre-pandemic standards. The social contact index is computed by estimating the movement trajectories of individuals from mobile phone location data (Yabe et al. 2020).

limited entertainment, and shopping trips, etc. This resulted in about a 70% reduction in social contacts, and the corresponding R(t) value was reduced to below 1, which is the threshold for containing the disease. Figure 1A shows the decrease in social contacts and the resulting changes in R(t).

Due to cultural norms in Japan, it was observed that there was already a decrease of around 60% in travel trips even before the emergency declaration. A key observation from the figure is that there is a marginal decrease in social contacts and the corresponding R(t) even with severe restrictions of mobility of around 80%. In other words, when we look at the association between mobility restrictions beyond 60% and the COVID-19 infection rates in Tokyo, there is no significant correlation between the decrease in social contacts and R(t) values (Figures 1B and 1C). A key implication of this finding is that there is a close association between the mobility restrictions and the COVID-19 infections and that the marginal benefit of mobility restrictions decreases beyond 60% in Tokyo. Clearly, understanding the relationship between the mobility restrictions (contact networks) and the spread of COVID-19 infections is important. Based on these observations and a closer analysis of the data, one could possibly take a more targeted approach to closing businesses without restricting mobility significantly.

By disaggregating the results by administrative region, we are able to analyze the regional heterogeneity of social contact reduction in the 23 wards in Tokyo

Figure 1: Relationship between Social Contact Index and COVID-19 Transmissibility



HH = household, SoE = state of emergency.

Source: Yabe et al. (2020).

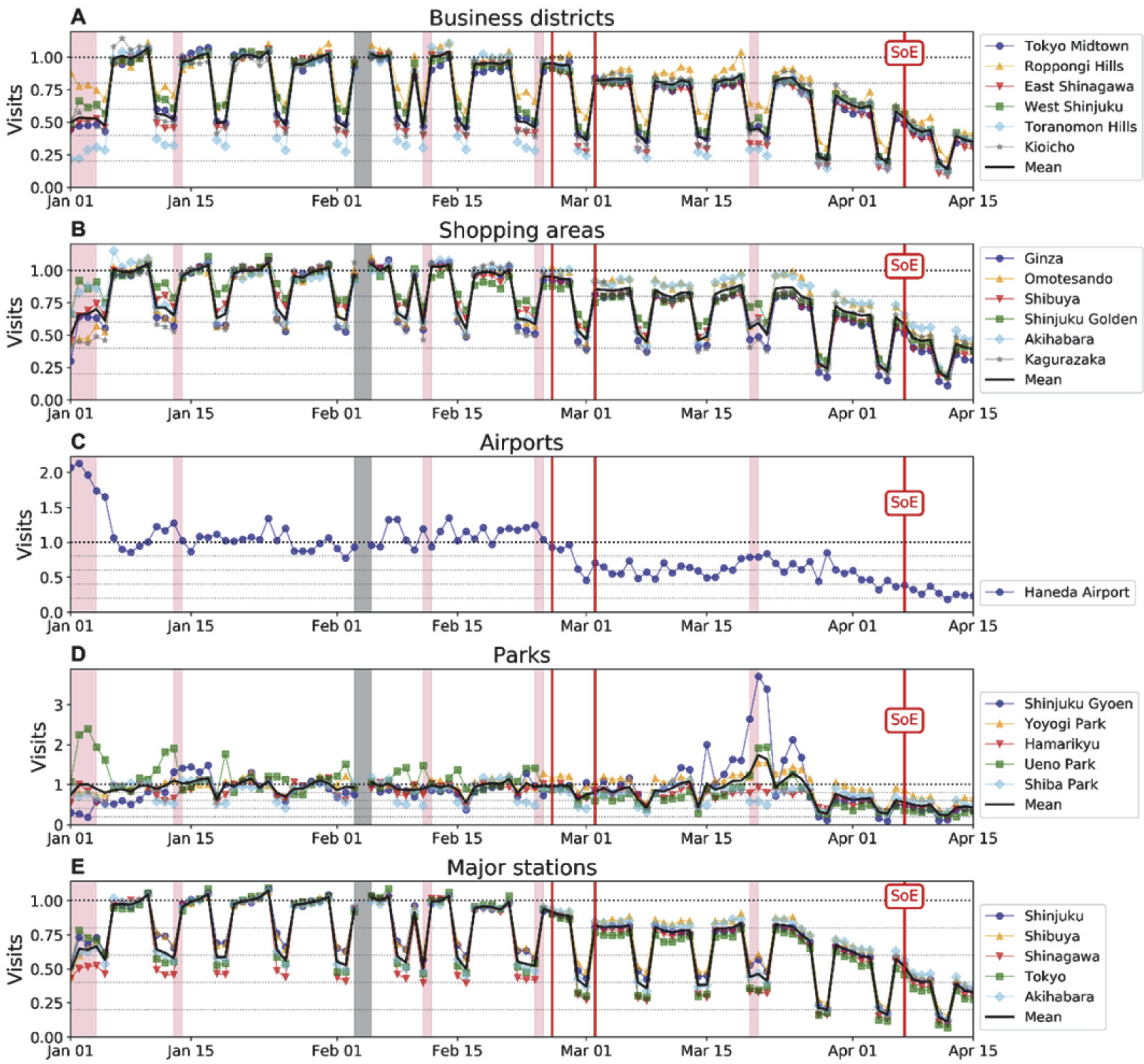
(Figure 1D). We observe a strong negative correlation ($\rho = -0.696$***) between taxable income per household and contact index, indicating that households in higher-income regions were able to reduce their amount of social contact and risk of COVID-19 transmission more than households in lower-income regions (Figure 1E). The difference is observed to be in the range of 0.11–0.25. Higher income households are more likely to be able to reduce their social contact by reducing mobility; however, lower income households may not have this flexibility. This type of inequality in terms of mobility restriction is observed in other analyses in US cities (Gao et al. 2020). This inequality has significant implications in terms of disease spread and will require holistic policy planning. Figure 1F further shows the log-log plot between the relative contact index on 15 April and average taxable income per household for each ward in Tokyo. The average taxable income per household was calculated using data provided by the Official Statistics of Japan through the Portal Site (Statistics Bureau of Japan 2020).

The relationship between mobility and economy has been well established in the literature (Bouton et al. 2017). Urbanized areas with more travel activity are directly correlated with higher GDP levels. A reduction in the number of relative visits to various census tracts or activities has a direct impact on the economy. As can be seen in Figure 2, compared to weekdays in January 2020, the relative number of visits to various businesses and shopping decreased by almost 80% or more. Activities such as shopping and visiting train stations took the biggest hit, clearly indicating that people reduced their physical visits to these locations. Clearly, there is a direct relationship in terms of the decrease in GDP at the local level due to the mobility reductions. The presented empirical results should be considered in light of the limitation that the analysis does not consider the possible effects of other measures, such as mask wearing, hand washing, and social distancing, which were implemented at the same time. Household or online surveys need to be conducted to understand the effects of other measures, in addition to the mobile phone data analysis presented in this study.

Rather than taking the severe restrictive approaches adopted by many other governments, cities should take a more surgical and nuanced approach to lockdowns.

“Activities such as shopping and visiting train stations took the biggest hit, clearly indicating that people reduced their physical visits to these locations”

Figure 2: Number of Visits Observed in Different Points of Interest in Tokyo



SoE = state of emergency.

Note: Points of interest include business districts, shopping areas, airports, public parks, and major stations. Reduction in number of visits can be observed in all point of interest types except for several public parks.

Source: Yabe et al. (2020).

Mobility analytics using cell phone data and Facebook business surveys (Facebook 2020) provide a clear indicator of these effects. Big data analytics based on these sources will aid city- and country-level policy makers to use various supply-side levers to reduce the economic impacts of COVID-19. Policy makers can use data analytics to understand the inequalities and determine the "sweet spot" that balances business openings with the COVID-19 spread so that the economy can recover much more quickly when the pandemic risk has decreased. It is much more difficult to start the economic engine when it has ground to a complete halt than when a certain portion of the economy is open. In our view, there is no magic bullet to determine what this optimal number is and which economic activities should remain open; further analysis using

"Future policies should be city-specific and determined based on the distribution of business types and the needs of the local community, health considerations, and infection rates"

big data is needed to determine this, along with what the mobility patterns should be. Our analysis shows that this can be achieved by keeping different kinds of businesses open. The analysis further demonstrates the income divide that exists in the mobility restrictions, with priority given to essential workers and low-income workers/businesses with appropriate health precautions, such as face coverings and social distancing practices.

Future policies should be city-specific and determined based on the distribution of business types and the needs of the local community, health considerations, and infection rates. We recommend that each city determine the optimal mobility restrictions based on the data analytics and local conditions, including the spatial distribution of high-risk groups, the types of mobility patterns, city structure, social norms, and the built environment.

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