Investigating the Epidemiological and Economic Effects of a Third-Party Certification Policy for Restaurants with COVID-19 Prevention Measures

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Investigating the epidemiological and economic effects of a third-party certification policy for restaurants with COVID-19 prevention measures

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ABSTRACT

This study investigates the effects of a third-party certification policy for restaurants (including bars) that comply with indoor infection prevention measures on COVID-19 cases and economic activities. We focus on the case of Yamanashi Prefecture in Japan, which introduced a third-party certification policy that accredits facilities, predominantly restaurants, that comply with the designated guidelines. We employ a difference-in-differences design for each of our epidemiological and economic analyses. The estimation results show that, from July 2020 to April 2021, the certification policy reduced the total number of new infection cases by approximately 45.3% (848 cases) while increasing total sales and the number of customers per restaurant by approximately 12.8% (3.21 million Japanese yen or $30,000) and 30.3% (2,909 customers), respectively, compared to the non-intervention scenarios. The results suggest that a third-party certification policy can be an effective policy to mitigate the trade-off between economic activities and infection prevention during a pandemic, especially when effective vaccines are not widely available.

Introduction

During the COVID-19 pandemic, national and regional governments have introduced various types of non-pharmaceutical interventions to prevent its spread. A common intervention is to place operating restrictions, if not completely shut down, on restaurants as eating and drinking indoors are associated with high risks of COVID-19 transmission [1][2][3][4][5][6]. With consumers also cautious about dining out, food and beverage (F&B) has been one of the hardest hit industries [7][8][9][10].

To mitigate the sharp trade-off between infection prevention and economic activities, some governments have implemented measures to reduce the likelihood of COVID-19 transmission in physical interactions instead of eliminating interactions entirely. One example is introducing indoor infectious disease control guidelines. Through complying with guidelines on ventilation, disinfection, mask-wearing, social distancing, restaurants can continue operations while minimizing transmission risks in their premises. In Japan, prefectural governments have established third-party certification policies to recognize businesses that comply with designated COVID-19 safety measures. Prior research has demonstrated the effectiveness of relevant interventions, such as mask-wearing, regular ventilation, distancing seats sufficiently, and setting maximum occupancy load limits, in preventing infection [3][11][12][13]. It has also been shown that restaurants' economic performance can be improved through signaling their safety [14][15]. However, few studies empirically examined the effect of a third-party certification policy on the number of new cases and business revenues. We fill in this gap by assessing the impact of a third-party COVID-19 safety certification policy for restaurants on the number of new infections and restaurant revenues, taking up the case of Yamanashi Prefecture in Japan.

In May 2020, Yamanashi Prefecture introduced the Yamanashi Green Zone Certification (GZ), a third-party certification policy for infection prevention measures. The purpose of this policy is to allow consumers to patronize businesses with peace of mind by officially certifying restaurants (including bars), hotels, wineries, breweries, and other businesses that comply with infection control guidelines [16][17]. Certification is conditional on passing a rigorous on-site inspection. Once a violation is found, the certification may be revoked. Certified businesses are generally exempted from the prefectural government's requests to close or shorten hours. In the unlikely event that such a request is necessary, they are given priority in receiving financial assistance. The number of GZ-certified restaurants has increased gradually since the first approvals on July 17, 2020. As of April 30, 2021, more than 4,000 restaurants in Yamanashi were certified, and the acquisition rate was around 96% [18] (see Supplementary Information Fig. C.2).

Many prefectures introduced similar policies later, but they are not as strict as that of Yamanashi. For example, some prefectures, including Tokyo, have provided stickers to businesses that declared to comply with infection prevention guidelines, but the accreditation only required their self-reporting documents [19]. Other prefectures, such as Gunma and Tottori, introduced a certification policy with both accreditation requirements and introduction timing similar to the GZ certification policy, but their area-wide accreditation rates remain considerably low (i.e., around 20% for Gunma as of October 2021 [20]) (see Supplementary Information E.2).

We hypothesize that the GZ certification policy had positive effects on both decreasing the number of new infection cases and increasing restaurant revenues in Yamanashi Prefecture during the COVID-19 pandemic. This expectation is based on the first-hand evidence that infection cases and economic damage to restaurants in the prefecture seem to be under control compared to neighboring prefectures after the introduction of the certification policy (see Fig. 1 for the geographical location and Figs. 2, 3, and 4 for time-series graphs).

In our study, we separately evaluate the epidemiological and economic effects of the GZ certification policy by using a difference-in-differences design, exploiting the incremental introduction of the certification. The epidemiological model analyzes the effect of an increase in the number of certified restaurants on the rate of change in the number of new COVID-19 cases. Incorporating the susceptible-infectious-recovered (SIR) model [21], our model captures the number of both susceptible and infected populations in a given time period to account for the area's infection status. To evaluate the economic effect, we analyze the effect of an increase in the number of certified restaurants on the average daily restaurant POS transactions and customers in the prefecture.

Results

The GZ certification policy considerably decreased the number of new COVID-19 cases and increased restaurants' sales and the number of customers in Yamanashi. From July 2020 to April 2021, the GZ certification policy reduced the number of new infection cases by approximately 45.3% (848 new cases) as compared to the non-intervention scenario (the model in column (3) of Supplementary Information D.1) (see Fig. 5). The GZ certification policy also increased total sales and the number of customers per restaurant by approximately 12.8% (3.21 million Japanese yen or $30,000, based on the 2020 average yearly exchange rate by the U.S. Internal Revenue Service) and 30.3% (2,909 customers), respectively, compared to the non-intervention scenario (the models in columns (1) and (5) of Supplementary Information Table 4) (see Figs. 6 and 7).

The treatment effects estimated above correspond to the light-blue-shaded areas in the Figs. 5, 6, and 7. The areas are the sum of the difference between the fitted value and the non-intervention scenario value of the corresponding models, indicating the effect size in absolute value. The effect sizes on percentage bases are calculated by the sum of fitted values divided by the sum of non-intervention scenario values (both are in absolute terms).

Statistical Testing

The non-intervention scenarios are calculated through statistical analyses. For both epidemiological and economic analyses, we compare Yamanashi Prefecture, the treatment group, with its surrounding prefectures with similar external conditions for infection spread. The inclusion of two fixed effects, a time-invariant prefecture effect (e.g., population) and a prefecture-invariant time effect (e.g., infection spread period), focuses the comparison of prefectures on the degree of infection spread, not the absolute quantity of infection cases. We use the two-tailed t-test because the estimated OLS coefficients for the number of new infections, restaurants' sales, and customers are known to follow normal distributions, and when the estimated coefficient is standardized by the standard error, it follows a t-distribution. Analysis methods are further discussed in the methods section and in Supplementary Information Table 1 for the summary statistics and D. Statistical Testing.

Epidemiological Effects

Our epidemiological analyses show a consistent and significant negative coefficient when we regress the log-transformed number of new infection cases with a two-week lag on the log-transformed cumulative number of GZ-certified restaurants (see Supplementary Information Table 1). The time lag is set because previous studies have demonstrated that the time lag between the infection and the announcement of the disease is six to twelve days [22][23]. For robustness, we repeated the analyses with a one-week lag, and obtained similar results (see Supplementary Information Table 2). The regression results indicate that a 1% increase in the number of cumulative GZ-certified restaurants is accompanied by a 0.088% decrease in the number of new COVID-19 cases (column (1)). The estimated coefficient is statistically significant at the 1% level with p-value 0.002. Our analyses control for the estimated number of potentially infected people, declarations of states of emergency, the average rainfall (mm), the average temperature (Fahrenheit), school closure, bans on large assembly, and the number of COVID-19 tests. Since economic variables are not controlled for, the results imply that the drop in the number of infection cases was caused by the reduction in the probability of getting infected with COVID-19 in a given restaurant even with the higher economic performance (i.e., more contact opportunities) than in the neighboring prefectures. In fact, when we control for the number of restaurants' customers (i.e., contact opportunities), the coefficient becomes 0.105%. This difference indicates that the probability of getting infected with COVID-19 in a given restaurant decreased as considerably as to offset the increase in contact opportunities in restaurants. When we repeat the analyses using the cumulative number of GZ-certified hotels along with that of certified restaurants in the same period, the coefficient attenuates but is still statistically significant with p-value 0.008 (column (4)). We do not treat the number of certified hotels as a control variable but add it to the total number of restaurants because the guidelines for the GZ certification in hotels mainly target dining areas within their facilities. Thus, we assume that the same infection prevention mechanism works.

Economic Effects

Our economic analyses suggest that there are consistently significant positive coefficients when we regress the log-transformed restaurants' sales and the log-transformed number of customers on the log-transformed cumulative number of GZ-certified restaurants (see Supplementary Information Table 4). The regression results indicate that a 1% increase in the number of cumulative GZ-certified restaurants is accompanied by 0.018% and 0.040% increases in the restaurants' sales and the number of customers respectively (column (1) and (5)). The estimated coefficient is statistically significant at the 1% level with p-values 0.001 and 0.0001, respectively. We control for the declarations of states of emergency, the average rainfall (mm), the average temperature (Fahrenheit), school closure, and bans on large assembly. Given that we did not control for the number of new COVID-19 cases, we can interpret fewer infection cases brought by the GZ certification resulted in a smaller number of consumers refraining from going out and a smaller number of stores refraining from doing business. Even when we control for the number of infection cases, the magnitude of positive coefficients remains at 0.16% and 0.37% respectively. A plausible interpretation of these results is that GZ certification may have motivated customers to visit restaurants by lowering their risk perception to possible infection. Meanwhile, the higher elasticity of the number of customers relative to that of sales indicates that per-customer spending might have been lower than before the COVID-19 crisis due to a decrease in time spent and consumption of alcoholic beverages, which resulted from infection prevention measures. The positive coefficient of the number of cumulative GZ-certified restaurants is robust even if we replace restaurants' sales and visitors with the percentage increase in restaurant website visits (see Supplementary Information Table 5).

To investigate the mechanism of the economic effects, we ran three separate regressions for (i) human mobility by facility type, (ii) human mobility by resident type, and (iii) the stay-home rate by age against the number of cumulative GZ-certified restaurants (see Supplementary Information Tables 6–10). For (i), the analysis using Google mobility data shows a statistically significant positive effect of GZ-certified restaurants on human mobility in retail and recreation (p-value = 0.0004) and parks (p-value = 0.00001), which include target facilities of the GZ-certification, and no statistically significant effects on grocery and pharmacy (p-value = 0.235), which are not target facilities (see Supplementary Information Table 6). In terms of (ii) human mobility by resident type, the coefficient for interprefectural mobility is positive and statistically significant (p-value = 0.001 (column (7))), while the positive coefficient for intercity mobility is smaller and the coefficient for intracity is negative. It suggests that the GZ certification may have attracted more restaurant visitors from outside the prefecture than within the prefecture (see Supplementary Information Table 7). Finally, concerning (iii) the stay-home rate by age group, we consistently observe statistically significant negative coefficients at the 5% level for males in all generations, except in their 60s (p-value = 0.086); and females aged 30s or older, except in their 50s (p-value = 0.074) (see Supplementary Information Table 9). The coefficient for males aged 15–19 is positive, and the coefficient for females aged 15–19 and in their 20s is negative, but not statistically significant at the 10% level. It suggests that the GZ certification policy, which lowers the psychological hurdle for consumers to go out may have encouraged people to go out particularly among people aged 30s and above. In addition, we observe a statistically significant positive coefficient for the percentage of people going out at night. It suggests that the number of people going out for dinner increased due to the policy (see Supplementary Information Table 10).

Discussion

The GZ certification policy was introduced in an effort to cut down the probability of getting infected with COVID-19 in given facilities, primarily restaurants, while maintaining economic activities. The results of our analyses are in line with the policy objectives, as the GZ certification policy likely dropped the number of infection cases while increasing restaurants' sales and the number of customers.

The reason why Yamanashi Prefecture was able to reduce the infection probability substantially relative to neighboring prefectures is that the GZ-certification increased the percentage of restaurants that comply with the infection prevention guidelines, compared to the cases where prevention is entrusted to each restaurant. As for mechanisms, we assume multiple factors that incentivize restaurants to apply for and keep abiding by the certification guidelines. For example, subsidies on necessary equipment to certified restaurants have lowered the investment cost for the measures. Also, the certification reduced information asymmetry about infection prevention between restaurants and customers. More restaurants applied for the certification, as consumers are more likely to choose certified restaurants that take measures. Additionally, third-party inspections have lowered restaurants' incentives to deviate from compliance to the guidelines. Without a certification policy, infectious disease control in restaurants would be a collective action problem. In such a case, restaurants do not know other restaurants' compliance. If one complies while others do not, one suffers economic losses as the number of cases hikes, exposing the restaurant equally to business closure requests. Therefore, restaurants choose to deviate from compliance to avoid sales damage. Since the certification secures a clear commitment of individual restaurants' conformity, restaurants switch to abide by the rules. As a result, the commitment rate increased and the possibility of infection diminished.

We assume a third-party certification policy brought positive economic spillovers in the following two ways. First, the small numbers of infection cases supported the prefecture's decision to maintain restaurants' usual operating hours, allowing them to make sales while restaurants without proper measures faced shortened operation hours. This is evidenced by the fact that the number of business closure requests in Yamanashi Prefecture was smaller than that of the neighboring prefectures (see Supplementary Information E.3). Second, the policy made consumers feel at ease when dining out. Consequently, consumers continued to visit restaurants nearly as much as they did pre-pandemic, which helped businesses to survive.

Taken together, these two effects suggest the possibility of mitigating the trade-off between maintaining restaurant operations and preventing the spread of infection. The certification policy could help to both sustain the economy and prevent infection.

This research has two main contributions. First, it demonstrates the effectiveness of a third-party certification policy in mitigating the trade-off between infection prevention and economic sustainability. Given the uncertain prospects of the pandemic and finite administrative budget, policymakers are increasingly required to seek a balance between infection risks and economic sustainability in the long run. To this end, some countries, such as Japan and Singapore [24], have implemented third-party certification policies. However, little is known for their effectiveness. As far as we know, this paper provides the first evidence that has evaluated their policy impacts from the both epidemiological and economic points of view. Our results inform the design of a policy that achieves both infection prevention and economic sustainability, as the certification guidelines and government's screening are replicable in other regions regardless of the country or the characteristics of rural or urban areas (see Supplementary Information E.4).

The second contribution is the application of the SIR model, a classical mathematical model of epidemiology, to policy evaluation in a form that removes endogeneity. Many econometric analyses have simulated the epidemiological effects of non-pharmaceutical policies. Nonetheless, only a few examine the actual policy effect by exploiting a natural experiment. Even when they do exist, the results are likely to be biased because they often do not control for factors that can significantly affect the way infection spreads, such as population density, distance from urban areas, and the number of infected people that would have existed in an area at a given time. In this paper, we have made four efforts to overcome endogeneity. First, we include prefecture and time fixed effects to control for the heterogeneity across prefectures and time periods. Second, we limit our sample to prefectures with similar population density and distance from metropolitan areas, the epicenters of infection, to construct the control group. Third, we take into account the potential migration of infected people between prefectures by deploying the method developed by Kurahashi et al. (2021). Their model enables us to fix the number of potentially infected people, and therefore we can examine the extent to which infection spreads. Lastly, we control for other policies that could influence the outcome variables as much as possible. For example, we introduce school closure dummy variables and bans on large assembly dummy variables. We also confirm the similarity in the policies of the treatment and control prefectures except for the presence of the GZ certification by qualitatively studying restaurant-related policies.

To sum up, our study suggests the effectiveness of a third-party certification policy on infectious disease control in restaurants. The policy successfully reduced the number of infections in the targeted prefecture roughly by 45.3%. Furthermore, these measures successfully maintained restaurants' sales and the number of customers, suggesting that the economic impact is low. In this way, the policy could mitigate the trade-off between infection prevention and economic operation. We hope that the findings of this study will be used in policy planning to balance the infection prevention and economic sustainability in the current as well as future pandemics.

Methods

This section describes the main datasets, estimation equations, and treatment and control groups.

Main Datasets

In this section, data for the main explanatory and dependent variables are described. (Data for control variables are explained in the Supplementary Information.)

Green Zone Certification

The explanatory variable is the cumulative number of GZ-certified restaurants. The certification policy targets various types of facilities, such as restaurants, hotels, breweries, and wineries. In this paper, we focused on restaurants, which are deemed to be the main route of infection [1]. The dataset of individual establishments' GZ certification acquisition dates was provided by the department in charge of the certification policy at the Yamanashi Prefectural Office.

COVID-19 cases
One of the dependent variables is the number of daily new COVID-19 cases in each prefecture. The data was obtained from NHK's "Special site: New coronaviruses—Number of cases by prefecture" [25]. The dataset contains the number of publicly announced new infections and deaths since January 16, 2020, when the first cases in Japan were discovered. In order to exclude the influence of new variants and vaccination, the analysis covers the data published until April 30, 2021.

Restaurant sales and the number of customers
The other dependent variable is restaurant sales and the number of customers. They are used as proxy variables for the business conditions of restaurants (including bars). The dataset was provided by Postas Corporation, and it contains daily sales and the number of customers of restaurants that have installed the cloud POS register "Postas" provided by the corporation, which covers the period from January 1, 2019, to April 30, 2021.

Estimation Methods
The estimation model in this study is a two-way fixed effects model with prefecture as the regional unit and week as the time series unit. The dataset provided by Postas Corporation is at the prefectural level. It is also the lowest level at which data on infections can be obtained due to privacy concerns. New infection cases are calculated on a weekly basis rather than a daily basis to reflect infection dynamics more accurately by minimizing errors such as discrepancies in the number of tests and reports.

The equations for estimating the infection prevention effect and the economic effect are as follows.

First, the infection prevention effect is estimated by the following two-way fixed effects model. The derivation process of the equation (1) from the SIR model is described in B. Estimation Equation of the Supplementary Information.

$$\begin{aligned}\ln(New\ cases_{p,t}+1) = {} & \beta_1 \ln(GZ_{p,t-2}+1)+\beta_2 \ln(Susceptible_{p,t-2})+\beta_3 \ln(Infectious_{p,t-2}+1) \\ & +\beta_4 \ln(Customer_{p,t-2})+\sum_{i=1}^{k}\gamma^i \ln\left(Control^i_{p,t-2}\right)+c_p+\tau_t+u_{pt}\end{aligned} \tag{1}$$

$$Susceptible_{p,t-2} = Pop_p - \sum_{k=1}^{t-2} New\ cases_{p,k} \tag{2}$$

$$Infectious_{p,t-2} = \sum_{k=1}^{2} New\ cases_{p,t-k} + \sum_{i=1,i\neq p}^{47} \frac{\sum_{k=1}^{2} New\ cases_{i,t-k} * flow_{i,p,t-k}}{Pop_i} \tag{3}$$

The subscripts p and t denote prefecture and week, respectively. For logged variables, we add one to the variable to avoid the issue that log(0) cannot be defined. This process aims to follow the SIR model and to estimate the elasticity of effect. The outcome variable, $New\ cases_{pt}$ is the published number of new infections at time t in prefecture p. The variables in the right-hand side are the values at $t-2$. This is because it takes about six to twelve days from exposure to the virus, through the incubation period, to onset of symptoms, testing, and publication [22][23]. Since the lag between exposure and announcement may vary depending on the region and time of year, analyses will be conducted with a lag of one week as well as two weeks. $GZ_{p,t-2}$ is the cumulative number of restaurants that have received the GZ certification. The parameter β_1 is the treatment effect, and if this coefficient is negative and significant, it implies a high possibility of infection prevention effect. As described in equation (2), $Susceptible_{p,t-2}$ is the susceptible population that can potentially be infected, and is defined as the population in a prefecture (Pop_p) minus the total number of infection cases in p ($New\ cases_{p,k}$).

The variable $Infectious_{p,t-2}$ is the estimated total number of infectious people who can infect others in p at $t-2$. As the derivation process is described in (3), it is the sum of the total number of infected people who existed in prefecture p at $t-2$ and $t-1$ (the first term) and the total number of infected people who flowed in from other prefectures (the second term). The second term is the sum of the number of newly infected people in prefecture i ($New\ cases_{i,t-k}$) divided by the population (Pop_i) multiplied by the number of people flowing into prefecture p from prefecture i ($flow_{i,p,t-k}$) at $t-2$ and $t-1$. This is based on a previous study by Kurahashi et al. (2021), and is used to accurately measure the potential number of infected persons, who can infect others at a given point in time, in order to more strictly control for the infection situation. Since this paper assumes a trade-off in which increased economic activities come at the cost of increased infections, we also control for the number of restaurant customers, $Customer_{p,t-2}$. For control variables, we include dummy variables for the declaration of a state of emergency, school closure, bans on large assembly. We also control for the mean temperature, mean precipitation, and the

COVID-19 test cases for infections. Lastly, c_p and τ_t represent prefecture and week fixed effect, respectively, and u_{pt} is an error term.

Second, the economic effect is estimated by the following fixed-effects model.

$$Y_{pt} = \beta_1 \ln(GZ_{p,t}+1) + \beta_2 \ln(New\ cases_{p,t}+1) + \sum_{i=1}^{k} \gamma^i \ln\left(Control^i_{p,t-2}\right) + c_p + \tau_t + u_{pt} \tag{4}$$

As before, for logged variables, we add one to the variable to avoid the issue that log(0) cannot be defined. For the outcome variable, Y_{pt}, the main variable is (i) per restaurant sales and customers. For robustness and mechanism check, (ii) the rate of increase in restaurant website visits, (iii) the rate of change in human flow by facility type, (iv) the rate of change in human flow in residential areas, and (v) the stay-home rate by age group are additionally used. $GZ_{p,t}$ is the cumulative number of restaurants that have received GZ certification. The parameter β_1 is the treatment effect, and if this coefficient is positive and significant, it implies a high possibility of positive economic effects. $New\ cases_{pt}$ is the number of new infection cases in prefecture p at time t, which we added to control for the effect of people voluntarily refraining from going out due to the spread of infection. For control variables, we include a dummy variable for state of emergency declarations, a dummy variable for school closure, a dummy variable for bans on large assembly, the squared term of mean temperature, mean precipitation, and test cases for infections. Lastly, c_p and τ_t represent prefecture and week/day fixed effect, respectively, and u_{pt} is an error term.

Treatment and Control

To eliminate endogeneity as much as possible, the control group was selected from five neighboring prefectures with similar population density and distance from Tokyo, the epicenter of infection (see Supplementary Information E.1). The treatment effect of the infection prevention is to have the restaurants comply with the comprehensive infection prevention guidelines through on-site checks. The estimated effect is not a comparison with the scenario when no infection prevention or economic measures were taken at all. As shown in the table (see Supplementary Information E.2), certification and subsidy policies for restaurants existed in other prefectures, but either the programs had not been launched by April 2021 or they had lower infection prevention standards and did not require on-site checks by the government.

The infection prevention guidelines include the following five categories. The first is measures for customers, which can be divided into two cases: (i) entering the store, ordering, and paying, and (ii) dining and in-store use. For the rules concerning (i), disinfection equipment should be installed at the entrance of the store, partitions should be set up to separate clerks and customers at the cash register, and customers should be reminded to wear masks except when eating or drinking. For (ii) dining and in-store use, there should be space between each group and also between seats within a group. The space should be at least one meter wide, but the partitions at all intervals can substitute for the space. Other restrictions include limiting the length of stay and serving food to individual customers rather than on platters. The second is measures for employees. It includes wearing masks at all times, checking temperature and health conditions before starting to work, and regular hand disinfection and hand washing. The third is measures to ensure the hygiene of facilities and equipment. There should be constant ventilation through ventilation equipment or open windows, and the use of hand dryers should be prohibited. The fourth is the creation and publication of a checklist. It mandates the facility administrators to make a checklist to check the above infection prevention measures and publicize the daily checks. The last is measures in the case of infection outbreak. The guidelines stipulate that employees who are suspected of being infected should refrain from coming to work until the test results turn out to be negative. Besides, if necessary, information to prevent the spread of infection, such as business days for possible infection, should be disclosed. Further details are described in E.4 GZ Cerification criteria of the Supplementary Information.

The treatment effect on economic activity operates through both supply and demand. On the supply side, due to the low number of infected cases, restaurant operation is maintained because the government does require them to close or shorten their operation hours. In fact, except for the time of the explosive spread of the infection from December 2020 to January 2021, Yamanashi Prefecture has not declared business suspension requests unlike other prefectures (Supplementary Information Table E.3). On the demand side, customer demand is maintained because consumers do not refrain from going out due to the low number of infected people.

Data Availability

The datasets generated and analysed are available in the Github repository, https://github.com/jhirota/GZ. However, restrictions apply to the availability of the following raw datasets, which were used under license for the study, and so are not publicly available: (i) the list of restaurant names, address, and GZ certification date provided by Yamanashi Prefecture; (ii) the number of restaurants used when constructing sales and the number of customers panel data provided by Postas Corporation; and (iii) the population moving from one prefecture to another (for 47 prefectures) per day provided by Agoop Corporation. Datasets from Agoop Corporation. are publicized in the Github repository.

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Author contributions statement

Conceptualization, K.H., J.H., D.K., Y.M., and C.O.; research design, K.H., J.H., D.K., Y.M., and C.O.; data collection, K.H., J.H., and C.O.; formal analysis, K.H. and J.H.; visualization, J.H.; manuscript writing, K.H., J.H., and C.O.; editing, K.H., J.H., D.K., Y.M., and C.O.

Additional information

The authors declare no competing interests.

Figure Legends

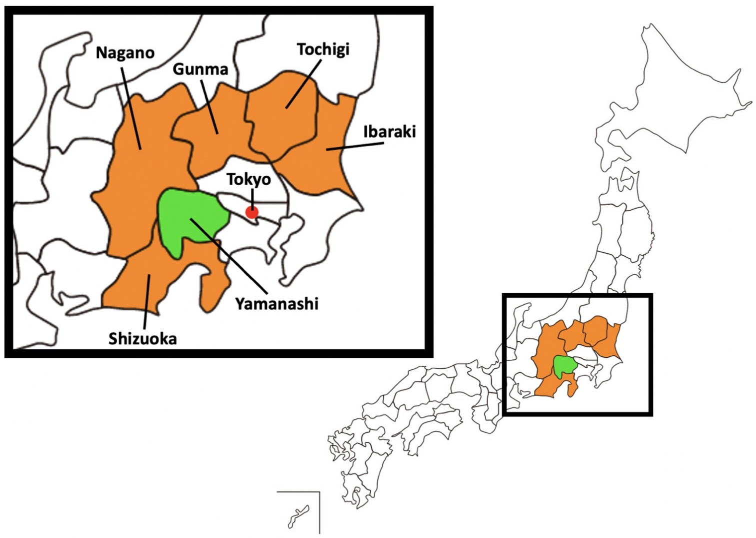

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Figure 1. Location of treatment and control prefectures. Treatment (Yamanashi) and control (Shizuoka, Nagano, Gunma, Tochigi, and Ibaraki) prefectures are in green and orange colors, respectively. Control prefectures were selected because their population density and distance from Tokyo are similar to those of the treatment prefecture.

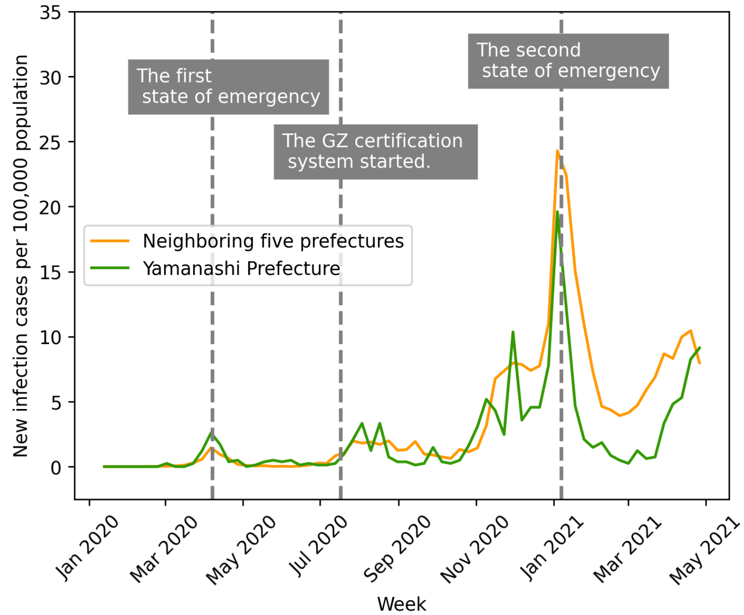

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Figure 2. Time series of new infection cases by week. The vertical axis is the new infection cases per 100,000 population per week. The green line is the trend in Yamanashi Prefecture, while the orange line is the average trend of five neighboring prefectures. The gray dotted lines signify the onset of the first and second state of emergency declaration in Tokyo.

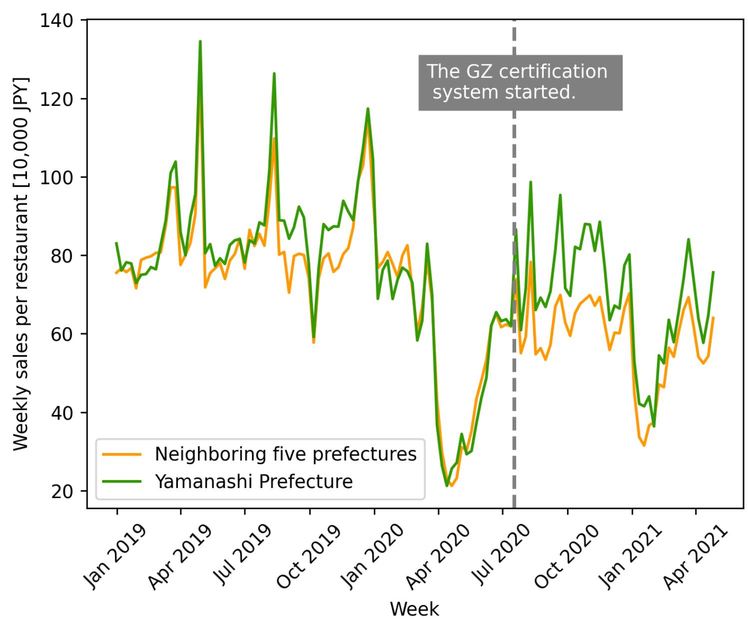

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Figure 3. Time series of weekly sales per restaurant in Yamanashi Prefecture and neighboring 5 prefectures. The vertical axis shows the weekly sales per restaurant (JPY 1 million) made through the cloud POS register “Postas” provided by Postas Corporation. The green line is the trend in Yamanashi Prefecture, while the orange line is the average trend of five neighboring prefectures. The gray dotted line signifies the week when the GZ certification policy approved the first group of restaurants.

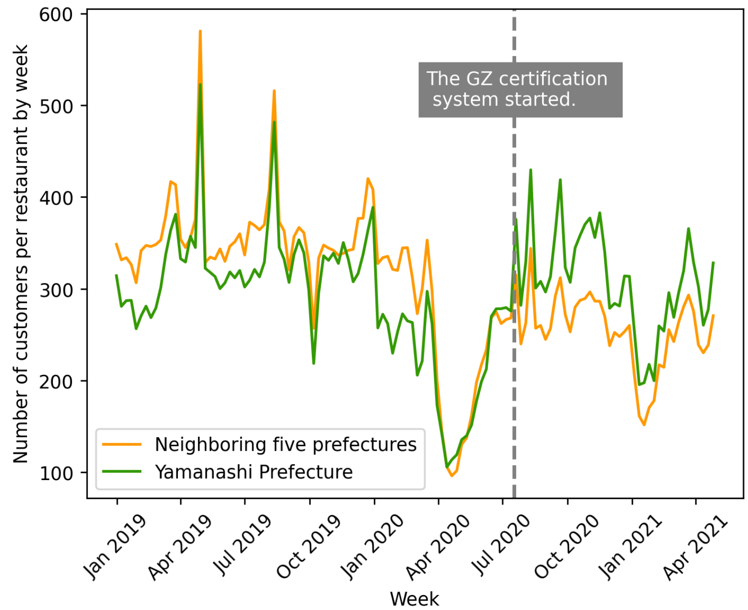

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Figure 4. Time series of the number of customers per restaurant by week in Yamanashi Prefecture and neighboring 5 prefectures. The vertical axis is the weekly number of customers per restaurant recorded through the "Postas" registration system. The green line is the trend in Yamanashi Prefecture, while the orange line is the average trend of five neighboring prefectures. The gray dotted line signifies the week when the GZ certification policy approved the first group of restaurants.

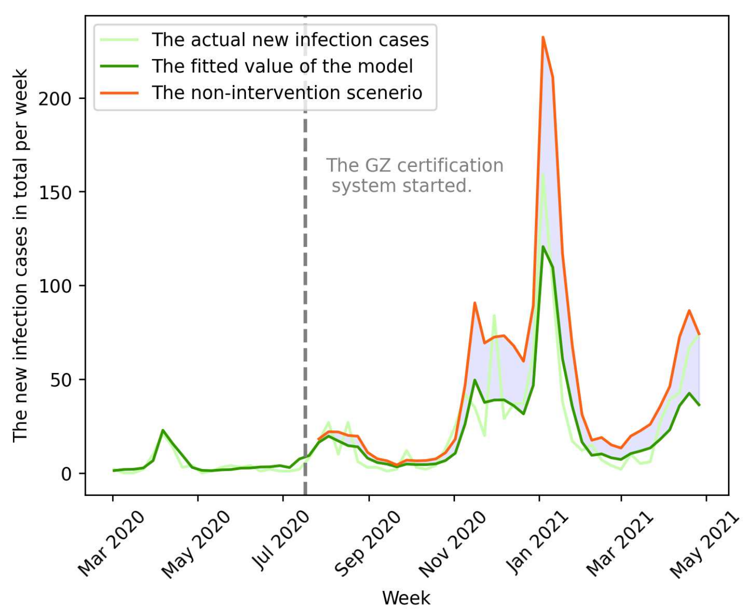

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Figure 5. GZ-certification policy effect on the number of COVID-19 new infection cases in Yamanashi Prefecture. The vertical axis is the prefecture-wide new infection cases per week. The light green, green, and orange lines show the actual, fitted, and non-intervention (counterfactual) scenarios. The green and orange lines are based on model (1) of Table 2 (see Supplementary Information). The green dotted line signifies the week when the GZ certification policy approved the first group of restaurants. The light-blue-shaded area corresponds to the treatment effect.

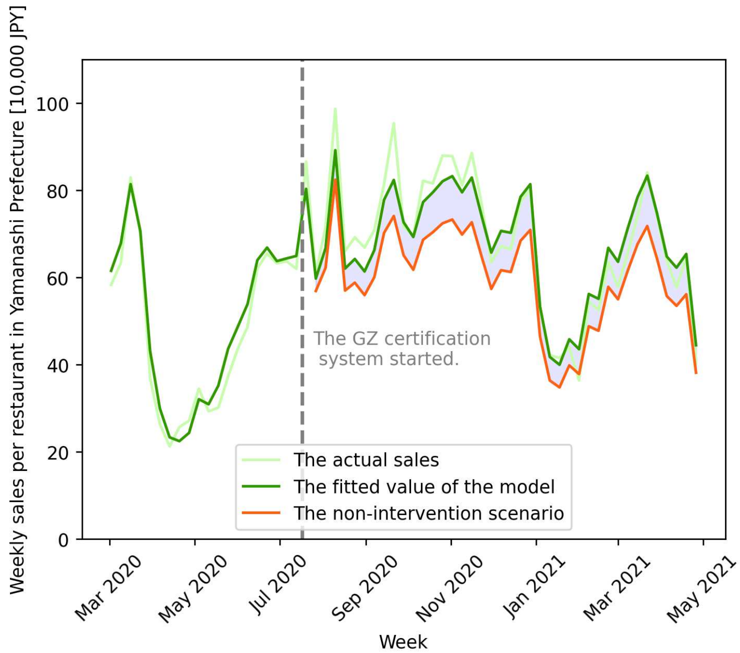

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Figure 6. GZ-certification policy effect on restaurant sales in Yamanashi Prefecture. The vertical axis is the weekly sales per restaurant in Yamanashi Prefecture (in JPY 100,000). The light green, green, and orange lines show the actual, fitted, and non-intervention (counterfactual) scenarios. The green and orange lines are based on model (1) of Table 4 (see Supplementary Information). The green dotted line signifies the week when the GZ certification policy approved the first group of restaurants. The light-blue-shaded area corresponds to the treatment effect.

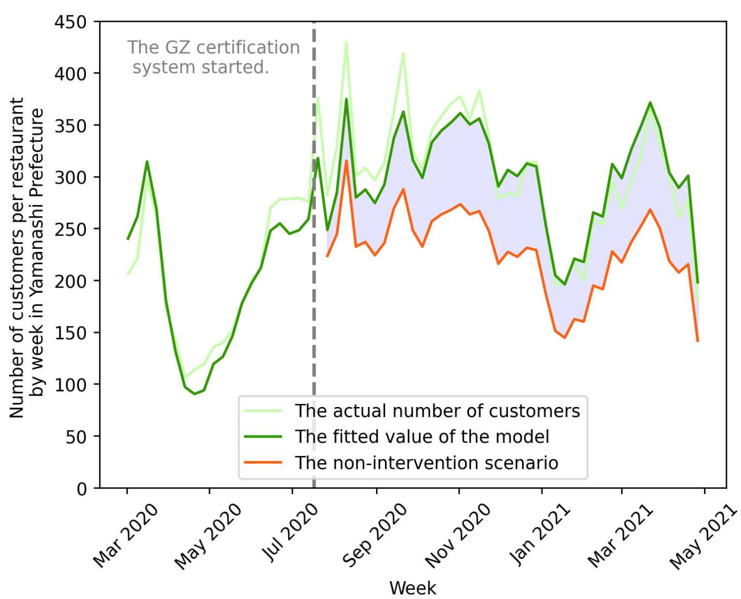

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Figure 7. GZ-certification policy effect on the number of restaurant customers in Yamanashi Prefecture. The vertical axis is the weekly number of customers per restaurant in Yamanashi Prefecture. The light green, green, and orange lines show the actual, fitted, and non-intervention (counterfactual) scenarios. The green and orange lines are based on model (5) of Table 4 (see Supplementary Information). The green dotted line signifies the week when the GZ certification policy approved the first group of restaurants. The light-blue-shaded area corresponds to the treatment effect.

Supplementary Files

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