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# Severity of COVID-19 Infection and the Adoption of Contact-Confirming Application in Japan

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**Keywords:** COVID-19, COCOA, Contact-confirming application, platform, ineffectiveness, network externality

## 1. Objective and Background

This paper aims to analyze how the prevalence of COVID-19 infection has affected the adoption of the contact-confirming application in Japan and how network externalities have emerged in the diffusion process. Japan's COVID-19 contact-confirming application (COCOA), launched on June 19, 2020, was expected to be a digital platform to work against COVID-19 by notifying users of contact with a positive person, thereby encouraging them to change their behavior. However, the utilization of the app has not been advanced as expected. Given the app's purpose, the number of downloads must be influenced by the spread of infection. A synergetic effect caused by user interdependencies is expected to work for further utilization. In this sense, the effectiveness of the app should depend on the number of users and is therefore affected by network externalities.

In addition, registration by positive patients is inevitable for the app to work. In Japan, it is left to the discretion of each infected person to register positive in the app. The number of positive registrations can represent how people are cooperative with the app and thus the Government policy. It would also be interesting to analyze how the spread of infection affects positive registrations. This paper investigates the influence of indices representing the seriousness of the disease on the number of app downloads and positive registrations. Data was collected from the open data published by the Ministry of Health, Labour and Welfare (MHLW).

Mitomo et al. (2021) showed a preliminary result of the analysis by formulating a regression model in a static framework, using the data collected between June 2020 and March 2021. This paper extends the analysis by reformulating it as a dynamic regression model. The time frame for data collection was extended until September 2021. It was before a new COVID-19 variant, 'Omicron,' was spreading across the world. The result suggests that people have not supported Japan's new coronavirus contact-confirming application, and, in effect, the app has been ineffective in preventing the spread of infection of COVID-19. Figure 1(a) – (c) shows the scope of the analysis, the number of weekly new positives and the cumulative number of positives.

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Figure 1(a) – (c)

The COCOA application was expected to promote behavioral change in users by notifying them of contact with a positive person. The API (Application Programming Interface, that is, connection specifications required for interactions between applications) developed by Google and Apple was adopted to ensure privacy. The Bluetooth function allows a contact confirmation mechanism to work without collecting personal information. It is evident that the more smartphone users install the application, the more it is expected to contribute to the prevention of the spread of infection. However, as Lowy Institute(2021) and XDA (2021) indicated, the average performance of COVID-19 infection control in the countries adopting these technologies was not higher than in those not adopting them. The Japanese government has promoted the installation of the COCOA by emphasizing the social benefits of the app to help prevent the spread of the disease. However, as of September 2021, the total downloads had reached only 30 million (24% of the total population), and the positive registration rate was only 2.3% of all positive cases.

## 2. Literature review

Evidence from a cross-country survey indicates that the application can suppress the spreading once sufficiently high population penetration is attained (Altmann et al., 2020). In the study, an online survey was carried out in France, Germany, Italy, the United Kingdom, and the United States in March and April 2020 and sampled over a total of 5,995 respondents. The survey investigated the intention to install the application under two conditions, opt-in and opt-out, then multivariate regression analysis was applied. The finding shows that the application gained strong support in all countries but points out an obstacle that may interfere with the adoption: concerns about cybersecurity and privacy, and lack of trust in government. In Germany and the United States, where the concern for security and privacy is serious, support for the application is less. Lower trust in government negatively affected the intention to install the application on their phone. The result of the study suggests that the effectiveness of a contact tracking and tracing application depends on the level of its adoption in the country.

From a governmental government point of view, Jacob and Lawarée (2020) studied the adoption of a contact tracking and tracing application by the European governments through collecting documents and articles from print media. Notably, relevance, security, and data protection play an important role in adopting the app. It also referred to the influence of the digital divide since people who do not own a smartphone cannot access the app. In addition, security and data protection are considered political challenges.

### **3. COCOA, Japan's contact-confirming application**

#### **3.1 Dissemination of COCOA**

Ministry of Health, Labor, and Welfare (MHLW) of Japan released the coronavirus close contact tracking and tracing application on June 17, 2020. The ministry requests to install the application COCOA to prevent the spreading of COVID-19 in Japan.

It is pointed out that COCOA is not working well enough despite its high expectations. As of March 31st, 2021, the number of downloads of COCOA reached 26.53 million, which is approximately 21.3% of the total population<sup>4</sup>. As of May 27, 2022, the downloads had reached 36.70 million, approximately 29.4% of the total population. Even after the pandemic of the Omicron variant, its penetration was still low. In addition, a significant percentage of users have uninstalled it, which is not reflected in the statistics of the adoption. For the application to be more effective, positive patients should also register in the application that they are positive. There were only 12,068 positive registrants, equivalent to 2.6% of the total number of infected people. Mass media questions the government's capability to manage the application. For example, Nikkei Asia (Ando, 2021) criticized that the application failed to run at full capacity, and the Asahi Shimbun (Yamamoto, 2021) reported the bug that could not be solved despite the ministry's attempt to fix it. At the same time, Reuters (Swift, 2021) reported the application's malfunction that failed to notify some warnings.

Figures 2 (a) – (d) show the weekly new number and the cumulative number of COCOA downloads and positive registrations. The adoption of COCOA and the registration of positive are both smoothly increasing. However, as shown in the weekly downloads, the number of weekly downloads is showing a declining trend and is still limited compared to the total population. The number of positive registrations shows a peak in January 2021. It would be affected by the second peak of infection spread, as shown in Figure 1(b).

Figure 2(a) – (d)

#### **3.2. Why the low penetration rate?**

COCOA is an app developed by the Japanese government. When COCOA was introduced, Prime Minister Shinzo Abe held a press conference<sup>5</sup> and emphasized the following two points:

- 1) The app takes privacy protection very seriously and does not collect any personal information.

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<sup>4</sup> The estimated total population of Japan as of the end of 2020 is approximately 12.5 million. (MIC, 2021)

<sup>5</sup> [https://www.kantei.go.jp/jp/98\\_abe/statement/2020/0618kaiken.html](https://www.kantei.go.jp/jp/98_abe/statement/2020/0618kaiken.html)

2) According to a study by the University of Oxford, if the app covers nearly 60% of the population and if it can lead to early isolation of close contacts, lockdowns can be avoided.

P.M. Abe urged as many people as possible to adopt the app as soon as possible. He also stressed that the app does not store any personal information, and all personal information used is highly encrypted, so that no one can identify any positive or close-contact person. The system uses the API developed jointly by Google and Apple. It does not record personally identifiable information such as phone numbers and location information. The contact history and other information are not transmitted to anyone, including the government, but will be encrypted and recorded only in each individual's smartphone, which will automatically become invalid after 14 days. Subject to the consent of individuals, privacy is ensured by using the proximity communication function (Bluetooth) of smartphones so that they do not know each other.

Since Japanese citizens are reluctant to have their personal information collected by the government, he wanted to emphasize strict privacy protection of COCOA to relieve people and promote the app. In addition, downloading the app and registering positive are totally at the discretion of each individual. Consent to use can be withdrawn at any time, the app can be deleted, and the records can be erased. This means that users can quit using the app at any time.

The function of the app is also limited. It provides only the fact of close contacts. The information that the recipient wants to know, such as when and where, is not provided. Excessive privacy protection and information limitation have limited the benefits this app brings. Consequently, most people do not possess strong incentives to use. As a first step in approaching this problem, we will examine how the number of new downloads and the number of new positive registrations remain stagnant and the factors influencing the numbers of new downloads and the number of new positive registrations.

#### **4. Method**

The number of downloads and positive registrations are used as indicators of the utilization of COCOA. The MHLW (2020) has disclosed and accumulated daily data related to the coronavirus, such as the number of new positive cases, the number of people requiring hospitalization and treatment, deaths and critical cases, and the number of PCR tests performed. Indicators used in the analysis were collected from the database. We aggregated the daily data into weekly data to avoid daily fluctuations. The period over which the data was collected was between July 2020 and September 2021.

Two time-series multiple regression analyses were carried out using the number of new downloads and positive registrations per week as the explained variable, respectively. The number of downloads, the number of positive registrations, the number of PCR tests, and emergency

declaration (dummy) were adopted as explanatory variables. Since the data is time-series data, serial correlation and multicollinearity of explanatory variables were examined by applying the Durbin-Watson test and checking the Variance Inflation Factor (VIF). Mitomo et al. (2021) applied an ordinary multiple regression method to the pooled data, mainly due to the insufficient number of data. After including the data from the extended collection period, the results of the test still suggested the existence of significant serial correlations. In order to deal with the influence of serial correlation, the Cochran-Orcutt method was applied.

The analysis was designed to confirm the correlation of the number of new downloads and the number of new positive registrations with other indicators representing the spread of infection. Furthermore, It examines how the network externality affects diffusion. The data used in the analysis are as follows:

1) COCOA-related indicators

- ① *NWnd*: Number of weekly new downloads
- ② *CNnd*: Cumulative number of new downloads
- ③ *NWnpr*: Number of weekly new positive registrations
- ④ *CNnpr*: Cumulative number of new positive registrations<sup>6</sup>

2) COVID-19-related indicators

- ⑤ *NWnp*: Number of weekly new positives
- ⑥ *CNnp*: Cumulative number of new positives
- ⑦ *NWpcr*: Number of weekly PCR tests
- ⑧ *CNpcr*: Cumulative number of PCR tests
- ⑨ *Dummy*: Emergency state declaration

In addition to the indicators related to COCOA and COVID-19 infection, an emergency state declaration may influence people's behavior and thus on the indicators. A state of emergency has been declared four times until now: the first from April 7 to May 25, 2020 (nationwide), the second from January 8 to March 21, 2021 (11 prefectures), the third from April 25 to March 21, 2021 (10 prefectures) and the fourth from July 21 to September 30, 2021. The second and the third were declared during the observation period. The influence of the emergency declaration was included as a dummy variable in the models. Japan cannot issue a lockdown to restrict individual sovereignty, but a declaration of a state of emergency restricts people's movement and the operation of stores and restaurants.

This paper focuses on the number of downloads of the app and the number of positives registered for the app. We assume that the effectiveness of the application can be defined by the

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<sup>6</sup> This variable is not used in the analysis in this paper because it may not affect new downloading and new positive registration in this model framework.

number of downloads and the number of positive registrations. The former represents how it is adopted by Japanese people. It is evident that if the majority of the population adopts the app, more contacts will be monitored, and it will eventually increase the chances of capturing the contact with positive persons. The latter relates to how many positive persons are actively captured in the app, and as it increases, contacts with positive persons can be more accurately confirmed. If all positive patients register positive in the app, it will provide a maximum chance to get contact with positive persons in the app.

The models to be estimated are listed in Table 1. For the number of weekly new downloads, the four log-linear regression models are to be estimated. The basic model (D-1) assumes that the number of weekly new downloads is explained by the number of weekly new positives and the number of weekly PCR tests, defined as<sup>7</sup>:

$$(D-1) \quad NWnd = C_1 + a_{11} \ln NWnp + a_{12} \ln NWpcr + Dummy + u_1 \quad (1)$$

Each model (D-2) through (D-4) includes one cumulative indicator. Here, we assume the cumulative number of downloads or new positives or PCR tests may accelerate weekly new downloads due to network externality. The model (D-2) is represented as Eq. (2).

$$(D-2) \quad NWnd = C_2 + a_{21} \ln NWnp + a_{22} \ln NWpcr + a_{23} \ln CNnd + Dummy + u_2 \quad (2)$$

As the coefficient for the indicator,  $a_{23}$ , represents the elasticity of the number of downloads with respect to the indicator, it suggests the existence and scale of network externality.

In the same way, models can be formulated for the number of weekly positive registrations. The basic model that does not include cumulative indicators is given as Eq. (3).

$$(P-1) \quad NWnpr = K_1 + b_{11} \ln NWnd + b_{12} \ln NWnp + b_{13} \ln NWpcr + Dummy + e_1 \quad (3)$$

Models including a cumulative indicator are defined as (P-2) – (P-4) in Table 1, formulating the existence of network externality. For example, the model (P-2) is expressed as:

$$(P-2) \quad NWnpr \\ = K_2 + b_{21} \ln NWnd + b_{22} \ln NWnp + b_{23} \ln NWpcr + b_{24} \ln CNnd + Dummy + e_2 \quad (4)$$

Table 1

## 5. Results: Factors influencing the diffusion of the application

### 5.1 Serial correlation and multicollinearity

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<sup>7</sup> The time index  $t$  has been omitted for simplicity of expression.

In conducting regression analysis, the Durbin-Watson test was used to verify the presence or absence of serial correlation in the error terms since the analyzed data are time-series data. For the number of weekly new downloads, as the result of applying the Cochrane-Orcutt method, the serial correlations were eliminated except for Model (D-1). In the same way, for the number of weekly positive registrations, the serial correlations were eliminated except for Model (P-4) as the result of the Cochrane-Orcutt method. If the correlations of the explanatory variables are high, a problem arises with the inverse matrix generation in the least-squares method, and the output of the multiple regression analysis is not properly obtained. We checked each model's variance inflation factor (VIF), and if  $VIF > 10$ , multicollinearity is suspected. As shown in Tables 2 and 3, multicollinearity was not observed in all models treated with the Cochran-Orcutt method.

## 5.2 Impacts on the number of downloads

Table 2 shows the estimation results of the models (D-1) through (D-4).

### (D-1)

The result indicates that the number of weekly PCR tests and the dummy were significant at the 10% level. We could say that the number of weekly PCR tests correlates with downloading the app and the emergency declaration, but their significance is not high.

### (D-2) – (D-4)

As explained in the previous section, the coefficient for each cumulative indicator represents the elasticity of the number of downloads with respect to the indicator, and the existence of network externality is implied if it is more than unity. The estimated coefficients are -0.153, 0.196 and 0.183 for the cumulative numbers of new downloads, new positives and PCR tests, respectively. They are all significant, but the cumulative number of new downloads (D-2) affects negatively. The model (D-2) suggests that the number of total downloads has had a reverse impact on weekly new downloads. On the other hand, it is observed that the total number of new positives and PCR tests have had a slightly positive impact on weekly downloads. Since these coefficients can be interpreted as the elasticity of weekly new downloads with respect to each explanatory variable in the log-linear formulation, the result indicates that, in the diffusion of COCOA, none of the cumulative numbers of new downloads, new positives, or PCR tests is working as an accelerator. The result does support the existence of a positive network externality.

Table 2

## 5.3 Impacts on the number of positive registrations

In addition to the basic model, three models, including a cumulative indicator, were estimated.



#### **(P-1)**

Among the three weekly indicators, the number of new downloads and new positives significantly affected the number of positive registrations. The dummy variable representing the emergency state declaration has a significantly positive impact on the number of positive registrations. From the reason why the emergency state was declared, it is plausible to consider that the number of positives and consequently the number of positive registrations increased.

#### **(P-2) – (P-4)**

The models with a cumulative indicator showed similar characteristics. Except for the model (P-3), the number of weekly new downloads and the number of weekly new positives are significant, and they have a positive impact on the number of positive registrations. In each model, the cumulative indicator demonstrated a positive influence. Since the estimated coefficients are -0.054 for the model (P-2), the cumulative number of new downloads will negatively affect the explained variable. For the models (P-3) and (P-4), the coefficient for the cumulative indicator is positive, but the impact was not so large as accelerating registrations. The result does not support the existence of network externalities that the more positive people exist, or the more people take a PCR test, the more people will register positive. Therefore, these cumulative indicators accelerate the registration. In addition, except for (P-1), the coefficient for the dummy variable is not significant. The emergency state declaration did not influence the number of positive registrations.

**Table 3**

### **5.4 Existence of network externalities**

The analysis selected three cumulative indicators regarding the adoption of COCOA and COVID-19 infection and protection to observe the existence of network externality:

A COCOA-related indicator: ② Cumulative number of new downloads

COVID-19-related indicators: ⑥ Cumulative number of new positives and ⑧ Cumulative number of PCR tests

If the cumulative number of possible influences on the adoption of COCOA, such as the number of COCOA users, positive registrations and PCR tests, has a positive impact on the adoption of new apps, the existence of network externality is indicated.

A direct network externality effect is found if the cumulative number of downloads positively impacts the number of new downloads. However, the result indicates that it has a negative impact. This could be a reasonable result since a long-term downward trend in the number of new downloads and PCR tests had been observed. It was found that no influence such as synergy or

peer pressure was exerted to cause behavior to protect the expansion of infection cooperatively.

On the other hand, the cumulative number of new positives and the cumulative number of PCR tests showed a significantly positive influence on new downloading and positive registration. A direct externality effect on positive registration was observed with the cumulative number of new positives.

The behavior of people downloading the app or registering positive indicates a positive correlation with indicators of the spread of infection. Regarding the downloading of COCOA, no direct positive network externality was found, and it can be concluded that people were instead downloading the application in response to the spread of infection.

## **6. Conclusion**

This paper focused on the insufficient use of COCOA, Japan's new coronavirus contact confirmation application. Using the statistical data published by MHLW, we tried to explain how the number of downloads and the number of positive registrations in the app are affected by the indicators related to the use of COCOA and the diffusion of COVID-19. The eight regression models were estimated in the analysis.

The models on the number of positive registrations yielded overall consistent results. The analysis indicated a positive correlation between the number of weekly downloads and the number of new positives. The existence of network externality was also observed in terms of the cumulative indicators.

In Japan, COVID-19 seems relatively controlled compared with many other countries. Despite the lack of government leadership, people think well and restrain their behavior. It is sometimes called a "Japan" model. Insufficient government policies appear in various aspects of COVID-19 measures. The COVID-19 contact confirmation application is not an exception. When the app was developed, the Japanese government was afraid of being accused of collecting personal information or infringing privacy. As a result, the function of the app was limited, and the number of downloads has shown only a slow increase. In addition, even if people become PCR test positive, very few of them register positive. Consequently, its efficacy remains extremely low. It seems that a trade-off between efficacy and privacy exists.

However, this is not the case that happened only in Japan. A phenomenon of low app penetration is observed in the countries that have adopted the Apple/Google API for the contact confirmation application. AFP (2020) and Lowy Institute (2020) suggest that none of the top 10

countries with successful corona countermeasures have adopted the API.

In order to increase the effectiveness of COCOA, it is necessary to increase the number of registrations, which are left to the autonomy of infected persons. Alternatively, to make COCOA effective, at least one of the following measures should be taken:

- Government incentives, e.g., subsidizing people
- Government enforcement or more vital leadership
- Implementation of a system that allows individuals to feel the benefits of using COCOA in society.

Comparison with South Korea and China, where the utilization of personal data is prioritized, will show an interesting contrast. In these countries, people were frustrated by the lack of privacy protection but were finally relieved when the actions of positive people were made public. Although there are differences in social systems and privacy concepts, it would suggest that privacy concerns can be overcome by making people realize private benefits. Bringing a sense of security may take precedence over privacy in times of emergency. In addition, the formation of trust in the government and society must also be a vital factor for the application to be more effective. These are under study and will be presented soon.

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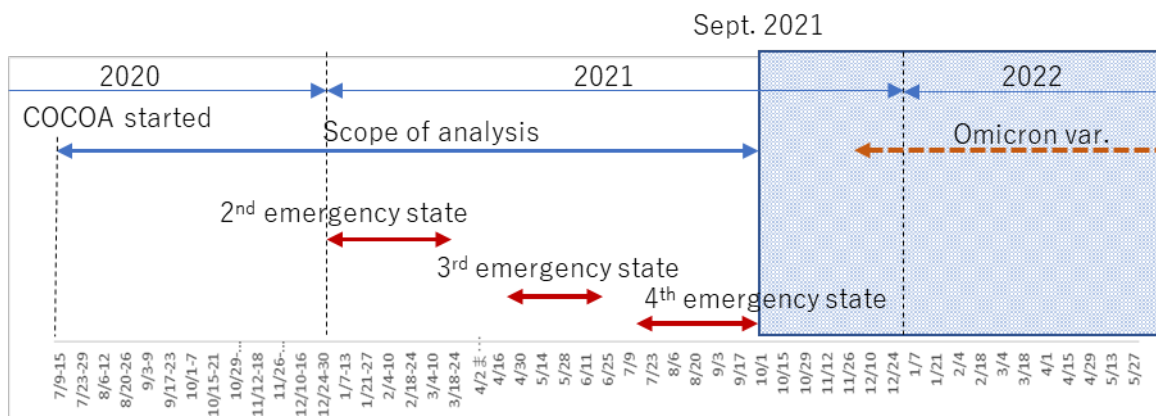


Figure 1(a): Scope of the analysis

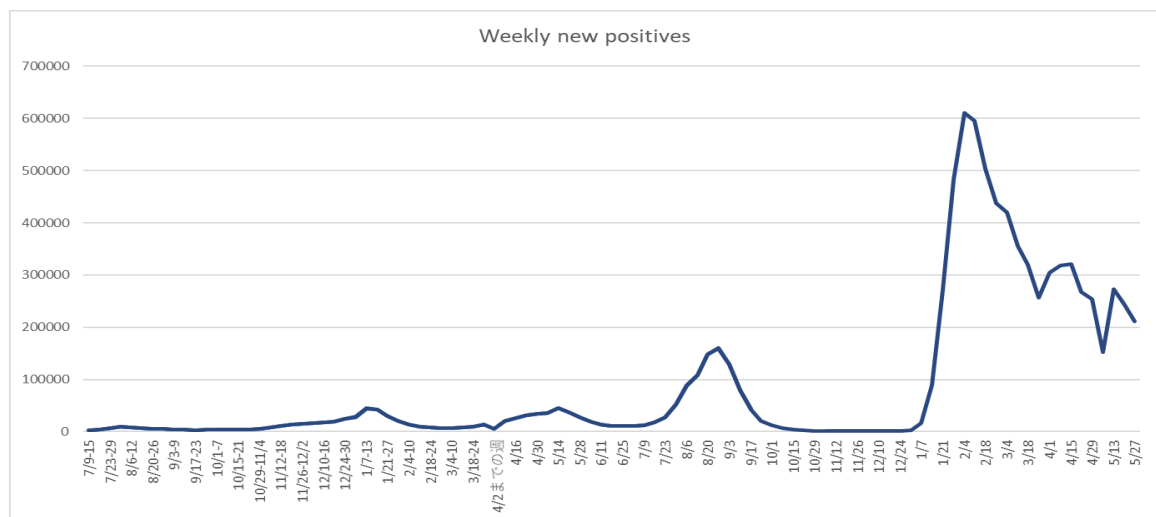


Figure 1(b): The number of new positives

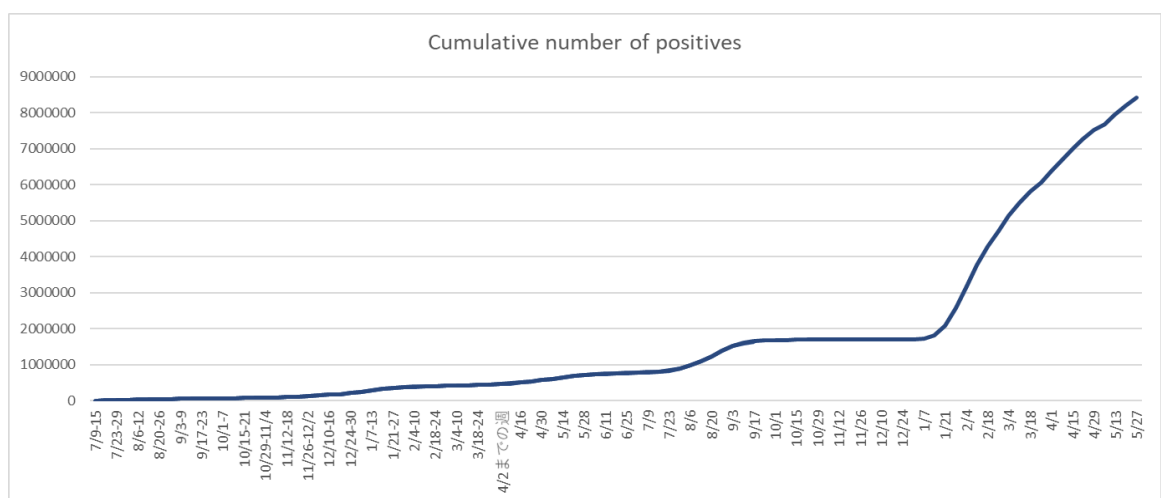


Figure 1(c): The cumulative number of positives

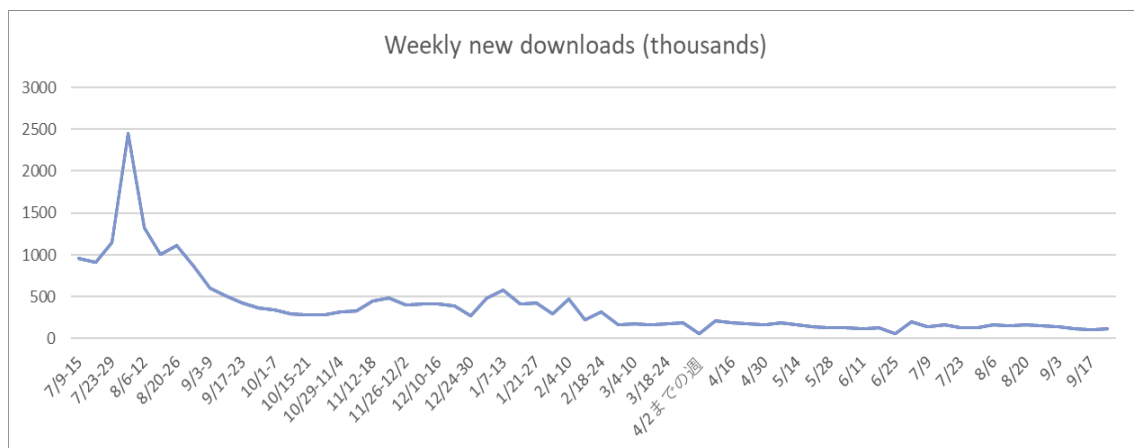


Figure 2(a): Weekly new downloads (July 9, 2020 – Sept. 27, 2021)

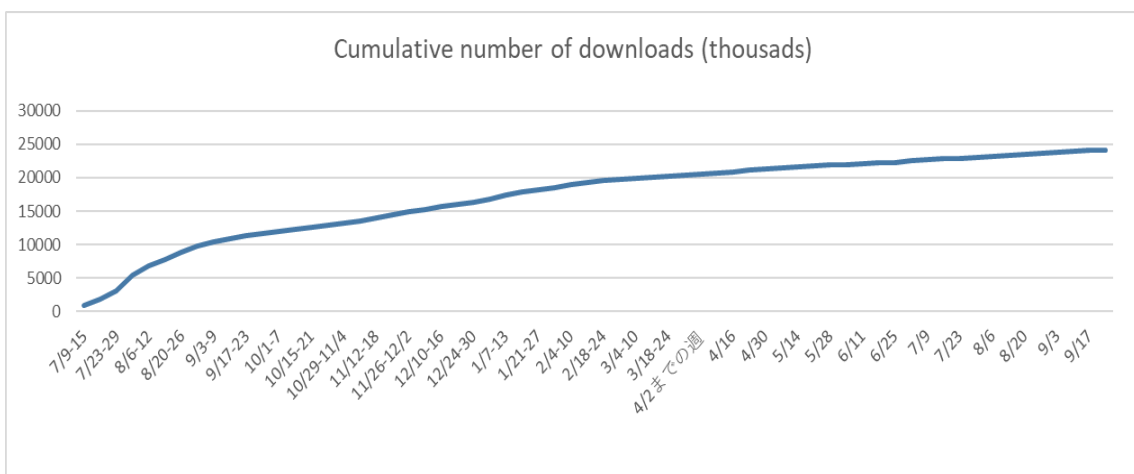


Figure 2(b): Cumulative number of downloads (July 9, 2020 – Sept. 27, 2021)

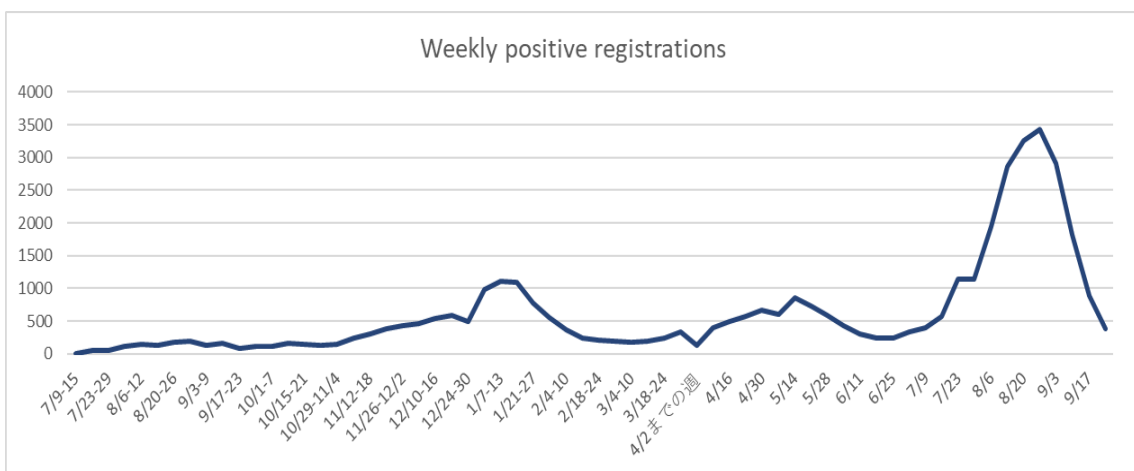


Figure 2(c): Weekly new positive registrations (July 9, 2020 – Sept. 27, 2021)

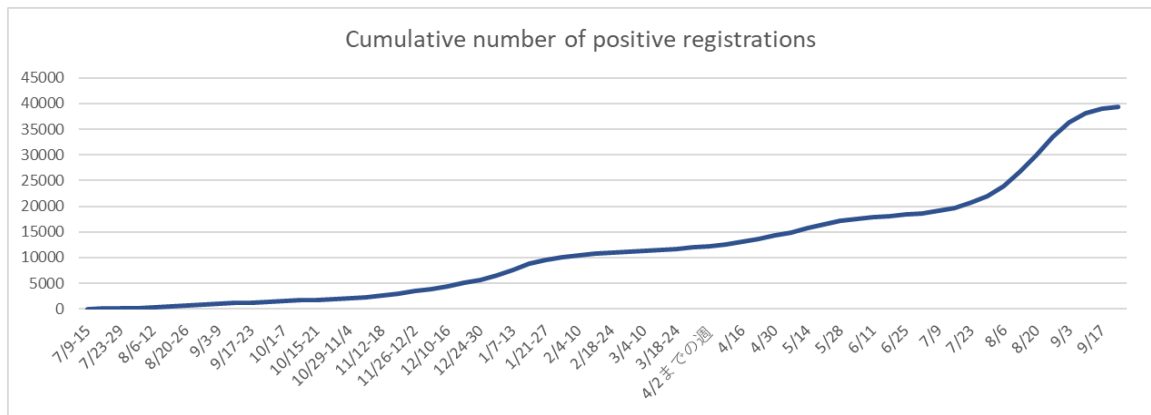


Figure 2(d): Cumulative number of positive registrations (July 9, 2020 – March 31, 2021)

Table 1: List of the models to be estimated

Model		Dependent variable	Independent variables	Dummy variable
(D-1)	Basic	① Number of weekly new downloads	⑤ Number of weekly new positives ⑦ Number of weekly PCR tests	⑨ Emergency state declaration
(D-2)	Network externality		② Cumulative number of new downloads ⑤ Number of weekly new positives ⑦ Number of weekly PCR tests	
(D-3)			⑤ Number of weekly new positives ⑥ Cumulative number of new positives ⑦ Number of weekly PCR tests	
(D-4)			⑤ Number of weekly new positives ⑦ Number of weekly PCR tests ⑧ Cumulative number of PCR tests	
(P-1)	Basic	③ Number of weekly new positive registrations	① Number of weekly new downloads ⑤ Number of weekly new positives ⑦ Number of weekly PCR tests	
(P-2)	Network externality		① Number of weekly new downloads ② Cumulative number of new downloads ⑤ Number of weekly new positives ⑦ Number of weekly PCR tests	
(P-3)			① Number of weekly new downloads ⑤ Number of weekly new positives ⑥ Cumulative number of new positives ⑦ Number of weekly PCR tests	
(P-4)			① Number of weekly new downloads ⑤ Number of weekly new positives ⑦ Number of weekly PCR tests ⑧ Cumulative number of PCR tests	

1) COCOA-related indicators

- ① Number of weekly new downloads
- ② Cumulative number of new downloads
- ③ Number of weekly new positive registrations
- (④ Cumulative number of new positive registrations)

2) COVID-19-related indicators

- ⑤ Number of weekly new positives
- ⑥ Cumulative number of new positives
- ⑦ Number of weekly PCR tests
- ⑧ Cumulative number of PCR tests
- ⑨ Emergency state declaration



Table 2: Estimation result for the number of weekly new downloads

	D-1				D-2				D-3				D-4			
	Estimated coefficient	Significance level	P-value	VIF	Estimated coefficient	Significance level	P-value	VIF	Estimated coefficient	Significance level	P-value	VIF	Estimated coefficient	Significance level	P-value	VIF
Constant	4.089	***	0.000		9.445	***	0.000		3.629	***	0.000		3.039	***	0.000	
Dummy (emergency declaration)	0.036	.	0.070	1.047	0.010		0.733	1.502	-0.004		0.557	1.140	0.001		0.858	1.091
Number of weekly new positives	0.018		0.412	2.371	0.008		0.745	3.110	-0.012		0.104	2.465	0.000		0.953	2.363
Number of weekly PCR tests	0.049	.	0.095	2.343	0.189	***	0.000	3.595	0.013		0.170	2.415	0.004		0.631	2.353
Cumulative number of new downloads					-0.153	***	0.000	1.247								
Cumulative number of new positives									0.196	***	0.000	1.464				
Cumulative number of PCR tests													0.183	***	0.000	1.306
The number of data	56				56				56				56			
Multiple R2	0.276				0.822				0.926				0.893			
Adjusted R2	0.239				0.808				0.920				0.884			
F value	6.595		0.001		58.860		0.000		159.800		0.000		106.200		0.000	
Durbin Watson ratio	0.698		0.000		1.972		0.359		2.297		0.715		2.359		0.883	
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1																

Table 3: Estimation result for the number of weekly new positive registration

	P-1				P-2				P-3				P-4			
	Estimated coefficient	Significance level	P-value	VIF	Estimated coefficient	Significance level	P-value	VIF	Estimated coefficient	Significance level	P-value	VIF	Estimated coefficient	Significance level	P-value	VIF
Constant	-35.111	***	0.000		-29.482	***	0.000		-4.768	***	0.000		-4.802	***	0.000	
Dummy (emergency declaration)	0.054	*	0.048	1.319	0.034		0.183	1.290	0.000		0.967	1.100	0.016		0.255	1.055
Number of weekly new downloads	5.035	***	0.000	1.956	4.888	***	0.000	3.183	1.385	***	0.000	6.377	1.675	***	0.000	3.266
Number of weekly new positives	0.076	**	0.005	2.763	0.085	**	0.002	2.751	0.011		0.284	2.443	0.050	**	0.005	2.293
Number of weekly PCR tests	-0.027		0.517	3.601	-0.009		0.829	3.450	-0.007		0.568	2.334	-0.040	.	0.063	2.246
Cumulative number of new downloads					-0.054	*	0.024	2.032								
Cumulative number of new positives									0.787	***	0.000	6.743				
Cumulative number of PCR tests													0.728	***	0.000	3.344
The number of data	56				56				56				56			
R2	0.990				0.989				0.992				0.955			
Adjusted R2	0.990				0.988				0.991				0.951			
F value	1319		0.000		884.3		0.000		1190		0.000		214.1		0.000	
Durbin Watson ratio	1.808		0.164		1.722		0.111		1.472		0.015		0.942		0.000	
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1																

