# Containment and Financial Policies to Confront Infectious Diseases

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**ABSTRACT**

Since 2020, the international community has been threatened by the new severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Governments are under pressure to stop the spread of infection while continuing economic activities. This study examines the effects of containment policies and financial support based on the susceptible-infected-macro model. Results show that an immediate containment policy is effective, and strong financial support is effective from viewpoint of maintaining economic activity.

**Key words:** SARS-CoV-2, SIR-macro model, Containment policy, Financial support

**JEL Classification:** E21, E32, E65

## 1. Introduction

In 2020, the world was hit hard, medically and economically, because of the infectious disease, coronavirus disease (COVID-19), which became a pandemic. The new severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which originated in Wuhan, China, has since spread worldwide. Infectious diseases and pandemics can significantly impact economic activities. A possible impact of infectious diseases on the economy is a recession, which results from the reduction in the labor supply owing to infection risk and actual infection, thereby decreasing the supply of goods. Additionally, people stay at home because they are afraid of infection, and thus, consumption activities become stagnant, further decreasing the level of consumption.

Governments have implemented various policies to combat the spread of SARS-CoV-2. For example, some cities have implemented lockdowns or requested that people stay at home to prevent the spread of the virus. However, financial policies are necessary to counteract the stagnation of consumer activity or the deterioration of employment conditions because of lockdowns or stay-at-home requests. Additionally, governments should create a system in which vaccines are developed and distributed worldwide.

This paper focuses on the first and second set of policies: policies to stop the spread of SARS-CoV-2 (“containment policies”) and financial policies to support the economy (“financial support”). First, we examine the policies implemented by several countries. Thereafter, we construct a simple macroeconomic dynamic model and investigate how exogenous policy shocks drive the economy. The base model is the susceptible-infected-recovered (SIR)-macro model proposed by Eichenbaum et al. (2021), which incorporates the behavior of economic agents into the SIR model proposed by Kermack and McKendrick (1927). The model by Eichenbaum et al. (2021) considers infection through economic activities, which Kermack and McKendrick’s (1927) SIR model does not envision[1]. Eichenbaum et al. (2021) examined the effectiveness of strict containment policies. They proposed that without a containment policy, consumption would initially decrease by 7%, whereas with a containment policy, consumption would decrease by 22%. Thus, Eichenbaum et al. (2021) show that containment policies can significantly reduce consumption, necessitating financial support policies[2].

In this paper, we add containment policies and government funding to entrepreneurs to the model by Eichenbaum et al. (2021). Results show that an immediate containment policy is effective, and strong financial support is effective for maintaining economic activity. Special loans to entrepreneurs are provided by companies. We assume that this source of funding is financed by issuing new money.

The remainder of this paper is organized as follows. In the next section, we provide an overview of the world's pandemic and economic conditions and then discuss the responsive government policies in several countries. In section 3, we construct a dynamic stochastic general equilibrium (DSGE) model based on the SIR-macro model proposed by Eichenbaum et al. (2021). The model is considerably simplified, using only households and entrepreneurs, and government policy is exogenously inserted. In section 4, the parameter values and steady-state values are calibrated, and the DSGE model is used to simulate the effects of containment policy and financial support. The concluding remarks are presented in section 5.

## 2. Global Environment

### *2.1. Infectious and economic status*

The world has been fighting COVID-19 since 2020. As of 2021, several vaccines have been developed, and it is expected that the spread of the infection will end through vaccination.

COVID-19 was first found in Wuhan, Chain, and it spread worldwide. Subsequently, the number of infected people and deaths sharply increased in the United States and the United Kingdom. By contrast, as is discussed later, Taiwan and New Zealand have achieved early infection control by implementing immediate lockdowns. Additionally, Australia successfully controlled the infection at an early stage. Japan, as an island country like Taiwan and New Zealand, took additional time to control the spread of the infection. Fig. 1 shows the changes in the number of infected people and deaths by country.

As shown in Fig. 1, the number of infected people and deaths has increased in the United States and the United Kingdom since January 2020, when the first infection was confirmed. Particularly in the United Kingdom, the number of infected people rapidly increased in the early stages. Conversely, in Japan, the number of infected people was not significantly high at the beginning; however, since December 2020, the number of infected people has explosively increased, and the number of deaths has rapidly increased.

By contrast, New Zealand implemented lockdowns, including closing its borders, when the infection was first identified, suppressing the spread of the infection at an early stage. From the experience of SARS, Taiwan already has a specialized department and successfully identified infected persons by immediately strengthening quarantine. Compared with other countries, New Zealand and Taiwan's early containment policy was effective.

Next, we examine the economic trends during this period. Fig. 2 shows the changes in the gross domestic product (GDP) in the United Kingdom, the United States, and Japan.

Although it is temporary, the COVID-19 shock — which caused a rapid recession that surpassed the Lehman shock beginning in 2008, — caused the most serious damage in these three countries. Both the United States and Japan plunged into a recession; however, their

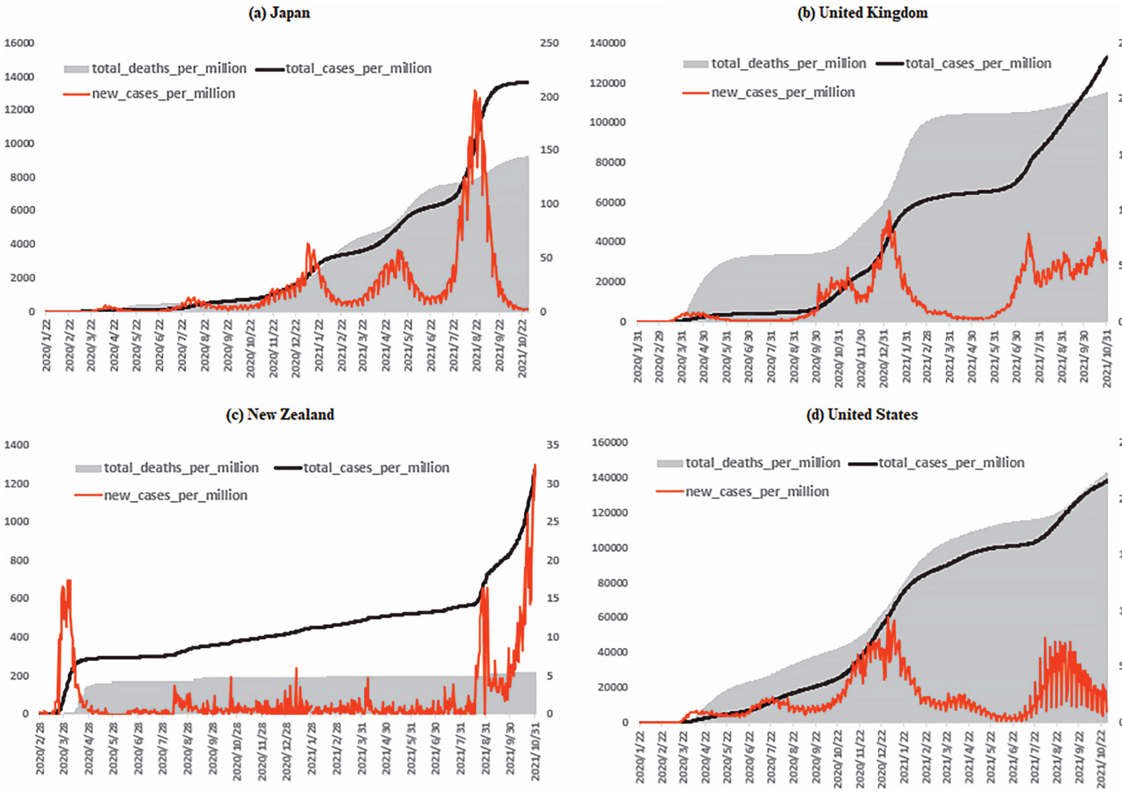


**Fig. 1.** Total and new cases, and total deaths per million
Source: Our World in Data, https://ourworldindata.org/

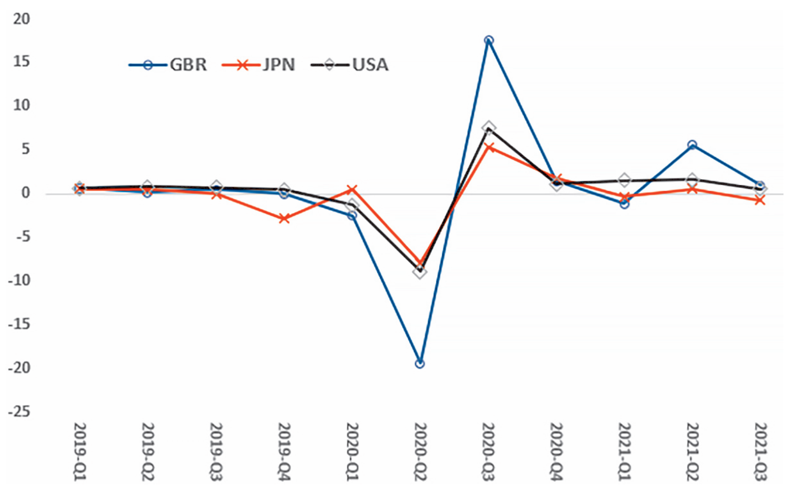


**Fig. 2.** The rate of change in GDP
Source: OECD, https://www.oecd.org/tokyo/statistics/

economies are not as seriously depressed as the United Kingdom, resulting in a small decline in goods consumption in the United States and Japan.

Fig. 3 shows changes in personal consumption expenditures in Japan and the United States. In both Japan and the United States, personal consumption expenditures sharply decreased in the second quarter of 2020. As shown in the figure, the decline in GDP was affected by the decline

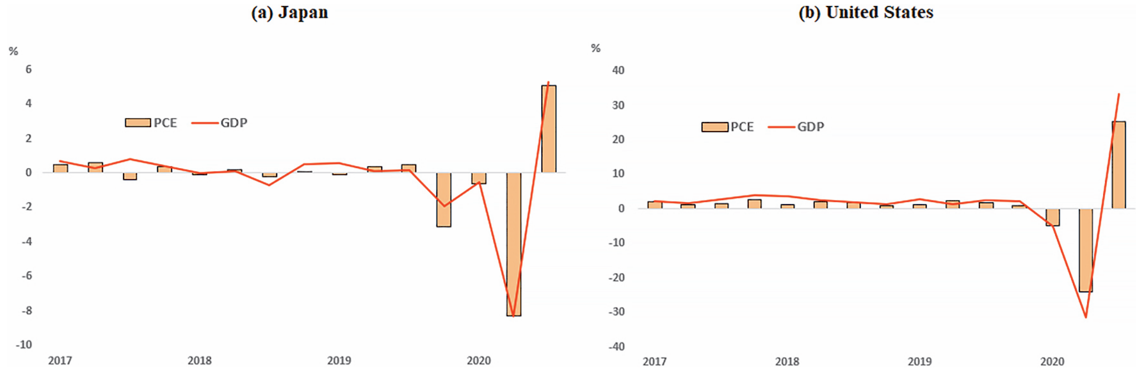


**Fig. 3.** GDP and personal consumption expenditures
Source: Japan Cabinet Office, U.S. Department of Commerce


**Fig. 4.** Service spending in Japan and the United States
Source: Japan Food Service Association, Japan Tourism Agency, and U.S. Department of Commerce

in personal consumption expenditures.

However, as shown in Fig. 4, when personal consumption expenditures were classified into goods and services, the decline in goods consumption was low and the decline in service consumption was exceptionally high. Fig. 4 (a) shows consumption in restaurants and the travel industry in Japan, which dropped sharply in March 2020 when requests to stay at home and reduce business hours were issued. Fig. 4 (b) shows changes in goods and service consumption in the United States: in 2020, goods consumption declined by approximately 2%, while service consumption declined by approximately 20%. For personal consumption spending in both countries, goods consumption was not significantly affected, whereas service consumption was significantly damaged[3].

*2.2. Containment policies and financial support*

2.2.1. Containment policies

Next, we review the containment policies and financial support implemented in several countries. Lockdown is considered the most common containment policy. It has been implemented in most countries and/or regions, including Western countries. Additionally, Australia and Japan have implemented loose regulations, known as self-restraint. By contrast, Sweden and Brazil have not implemented any containment policies that impact independence.

New Zealand has adopted lockdown, allowing it to successfully control infection. Lockdown and immigration restrictions were imposed early by New Zealand, which curbed the increase in the number of infected people. Resultantly, the lockdown has gradually eased in New Zealand since the end of April 2020, and economic activities have been restored to pre-epidemic levels.

Similarly, Germany has successfully limited the infection. In Germany, although the number of infected people has increased, the COVID-19 fatality rate is extremely low compared to Western countries. In addition to early lockdown restrictions, its success has been attributed to contact tracing and its sophisticated healthcare system.

By contrast, in Italy and Spain the infection has been vastly spread, which has forced both countries into lockdown. In Spain, sports events and large-scale demonstrations have continued even after the spread of the infection, and outbreaks at healthcare facilities are the biggest factor leading to lockdown. Looking back, adopting lockdown at the beginning stage of infection may have reduced health and economic consequences.

Japan and Australia are examples of countries that have adopted self-restraint measures. In April 2020, Japan requested that residents stay at home during the first state of emergency. However, to continue the economic activity, Japan has provided consumption support for travel and eating out. Although it is difficult to identify the precise cause, since December 2020, Japan has experienced the third wave of COVID-19, which is larger than the first and second waves. Resultantly, in January 2021, Japan issued a second state of emergency. Given that Japan's measures appeal to self-restraint, its infection control policies are not compulsory.

Similarly, Australia is a great example of a county that has successfully controlled the spread of the infection using self-restraint measures. Australia has thoroughly implemented social distancing, limited gatherings to two people, and minimized economic harm by promoting take-out sales in restaurants. Resultantly, Australia has suppressed the number of infected people to almost the same level as New Zealand.

Based on the above, countries that have successfully controlled the infection have adopted early lockdown or strict infection control policies. However, given the decline in economic activity due to infection control, it is necessary to look at the importance of financial support policies.

2.2.2. Financial supports

Infectious diseases weaken consumption and labor supply activities, which can trigger a recession. Fig. 5 shows the ratio of financial support to the GDP of major countries during the COVID-19 pandemic.

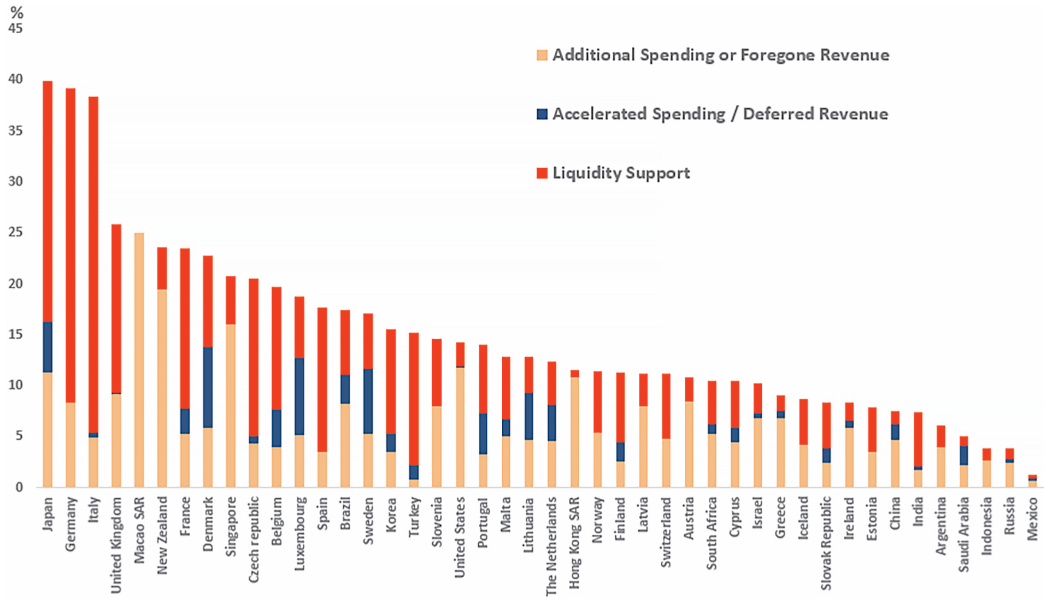


**Fig. 5.** Financial support in response to the COVID-19 pandemic
Source: IMF Database of Country Fiscal Measures in Response to the COVID-19 Pandemic

As shown in Fig. 5, Japan, Germany, and Italy have provided the most substantial financial support as a percentage of GDP. Notably, this is not a ranking of countries that have achieved excellent results through countermeasures against COVID-19. Here, we provide a brief overview of the financial support of several countries[4].

a. United States

In the United States, economic measures have been formulated four times since March 2020. The first measure was an $8.3 billion package based on the Coronavirus Preparedness and Response Supplemental Appropriation Act, and the second was a $100 billion package based on the Families First Coronavirus Response Act. The third was a $2.2 trillion package based on the Coronavirus Aid, Relief, and Economic Security (“CARES”) Act, and the fourth was a $4,830 billion package based on the Paycheck Protection Program and Health Care Enhancement Act. Federal spending from these economic measure totals approximately 13% of the GDP.

Next, as a support for consumers, the Economic Impact Payment was provided to US citizens with a valid social security number, foreigners with permanent residence, and limited other foreign nationals under the CARES Act. Benefits are up to $1,200 per eligible person, plus up to $500 per child.

Additionally, the federal government created the Paycheck Protection Program which provided small and medium-sized enterprises (SMEs) with 500 or fewer employees with a loan equivalent of 2.5 months of the average monthly salary of all employees and exempts repayment within a specific period after the start of the loan. Further, they introduced an Employee

Retention Credit, which is a tax credit for payroll taxes paid by employees, which applies to 50% of the salary paid by employers who are in financial difficulties because of the pandemic.

Furthermore, the following these programs have been introduced to expand unemployment insurance benefits in the US: (1) Pandemic Unemployment Assistance, which provides benefits to self-employed individuals who are not eligible for regular unemployment insurance; (2) Pandemic Emergency Unemployment Compensation, which provides up to an additional 13 weeks of unemployment insurance benefits; (3) Federal Pandemic Unemployment Compensation, which increases unemployment insurance benefits through the end of July 2020 by an additional $600 per week.

The federal government does not provide direct benefits for businesses. However, it provides cash flow support, which also benefits SMEs.

b. Germany

In March 2020, the German federal government announced an economic package of approximately 750 billion euros. In April, the second package of approximately 10 billion euros was announced, followed by an additional supplementary package of 130 billion euros in June.

Second, to protect employment, Germany eased the existing operational shortening allowances (Kurzarbeitergeld). Additionally, as support for businesses, an emergency support program (Soforthilfe) of 50 billion euros was initiated in March 2020. This was provided to SMEs and sole proprietors affected by the pandemic.

c. Japan

In April 2020, Japan creased an economic package, totaling approximately 117.1 trillion yen, and the first measures were established. In June, the second package was enacted, totaling approximately 117.1 trillion yen. The amount of these two packages totals approximately 42% of the GDP.

Notably, there was a per capita benefit of 100,000 yen, which was included in the first measures in April 2020. However, the benefits were not satisfactory to the public because of the country’s poor containment policies. Additionally, to protect businesses, existing employment adjustment subsidies have expanded coverage to the employment insurance of workers employment. Furthermore, to facilitate the government’s request for reduced operating hours for restaurants, a daily leave allowance has been provided to the restaurants that comply with the request.

In many other countries, financial support is being provided to rebuild economies that have suffered from the pandemic. Furthermore, government support and loans from financial institutions are being prepared.

### 3. The model

After the emergence of COVID-19, macroeconomic models with the externalities of the virus were developed. These models added economic dynamics to the SIR model proposed by Kermack and McKendrick (1927). This was because activities, such as consumption and labor supply, would not be possible without human contact, which, if allowed, could increase the probability of infection. In Kermack and McKendrick's (1927) SIR model, the transition probability between health states is treated as an exogenous parameter, while Eichenbaum et al., (2021) allow this probability to change as a function of consumption and labor supply. That is, Eichenbaum et al. (2021) suppose that economic activities increase the spreading probability of an infectious disease.

The role of the government is not only to stop the recession but also to stop the spread of the infection. However, the challenge is that there is a trade-off between stopping the spread of the infection and recovering the economy. Not surprisingly, the extreme constraint policies adopted to stop the spread of the infection resulted in a severe economic downturn. Conversely, if the economy continues to progress without containment policies, the economic downturn may not occur; however, the number of infected people and the mortality rate are likely to increase. Although this may not lead to an extreme economic downturn, it is expected to cause a decline in labor supply and consumption for a relatively long period.

As mentioned above, to prevent the spread of the infection, lockdown, which is an extreme containment policy, is necessary. For example, Alvarez et al. (2021) extended the SIR model presented by Atkeson (2020) to assess the existence of optimal lockdown policies. They pointed out that the optimal lockdown policy is a function of the number of infections and the mortality rate.

Our model was based on the SIR-macro model proposed by Eichenbaum et al. (2021). In our study, the economic agents were households that survive infinitely and simplified entrepreneurs. Additionally, we assumed that the government did not model concretely and all policy variables were based on exogenous shocks[5].

As in the SIR-macro model, we assumed a steady state before the discovery of the infection. In the steady state, susceptible are $S_0 = 1$, and infected are $I_0 = 0$. The first driving force of the model is the detection of infected individuals. This is perceived as an infectious shock and was added to $I_0$ in the form of $\epsilon_0 = 0.001$.

Next, we specified the movement of the population in period $t + 1$. Susceptible in $t + 1$ is

$S_{t+1} = S_t - \tau_t S_t$ and infected is $I_{t+1} = \tau_t S_t + (1 - \pi_r - \pi_d)I_t$, where $\tau_t$ is the infection probability faced by conducting social activities and is defined by the following transition probability.

$$\tau_t = \pi_c c_t^s\left(vI_t c_t^i\right) + \pi_l l_t^s\left(vI_t l_t^i\right) + \pi_o vI_t \tag{1}$$

In this equation, $v$ represents the proportion of asymptomatic individuals among infected individuals, and $\pi_c$ and $\pi_l$ represent the probability of infection from consumption and labor activities, respectively. Additionally, $\pi_o$ represents the probability of infection with susceptible and infected people can meet. $c_t^s$ and $l_t^s$ are the consumption and labor supplies of the susceptible, and $c_t^i$ and $l_t^i$ are the consumption and labor supply of the infected, respectively. The third term on the right-hand of this equation is the probability of infection from other social activities. The movements of recovery and death are $R_{t+1} = R_t + \pi_r I_t$ and $D_{t+1} = D_t + \pi_d I_t$, respectively. $\pi_r$ and $\pi_d$ are the recovery and mortality rates, respectively.

*3.1. The households*

According to Eichenbaum et al. (2021), a consumer group is a continuum of individuals that maximize the objective function:

$$U = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t\left[S_t u\left(c_t^s, m_t^s, l_t^s\right) + I_t u\left(c_t^i, m_t^i, l_t^i\right) + R_t u\left(c_t^r, m_t^r, l_t^r\right)\right] \tag{2}$$

where $\beta$ denotes the weekly discount factor. Notably, this objective function depends on the stochastic health conditions of the individuals. Additionally, similar to Eichenbaum et al. (2021), we assume that the preference is as follows:

$$u\left(c^x, l^x\right) = \ln c^x + \frac{m^{x1-v}}{1-v} - \frac{\theta}{2} l^{x2} \tag{3}$$

This preference is the same for all groups ($x = s, i, r$) of consumers: susceptible ($s$), infected ($i$), and recovered ($r$).

The budget constraint of this household group is simply defined as follows:

$$S_t l_t^s + vI_t l_t^i + R_t l_t^r + m_{t-1} = S_t c_t^s + I_t c_t^i + R_t c_t^r + m_t \tag{4}$$

Here, we assume that $(1 - v)I_t$ of the infected must be hospitalized. However, such infected people also need to consume. Therefore, the right-hand of the budget constraint includes the consumption of all infected. Moreover, $m_t = S_t m_t^s + I_t m_t^i + R_t m_t^r$ denotes the real balance of the household holdings.

The dynamics of each group – $S$, $I$, and $R$ – are reprinted as follows:

$$S_t = S_{t-1} - I_t \tag{5}$$

$$I_t = S_{t-1}\left[\pi_c c_t^s\left(\nu I_t c_t^i\right) + (1-\xi_t)\pi_l l_t^s\left(\nu I_t l_t^i\right) + (1-\chi_t)\pi_o \nu I_t\right] + (1-\pi_r-\pi_d)I_{t-1} \tag{6}$$

$$R_t = R_{t-1} + \pi_r I_t \tag{7}$$

where, $\xi_t$ and $\chi_t$ represent the degree of containment and are defined as exogenous variables. If $\xi_t = \chi_t = 1$, the containment policy is a lockdown.

The optimal conditions for households are as follows:

$$\frac{1}{c_t^s} = \lambda_t^b - \lambda_t^i \pi_c\left(\nu I_t c_t^i\right) \tag{8}$$

$$\frac{1}{c_t^i} = \frac{1}{c_t^r} = \lambda_t^b \tag{9}$$

$$\theta l_t^s = \lambda_t^b A + \lambda_t^i(1-\xi_t)\pi_l\left(\nu I_t l_t^i\right) \tag{10}$$

$$\theta l_t^i/\nu = \theta l_t^r = \lambda_t^b \tag{11}$$

$$\begin{aligned}\lambda_t^s = {} & u\left(c_t^s, l_t^s\right) + \lambda_t^b\left(l_t^s - c_t^s\right) + \\ & \beta\left\{\mathbb{E}_t\lambda_{t+1}^s + \mathbb{E}_t\lambda_{t+1}^i\left[\pi_c c_t^s\left(\nu I_t c_t^i\right) + (1-\xi_t)\pi_l l_t^s\left(\nu I_t l_t^i\right) + (1-\chi_t)\pi_o \nu I_t\right]\right\}\end{aligned} \tag{12}$$

$$\begin{aligned}\lambda_t^i = {} & u\left(c_t^i, l_t^i\right) + \lambda_t^b\left(l_t^i - c_t^i\right) + \lambda_t^s + \\ & \beta\mathbb{E}_t\lambda_{t+1}^i\left\{S_t\left[\pi_c c_t^s \nu c_t^i + (1-\xi_t)\pi_l l_t^s \nu l_t^i + (1-\chi_t)\pi_o \nu\right] + (1-\pi_r-\pi_d)\right\} + \pi_r\mathbb{E}_t\lambda_{t+1}^r\end{aligned} \tag{13}$$

$$\lambda_t^r = u\left(c_t^r, l_t^r\right) + \lambda_t^b\left(l_t^r - c_t^r\right) + \beta\mathbb{E}_t\lambda_{t+1}^r \tag{14}$$

$$\frac{1}{m_t^v} = j_t\left(\lambda_t^b - \beta \mathbb{E}_t \lambda_{t+1}^b\right), \text{ where } j = S, I, R \tag{15}$$

where, $\lambda_t^b$ is the Lagrange multiplier of household budget constraint (Eq. 4). Additionally, $\lambda_t^i$, $\lambda_t^s$, and $\lambda_t^r$ are the Lagrange multipliers of infection probability (Eq. 6), and on the dynamics of $S_t$ (Eq. 5) and the dynamics of $R_t$ (Eq. 7).

*3.2. The entrepreneurs*

Here, we identified the behavior of entrepreneurs, defined as those who engage in production activities using the labor provided by a household. If the production function is linear and the nominal wage is normalized to one, the real marginal cost is constant at $mc = 1/A$. Therefore, if the markup ratio is set to 1, the price is constant at $P_t = \bar{P} = 1/A$.

Entrepreneurs maximize utility,

$$U_e = \mathbb{E}_0 \textstyle\sum_{t=0}^{\infty} \beta_e^t \ln c_t^e \tag{15}$$

subject to budget constraints,

$$c_t^e + \mathbf{L}_t + (1 - \gamma_t)L_{t-1} = A\mathbf{L}_t + L_t \tag{16}$$

and to credit constraints as follows:

$$L_t \leq \kappa_t(c^{ss} - c_t) \tag{17}$$

where $\beta_e < \beta$ is the discount factor of the entrepreneur, and $\mathbf{L}_t = S_t l_t^s + v_t I_t l_t^i + R_t l_t^r$. Additionally, $L$ is a special loan from the government that repayment is premised and it is assumed that the size of special loans that entrepreneurs can borrow is equal to the amount of consumption, which is relatively low after the infection. Further, for simplicity, we assumed the government budget as follows[6]:

$$\Delta m_t - \gamma_t L_{t-1} = \Delta L_t \tag{18}$$

That is, the government finances a stochastic (real) expenditure $L_t$ by issuing new money in period $t$.

Additionally, $\gamma_t$ is the ratio of special loans that entrepreneurs need to repay in the next period, which is assumed to be uniquely determined by society. For example, when $\gamma_t = 1$, the government compensate for the full decline in sales. Furthermore, $\kappa$ represents the loan-to-value ratio. Note that $\kappa$ is zero in the pre-epidemic steady state.

The optimal condition(s) for entrepreneurs are as follows:

$$\frac{1}{c_t^e} = \frac{\beta(1-\gamma_t)}{\mathbb{E}(c_{t+1}^e)} + \frac{\lambda_t^e}{\kappa_t} \tag{19}$$

where, $\lambda_t^e$ denotes the Lagrange multiplier on the financial constraint of the entrepreneurs.

## 4. Calibration and simulation

### *4.1. Calibration*

In the steady state, because it is assumed that consumption is equal in all state $x = s, i, r$, $c_{ss}^x = c_{ss}$. Furthermore, in the pre-epidemic steady state, $S = 1$ and $I = R = D = 0$. The percentage of infected who must be hospitalized $(1 - \nu)$ is defined as the ratio of hospitalized to infected in November 2020.

Since our model follows a weekly frequency, following Eichenbaum et al. (2020), we set $\pi_c = 2.569 \times 10^{-7}$, $\pi_l = 1.59310^{-4}$, and $\pi_o = .499$. Further, we set $\beta = -.98^{1/52}$ and $\beta_e = .96^{1/52}$. We choose $A = 8.61$ and $\theta = 1.275 \times 10^{-3}$ to ensure that the weekly working hours in the pre-epidemic steady state are valid. We summarize these parameters in Table 1.

From the first-order conditions for labor, we obtain $l_{ss}^s = \nu l_{ss}^i = l_{ss}^r$; thus, in the steady state, $l_{ss}^s = l_{ss}^r = l_{ss} = 1/\sqrt{\theta}$ and $l_{ss}^i = 1/\left(\nu\sqrt{\theta}\right)$. Therefore, $l_{ss}^s = l_{ss}^r = 28.0056$ and $l_{ss}^i = 32.9487$. Next, because $c_{ss} = l_{ss}$ from the household's budget constraint, in the steady state $c_{ss} = 28.0056$. Additionally, the Lagrange multiplier for the budget constraint $\lambda_t^b$, in the steady state is $\lambda_{ss}^b = \theta l_{ss}/A = .005692$.

**Table 1.** Parameter values

| Parameter | Description | Value |
|---|---|---|
| $\beta$ | Discount factor (weekly) | $.98^{1/52}$ |
| $A$ | Productivity | 8.61 |
| $\pi_c$ | Consumption infection intensity | $2.568 \times 10^{-7}$ |
| $\pi_l$ | Labor infection intensity | $1.593 \times 10^{-4}$ |
| $\pi_o$ | Autonomous infection intensity | .499 |
| $\pi_r$ | Recovery rate | .387 |
| $\pi_d$ | Death rate | $1.944 \times 10^{-3}$ |
| $\theta$ | Labor supply parameter | $1.275 \times 10^{-3}$ |
| $\nu$ | Percentage of asymptomatic people | .85 |

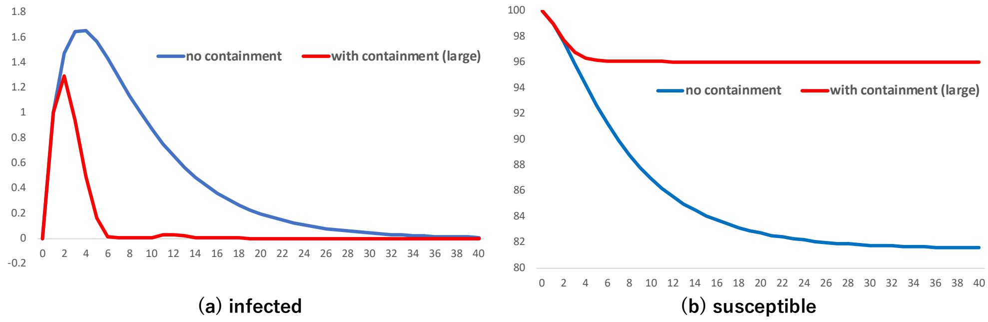


**Fig. 6.** Infected and susceptible

*4.2. Simulation results*

4.2.1. Baseline simulation

First, Fig. 6 shows the results of the baseline simulation. Here, it was assumed that no containment was performed (i.e., $\xi = \chi = 0$) and no financial support was provided (i.e., $\kappa = 0$). In this figure, the black solid line shows the number of infected when the containment policy is not implemented, and the dashed line shows the number of infected when the policy of $\xi = \chi = 1$ is implemented. Additionally, we assumed that the number of deaths is $\pi_d = 1.944 \times 10^{-3}$ of the number of infected, and thus, the dynamics of deaths were the same as the number of infected. In other words, without a containment policy, the number of deaths can increase, and with a stronger containment policy, the number of deaths can be reduced.

We turn to the model simulation. The simulation we examined is determined if containment policies and financial support can curb economic fluctuations. The first thing we observed was the movement of aggregate consumption and labor when the infected appeared on the first day in only 0.1% of the susceptible; that is, consider the economic dynamics in this model when the shock of $\epsilon_0 = .001$ occurs at $t = 0$.

Fig. 6 (a) shows the cumulative movement of the infected individuals. The blue line represents the baseline movement of the infected, while the red line represents the movement of the infected for the ultimate case of the lockdown in the first phase, i.e., immediately after the epidemic. Without the lockdown (blue line), the number of infected individuals will immediately increase after the infection is discovered, the spread of the infection will be significantly increased. Specifically, it may be difficult to implement a lockdown immediately after the infection is discovered; however, it may be more effective to implement it early. Moreover, labor activities are restricted; thus, it may not be a realistic measure. It will be necessary to clarify this point with a model considering the possibility of working from home.

Fig. 6 (b) shows the movement of the susceptible group. Not surprisingly, without the lockdown, the number of susceptible individuals decreased by ~18% in a few weeks, while with immediate lockdown, the decrease in the number of susceptible individuals was ~6.5%.

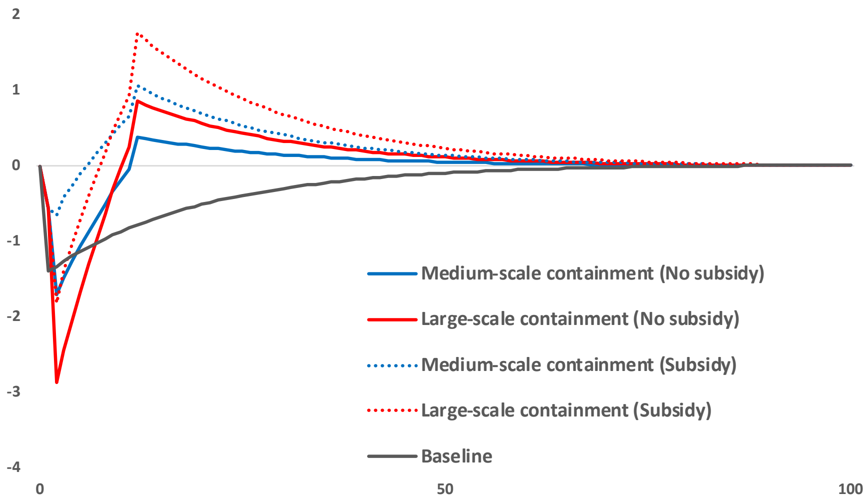


**Fig. 7.** Simulation result: Immediate containment policy and financial support

4.2.2. Simulation with policies

Thus, we showed that the model we constructed behaves realistically after the discovery of the infection. The next step was to examine the effectiveness of containment policies and financial support. First, we simulated the immediate implementation of containment policies and financial support. The first simulation envisions a 10-week containment policy the infection was discovered. The results are shown in Fig. 7.

The black solid line represents the dynamics of aggregate labor and aggregate consumption, respectively. In this model, because only the infection route is considered from the initial infection, the decrease in aggregate consumption was low; however, as the number of infected increased, this decrease naturally increased. Further, the results showed that waiting for society to return to its pre-epidemic steady state prolonged the decline in aggregate consumption. The blue solid line represents a simulation with a medium-scale containment policy, where $\xi_t = \chi_t = 0.5$ and $\kappa_t = 0$. Even if only this medium-scale containment policy was adopted, while the decline in consumption will be temporarily higher than if no policy is implemented, the economy will immediately return to the pre-epidemic steady state. It has been shown that slight positive consumption can be achieved.

By contrast, the red solid line is the simulation result with a large-scale containment policy, where $\xi_t = \chi_t = 1$. As a result of this policy, the decline in consumption is higher than that of the medium-scale containment policy, resulting in a higher consumption growth after returning to the pre-epidemic steady state than with a medium-scale containment policy. In other words, a large-scale containment policy will exacerbate the decline in consumption at the cost of reducing the number of infected and deceased people.

The two dashed lines in Fig. 7 show the simulation results when the containment policy is implemented and 100% financial support is provided, that is, where $\kappa_t = 1$ and $\gamma_t = 0.5$. We assumed that financial support was provided to prevent employment loss owing to a decrease in consumption. By providing strong financial support, it is possible to suppress the decline in consumption and increase the degree of recovery in consumption compared to the simulation where financial support is not provided. If the size of the financial support was reduced, the dynamics of consumption will approach the solid line corresponding to each containment policy. Notably, simulations of large-scale containment policies and financial support showed the accelerated recovery of consumption and a decrease in the number of infected and dead, compared to medium- scale containment policies.

Naturally, the revitalization of economic activities through the provision of special loans will have an impact on the dynamics of the infected. Fig. 8 depicts the original infectious dynamics and the infectious dynamics when special financing was provided. The blue line represents case dynamics without a containment policy. If we were to provide special loans without implementing containment policies, we would expect a large increase in the number of infected. This reflects an increase in the number of infections not only through consumption but also through work and community activities. Similarly, even if large-scale containment policies such as lockdowns are implemented, it is suggested that the number of infected people will increase because of economic measures. This is drawn with a red line. Owing to the large-scale containment policy, the only infection route exists via consumption activities. Thus, although the scale of the spread of infection due to economic measures temporarily increases, it is small overall. Conversely, economic measures such as the Go-to-Travel implemented in Japan are expected to increase the number of infected people because they allow transmission through communities.

Fig. 9 shows a simulation in which a containment policy was implemented 15 weeks after the infection was first confirmed. As shown, the containment policy, regardless of its scale, caused a

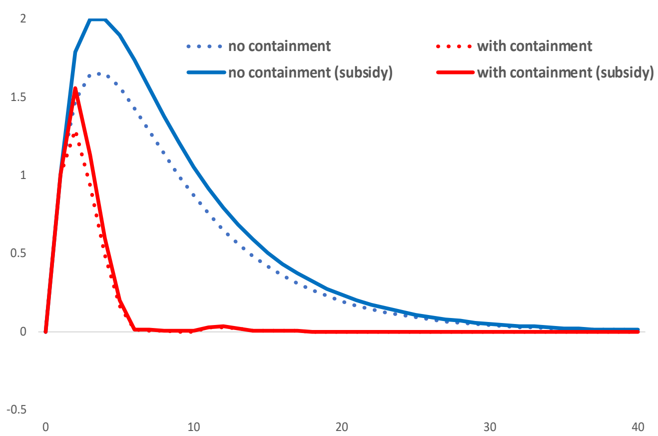


**Fig. 8.** Infectious dynamics

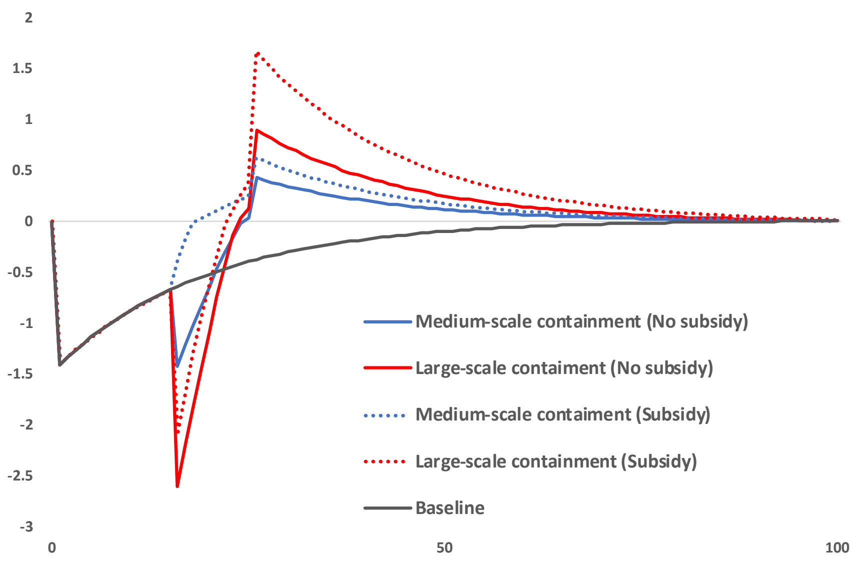


**Fig. 9.** Simulation result: Delayed containment policy

decrease in consumption. Consumption eventually increased, as containment can control the number of infected and dead for immediate containment policies. However, a containment policy at the beginning of the first wave produced a very large decline in consumption. The most effective policy was the combination of medium-scale containment policy and financial support, which is shown by the blue dashed line in Fig. 8. This shows that it is possible to curb the decline in consumption immediately after a containment policy is implemented through subsidies. The notable benefit of large-scale containment policies is the reduction in the number of infected and dead.

In sum, it is more effective to implement containment policies immediately. Such policies significantly reduce consumption temporarily; however, they limit the number of infected and dead, which accelerates the subsequent recovery of consumption. Additionally, the results revealed that financial support alleviates the decline in consumption. Further, if the containment policy is delayed and the infection is in the final stage, a medium-sized containment policy is best, coupled with financial support. The scale of the containment policy is independent upon non-economic issues, such as the strength of the healthcare system.

## 5. Concluding remarks

In this study, we provided one answer to a pressing question: what policy actions should be taken after a pandemic begins. The COVID-19 pandemic has revealed a trade-off between healthcare policy and economic activities. People who did not want to cease economic activities insisted that they could tolerate some infected people; however, they were not prepared for the surge in the number of infected and the resulting impact on the healthcare system. Therefore, it is necessary to explore how to support the economy while limiting the number of infected.

We conducted simulations on the effect of strong containment policies such as lockdown and containment policies with measures that are half as restrictive as the lockdown. Further, we simulated the timing of the implementation: whether the containment policy was immediate or delayed. We found that immediate containment policies significantly reduce consumption but accelerate the recovery of consumption by reducing the number of infected and dead. Further, we found that stronger containment policies have more negative impacts on the economy. Even if delayed, containment policies help reduce the number of infected and dead.

Additionally, we simulated the impact of financial support on businesses. In particular, we revealed the economic consequences of a government paying the salaries of all employees and financial institutions and lending to businesses interest-free based on a decline in sales. We found that this financial support further accelerates the recovery of consumption when implemented in combination with the containment policy. Notably, this financial support is provided to prevent job loss owing to a decrease in sales.

Turning to real-life examples of the issues explored in our simulation. New Zealand and Taiwan have succeeded in stopping the spread of the infection through strong containment policies. In these countries, people are living post-COVID-19 lifestyles; however, economic activity has recovered to almost the pre-COVID-19 level. Australia and Germany have succeeded in containing COVID-19, albeit by requesting self-restraint from their residents. Additionally, Germany has actively provided financial support and has a better healthcare system than other European countries; it has taken excellent measures against COVID-19.

By contrast, the United States, United Kingdom, and France have failed to contain SARS-CoV-2. In these countries, containment policies have been problematic. However, the number of infected is gradually decreasing since the development of vaccines and initial phases of inoculation. Additionally, although Japan has provided some of the largest financial support relief in the world, its containment is weak, and the distribution of financial support is ambiguous, preventing containment of the infection.

In sum, governments are required to properly implement containment and financial support when infectious diseases become a social problem. Conversely, it was also shown that economic measures acted to increase the number of infected people. If a strong containment policy such as lockdown is implemented, the number of infected people will slightly increase temporarily. This study reveals that immediate containment policies are effective in reducing economic damage.

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## NOTES

1. Eichenbaum et al. (2020) examined the impact of the spread of infection on economic dynamics, using the neoclassical model, monopolistic competition model, and New Keynesian model. They revealed that the monopolistic competition model and the NK model showed plausible movements of economic variables. Further, Guerrieri et al. (2021) determined if supply shocks could be a factor in relatively large demand fluctuations, assuming sticky prices.
2. By contrast, it has been pointed out that the decline in the consumption of goods is not significantly drastic; however, the decline in the consumption of services should be observed, given the possibility of shifting from high risk of infection to low risk in a field with high substitutability (Krueger et al., 2020). Further, it has been suggested that the decreases in the labor supply may be smaller than initially expected, particularly in fields where telecommuting is permitted (Callum et al., 2021).
3. One possible factor is substituting consumption. Guerrieri et al. (2021) and Krueger et al. (2020) consider the possibility of a shift in consumption from a sector with a high probability of infection to a sector with a low probability of infection.
4. The IMF's database of financial policy response to COVID-19 has a Policy Tracker, which details the fiscal and monetary policies of each country. To examine the financial support of countries other than those listed here, refer to the Policy Tracker of the IMF.
5. Faria-e-Castro (2021) constructs a DSGE model with two households (savers and borrowers) and two sectors (non-service and service). Using the model, the author compares different types of fiscal policies. He points out that while unemployment benefits are the most effective tool for stabilizing the income borrowers, liquidity assistance is most effective if the policy objective is to stabilize employment.
6. This formulation is by Galí (2020). Galí (2020) models the effect on real variables as well as on the price level, of increased government spending financed with helicopter money. The results point out that helicopter money can increase output, given sufficient nominal rigidities. However, it should be noted that our paper does not focus on analyzing the effects of seigniorage or helicopter money.

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