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Impacts of the Substitutability of Consumption on Infection Dynamics

Shin Fukuda*

Komazawa University, Japan. Email: fukuda@komazawa-u.ac.jp

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ABSTRACT

In this study, we construct a dynamic stochastic general equilibrium (DSGE) model to examine the impacts of infectious diseases on consumption dynamics. Assuming a model that considers the substitutability of consumption, we show that the slump in demand for consumption goods will be low in high-substitutability economy. Further, we show that immediate lockdown implementation upon the emergence of an epidemic can lead to a significant reduction in consumption, as well as alleviate the persistent stagnation of consumption, Although the analysis model in this study is simple, it reproduces the situations in United States and Japan, and it could be said that the impact of contingent policies, such as lockdown, has already been confirmed in Taiwan and New Zealand.

Keywords: Consumption substitutability, COVID-19, Lockdown, DSGE model
JEL Classifications: E21, E32, E65

1. INTRODUCTION

In 2020, the global economy was significantly affected by the impact of COVID-19. Some countries experienced a sharp recession beyond the Leman shock. What led to this sharp recession is undoubtedly the degree of uncertainty regarding the virus. In fear of this invisible enemy, people stayed indoors, and businesses explored the possibility of working from home. In addition, some people considered changing their profession, while others quit their jobs. The major difference from the Lehman shock is that for the coronavirus shock, the factors behind the recession depended not only on the decline in demand but also on the decline in labor supply and the duration of the virus threat.

Information on the development of treatments and vaccines is important to reduce the threat of a virus. Currently, vaccines have been developed globally, and some countries have already started vaccine administration. However, due to the uncertainties associated with vaccines, it may take some time before vaccination becomes widespread globally.

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 infection and recovering the economy. Not surprisingly, the extreme constraint policies adopted to stop the spread of infection let to a serious 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.

After the emergence of COVID-19, macroeconomic models with the externalities of the virus were developed. These models add economic dynamics to the susceptible-infected-recovered (SIR) model proposed by Kermack and McKendrick (1927). This is 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. (2020a) allow this probability to change as a function of consumption and labor supply. That is, Eichenbaum et al. (2020a) suppose that economic activities, such as consumption and labor supply, increase the spreading probability of an infectious disease.

As mentioned above, to prevent the spread of infection, there is the idea that lockdown, which is an extreme containment policy, is necessary. For example, Alvarez et al. (2020) 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 infection and the mortality rate[1].

Lockdowns are expected to being about an explicit economic downturn, as they limit economic activities such as consumption and labor supply, meetup at restaurants, and parties. Contrarily, by shifting consumption from a high-risk sector to a low-risk sector, the excessive slump in the economy is expected to be avoided, as was the case in the past. For example, instead of eating pasta at a restaurant, we can have home delivery or we can hold an online dinner. Certainly, it is also possible to buy take out at a restaurant. In addition, some companies will allow their employees to work from home. To response to suck a shift in consumption, the behavior of companies also needs to change, and it can be said that the government plays a major role in immediately enforcing such changes in an emergency[2]. Krueger et al. (2020) developed a macroeconomic model that considers these consumption choice problems and points out that the decline in economic activity will be limited to approximately 10%. This implies that 80% of the decline in economic activity is reduced compared to the case in simulation without heterogeneity[3].

We consider the economic implications of a containment policy based on Eichenbaum et al. (2020b)[4]. The objects to be contained here are all economic activities other than consumption. However, it should be noted that the model does not consider telecommuting, which has been verified by Krueger et al. (2020) and Callum et al. (2020). Furthermore, to consider the current consumption pattern, we adopt the heterogeneity of consumption verified by Krueger et al. (2020)[5]. We show that policies that contain non-consumption economic activities can lead to a significant recession while dramatically reducing the number of infected people and accelerating the recovery of the economy. Furthermore, as mentioned in Krueger et al. (2020), switching consumption from a high-risk sector to a low-risk sector alleviates the decline in consumption.

The remainder to this paper is organized as follows. In the next section, we briefly summarize the situation of infected people and government policies globally. In Section 3, we construct a dynamic stochastic general equilibrium (DSGE) model with heterogeneous consumption sector. In Section 4, we perform parameterization and simulation. Concluding remarks are presented in Section 5.

2. GLOBAL ENVIRONMENT

2.1. Infection Status and Countermeasures

All countries spent 2020 fighting COVID-19 and are still fighting it. The first point of occurrence was Wuhan, China, followed by the world. In particular, Italy was significantly affected. Subsequently, the number of infected people and deaths increased sharply in the United States and United Kingdom. Now, the infection is spreading rapidly globally except for countries such as New Zealand, where the islands are exploited to successfully contain the infection. (Figure 1c) shows that the mortality rate in New Zealand increased slightly, although the number of new infections remained close to zero.

Contrarily, Japan, which is an island country like New Zealand, initially had a small number of infected people; however, currently, the number of infected people and deaths is increasing rapidly as of December 2020. Initially, the number of people infected in the first wave in Japan was not remarkably high, despite the global spread. When the number of infected people began to increase in mid-March, the government declared a state of emergency and requested the people to refrain from going out. Unlike lockdown, this stance requires the public to self-regulate. This is not legally binding, as it does not restrict people from going out or restaurants from running. However, as many people abided by this request, the number of infected people in Japan began to decline in May.

The Japanese government decided to provide financial support to rebuild the economy that was sluggish due to the state of emergency. As shown in Figure 2, the tourism industry and restaurants were significantly affected; therefore, in October, a campaign called "Go to" was implemented to support the travel and hospitality industries. The campaign was successful in supporting the economy; however, when the number of infected people increased dramatically in December, it was stopped and request to refrain from going out was issued again in January. However, this request was less strict than the first request in May

1 The Eichenbaum et al. (2020a) also examine the effectiveness of strict containment policies. They propose that in the absence of containment policy, consumption would initially show a 7% decline, while with containment policy, it would be 22%.

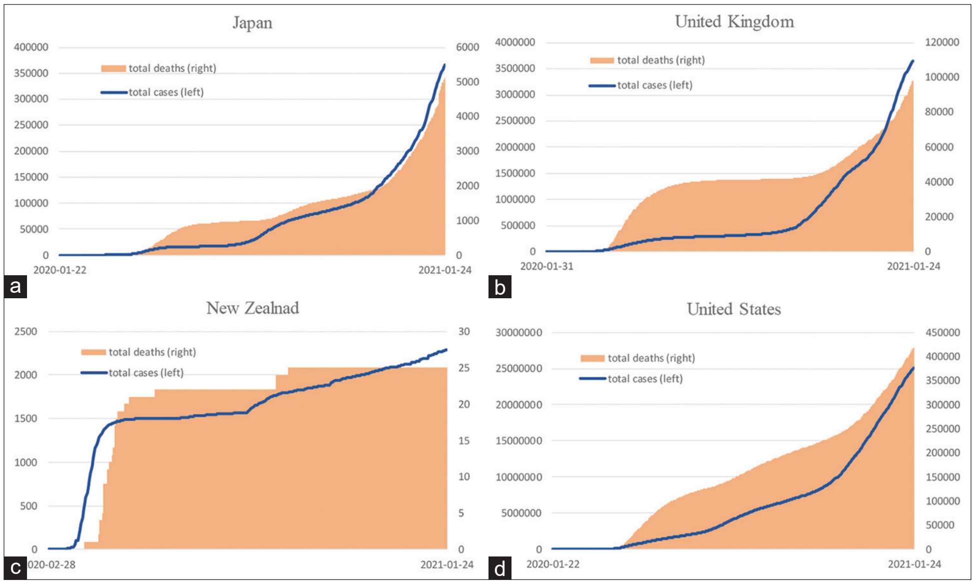
2 In Japan, there are many restaurants that challenge these new styles using the sustainable benefits that government provide to SMEs.

3 Krueger et al. (2020) also examine the heterogeneity of labor. The purpose is to consider the possibility of working from home. In addition, Jones et al. (2020) is also developing a model that considers working from home. They examine social distancing and how to work from home to avoid a pandemic.

4 Eichenbaum et al. (2020b) examine the impact of spread of infection on economic dynamics, depending on the neoclassical model, monopolistic competition model, and New Keynesian model. Consequently, it is revealed that the monopolistic competition model and the NK model show plausible movements of economic variables. Guerrieri et al. (2020) also examine whether supply shocks can be a factor in relatively large demand fluctuations, assuming sticky prices.

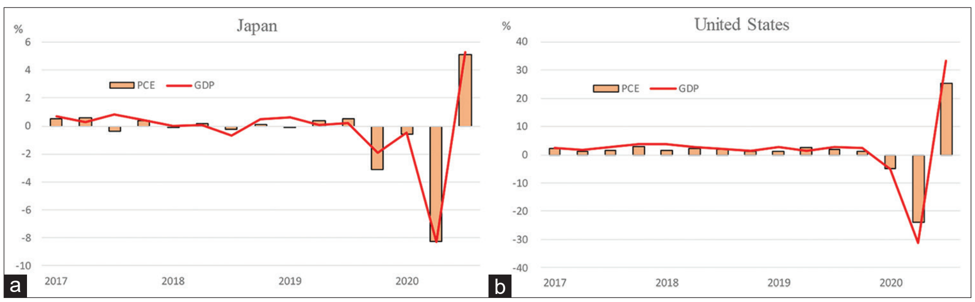
5 Bodenstein et al. (2020) deals with a multi-sectoral model of infection with capital accumulation. They imply that the spread of the infection may reduce the workers, as a result, exacerbate the social costs of the epidemic.

Figure 1: Total cases and total deaths



Source: Our World Data. https://ourworkdindata.org

Figure 2: GDP and personal consumption expenditures



Source: U.S. Department of Commerce
Source: Japan Cabinet Office

2020, and there were many uncertainties as to whether the effect of the first request can be expected.

Similar to Japan, Australia is self-regulating. While maintaining social distancing by limiting the number of people gathering in public places, the government is implementing policies to continue corporate activities and promote take-out at restaurants. Australia has succeeded in reducing the number of infected people at approximately the same rate as that in New Zealand.

Many countries, including the United States and European countries, have adopted a lockdown policy. The United Kingdom has implemented a lockdown for the 3rd time; regardless, she is still struggling to reduce the number of infections and deaths. As shown in Figure 1, the number of infected people and deaths in the United States and the United Kingdom is extremely high. The United States has also had a presidential election, which increased opportunities for people to gather. In addition, the reason the United Kingdom is struggling may be the prevalence of mutant strains. Furthermore, it can be said that Spain and Italy are also suffering from infection control. Possible causes of the spread of infection in these Spanish-speaking countries are sports viewing and continuous large-scale demonstrations.

In contrast, countries that have succeeded in controlling the infection by implementing a lockdown include New Zealand, Germany, and Vietnam. New Zealand implemented a lockdown from an early stage, leading to economic downturns; however, she succeeded in controlling infections. Consequently, the lockdown was gradually released from April 2020, and it can be said that New Zealand has returned to a semblance of normality. Although the number of infected people is increasing in Germany, the mortality rate is <1%, which is considerably low among European countries. The reasons are infection tracking, early outing restrictions, and abundant medical resources. Vietnam has also succeeded in reducing the number of infected people through early lockdown implementation.

2.2. Economic Situations

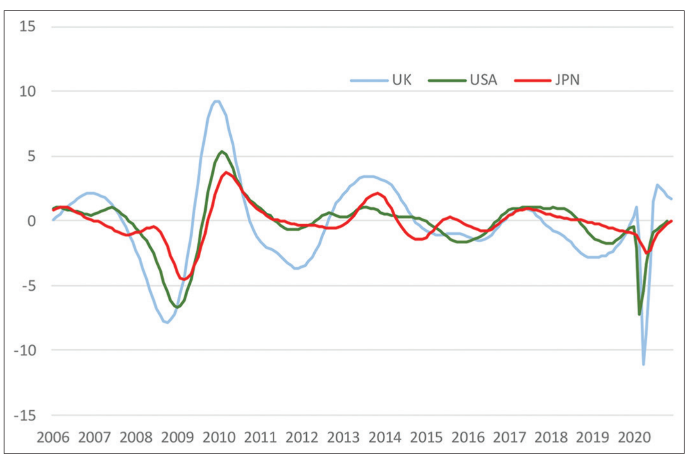
Thus far, we have introduced the infection situation in each country and the response of the corresponding government. Next, we briefly examine the economic situation during this period, focusing on the United States and Japan. Generally, the current economic downturn caused by the coronavirus will outweigh the Lehman shock even if it is temporary. Figure 3 plots the rate of change in the GDP of the United States, Japan, and United Kingdom.

As the Figure 3 shows, the rate of change in the GDP was significantly negative from the first quarter to the second quarter in all counties. While the GDP decline in Japan is smaller than it was during the Lehman shock, the decline in the United States and the United Kingdom outweighs those during the Lehman shock. Conversely, it should be noted that the United States exhibited signs of recovery soon after that. The factors that caused the economic downturn in these countries are stagnant consumption and a decrease in labor supply.

Next, we examine the changes in GDP over the past year, focusing on the United States and Japan. Figure 2 shows this transition. Both Japan and the United States had significantly reduced GDPs in the second quarter, which may be largely due to the decrease in consumer spending. Japan experienced a decline of ~8% in both personal consumption expenditures and GDP, while the United States experienced a decline of ~30% in GDP and ~24% in personal consumption expenditures. The reason for this is thought to be the lockdown of large cities and restrictions on going out. Both countries achieved significant economic recovery in the third quarter, with the United States achieving a recovery of ~33% due to improved personal service consumption.

We examine the consumer spending behaviors in Japan and the United States. (Figure 4a) shows the number of domestic travelers and restraint sales in Japanese personal consumption expenditure, while (Figure 4b) shows purely U.S. goods and service consumption.

Figure 3: The rate of change in the GDP



Source: OECD

What the two countries have in common is that, despite a significant decline in service consumption, goods consumption remains slightly unchanged. One possible reason is the consumption smoothing in the first place, although the diversity of consumption can be considered in addition. For example, it is possible to purchase products at home that could otherwise not be purchased without going out. Amazon is a well-known platform; however, in Japan, a system has been built in which supermarkets also order form the internet and deliver at home. It can also be said hat Uber, which started in the United States, has greatly contributed to promoting the stay-at-home strategy. As a result, the demand for services decreased, while the demand for goods did not decrease significantly. We focus on this point and consider the possibility that consumption will not decrease significantly, even during a lockdown.

3. MODEL

From here, we construct a macroeconomic model to examine the effects of free choice of consumption and lockdown. First, we introduce the economic environment assumed by the model. Then, we construct a macroeconomic model with infection dynamics.

3.1. The Epidemic

A typical macroeconomic model sets the frequency to quarterly or yearly. However, we assume that the frequency of the model is 1 week, as infection dynamics should assume a short frequency.

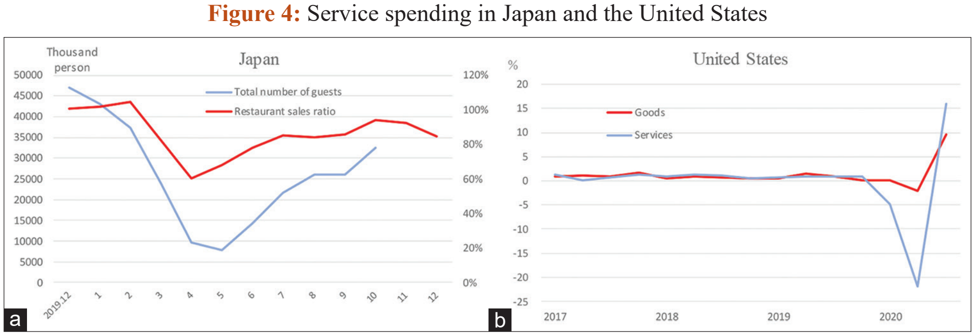
As mentioned in Eichenbaum et al. (2020a), the economy is initially in a steady state (pre-infection). When the economy is in a steady state, we assume that the population is normalized at 1, that is, $Pop_0 = 1$. The population comprises four groups: Susceptible (S), infected (I), recovered (R), and died (D). In addition, the population composition pre-infection ($t = 0$) is $S_0 = 1$ and $I_0 = R_0 = D_0 = 0$.

Now, suppose that the persons infected appear at time 0 and the ratio is ϵ_0, that is, $I_0 = \epsilon_0$. Therefore, the susceptibility to the virus is the ratio of the remaining population:

$$S_0 = 1 - \epsilon_0$$

Some of the infected, $(1-v)\,I_t$, will be quarantined in hospitals and sanatoriums, while the remaining, vI_t, will be asymptomatic and

Figure 4: Service spending in Japan and the United States



Source: U.S. Department of Commerce

Source: Japan Food Service Association, Japan Tourism Agency confused with the susceptible. This is thought to be the cause of the spread of infection.

As in Krueger et al. (2020), we assume that similar goods can be consumed in different ways. ϕ_k indicates the degree of social interaction in sector k. We normalize function ϕ_k to integrate to unity; that is, $\int \phi_k dk = 1$. Conversely, in either sector, the probability of infection due to consumption is constant at ϖ_c. Krueger et al. (2020) also analyzed labor heterogeneity; however, for simplicity, we assume that there is no difference in the transmission mechanism of labor and that the infection probability is constant at π_1. The probability of infection in other social activities, such as dinner and travel, is constant at π_0.

According to Eichenbaum et al. (2020a) and Krueger et al. (2020) and assuming that there are k sectors in the consumption sector, the overall infection transition probability, τ_t, is as follows:

$$\tau_t = \pi_c \nu I_t \int \phi_k c_{tk}^s c_{tk}^i dk + (1-\xi)\pi_l \pi_l l_t^s (\nu I_t l_t^i) + (1-\gamma)\pi_o \nu I_t \quad (1)$$

Where c_{tk}^s and c_{tk}^i are the consumption of the susceptible and infected in sector k, respectively. In addition, l_t^s and l_t^i represent the labor supply of the susceptible and infected, respectively. ξ and γ are the degree of lockdown, and when these are set to 1, social activities other than consumption are restricted.

Finally, the population dynamics after the discovery of the infected are as follows:

$$S_{t+1} = S_t - \tau_t S_t$$

$$I_{t+1} = \tau_t S_t + (1-\pi_r - \pi_d) I_t$$

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

$$D_{t+1} = D_t + \pi_d I_t$$

Where π_r represents the rate of recovery from infection, and π_d represents the mortality rate of the infected.

3.2. The Economic Environment

Since we focus on consumer behavior and suppose a short-run model, we assume that output is produced using labor only. Therefore, the production function is linear, i.e., $\int c_{tk}\, dk = Al_t$, where A represents constant technological progress. If the production function is linear and the nominal wage is normalized to 1, the real marginal cost is constant at mc = 1/A Therefore, if the markup ratio is set to 1, the price is constant at $P_t = \bar{P} = 1/A$

Those who belong to group $x = s, i, r$ consume $c_t^x = \int c_{tk}^x dk$. According to Eichenbaum et al. (2020b), a consumer group is a continuum of individuals, maximizing the objective function:

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

Where β denotes the weekly discount factor. Notably, this objective function depends on the stochastic health condition of the individual. In addition, similar to Eichenbaum et al. (2020a), we assume that the preference is as follows:

$$u(c,l) = \ln c - \frac{\theta}{2} l^2$$

This preference is the same for all groups of consumers.

According to Krueger et al. (2020), we assume a bundle of consumption as follows:

$$c_t^x = \left[\int (c_{tk}^x)^{(\eta-1)/\eta} dk \right]^{\eta/(\eta-1)} \quad (3)$$

Where $\eta \geq 0$ is the elasticity of substitution across goods, and c_{tk}^x is the consumption of individual $x = s, i, r$ of sector k. The consumer budget constraint is given by

$$\int (S_t c_{tk}^s + I_t c_{tk}^i + R_t c_{tk}^r) dk = A(S_t l_t^s + \nu I_t l_t^i + R_t l_t^r) \quad (4)$$

3.3. Optimal Choices

Families belonging to each group of $x = s, i, r$ maximize the objective function subject to consumption bundle (3), budget constraint (4), and infection dynamics (1). Here, in the infection transition probability, τ_t, the household takes $I_t c_t^i$ and $I_t l_t^i$ as given.

We assume that it can be divided into two sectors according to the degree of infection; thus, the consumer interaction indicator is defined as follows. The size, υ_1, of the sector has a lower consumer interaction indicator, ϕ_1, and the remaining, υ_2, has a higher consumer interaction indicator, ϕ_2, where $\upsilon_1 + \upsilon_2 = 1$.

The first-order conditions for and l_t^x are

$$\upsilon_1^{1/\eta} \frac{1}{c_t^s} \left(\frac{c_t^s}{c_{t1}^s} \right)^{1/\eta} = \pi_c \phi_1 \beta \mathbb{E}_t (\lambda_{t+1}^i) \nu I_t c_{t1}^i - \lambda_t^b \quad (5)$$

$$\upsilon_2^{1/\eta} \frac{1}{c_t^s} \left(\frac{c_t^s}{c_{t2}^s} \right)^{1/\eta} = \pi_c \phi_2 \beta \mathbb{E}_t (\lambda_{t+1}^i) \nu I_t c_{t2}^i - \lambda_t^b \quad (6)$$

$$\upsilon_{k=,12}^{1/\eta} \frac{1}{c_t^i} \left(\frac{c_t^i}{c_{t,k=1,2}^i} \right)^{1/\eta} = -\lambda_t^b \quad (7)$$

$$\upsilon_{k=,12}^{1/\eta} \frac{1}{c_t^r} \left(\frac{c_t^r}{c_{t,k=1,2}^r} \right)^{1/\eta} = -\lambda_t^b \quad (8)$$

$$\theta l_t^s = A\lambda_t^b + \pi_l \beta \mathbb{E}_t (\lambda_{t+1}^i) I_t l_t^i \quad (9)$$

$$\theta l_t^i = A\nu\lambda_t^b \quad (10)$$

$$\theta l_t^r = A\lambda_t^b \quad (11)$$

Where λ_t^b and λ_t^i are the Lagrange multipliers of the household budget constraint (4) and infection transition probability (1), respectively. It is noted that the infected and recovered individuals make the same decisions regarding consumption and labor supply. In addition, note that we set $\xi = \gamma = 0$.

Next, the first-order conditions with respect to s_t, i_t, and r_t are as follows:

$$\lambda_t^s = -\left[\log c_t^s - \frac{\theta}{2} l_t^{s2}\right] + \lambda_t^b\left[A l_t^s - \left(c_{t1}^s + c_{t2}^s\right)\right] + \beta \mathbb{E}_t \left\{\lambda_{t+1}^s + \lambda_{t+1}^i\left[\pi_c \nu I_t\left(\phi_1 c_{t1}^s c_{t1}^i + \phi_2 c_{t2}^s c_{t2}^i\right) + \pi_l l_t^s\left(\nu I_t l_t^i\right) + \pi_o \nu I_t\right]\right\} \quad (12)$$

$$\lambda_t^i = -\left[\log c_t^i - \frac{\theta}{2} l_t^{i2}\right] + \lambda_t^b\left[A l_t^i - \left(c_{t1}^i + c_{t2}^i\right)\right] - \lambda_t^s + \beta\left(1-\pi_r-\pi_d\right) \mathbb{E}_t\left(\lambda_{t+1}^r\right) + \beta \mathbb{E}_t\left(\lambda_{t+1}^i\right)\left[\pi_c S_t\left(\phi_1 c_{t1}^s c_{t1}^i + \phi_2 c_{t2}^s c_{t2}^i\right) + \pi_l S_t \nu l_t^i + \pi_o \nu S_t\right] - \pi_r \beta \mathbb{E}_t\left(\lambda_{t+1}^r\right) \quad (13)$$

$$\lambda_t^r = -\left[\log c_t^r - \frac{\theta}{2} l_t^{r2}\right] + \lambda_t^b\left[A l_t^r - \left(c_{t1}^r + c_{2t}^r\right)\right] + \beta \mathbb{E}_t\left(\lambda_{t+1}^r\right) \quad (14)$$

Where λ_t^s and λ_t^r are the Lagrange multiplier on the dynamics of S_t and R_t.

4. CALIBRATION AND SIMULATION

In this section, we calibrate the model parameters, derive the steady-state values, and perform model simulations. As for the parameter values, the general values used in Eichenbaum et al. (2020b) and Krueger et al. (2020) are assumed.

4.1. Calibration

In the steady state, since it is assumed that the consumption is equal in all states, x, $c_{ss}^s = c_{ss}^i = c_{ss}^r = c_{ss}$ Furthermore, in the pre-epidemic steady state, $S = 1$ and $I = R = D = 0$. According to Krueger et al. (2020), we set $\upsilon_1 = \upsilon_2 = 0.5$, and the degree of infection are $\phi_1 = 0.2$ and $\phi_1=1.8$. This condition indicates that the total infection degree is 1.

Since our model works with a weekly frequency, following Eichenbaum et al. (2020a), we set $\pi_c=2.568\times10^{-7}$, $\pi_1=1.593\times10^{-4}$, and $\pi_0=0.499$. Further, we set $\beta = 0.96^{1/52}$. We choose A=39.835 and ¥theta =0.001275 so that the weekly working hours in the pre-epidemic steady state are valid. Furthermore, according to Krueger et al. (2020), we set $\eta = 10$. We summarize these parameters in Table 1.

From the first-order conditions with respect to labor, we can obtain $l_{ss}^s = l_{ss}^i / \nu = l_{ss}^r$; thus, in the steady state, $l_{ss}^s = l_{ss}^i / \nu = l_{ss}^r = l_{ss} = 1/\sqrt{\theta}$ Therefore, $l_{ss}^s = l_{ss}^r = 28.0056$ and $l_{ss}^i = \nu / \sqrt{\theta} = 19.60392$. Next, since $c_{ss} = \upsilon^{1/2}\left(2\right)^{1/\eta} A/\sqrt{\theta}$ can be obtained from the first-order conditions for consumption, in the steady state, $c_{ss} = 1115.603$. In addition, the Lagrange multiplier on the budget constraint, λ_t^b in the steady state is

$$\lambda_{ss}^b = \theta l_{ss} / A = 0.000896$$

4.2. Simulations

The results of the simulation analysis are shown in Figure 5. As Eichenbaum et al. (2020a) and Krueger et al. (2020), we assume that the epidemic is caused by the initial conditions, $I_0 = \epsilon_0$ and $S_1 = 1-\epsilon_0$.

Table 1: Parameter values

Parameter	Description	Value
β	Discount factor (weekly)	$0.96^{1/52}$
A	Productivity	39.835
π_c	Consumption infection intensity	2.568×10^{-7}
π_l	Labor infection intensity	1.593×10^{-4}
π_o	Autonomous infection intensity	0.499
π_r	Recovery rate	0.387
π_d	Death rate	1.944×10^{-3}
η	Elasticity of substitution	10
ϕ_1	Low interaction intensity	0.2
ϕ_2	High interaction intensity	1.8
υ_1	Size of low-interaction sector	0.5
υ_2	Size of high-interaction sector	0.5
θ	Labor supply parameter	1.275×10^{-3}

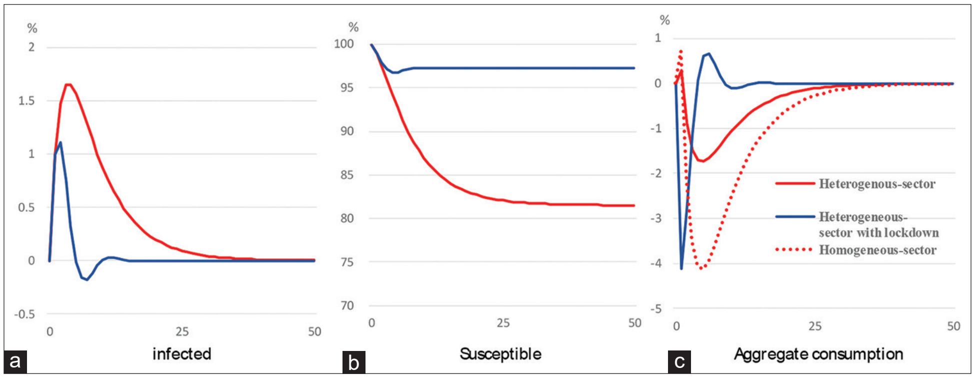
(Figure 5a) shows the cumulative movement of the infected individuals. The solid red line represents the baseline movement of the infected, while the solid blue line represents the movement of the infected for the ultimate case of the lockdown in the first phase, i.e., immediately after the epidemic. Without the lockdown (solid red line), the number of infected individuals will immediately after the infection is discovered (solid blue line), the spread of the infection will be significantly reduced. Certainly, 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 also 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.

(Figure 5b) shows the movement of the susceptible group. Not surprisingly, without the lockdown, the number of susceptible individuals decrease by ~18% in a few weeks, while with immediate lockdown, the decrease in the number of susceptible individuals would be ~4%.

Finally, (Figure 5c) illustrates the dynamic path of consumption. The dashed line is the consumption path assuming the economy of the homogeneous sector. Since there are only relatively high-infection degree types of consumer goods that require one to go out, people are affected by the epidemic as they refrain from going out, which reduces consumption. Consequently, consumption will fall by up to 4%. Following the hump-shaped impulse response function.

The solid red line in (Figure 5c) represents the consumption dynamics considering heterogeneous sectors. The spread of infection will increase consumption in the low-intensity sector and compensate for the decrease in consumption in the high-intensity sector; therefore, the homogenous sector, in an economy where there are alternative consumption destinations, the decrease in consumption can be suppressed by 2.5%. This can be inferred from data from United States and Japan. Conversely, the method through which the government hedges the service industry, which is difficult to substitute, and how companies in such industries develop sales channels are also important. In this study, we do not predict this possibility.

Figure 5: Impulse response functions



In this study, we only examine a strict lockdown case, i.e., $\xi = \gamma = 1$. The result of this simulation is described by the solid blue line in (Figure 5c). If the government implements a lockdown immediately after the epidemic, the economy will experience an extreme decline in consumption, even assuming a heterogeneous sector, as in the case of homogeneous sector. However, the containment policy does not cause a sustained increase in the infected individuals; therefore, the decline in consumption is also temporary. After that, the economy is expected to return to its pre-epidemic steady state immediately.

It may be difficult for the government to implement a lockdown immediately after an epidemic; however, stopping the mobility of people as quickly as possible is one of the important strategies for preventing the spread of the infection and economic downturn. Certainly, the characteristics of the country would determine whether the government implements a strict lockdown, similar to the United Kingdom and Germany, or relies on self-regulation similar to Australia and Japan.

5. CONCLUDING REMARK

In this study, we constructed a simple DSGE model to examine the impacts of the novel coronavirus on consumption dynamics. The focus is that the existence of substitutability for consumption may prevent a serious decline in aggregate consumption. This may also be observed in the trend of consumption in the United States and Japan. Contrarily, the decline in the demand for services that are unlikely to be substituted may require the government to provide subsidies.

Another focus of this study is the effectiveness of immediate lockdown after the emergence of an epidemic. This is clear from the results of the containment policies of Taiwan and New Zealand. However, in countries with state-specific policies, such as the United States or bordered countries such as Europe, immediate overall lockdown may be difficult. Furthermore, even in Japan, an island country similar to Taiwan and New Zealand, there is still a debate as to whether it is appropriate to implement a uniform containment policy in areas where there are many infected individuals or not.

The model presented in this paper does not consider the heterogeneity of labor types; thus, it is not possible to analyze the switch to work-from-home case in detail. In addition, it can be said that the important role of the government is the implementation and timing of subsidies. The model in this study can be extended to analyze this case. Considering the potential for a pandemic in the future, this experience and forecast analysis using economic model will prove useful and should be accumulated.

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