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Macroeconomic Effects of Economic Policies During the COVID-19 Pandemic

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Macroeconomic Effects of Economic Policies During the COVID-19 Pandemic[†]

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Abstract

During the spread of COVID-19, behavioral restrictions were implemented as policy measures. These included avoiding non-essential outings, refraining from dining out, and reducing tourism, all of which suppressed economic activity. As a result, industries such as food services and tourism suffered severe blows, leading to a significant decline in GDP (Gross Domestic Product) in 2020. However, the government's proactive fiscal policies, particularly employment measures, such as the Employment Adjustment Subsidy, are believed to have mitigated the rise in unemployment rates.

To what extent did the Employment Adjustment Subsidy help suppress the increase in unemployment? While prior studies have evaluated its effects, this paper employs a DSGE (Dynamic Stochastic General Equilibrium) model based on microeconomic foundations, deriving parameters for simulations through calibration using real-world data. It calculates the increase in unemployment resulting from GDP declines caused by consumption shocks under behavioral restrictions in the absence of the subsidy, comparing it to actual data to determine the subsidy's effectiveness in curbing unemployment.

The analysis revealed that the subsidy's effect in suppressing unemployment was about half of what the government's evaluations suggested. Additionally, using input-output analysis, it was demonstrated that the Employment Adjustment Subsidy also contributed to mitigating GDP declines.

Keywords：DSGE Model, Employment Adjustment Subsidy, The Spread of COVID-19
JEL Code: E24 H20

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1. Introduction

Since 2020, when the spread of COVID-19 became a significant issue, the government issued requests for self-restraint, and a general atmosphere of caution discouraged activities such as dining out and tourism. These circumstances imposed substantial restrictions on economic activity, particularly in these industries, resulting in a significant decline in the country's GDP (Gross Domestic Product).[1] According to data from Ministry of Internal Affairs and Communications, consumption in the second quarter of 2020 declined by 10% compared to the end of 2019, while outings decreased by 25% compared to the average level in a typical year, indicating a significant suppression of economic activity.[2] The significant suppression of economic activity can be confirmed in various studies and reports. For instance, data from Cabinet Office, Government of Japan shows that in April 2020, consumer spending on services had declined by approximately 35% compared to the average from 2016 to 2018.[3] This was due to behavioral restrictions such as the state of emergency declaration.

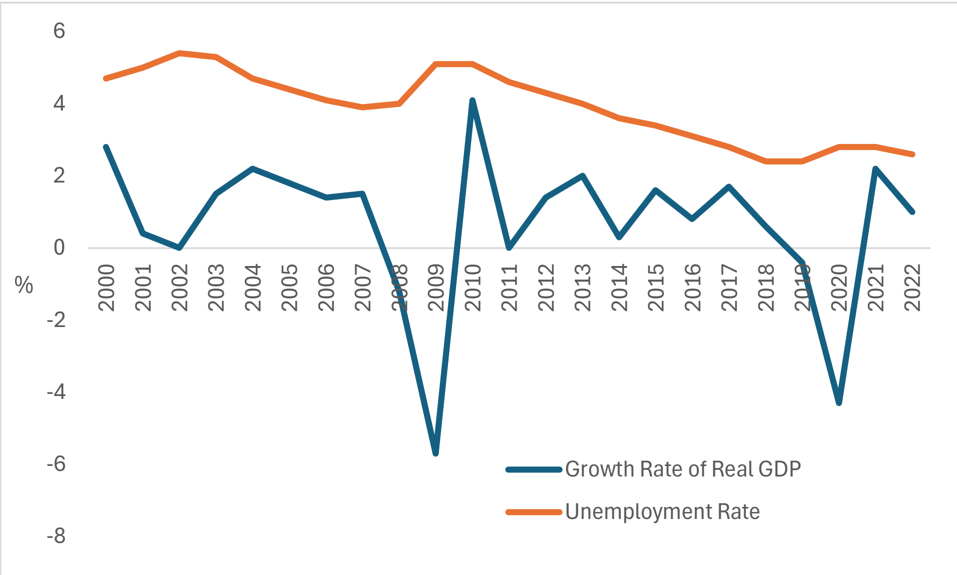

Fig. 1 ：Real GDP and Unemployment Rate（Data：Cabinet Office, Government of Japan (2023), "Economic and Fiscal White Paper: Long-Term Economic Statistics, FY2023", Japan Institute for Labour Policy and Training (2024), "Quick Reference: Long-Term Economic Statistics in Graphs - Figure 1: Unemployment Rate and Job Openings-to-Applicants Ratio")

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1 NHK "Situation During the First State of Emergency"

2 Ministry of Internal Affairs and Communications (2021b) "White Paper on Information and Communications, 2021 Edition"

3 Cabinet Office, Government of Japan (2022), "Annual Economic and Fiscal Report, FY 2022"

On the other hand, according to the aforementioned Cabinet Office report, large-scale economic measures resulted in a substantial fiscal deficit in the primary balance and a significant increase in public debt. The total amount of successive economic stimulus packages reached approximately 293 trillion yen, equivalent to 55% of GDP, reflecting the scale of the measures. Specifically, support included unsecured loans and cooperation subsidies for shortened business hours for companies, as well as Employment Adjustment Subsidies aimed at maintaining employment.

Thanks to such employment subsidies, the significant rise in the unemployment rate seen during the Lehman Shock was avoided. Despite the behavioral restrictions, such as the state of emergency declarations, which suppressed economic activity during the COVID-19 pandemic in 2020, the increase in the unemployment rate was kept in check. However, an increase in unemployment was still observed, primarily due to demand-deficient unemployment.[4]

The Employment Adjustment Subsidy is a system that "provides financial assistance to business owners who are forced to scale down their operations due to economic reasons, covering costs incurred from implementing temporary closures to maintain employment." This subsidy is believed to help suppress the rise in unemployment rates by enabling businesses to retain their employees without resorting to layoffs, even during temporary closures.[5] In fact, according to data from Ministry of Health, Labour and Welfare, the Employment Adjustment Subsidy helped suppress the unemployment rate increase by 2.1 percentage points, while the Emergency Employment Stabilization Subsidy contributed a further 0.5 percentage points, resulting in a total suppression of 2.6 percentage points.[6]

Several prior studies have examined the effectiveness of economic policies during the COVID-19 pandemic. Sato, Tsutsumi, and Meguro (2020) estimated the amount of Employment Adjustment Subsidy required to restore economic activity to pre-COVID levels, showing that an expenditure of 1 trillion yen per quarter would be necessary until the third quarter of 2021. The general account burden of the Employment Adjustment Subsidy

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[4] Japan Institute for Labour Policy and Training (2024), "Statistical Topics: Equilibrium Unemployment Rate and Demand-Deficient Unemployment Rate"

[5] Ministry of Health, Labour and Welfare, "Employment Adjustment Subsidy" and "Employment Adjustment Subsidy (Special Measures in Response to the Impact of COVID-19)." Notably, during the COVID-19 pandemic, the Employment Adjustment Subsidy provided full support with a subsidy rate of 10/10, provided certain conditions were met.

[6] Ministry of Health, Labour and Welfare (2021), "Analysis of Labor Economy, 2021 Edition"

amounted to 6.4 trillion yen, and when compared to this estimate, it becomes clear that the actual amount closely aligns with the estimated required amount.[7]

This study aims to clarify the extent to which unemployment increased as a result of GDP decline by constructing and analyzing an economic model in the absence of the Employment Adjustment Subsidy. Specifically, it develops a DSGE (Dynamic Stochastic General Equilibrium) model to introduce a negative shock to consumption, simulating the GDP decline caused by consumption reduction under behavioral restrictions. By comparing the resulting increase in unemployment in this scenario with the actual increase in unemployment observed in a world with the Employment Adjustment Subsidy, the study evaluates the effectiveness of the subsidy.

As a result of the analysis, it was determined that GDP declined by 4.5% in 2020, and a corresponding shock was modeled. This simulation revealed an approximately 40% increase in unemployment, meaning the unemployment rate, which was around 2.5% before the spread of COVID-19, would rise to about 3.5%. This result indicates that the effect of the Employment Adjustment Subsidy is smaller compared to the findings of previous studies.

Additionally, using input-output analysis, the study examined the reduction in GDP decline due to the mitigation of unemployment. The analysis showed that the reduction in consumption decline amounted to 818 billion yen, which further mitigated the decline in domestic production by approximately 1.2 trillion yen. In other words, the input-output analysis demonstrated that without the Employment Adjustment Subsidy, the drop in GDP would have been significantly larger, a key finding of this study.

The structure of this paper is as follows. Section 2 describes the model setup. Section 3 explains the labor market, focusing on frictional unemployment, including the matching process between workers and firms and the wage determination framework. Section 4 derives the equilibrium solution and the steady-state solution. Section 5 discusses calibration, explaining the estimation of parameters used for the simulations in this study. Section 6 introduces a consumption decline shock due to behavioral restrictions, leading to a GDP shock, and derives the corresponding change in unemployment. This section examines how much unemployment increased compared to a scenario without the Employment Adjustment Subsidy, effectively evaluating the subsidy's impact. Section 7 investigates the effectiveness of the Employment Adjustment Subsidy from the perspective of input-output analysis. Finally, Section 8 provides a conclusion.

[7] Government Administrative Reform (2023), "Employment Adjustment Subsidy (COVID-19 Related)"

2. Model

The model economy in this paper consists of three economic agents: households, firms, and the government. The DSGE (Dynamic Stochastic General Equilibrium) model used in this study follows the standard framework described in Kato (2007) and Eguchi (2011). Based on these models, this study incorporates frictional unemployment, as will be explained later.

2.1 Household

We assume that individuals in households derive utility from consumption c_t and real money holdings m_t. The instantaneous utility function u_t^h is assumed to follow a CRRA (Constant Relative Risk Aversion) type utility function, as shown below:

$$u_t^h = (1 + z_{ct})\frac{c_t^{1-\theta}}{1-\theta} + \frac{m_t^{1-\mu}}{1-\mu}, 0 < \theta, 0 < \mu \tag{1}$$

z_{ct} represents a preference shock. When a shock occurs that leads to a desire to reduce consumption, $z_{ct} < 0$. For instance, this could apply in situations where the spread of the coronavirus leads to requests or voluntary decisions to avoid activities such as dining out or traveling. Here, t denotes the time period. Regarding labor supply, this model does not consider the choice between labor and leisure. Instead, it is assumed that all available time (one unit) is allocated to labor. Individuals within households are assumed to live infinitely, deriving utility in each period. Let β represent the discount factor for each period. The lifetime utility function U_t is expressed as follows:

$$U_t = \sum_{s=t}^{\infty} \beta^{s-t} u_t^h, 0 < \beta < 1. \tag{2}$$

Next is the household budget constraint. Households hold assets in the form of money, risk-free assets b_t, and capital stock K_{t-1}. The return on risk-free assets is the nominal interest rate i_t, while the return on holding capital stock is the real interest rate r_t. Capital stock can be increased through investments I_t in physical capital.

Individuals within households supply labor inelastically at a rate of n_t, earning a wage w_t. On the other hand, a proportion $1 - n_t$ is unemployed and receives unemployment benefits b_t^u. These unemployment benefits are financed through lump-sum taxes T_t. Here, n_t and $1 - n_t$ represent the employment rate and unemployment rate, respectively.

Additionally, households own firms and receive profits ϕ_t generated from monopolistic competition. Prices fluctuate in each period, with the rate of change expressed as the inflation rate π_t. Under these conditions, the budget constraint at time t is expressed as follows:

$$m_t + b_t + c_t + I_t = \frac{1}{1+\pi_t}\left((1+i_t)b_{t-1} + m_{t-1}\right) + \phi_t + w_t n_t + (1-n_t)b_t^u + r_t K_{t-1} - T_t \quad (3)$$

The transition equation for capital stock is expressed as follows, where δ_K represents the depreciation rate and $S\left(\frac{I_t}{I_{t-1}}\right)$ denotes the adjustment cost:

$$K_t = I_t + (1-\delta_K)K_{t-1} - S\left(\frac{I_t}{I_{t-1}}\right)I_t, 0 < \delta_K < 1, S' > 0, S'' > 0, S(1) = S'(1) = 0 \quad (4)$$

Here, the allocation that achieves the maximization of the utility function shown in (2), subject to the constraints in (3) and (4), is solved as the household's optimization problem. Let λ_t be the Lagrange multiplier for the constraint in (3) and γ_t the Lagrange multiplier for the constraint in (4). Tobin's q is defined as $q_t = \frac{\gamma_t}{\lambda_t}$. The detailed derivation of the optimal allocation is omitted here.

2.2 Firms

It is assumed that there are two types of firms: firms producing final goods and firms producing intermediate goods.

2.2.1 Firms Producing Final Goods

The market for firms producing final goods operates under perfect competition. Final goods Y_t can be produced by utilizing intermediate goods Y_{jt} as inputs. The production function for final goods firms is assumed to follow a CES (Constant Elasticity of Substitution) production function, as shown below:

$$Y_t = \left(\int_0^1 Y_{jt}^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}}, 1 < \varepsilon. \quad (5)$$

The profit function π_t for final goods firms is expressed as follows:

$$\pi_t = p_t Y_t - \int_0^1 p_{jt} Y_{jt} dj. \quad (6)$$

Intermediate goods firms are continuously distributed between 0 and 1. By solving the profit maximization problem, the demand function for intermediate goods is derived.

$$Y_{jt} = \left(\frac{p_{jt}}{p_t}\right)^{-\varepsilon} Y_t. \quad (7)$$

2.2.2 Firms Producing Intermediate Goods

Intermediate goods firms produce intermediate goods using capital stock and labor as input factors. The production function for intermediate goods at firm j is expressed as follows:

$$Y_{jt} = AK_{jt-1}^{\alpha_1} n_{jt}^{1-\alpha_1}, 0 < \alpha_1 < 1, 0 < A. \tag{8}$$

Here, the firm considers a cost minimization problem with the total cost $C = w_{jt}n_{jt} + r_{jt}K_{jt-}$. This is subject to the production function (8), with ω_{jt} as the Lagrange multiplier for the constraint. From the cost minimization conditions, the following equations can be derived:

$$w_{jt} = \omega_{jt}A(1-\alpha_1)K_{jt-1}^{\alpha_1} n_{jt}^{-\alpha_1}, \tag{9}$$

$$r_{jt} = \omega_{jt}A\alpha_1 K_{jt-1}^{\alpha_1 - 1} n_{jt}^{1-\alpha_1}. \tag{10}$$

Next, we consider the profit maximization problem for intermediate goods firms. By using the demand function for intermediate goods as a constraint and substituting (9) and (10) into the cost function, the profit function can be expressed as follows:

$$\pi_{jt} = \frac{p_{jt}}{p_t}\left(\frac{p_{jt}}{p_t}\right)^{-\varepsilon} Y_t - \omega_{jt}\left(\frac{p_{jt}}{p_t}\right)^{-\varepsilon} Y_t. \tag{11}$$

By solving the profit maximization conditions, the following equation can be obtained:

$$\omega_{jt} = \frac{\varepsilon - 1}{\varepsilon}\frac{p_{jt}}{p_t}. \tag{12}$$

Homogeneous firms are assumed. In this case, under the steady state, $\frac{p_{jt}}{p_t} = 1$, yielding $\omega = \frac{\varepsilon-1}{\varepsilon}$.

2.3 Government

The government provides unemployment benefits to the unemployed. Assuming that unemployment benefits are distributed under a balanced budget, the government's budget constraint can be expressed as follows:

$$(1 - n_t)b_t^U = T_t. \tag{13}$$

The government also conducts monetary policy, determining the nominal interest rate based on the inflation rate and the GDP gap. The specific equation will be discussed later.

3. Labor Market

This paper does not assume a full-employment model. Instead, it assumes that due to imperfect information in the labor market, workers and firms do not match perfectly, and there is a certain proportion of job seekers who are unable to find employment as desired. A matching model for employment in such an imperfect labor market is considered. The model is based on Okada (2013), which adopts the matching model of Mortensen and Pissarides (1994). This paper also uses the matching model from Mortensen and Pissarides (1994).

Various models exist for conceptualizing the labor market. Okada (2013) assumes that the labor market is imperfect, where not all workers and employers can successfully match, resulting in a certain proportion of individuals remaining unemployed. This assumption is also present in Eguchi and Teramoto (2017). Both Okada (2013) and Eguchi and Teramoto (2017) incorporate labor market matching models within the DSGE framework to account for unemployment.

Kato (2007) and Eguchi (2011) present standard DSGE models that do not account for unemployment, though labor supply is endogenized. On the other hand, Hayashida, Yasuoka, Namba, and Ono (2018) consider unemployment using a model in which labor unions, as shown in Ono (2010), incorporate both the income of employed workers and the unemployment benefits of unemployed individuals into their objective function. They determine wage levels and employment levels to maximize this objective function.

While such models for determining unemployment are relatively straightforward to handle, the choice of unemployment model can significantly impact the outcomes of the model economy. In this study, we incorporate a matching model, which is relatively common in DSGE models, into the model economy for analysis.

3.1 Matching Model

First, the following matching function is assumed:

$$M_t = BU_t^{\alpha_2}V_t^{1-\alpha_2}, 0 < B, 0 < \alpha_2 < 1. \tag{14}$$

Here, M_t represents the number of newly employed individuals, U_t is the number of unemployed individuals, and V_t is the number of job vacancies.

Next, the probability of new employment per job vacancy, L_t, can be expressed as follows:

$$L_t = \frac{M_t}{V_t} = B\psi_t^{-\alpha_2}. \tag{15}$$

Here, $\psi_t = \frac{V_t}{U_t}$, which represents the tightness of the labor market and indicates the job openings-to-applicants ratio.

The probability of new employment per unemployed individual, S_t, can be expressed as follows:

$$S_t = \frac{M_t}{U_t} = B\psi_t^{1-\alpha_2}. \tag{16}$$

The employment transition equation can be expressed as follows. It is assumed that a fraction δ_n of employees leave their jobs. Here, V_{jt} represents the number of job vacancies at firm j.

$$n_{jt} = (1-\delta_n)n_{jt-1} + V_{jt}B\psi_t^{-\alpha_2}, 0 < \delta_n < 1. \tag{17}$$

The number of employed individuals in the next period consists of those who continue to be employed (a fraction $1-\delta_n$ of the currently employed) and those newly hired through matching.

3.2. Decision of Wage Rate

Under perfect competition with no information asymmetry, the wage level would be determined to equal the marginal productivity of labor. However, this paper assumes the presence of information asymmetry, meaning that wage determination does not follow the perfect competition model. Instead, it is assumed that the wage level is determined through a Nash bargaining solution. Here, ξ represents the bargaining power parameter, where a smaller ξ indicates greater bargaining power for workers in wage negotiations.

$$w_t = \mathrm{argmax}(\theta_t^E - \theta_t^U)^{\xi}\left(\theta_t^J - \theta_t^V\right)^{1-\xi}, 0 < \xi < 1. \tag{18}$$

θ_t^E, θ_t^U, θ_t^J and θ_t^V are shown as follows.

$$\theta_t^E = w_t + E_t\left[\beta_{t+1}\left((1-\delta_n)\theta_{t+1}^E + \delta_n\theta_{t+1}^U\right)\right] \tag{19}$$

$$\theta_t^U = b_t^u + E_t\left[\beta_{t+1}\left((1-\delta_n)B\psi_t^{1-\alpha_2}\theta_{t+1}^E + \left(1-(1-\delta_n)B\psi_t^{1-\alpha_2}\right)\theta_{t+1}^U\right)\right] \tag{20}$$

$$\theta_t^J = \frac{p_{jt}}{p_t}Y_t - w_t - r_tK_t + E_t\left[\beta_{t+1}(1-\delta_n)\theta_{t+1}^J\right] \tag{21}$$

$$\theta_t^V = -\frac{k\psi_t}{\lambda_t} + E_t\left[\beta_{t+1}\left((1-\delta_n)B\psi_t^{1-\alpha_2}\theta_{t+1}^J + \left(1-(1-\delta_n)B\psi_t^{1-\alpha_2}\right)\theta_{t+1}^V\right)\right] \tag{22}$$

The following relationship holds: $\beta_{t+1} = \beta\frac{\lambda_{t+1}}{\lambda_t}$. Here, θ_t^E represents the value of a worker being employed in the current period. In the next period, the worker has a certain probability of remaining employed and a certain probability of becoming unemployed, so the expected values of each state are included.

θ_t^U represents the value of a worker being unemployed in the current period. During this period, the worker receives unemployment benefits. In the next period, the worker has a certain probability of finding employment, obtaining the value θ_{t+1}^E, and a certain probability of remaining unemployed, obtaining the value θ_{t+1}^U.

Next, we explain the value from the firm's perspective. θ_t^J represents the value of hiring one worker. By hiring a worker, the firm receives a profit measured in real terms as $\frac{p_{jt}}{p_t}Y_t - w_t - r_tK_t$, and if the worker continues to be employed in the next period, the firm also gains the value associated with retaining the worker.

θ_t^V represents the value of not hiring a worker. Here, k is the cost of posting a vacancy. In practice, the number of vacancies posted by the firm is V_t, the number of unemployed individuals is U_t, and multiplying by the job openings-to-applicants ratio provides the cost of posting a vacancy per unemployed individual. Since this is a cost, it is represented as a negative value in the value calculation.

Moreover, due to the firm's free-entry condition, $\theta_t^V = 0$ is assumed.

The Nash bargaining solution shown in equation (18) can be solved for w_t, and is expressed as follows:

$$(1-\xi)(w_t - b_t^u) - \frac{\xi \psi_t k}{\lambda_t} = \xi \left(\frac{p_{jt}}{p_t} Y_t - w_t - r_t K_t \right) \tag{23}$$

The probability of new employment can also be determined as follows:

$$\frac{k}{\lambda_t \psi_t} = E_t \left[\beta \frac{\lambda_{t+1}}{\lambda_t} (1-\delta_n) \left(\frac{p_{jt+1}}{p_{t+1}} \frac{\partial Y_{t+1}}{\partial n_{t+1}} - w_{t+1} + \frac{k}{\lambda_{t+1} \psi_{t+1}} \right) \right] \tag{24}$$

4. Equilibrium

In this paper, we present the equilibrium solution. However, for the purpose of simulation analysis, we demonstrate a linear approximation of the solution here. The variable $\hat{x}_t$ represents the deviation rate of x_t from its steady-state value x, while $\tilde{x}_t$ indicates the deviation difference.

Euler Equation of consumption It can be derived from the equation for intertemporal consumption allocation.

$$\tilde{z}_t^c - \theta \hat{c}_t = E_t \tilde{z}_{t+1}^c + E_t \tilde{\imath}_{t+1} - E_t \tilde{\pi}_{t+1} - \theta \hat{c}_{t+1} \tag{A.1}$$

Tobin'*q* Tobin'q is equivalent to one at the steady state.

$$E_t \hat{q}_{t+1} = \frac{\hat{q}_t + \tilde{\imath}_{t+1} - \tilde{\pi}_{t+1} - r\hat{r}_{t+1}}{1-\delta_k} \tag{A.2}$$

Real Investment Adjustment cost of investment is given by $S(1) = S'(1) = 0$.

$$\hat{I}_t = \frac{\hat{I}_{t-1}}{2} + \frac{E_t \hat{I}_{t+1}}{2} + \frac{\hat{q}_t}{2S''} \tag{A.3}$$

Dynamics of Capital Stock We notify $I = \delta_k K$ at the steady state.

$$\hat{K}_t = \delta_k \hat{I}_t + (1-\delta_k) \hat{K}_{t-1} \tag{A.4}$$

Equilibrium of Goods Market Because of $I = \delta_k K$ at the steady state, we can obtain $\frac{I}{Y} = \frac{\delta_k}{\frac{Y}{K}}$.

$$\hat{Y}_t = \frac{C}{Y} \hat{c}_t + \frac{I}{Y} \hat{I}_t \tag{A.5}$$

Production Function

$$\hat{Y}_t = \alpha_1 \widehat{K}_{t-1} + (1-\alpha_1)\hat{n}_t \tag{A.6}$$

Real Interest Rate We solve the cost minimization problem to obtain the real interest rate.

$$\hat{r}_t = \widehat{\omega}_t + (\alpha_1 - 1)\widehat{K}_{t-1} + (1-\alpha_1)\hat{n}_t \tag{A.7}$$

Real Wage Rate We solve the cost minimization problem to obtain the real wage rate.

$$\widehat{w}_t = \widehat{\omega}_t + \alpha_1 \widehat{K}_{t-1} - \alpha_1 \hat{n}_t \tag{A.8}$$

Factor Price Ratio We consider $\frac{K_{t-1}}{n_t}$ as a variable.

$$\widehat{w}_t - \hat{r}_t = \widehat{\left(\frac{K_{t-1}}{n_t}\right)} \tag{A.9}$$

GDP Capital Stock Ratio We consider $\frac{Y_t}{K_{t-1}}$ as a variable.

$$\widehat{\left(\frac{Y_t}{K_{t-1}}\right)} = (\alpha_1 - 1)\widehat{\left(\frac{K_{t-1}}{n_t}\right)} \tag{A.10}$$

New Keynesian Phillips Curve (NKPC) The New Keynesian Phillips Curve (NKPC) is derived from the firm's pricing equation. Consider a model economy where prices cannot be adjusted with a certain probability, as shown by Calvo (1983). If the optimal price is denoted as p_t^* in equation (12), the following equation holds:

$$lnp_t^* = ln\frac{\varepsilon}{\varepsilon - 1} + ln\omega_t + lnp_t \tag{A.11.1}$$

If the probability of being able to adjust prices in period t is ρ, $(0 < \rho < 1)$, and the probability of not being able to adjust prices is $1-\rho$, the price-setting x_t in period t is expressed as follows:

$$lnx_t = \rho lnp_t^* + \rho(1-\rho)E_t lnp_{t+1}^* + \cdots = \rho lnp_t^* + (1-\rho)E_t lnx_{t+1} \tag{A.11.2}$$

The price in period t is the weighted average of the prices set by firms that can adjust their prices and those that cannot.

$$lnp_t = \rho lnx_t + (1-\rho)lnp_{t-1} \tag{A.11.3}$$

Because of (A.11.1)～(A.11.3), we derive NKPC as follows:[8]

$$\tilde{\pi}_{t-1} = \tilde{\pi}_t + \frac{\rho^2}{1-\rho}\widehat{\omega}_{t-1} \tag{A.11}$$

Monetary Policy Rule The government determines the nominal interest rate based on past nominal interest rates, future inflation rates, and the current GDP gap.

$$\tilde{\imath}_t = \chi \tilde{\imath}_{t-1} + (1-\chi)\left(\phi_1 \tilde{\pi}_{t+1} + \phi_2 \hat{Y}_t\right), 0 < \chi < 1, 0 < \phi_1, 0 < \phi_2 \tag{A.12}$$

Dynamics of Employment

[8] Refer to Hayashida, Namba, Ono and Yasuoka (2022) for a detail proof.

$$\hat{n}_t = (1-\delta_n)\hat{n}_{t-1} + \delta_n \widehat{M}_t \tag{A.13}$$

Matching Function

$$\widehat{M}_t = \alpha_2 \widehat{U}_t + (1-\alpha_2)\hat{V}_t \tag{A.14}$$

The probability of New Hires per Job Vacancy

$$\hat{L}_t = \widehat{M}_t - \hat{V}_t \tag{A.15}$$

Unemployment

$$\widehat{U}_t = -\frac{n(1-\delta_n)}{U}\hat{n}_t \tag{A.16}$$

Probability of New Employment for the Unemployed

$$\hat{s}_t = \widehat{M}_t - \widehat{U}_t \tag{A.17}$$

Effective Job Openings-to-Applicants Ratio (Degree of Employment Tightness)

$$\hat{\psi}_t = \hat{V}_t - \widehat{U}_t \tag{A.18}$$

Decision of Wage Rate ($C = \frac{\psi k}{\lambda}$ is defined.)

$$\frac{(1-\xi)w}{rK}\widehat{w}_t - \frac{\xi C}{rK}\hat{\psi}_t + \frac{\xi C}{rK}\hat{\lambda}_t = \xi\left(\frac{Y}{rK}\widehat{\omega}_t + \frac{Y}{rK}\hat{Y}_t - \frac{w}{rK}\widehat{w}_t - \hat{r}_t - \widehat{K}_t\right) \tag{A.19}$$

Decision of New Employment Determination ($D = \frac{k}{\lambda L}$ is defined.)

$$-\hat{\lambda}_t - \hat{L}_t = \hat{\lambda}_{t+1} - \hat{\lambda}_t + \frac{(1-\alpha)A\left(\frac{K}{n}\right)^{\alpha}\left(\widehat{\omega}_t + \alpha\widehat{K}_t - \alpha\hat{n}_t\right) - w\widehat{w}_{t+1} - D\left(\hat{\lambda}_t + \hat{L}_t\right)}{\frac{D}{\beta(1-\delta_n)}} \tag{A.20}$$

Consumption Shock Considering the shock of $f > 0$, it is possible to consider a consumption reduction shock by decreasing the preference parameter for consumption.

$$\tilde{z}^c_{t+1} = \phi_c \tilde{z}^c_t - f, 0 < \phi_c < 1. \tag{A.21}$$

Each variable is given as follows at the steady state.

Real Interest Rate

$$r = \delta_k \tag{B.1}$$

Real Wage Rate

$$w = (1-\alpha_1)\omega\left(\frac{K}{n}\right)^{\alpha_1} \tag{B.2}$$

Capital Stock Labor Ratio

$$\frac{K}{n} = \frac{\alpha_1}{1-\alpha_1}\frac{w}{r} \tag{B.3}$$

GDP Capital Stock Ratio

$$\frac{Y}{K} = A\left(\frac{K}{n}\right)^{\alpha_1 - 1} \tag{B.4}$$

Consumption GDP Ratio

$$\frac{c}{Y} = 1 - \delta_k \frac{K}{Y} \tag{B.5}$$

Employment Rate If we consider the population size to be 1 here, the number of employed and unemployed individuals can each be interpreted as the employment rate and unemployment rate, respectively.

$$n = \frac{M}{\delta_n} \tag{B.6}$$

Unemployment Rate

$$U = 1 - (1 - \delta_n)n \tag{B.7}$$

Capital Stock

$$K = \frac{\alpha}{1 - \alpha} \frac{w}{r} n \tag{B.8}$$

5. Calibration

Calibration is conducted using the model presented in Section 4. The calibration estimates parameters through Bayesian estimation via the MCMC method, as shown in Eguchi (2011). However, for certain parameters, values from existing studies will be used. The parameters adopted from existing studies are as follows:

$\theta = 1.5$	Eguchi (2011)
$\delta_K = 0.05$	Set with reference to Eguchi (2011).
$S'' = 0.14$	Eguchi (2011)
$\alpha_1 = 0.4$	Set based on the recent capital share ratio.
$\rho = 0.25$	Eguchi (2011)
$A = 1$	Set as unity.
$\phi_c = 0.1$	The shock is assumed to persist at a rate of 0.1 in the next period.
$\beta = 0.99$	Set with reference to Eguchi (2011).
$\delta_n = 0.15$	Set based on the recent separation rate. [9]

Table 1：Parameters Setting

[9] Ministry of Health, Labour and Welfare (2023), "Overview of the Results of the 2022 Employment Trends Survey"

For the parameters estimated in this paper, prior distributions are assigned as follows, and the expected values derived from the posterior distributions are used as the parameters.

	Prior Distribution			Posterior Distribution		
	Expected Value	Distribution Function	Standard Deviation	Expected Value	Confidence Interval	
χ	0.5	Beta	0.1	0.4951	0.3293	0.6617
ϕ_1	0.5	Norm	0.1	0.4501	0.2935	0.6036
ϕ_2	0.5	Norm	0.1	0.4616	0.2884	0.6402
ξ	0.5	Norm	0.1	0.7732	0.6576	0.8971
α_2	0.4	Norm	0.1	0.2748	0.1573	0.4197
B[10]	0.13	Norm	0.01	0.1467	0.1317	0.1611
C	0.25	Norm	0.1	0.0422	0.0104	0.1031
D	5	Norm	0.1	5.002	4.8406	5.1672
ε	3	Norm	0.1	2.9751	2.8119	3.1439

Table 2 ：Parameters Setting

At this time, the shock is modeled as a consumption preference shock, with the prior distribution assumed to follow an inverse gamma function with an expected value of 0.1 and an infinite standard deviation. The data used spans the period from 1994 to 2022.[11]

The data used for calibration includes the growth rates of GDP, consumption, real interest rates, real wage rates, and unemployment rates. The deviations from actual values relative to trends are obtained by applying the HP filter to extract trends. These deviations from the trends are regarded as the deviations from the steady state.

These five datasets are incorporated into the calibration model in the following manner:

---

[10] Here, B represents the matching function itself, as defined in equation (14). Furthermore, considering the recent unemployment rate, the expected value of the prior distribution is set at 0.13, with the standard deviation set at 0.01 to ensure the value does not deviate significantly from this expectation.

[11] The data for GDP, consumption, real interest rate, and unemployment rate are sourced from Cabinet Office, Government of Japan (2023) "Economic and Fiscal White Paper 2023: Long-term Economic Statistics." The real interest rate is calculated by subtracting the inflation rate from the nominal interest rate (government bond yields). Additionally, the data for real wages is referenced from the "Monthly Labour Survey" available through Portal Site of Official Statistics of Japan.

$$\hat{Y}_t^{obs} = \hat{Y}_t + u\hat{Y}_t \tag{C.1}$$
$$\hat{c}_t^{obs} = \hat{c}_t + u\hat{c}_t \tag{C.2}$$
$$\hat{r}_t^{obs} = \hat{r}_t + u\hat{r}_t \tag{C.3}$$
$$\widehat{w}_t^{obs} = \widehat{w}_t + u\widehat{w}_t \tag{C.4}$$
$$\hat{u}_t^{obs} = \hat{u}_t + u\hat{u}_t \tag{C.5}$$

Here, $\hat{x}_t^{obs}$ represents the deviation rate of the variable x_t from its trend, while $u\hat{x}_t$ denotes the error term. Specifically, $u\hat{Y}_t$, $u\hat{c}_t$, $u\hat{r}_t$, $u\widehat{w}_t$, $u\hat{u}_t$ are assumed to follow prior distributions with an expected value of 0.1, an infinite standard deviation, and an inverse gamma function.

Through the above calibration, the parameters shown in Table 2 can be obtained.

6. Simulation

In this paper, using the parameters estimated in Section 5, we adjust the consumption preference shock so that the GDP decline rate in 2020 matches the observed 4.5% decrease. Based on this adjustment, we calculate the corresponding unemployment rate. The results are illustrated in the following figure.

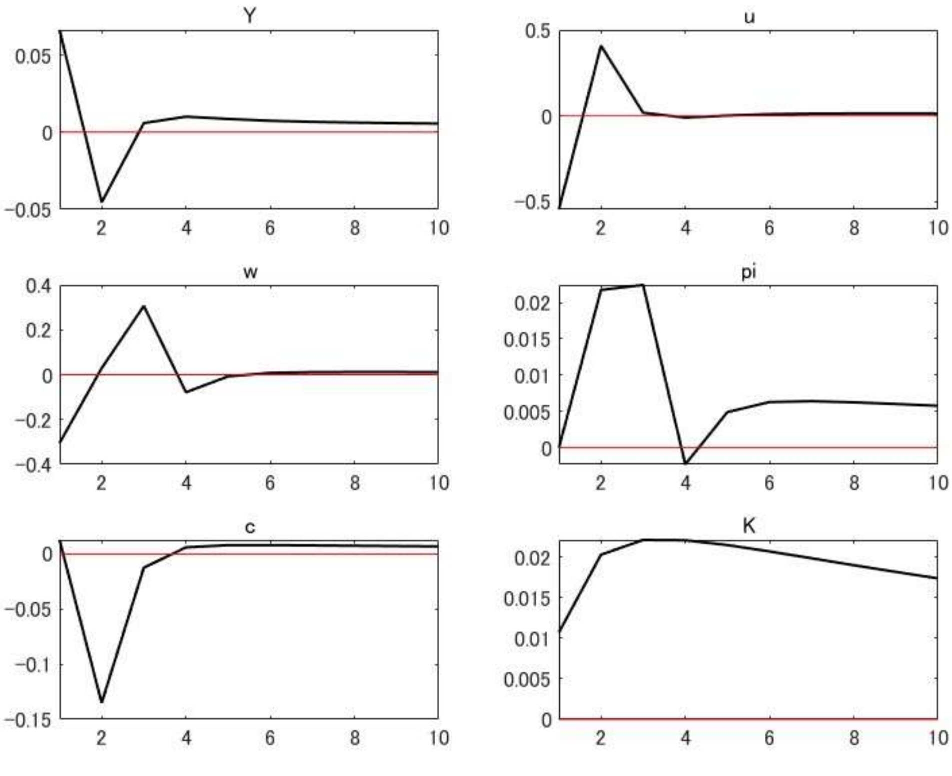

Fig.2：The GDP and Unemployment Rate Shocks in Response to a Consumption Preference Shock (pi denotes π.)

The consumption preference shock is modeled as representing behaviors such as avoiding dining out and refraining from tourism due to movement restrictions. When the consumption preference shock is adjusted to result in a 4.5% decrease in GDP, the unemployment rate increases by 40%. It is important to note that, due to the structure of the program, the shock appears starting in the second period, so the unemployment rate level in the second period should be observed. Considering that the unemployment rate in 2019 was around 2.5%, this represents an approximate increase of 1 percentage point.

In prior research that utilized data from government fiscal reviews, it was shown that employment adjustment subsidies suppressed the unemployment rate increase by 2.6 percentage points. However, the model in this paper reveals that it lacks a similar effect, suppressing the unemployment rate increase by only about 1 percentage point, or less than half the level of the previous studies.

7. Input-Output Analysis

The increase in the unemployment rate estimated by the DSGE model was 41%. According to the "Labor Force Survey" by Ministry of Internal Affairs and Communications (2024a), specifically the basic tabulations and long-term time-series data in the annual average results (calendar year basis), the unemployment rate in 2019 was 2.4%. Consequently, the unemployment rate rose to 3.384% in 2020.[12] However, the actual unemployment rate for the same year, according to the same statistical source, was 2.8%. Therefore, the difference of 0.584% can be regarded as the portion of the unemployment rate increase that was mitigated by the effects of the Sustainability Subsidy.

This section attempts to estimate the reduction in production losses across industries that could be avoided, based on the mitigated unemployment rate, using input-output analysis. Table 3 presents the mitigated reduction in consumption expenditures derived from the mitigated unemployment rate and related indicators. As shown in Table 3, the mitigated unemployment rate of 0.0584% corresponds to 403,000 unemployed individuals. The consumption expenditure for 2020 that these 403,000 individuals would have made can be calculated as 818.00706 billion yen, as shown in Table 3. This figure is derived by multiplying the number of unemployed individuals by the average wage per person, the disposable income rate, and the average propensity to consume.

[12] Ministry of Internal Affairs and Communications (2024a), "2023 Labor Force Survey," Statistics Bureau of the Ministry of Internal Affairs and Communications

		2019	2020	Note:
Labor force population (in tens of thousands):		6912	6902	Ministry of Internal Affairs and Communications (2024b)
Unemployment rate	DSGE model	0.024	0.03384	
	Observed value	0.024	0.028	Ministry of Internal Affairs and Communications (2024b)
	Difference: Mitigated increase rate:	—	0.00584	0.03384－0.028
Mitigated increase in unemployed persons (in tens of thousands):		—	40.3	6902×0.00584
Average wage per person (in ten thousand yen):		—	384.5	Ministry of Internal Affairs and Communications (2024a)
Disposable income		—	0.861	Ministry of Internal Affairs and Communications (2021a)[13]
Average propensity to consume		—	0.613	Ministry of Internal Affairs and Communications (2021a)
Mitigated reduction in consumption expenditure (in 100 million yen):		—	8180.0706	403000×384.5×0.861 ×0.613 =81800706(Ten thousand yen)

Table 3　Derivation of the mitigated reduction in consumption expenditure

[13] Ministry of Internal Affairs and Communications (2021a), "2020 Annual Report on the Family Income and Expenditure Survey," Statistics Bureau of the Ministry of Internal Affairs and Communications

Next, the induced production amount in domestic industries resulting from the mitigated reduction in consumption expenditure is estimated. This estimation utilizes the "2020 National Input-Output Table, Basic Transaction Table (Producer Price Basis, Integrated Major Classification with 37 Sectors)" by the Ministry of Internal Affairs and Communications (2024b).[14]

The mitigated reduction in consumption expenditure of 818.00706 billion yen is allocated by industry based on the sectoral composition ratios of private consumption expenditure in the input-output table. By applying this to an input-output model, as shown in Equation (1), the decrease in the induced production amount for each industry caused by this reduction in consumption is calculated.

$$\mathbf{\Delta x} = \{\mathbf{I} - (\mathbf{I} - \mathbf{M})\mathbf{A}\}^{-1}(\mathbf{I} - \mathbf{M})\mathbf{\Delta f} \tag{25}$$

Δf : Vector of consumption expenditure reduction amounts
M : Diagonalized matrix of import coefficients
A : Input coefficient matrix
I : Identity matrix
Δx: Vector of reduced induced production amounts

As shown in Equation (25), the reduction in domestically induced production amounts, $\mathbf{\Delta x}$, is derived by multiplying the Leontief inverse matrix with endogenous imports, $\{\mathbf{I} - (\mathbf{I} - \mathbf{M})\mathbf{A}\}^{-1}$, by the reduction in domestically supplied consumption expenditure, $(\mathbf{I} - \mathbf{M})\mathbf{\Delta f}$.

[14] Ministry of Internal Affairs and Communications (2024b), "2020 Input-Output Table," Statistics Bureau of the Ministry of Internal Affairs and Communications

(100 million yen)

Industrial sector		Amount	Industrial sector		Amount
1	Agriculture, Forestry, and Fishery	292.33	20	Miscellaneous Manufacturing Products	114.32
2	Mining	6.27	21	Construction	74.98
3	Beverages and Foods	965.35	22	Electricity, Gas, and Heat Supply	389.94
4	Textile Products	53.53	23	Water Supply	88.09
5	Pulp, Paper and Wooden Products	112.26	24	Waste Management Services	64.63
6	Chemical Products	217.41	25	Wholesale and Retail Trade	1619.48
7	Petroleum and Coal Products	194.63	26	Finance and Insurance	745.73
8	Plastic and Rubber Products	118.91	27	Real Estate	2169.27
9	Ceramic, Stone, and Clay Products	20.94	28	Transportation, Postal Services	675.46
10	Iron and Steel	61.73	29	Information and Communications	821.85
11	Non-ferrous Metals	25.49	30	Public Administration	38.2
12	Metal Products	50.99	31	Education and Research	264.37
13	General-purpose Machinery	12.85	32	Medical and Welfare	462.34
14	Production Machinery	11.68	33	Other Membership Organizations Not Classified Elsewhere	115.94
15	Business Machinery	9.59	29	Business services	961.34
16	Electronic Components	35.57	35	Personal Services	877.44
17	Electrical Machinery	90.02	36	Office Supplies	17.01
18	Information and Communication Equipment	41.46	37	Activities not Elsewhere	38.64
19	Transportation Equipment	282.73	Total		12142.76

Table 4 Mitigated reduction in induced production amounts

Table 4 shows the mitigated reduction in induced production amounts derived using Equation (25). Of the mitigated reduction in consumption expenditure of 818.00706 billion yen, the domestically supplied portion amounted to 771.96138 billion yen. This led to a total reduction in induced production across all industries of 1,214.276 billion yen. It should be noted that the induced production amounts for each industry correspond to the current composition ratios of induced production amounts resulting from private consumption expenditure in the 2020 Input-Output Table.

As discussed above, the reduction in domestic production resulting from the mitigation of the unemployment rate increase due to the Sustainability Subsidy was estimated to be 1,214.276 billion yen. However, this estimation only considers the impact through the reduction in consumption expenditure associated with the rise in the unemployment rate. Since the increase in unemployment is also expected to reduce domestic production through factors such as declines in savings and investment, the actual mitigated reduction in domestic production is likely to be even greater.

8. Conclusions

This paper employs a DSGE model to estimate the increase in the unemployment rate under conditions where economic activity is suppressed due to behavioral restrictions associated with the spread of COVID-19, in the absence of employment adjustment subsidies. By comparing the increase in unemployment in a model economy without employment adjustment subsidies to the actual unemployment rate in an economy with such subsidies, the paper attempts to derive the unemployment suppression effect of these subsidies.

The results indicate that, without employment adjustment subsidies, the unemployment rate would have increased by 1 percentage point in the actual economy. Conversely, it can be inferred that the subsidies effectively suppressed a 1 percentage point increase in the unemployment rate. The paper derives simulation parameters using calibration based on real-world data and employs a model grounded in microeconomic foundations. Thus, the conclusions reached are considered highly persuasive.

This analysis underscores that the effects of employment adjustment subsidies vary depending on the model used. It suggests that the structure of the simulation model and its parameters significantly influence the derivation of these effects. The paper highlights the importance of paying close attention to such differences when conducting simulation analyses.

In input-output analysis, it was shown that the suppression of an increase in the number of unemployed individuals due to employment adjustment subsidies also mitigated the decline in GDP, allowing specific numerical impacts to be estimated. While there is a limited number of studies that have attempted such analyses, this research is considered significant in its role as an evaluation of government policies during the COVID-19 pandemic.

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Appendix

This study estimated the unemployment rate increase based on GDP decline driven by reduced consumption due to a consumption preference shock. However, to assess the validity of attributing GDP decline solely to a consumption preference shock, this section examines GDP declines caused by other types of shocks.

A.1 Total Factor Productivity Shock

The production function of intermediate goods firms is restated as follows:

$$Y_{jt} = AK_{jt-1}^{\alpha_1} n_{jt}^{1-\alpha_1}, 0 < \alpha_1 < 1, 0 < A. \tag{8}$$

Here, we consider a total factor productivity (TFP) shock, where A decreases. When the capital stock and labor input are held constant, a decrease in A results in a reduction in output. This models a scenario where, despite having production inputs available, movement restrictions prevent sufficient production activity, leading to lower output.

In this case, the equilibrium solutions are modified as follows. Notably, the preference shock in the consumption Euler equation (A.1) is eliminated.

Production Function

$$\hat{Y}_t = \hat{A}_t + \alpha_1 \hat{K}_{t-1} + (1-\alpha_1)\hat{n}_t \tag{A.6'}$$

Real Interest Rate

$$\hat{r}_t = \hat{A}_t + \hat{\omega}_t + (\alpha_1 - 1)\hat{K}_{t-1} + (1-\alpha_1)\hat{n}_t \tag{A.7'}$$

Real Wage Rate

$$\hat{w}_t = \hat{A}_t + \hat{\omega}_t + \alpha_1 \hat{K}_{t-1} - \alpha_1 \hat{n}_t \tag{A.8'}$$

GDP Capital Stock Ratio

$$\widehat{\left(\frac{Y_t}{K_{t-1}}\right)} = \hat{A}_t + (\alpha_1 - 1)\widehat{\left(\frac{K_{t-1}}{n_t}\right)} \tag{A.10'}$$

Total Factor Productivity Shock

$$\hat{A}_{t+1} = \phi_A \hat{A}_t - f, 0 < \phi_A < 1. \tag{A.21'}$$

The exogenous shock f is adjusted so that the GDP decline reaches 4.5%. The results are illustrated in the following figure.

In this case, the unemployment rate shows little change. Considering this, it is difficult to explain the suppression of economic activity due to movement restrictions during the COVID-19 pandemic using a total factor productivity (TFP) shock.

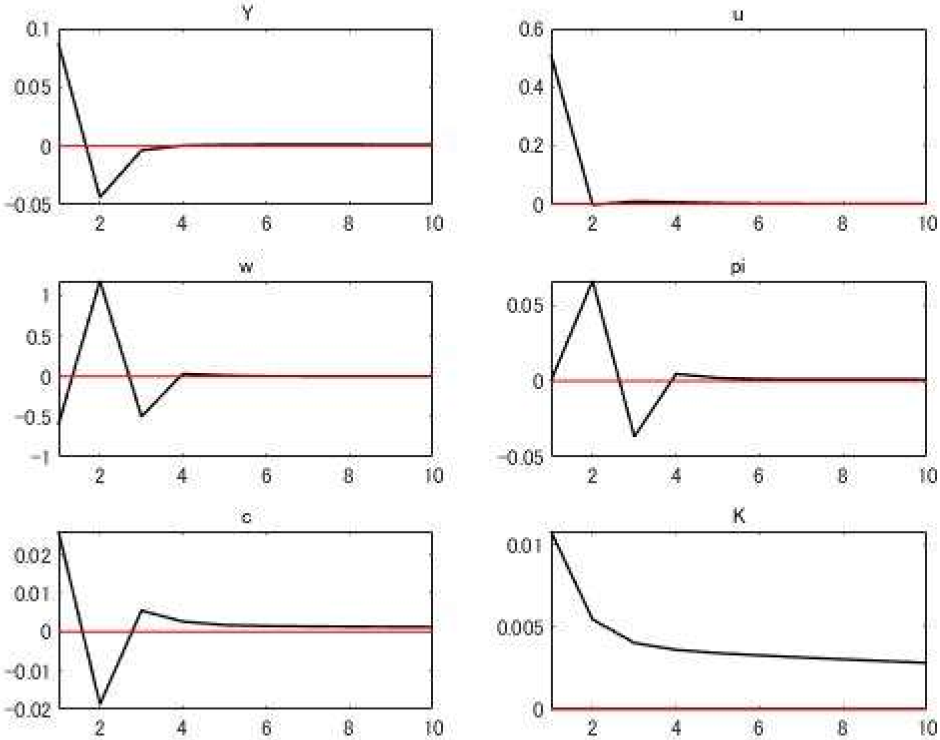

Fig. 3 ：The GDP and Unemployment Rate Shocks in Response to a Total Factor Productivity (TFP) Shock

A.2 Employment Shock

Considering movement restrictions, we introduce an exogenous shock where businesses, particularly in the service sector, are unable to operate, resulting directly in layoffs. While in the case of a consumption preference shock, layoffs are driven by a decrease in demand, here we focus on a situation where layoffs are caused directly by the shock itself. In this scenario, the equilibrium equations are modified as follows:

Dynamics of Employment

$$\hat{n}_t = (1-\delta_n)\hat{n}_{t-1} + \delta_n \widehat{M}_t + \hat{F}_t \tag{A.13}$$

Employment Shock

$$\hat{F}_{t+1} = \phi_F \hat{F}_t - f, 0 < \phi_F < 1. \quad \text{(A.21')}$$

As in the previous cases, the exogenous shock is adjusted to achieve a 4.5% decline in GDP, and the results are shown in the following figure. In this case, the unemployment rate increases by approximately 40%, similar to the results under the consumption preference shock. Since layoffs could plausibly occur due to the inability to operate under movement restrictions, considering such a shock is deemed reasonable.

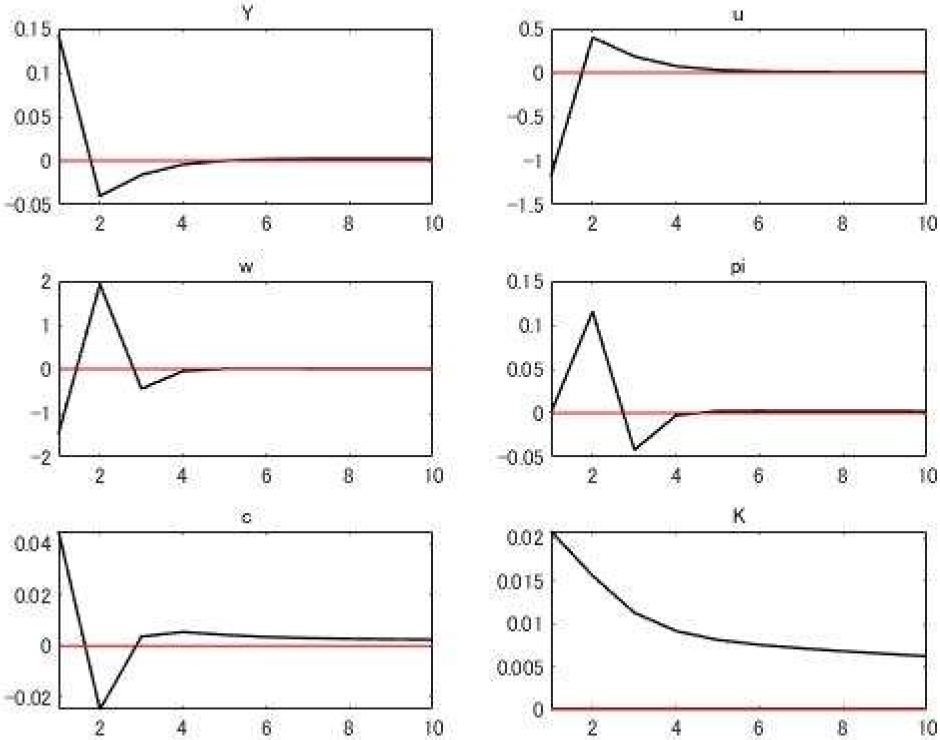

Fig. 4 ：The GDP and Unemployment Rate Shocks in Response to an Employment Shock

Calibration Code

```
//1. variables
var zc c i pi q r I K Y n omega m u v l lambda psi w s Kn YK Y_obs c_obs r_obs w_obs u_obs;
varexo uY uc ur uw uu cf;

//2. parameter
parameters theta deltak S alpha1 rho kai phi1 phi2 deltan zeta
alpha2 A phic phiy phim B beta C D epsilon;

//2.1 parametervalue
theta=1.5;
deltak=0.05;
S=0.14;
alpha1=0.4;
rho=0.25;
A=1;
phic=0.1;
beta=0.99;
deltan=0.15;

//3.equations
model(linear);
# rbar=1-(1-deltak);
# wbar=((1-alpha1)/alpha1*(1/((1-alpha1)*(epsilon-1)/epsilon))^(1/alpha1)*rbar)^(1/(1-
1/alpha1));
# Knbar=wbar/rbar*alpha1/(1-alpha1);
# YKbar=A*(Knbar)^(alpha1-1);
# CYbar=(YKbar-deltak)/YKbar; % CY denotes C/Y
# nbar=B/deltan; %B はマッチング関数
# ubar=1-(1-deltan)*nbar;
# Kbar=wbar/rbar*alpha1/(1-alpha1)*nbar;

zc-theta*c=zc(+1)+i(+1)-pi(+1)-theta*c(+1);
q=1/(1-deltak)*((q(-1)+(i-pi))-rbar*r);
I=1/2*I(-1)+1/2*I(+1)+1/(2*S)*q;
K=deltak*I+(1-deltak)*K(-1);
```

```
Y=CYbar*c+deltak*(1/(YKbar))*I; %YK denotes Y/K
Y=alpha1*K(-1)+(1-alpha1)*n;
w-r=Kn; % Kn denotes K/n
r=omega+(alpha1-1)*K(-1)+(1-alpha1)*n;
YK=(alpha1-1)*Kn; % YK denotes Y/k
pi(-1)=pi+rho^2/(1-rho)*omega(-1);
i=kai*i(-1)+(1-kai)*(phi1*pi(+1)+phi2*Y);
n=(1-deltan)*n(-1)+deltan*m;
m=alpha2*u+(1-alpha2)*v;
l=m-v;
u=-nbar/ubar*(1-deltan)*n;
zc(+1)=phic*zc-cf;
(1-zeta)*w*wbar/(rbar*Kbar)-zeta*C*psi/(rbar*Kbar)-
zeta*C*lambda/(rbar*Kbar)=zeta*(omega*YKbar/rbar+Y*YKbar/rbar-
w*wbar/(rbar*Kbar)-r-K); % C=psi*k/lambda
-lambda-l=lambda(+1)-lambda+(omega(+1)*(1-alpha1)*A*(Knbar)^alpha1+alpha1*(1-
alpha1)*A*(Knbar)^alpha1*(K-n(+1))-w(+1)*wbar-
D*(lambda(+1)+l(+1)))/(D/(beta*(1-deltan))); % D=k/lambda*l
w=omega+alpha1*K(-1)-alpha1*n;
s=m-u;
psi=v-u;

Y_obs=Y+uY;
c_obs=c+uc;
r_obs=r+ur;
w_obs=w+uw;
u_obs=l+uu;
end;

estimated_params;
kai, beta_pdf, 0.5, 0.1;
phi1, normal_pdf, 0.5, 0.1;
phi2, normal_pdf, 0.5, 0.1;
zeta, normal_pdf, 0.5, 0.1;
alpha2, normal_pdf, 0.4, 0.1;
B, normal_pdf, 0.13, 0.01; %Function of M
```

```
C, normal_pdf, 0.25, 0.1;
D, normal_pdf, 5, 0.1;
epsilon, normal_pdf, 3, 0.1;
stderr cf, inv_gamma_pdf,    0.1, inf;
stderr uY, inv_gamma_pdf,    0.1, inf;
stderr uc, inv_gamma_pdf,    0.1, inf;
stderr ur, inv_gamma_pdf,    0.1, inf;
stderr uw, inv_gamma_pdf,    0.1, inf;
stderr uu, inv_gamma_pdf,    0.1, inf;
end;

varobs Y_obs c_obs r_obs w_obs u_obs;

estimation(datafile = jpdata, mode_check, mh_replic =500000, mh_nblocks =2, mh_drop
=0.5, mh_jscale =0.5, bayesian_irf);
```

Data Used for Calibration

```
data_q = [
-0.01739486	-0.00945570	0.32095219	-0.01040744	-0.06551780
-0.00199480	0.00352477	0.22202068	-0.00253243	-0.03452526
0.01846705	0.01166869	0.07944803	0.00425818	-0.03592997
0.01820352	0.00610249	-0.95134823	0.01347124	-0.08132892
-0.00423208	-0.01138582	-0.34756651	0.01403592	0.01413694
-0.01702362	-0.01178603	-0.01853931	0.00927702	0.07150269
0.00087472	-0.00755098	0.24472031	0.00682555	0.03965757
-0.00453104	0.00178760	0.14579469	0.00416578	0.05705823
-0.01322634	0.00390698	0.04455300	-0.00587760	0.09116295
-0.00688572	-0.00001006	0.00522906	-0.01465950	0.07086449
0.00627531	0.00345938	-0.09404873	-0.01668771	-0.00764149
0.01639579	0.00970070	0.17943072	-0.02017074	-0.04683438
0.02318975	0.01080033	-0.03038917	-0.01824654	-0.08644461
0.03205642	0.01099060	0.14282128	-0.00189377	-0.11129827
0.01466503	-0.00703832	-1.20057633	0.01303450	-0.08524518
-0.04873585	-0.02238075	1.51912037	0.01510981	0.08957761
-0.01371674	-0.00515689	1.01334134	0.00927276	0.10969893
-0.01914146	-0.01581633	0.82164979	0.00432450	0.06508478
-0.01169433	-0.00059359	0.63010149	-0.00295571	0.04979645
0.00157513	0.02110128	0.26682749	-0.00615613	0.03512189
-0.00214229	0.00908099	-49.49777821	-0.00428983	-0.00253509
0.00684518	0.00519863	3.04822224	-0.00164055	-0.00229348
0.00832388	0.00040198	-1.49340235	0.00082574	-0.03738537
0.01959580	0.01148010	0.09927530	0.00934569	-0.08347123
0.02149366	0.01545883	0.87146921	0.00264469	-0.18596010
0.01371811	0.01175990	-0.20301241	0.00620188	-0.13942937
-0.03219065	-0.03060619	-0.97390801	-0.00015486	0.05688455
-0.00877322	-0.01961062	-1.30327405	-0.00341783	0.09683814
0.00000366	0.00496805	1.03961744	-0.00370264	0.06206313
];

Y_obs = data_q(:,1);
c_obs = data_q(:,2);
r_obs = data_q(:,3);
```

```
w_obs = data_q(:,4);
u_obs = data_q(:,5);
```

Consumption Shock Code

```
//1. variables
var zc c i pi q r I K Y n omega m u v l lambda psi w s Kn YK;
varexo f;

//2. parameter
parameters theta deltak S alpha1 rho kai phi1 phi2 deltan zeta
alpha2 A phic B beta C D epsilon;

//2.1 parametervalue
theta=1.5;
deltak=0.05;
S=0.14;
alpha1=0.4;
rho=0.25;
kai=0.4951;
phi1=0.4501;
phi2=0.4616;
deltan=0.15;
zeta=0.7732;
alpha2=0.2748;
A=1;
phic=0.1;
B=0.1467; % function of M
beta=0.99;
C=0.0422; %Y and u are seriously determined.
D=5.0020;
epsilon=2.9751;

//3.equations
model(linear);
# rbar=1-(1-deltak);
# wbar=((1-alpha1)/alpha1*(1/((1-alpha1)*(epsilon-1)/epsilon))^(1/alpha1)*rbar)^(1/(1-
1/alpha1));
# Knbar=wbar/rbar*alpha1/(1-alpha1);
# YKbar=A*(Knbar)^(alpha1-1);
```

```
# CYbar=(YKbar-deltak)/YKbar; % CY denotes C/Y
# nbar=B/deltan;
# ubar=1-(1-deltan)*nbar;
# Kbar=wbar/rbar*alpha1/(1-alpha1)*nbar;

zc-theta*c=zc(+1)+i(+1)-pi(+1)-theta*c(+1);
q=1/(1-deltak)*((q(-1)+(i-pi))-rbar*r);
I=1/2*I(-1)+1/2*I(+1)+1/(2*S)*q;
K=deltak*I+(1-deltak)*K(-1);
Y=CYbar*c+deltak*(1/(YKbar))*I; %YK denotes Y/K
Y=alpha1*K(-1)+(1-alpha1)*n;
w-r=Kn; % Kn denotes K/n
r=omega+(alpha1-1)*K(-1)+(1-alpha1)*n;
YK=(alpha1-1)*Kn; % YK denotes Y/k
pi(-1)=pi+rho^2/(1-rho)*omega(-1);
i=kai*i(-1)+(1-kai)*(phi1*pi(+1)+phi2*Y);
n=(1-deltan)*n(-1)+deltan*m;
m=alpha2*u+(1-alpha2)*v;
l=m-v;
u=-nbar/ubar*(1-deltan)*n;
zc(+1)=phic*zc-f;
(1-zeta)*w*wbar/(rbar*Kbar)-zeta*C*psi/(rbar*Kbar)-
zeta*C*lambda/(rbar*Kbar)=zeta*(omega*YKbar/rbar+Y*YKbar/rbar-
w*wbar/(rbar*Kbar)-r-K); % C=psi*k/lambda
-lambda-l=lambda(+1)-lambda+(omega(+1)*(1-alpha1)*A*(Knbar)^alpha1+alpha1*(1-
alpha1)*A*(Knbar)^alpha1*(K-n(+1))-w(+1)*wbar-
D*(lambda(+1)+l(+1)))/(D/(beta*(1-deltan))); % D=k/lambda*l
w=omega+alpha1*K(-1)-alpha1*n;
s=m-u;
psi=v-u;
end;

//steady state check
steady;
check;
```

```
//5. simulation
shocks;
var f=0.05;
end;

//6. results
stoch_simul(irf=10)Y u w pi c K;
```