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Social Distancing, Labor Supply, and Income Distribution†

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The effects of social distancing measures on income distributions and aggregate variables are examined with an off-the-shelf heterogeneous-agent incomplete-market model. The model shows that social distancing measures, which limit households' labor supply, can decrease the labor supply of low-income households who hold insufficient assets and need income the most given their borrowing constraints. Social distancing measures can therefore exacerbate income inequality by lowering the incomes of the poor. An equilibrium interest rate can fall when the social distancing shock is expected to be persistent because households save more to prepare for rising consumption volatility given the possibility of binding to the labor supply constraint over time. When the shock is expected to be transitory, in contrast, the interest rate can rise upon the arrival of the shock because constrained households choose to borrow more to smooth consumption given the expectation that the shock will fade away. The model also shows that social distancing shocks, which diminish households' consumption demand, can decrease households' incomes evenly for every income quantile, having a limited impact on income inequality.

Key Word: Covid-19, Income Distribution, Labor Supply, Social Distancing
JEL Code: D31, E21, E43, J20

I. Introduction

The COVID-19 economic crisis is distinguished from earlier crises in that the recent economic turmoil was derived from a pandemic. To counteract the infectious disease, the South Korean government has imposed preventive measures, termed 'social distancing', including bans on gathering and restrictions on businesses.

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This paper studies the economic impacts of the social distancing measures implemented in South Korea in the midst of the COVID-19 pandemic. I specifically focus on a prominent feature of social distancing shocks: the constrained labor supply.

The social distancing measures have restricted the labor supply of households. Businesses that rely on face-to-face interactions are forced to shut down during the day or to close late at night to contain the spread of the coronavirus. The number of persons employed in the face-to-face service sector fell sharply immediately after the outbreak of the pandemic in March of 2020, decreasing by more than 4.7% on average since then[1] and accounting for almost all of the decrease in the number of employed persons in South Korea.[2] Given the fact that aggregate employment variables are in general lagging over the business cycle, the immediate decrease in employment variables concentrated on the face-to-face service sector implies that the observed constrained labor supply is not only the result but also a source of the shock. If the decline in employment is a cause of the economic turmoil, the social distancing measures can be understood as a supply shock.[3]

To study the economic repercussions of the social distancing measures, I use an off-the-shelf heterogeneous-agent incomplete-market model (Aiyagari, 1994; Guerrieri and Lorenzoni, 2017; Achdou *et al*., 2020) to examine changes in households' optimal behaviors, their income distributions, and aggregate variables.

The model shows that a labor supply constraint, which limits the maximum level of the household labor supply, can decrease the income of poor households who must earn the most and increase income inequality by thickening the left side of the tail of the household income distribution.

The joint distribution of households' asset holdings and labor productivity is endogenously determined in the model. Most low-income households have low labor productivity and hold insufficient assets in the initial steady-state distribution given a borrowing constraint. They choose to supply longer hours for work due to an income effect. When the social distancing shock arrives, however, these households cannot increase their labor supply due to the binding labor supply constraint, and they suffer from declining incomes. In contrast, households with sufficient asset holdings choose to supply shorter hours for work than low-income households and thus are less likely to bind to the labor supply constraint. Given that most of these rich households have high labor productivity in the initial steady-state distribution, the labor supply constraint has a smaller impact on the incomes of rich, productive households.

The effects of the labor supply constraint on households' income distribution are in line with the observed data of South Korea in 2020. Figure 1 presents changes in households' market incomes by income quintile in 2020 from Household Income and Expenditure Trends of Statistics Korea. We observe that households' market income, representing the sum of their labor and business income, declines for every

[1]Year-on-year percent change for the period from March of 2020 to February of 2021.

[2]See the left panel of Figure A1 in the Appendix for year-on-year changes in the number of employed in South Korea by sector.

[3]The right panel of Figure A1 in the Appendix shows that the economically inactive population increased sharply in March of 2020 and increased by 3.6% on average for the period from March of 2020 to February of 2021. Because households determine whether or not to enter the labor market, the rising economically inactive population implies that the aggregate labor supply was reduced due to the social distancing measures.

quintile and that the lower the income quintile is, the greater the decrease in the market income is. Households in the first quintile experience a significant amount of market income shock (-9.1%), while those in the fifth quintile show a small drop (-0.4%), despite the fact that the social distancing measures were imposed regardless of the household income quintile. With a labor supply constraint calibrated to mimic the observed aggregate data of South Korea in 2020, the model produces changes in household incomes by income quantile comparable to the observed data in Figure 1.

The model also suggests that the effects of the labor supply constraint on aggregate variables depend on households' expectations. When the labor supply shock is expected to be permanent, households' permanent incomes decline significantly and they choose to consume less and save more given the possibility of binding to the labor supply constraint over time. Thus, the interest rate can fall immediately with the shock. When the labor supply shock is expected to be transitory, in contrast, constrained households choose to borrow more in order to smooth their consumption, while unconstrained households scarcely change their consumption and saving decisions given the expectation that the shock will fade away. Therefore, interest rates can rise directly after the arrival of the shock. In both cases, aggregate consumption drops due to the constrained labor supply.

Two other features of social distancing shocks, in this case asymmetric declines in sectoral production and constrained consumption demand, are examined as to whether these shocks can increase income inequality among households. First, the model shows that sectoral asymmetry is not essential to generate skewed changes in the household income distribution. Whether or not the labor supply constraint shock is applied to all households or only to households in the face-to-face sector does not change the qualitative result of the rising income inequality. This is true because in the model, the rising income inequality due to the labor supply constraint stems from changes in the income distribution within a sector in which households are subject to the labor supply constraint, not from the difference between sectors.

Second, households decrease their face-to-face consumption such as spending on clothing, dining out, or accommodation, due to their voluntary social distancing with the fear of infection as well as the restriction imposed by mandatory social distancing

FIGURE 1. CHANGES IN HOUSEHOLDS' LABOR AND BUSINESS INCOMES BY INCOME QUINTILE IN 2020

Source: KOSIS (Last Access Date: 2021. 3. 19). YoY changes in income are calculated by aggregating quarterly income data given the lack of yearly income data in Household Income and Expenditure Trends, Statistics Korea.

measures. The model shows that the economic impacts of this constrained consumption demand are similar to those of a standard aggregate demand shock. When households' marginal utility of consumption decreases due to the constrained consumption demand, households want to consume less and aggregate consumption drops. Households save more and the aggregate interest rate can fall. The consumption demand shock reduces every household's labor supply in equilibrium and cannot generate the skewed changes in income by income quintile observed in Figure 1; hence, the effects of the shock on the household income distribution are limited. This suggests that the increased income inequality observed in Figure 1 was more likely to derive from the labor supply constraint rather than from the constrained consumption demand.

Many studies examine the economic impacts of COVID-19 by combining macroeconomic and epidemiological models (e.g., Eichenbaum *et al*., 2020; Kaplan *et al.,* 2020). They shed light on how an economy reacts to the large-scale transmission of an infectious disease and examine the economic impacts of severe measures such as a national lockdown. Given that the numbers of confirmed cases and deaths related to COVID-19 have remained at limited levels in South Korea,[4] however, most of the economic shock stemmed from the preventive, less severe measures compared to the situations in other countries. In this paper, a standard macroeconomic model that does not depend on an epidemiological mechanism is used to focus on changes in economic agents' behaviors with several preventive social distancing measures in South Korea.

The rest of this paper proceeds as follows. In Section 2, the model is introduced with specific forms of social distancing shocks. In Section 3, the effects of a labor supply constraint on households' optimal decisions, income distributions, and aggregate variables are examined. Other features of social distancing, such as sectoral asymmetry and constrained consumption demand, are studied in Section 4. Lastly, Section 5 concludes the paper.

II. Model

A. *Economic Environment*

An economy consists of a continuum of infinitely lived households who are heterogeneous in their idiosyncratic labor productivity z, assets a, and sector $j \in \{\text{Face-to-face (FF), Contact-free (CF)}\}$. The FF sector is assumed to be more vulnerable to an infectious disease and is hit hard by social distancing measures, whereas the CF sector is assumed not to be directly affected by the social distancing measures. Suppose that households in the FF sector cannot move to the CF sector, and vice versa.[5] Let the share of the FF sector households α and that of the CF

[4]The total numbers of confirmed cases and deaths per 100,000 of the population in South Korea are 193.24 and 6.99, respectively, as of March 22, 2021. These numbers are greater by ten-fold in major advanced economies: 8,911.71 and 162.17 in the U.S. and 3,183.46 and 89.17 in Germany, for instance (World Health Organization, https://covid19.who.int/).

[5]Although extreme rigidity of movement across sectors is assumed in this paper, sectoral mobility could be an important issue because long-lived shocks concentrated in the FF sector can be mitigated by reallocating resources

sector be $(1-\alpha)$. The only asset traded in the economy is a risk-free bond, and each household can borrow up to an exogenous limit such that the household's assets must satisfy

$$a_t \geq \underline{a}.$$

With this borrowing constraint and incomplete markets, each household faces an uninsurable income risk given its idiosyncratic labor productivity shock.

Each household chooses its consumption flow $c_{j,t}$ and labor supply flow $n_{j,t}$ to maximize its preference, represented by the discounted expected utility function over an infinite time horizon,

$$E_0 \int_0^\infty e^{-\rho t} \left\{ \psi_{c,t} \frac{c_{j,t}^{1-\gamma}}{1-\gamma} + \psi_n \frac{(1-n_{j,t})^{1-\eta}}{1-\eta} \right\} dt,$$

where $\rho > 0$ is the time discounting rate, $\gamma > 0$ and $\eta > 0$ are respectively the coefficients of the relative risk aversion and the curvature of utility from leisure governing the Frisch elasticity of the labor supply, and $\psi_{c,t} > 0$ and $\psi_n > 0$ are likewise the coefficients of consumption and leisure. $\psi_{c,t}$ is initially normalized to 1, but it can be reduced due to social distancing shocks, decreasing the marginal utility of consumption. The time endowment is normalized to 1.

Household assets a evolve according to the following law of motion,

$$\dot{a}_t = z_t n_{j,t} + r_t a_t - c_{j,t},$$

where r_t is the interest rate and $z_t n_{j,t}$ represents consumption goods produced by the household using a linear technology. The idiosyncratic labor productivity shock z_t evolves stochastically over time following an Ornstein-Uhlenbeck process while reflecting barriers $\{\underline{z}, \overline{z}\}$ such that

$$d \ln z_t = \theta(\mu - \ln z_t) dt + \sigma dW_t,$$

$$dz_t = \left\{ \theta(\mu - z_t) + \frac{1}{2}\sigma^2 \right\} z_t dt + \sigma z_t dW_t,$$

where $\theta > 0$, μ, and $\sigma > 0$ are parameters, and W_t denotes a Wiener process. The second equation of the shock process is derived from the first equation with Ito's lemma. The Ornstein-Uhlenbeck process is used because it is a continuous-time analogue of the discrete-time AR(1) process, which has been commonly used to describe idiosyncratic labor productivity shocks in the literature.

into the CF sector.

Lastly, the labor supply of households is constrained up to an exogenous limit, as follows:

$$n_{j,t} \leq \overline{n}_{j,t}$$

The labor supply constraint $\overline{n}_{j,t}$ is initially set to 1, at which no households bind, but it will be tightened to capture social distancing measures. When the social distancing measures intensify to curb the spread of a disease, business hours are limited and $\overline{n}_{j,t}$ can decrease in sector j.

B. *Equilibrium*

Given a sequence of interest rates and social distancing shocks, $\{r_t, \overline{n}_{j,t}, \psi_{c,t}\}$, let $c_{j,t}(z,a)$ and $n_{j,t}(z,a)$ denote the optimal consumption and labor supply flows at time t of a household in sector j with productivity z and assets a. Given $c_{j,t}(z,a)$ and $n_{j,t}(z,a)$, a household's assets a_t evolve according to the above law of motion. Let $g_{j,t}(z,a)$ denote the joint distribution of idiosyncratic productivity and the assets of households in sector $j \in \{FF, CF\}$ at time t. The transition of $g_{j,t}(z,a)$ over time is fully determined by the function $c_{j,t}(z,a)$ and $n_{j,t}(z,a)$. Equilibrium is defined as follows.

Definition. Given the initial distributions $\{g_{j,t=0}(z,a)\}_{j\in\{FF,CF\}}$, equilibrium is a sequence of interest rates $\{r_t\}$, a sequence of social distancing shocks $\{\overline{n}_{j,t}, \psi_{c,t}\}$, a sequence of consumption and labor supply flows $\{c_{j,t}(z,a), n_{j,t}(z,a)\}$, and a sequence of joint distributions of labor productivity and assets $\{g_{j,t}(z,a)\}_{j\in\{FF,CF\}}$ such that

(i) $c_{j,t}(z,a)$ and $n_{j,t}(z,a)$ are optimal given $\{r_t, \overline{n}_{j,t}, \psi_{c,t}\}$,

(ii) the joint distributions $\{g_{j,t}(z,a)\}_{j\in\{FF,CF\}}$ are consistent with the optimal consumption and labor supply flows, and

(iii) the asset market clears,

$$0 = \alpha \int_{\underline{a}}^{\infty} \int_{\underline{z}}^{\overline{z}} a g_{FF,t}(z,a) dz da + (1-\alpha) \int_{\underline{a}}^{\infty} \int_{\underline{z}}^{\overline{z}} a g_{CF,t}(z,a) dz da.$$

The optimal consumption and labor supply flows of households are derived from the following system of equations for $j \in \{FF, CF\}$:

$$\begin{aligned} \rho v_{j,t}(a,z) = & \max_{\{c_t, n_t\}} \psi_{c,t} \frac{c_{j,t}^{1-\gamma}}{1-\gamma} + \psi_n \frac{(1-n_{j,t})^{1-\eta}}{1-\eta} + \lambda_t(\overline{n}_{j,t} - n_{j,t}) \\ (HJB) \qquad & + (z n_{j,t} + r_t a - c_{j,t}) \cdot \partial_a v_{j,t}(a,z) + \partial_t v_{j,t}(a,z) \\ & + \mu(z) \cdot \partial_z v_{j,t}(a,z,t) + \frac{1}{2}\sigma^2(z) \cdot \partial_{zz} v_{j,t}(a,z), \end{aligned}$$

$$(BC) \quad \partial_a v_{j,t}(\underline{a},z) \geq \psi_{c,t}(zn_{j,t}(z,\underline{a}) + r_t\underline{a})^{-\gamma},$$

$$(FP) \quad \begin{aligned} \partial_t g_{j,t}(a,z) = -\partial_a\{s_{j,t}(a,z)\cdot g_{j,t}(a,z)\} - \partial_z\{\mu(z)\cdot g_{j,t}(a,z)\} \\ +\frac{1}{2}\partial_{zz}\{\sigma^2(z)\cdot g_{j,t}(a,z)\}, \end{aligned}$$

$$(Saving) \quad s_{j,t}(a,z) = zn_{j,t}(z,a) - r_t a - c_{j,t}(a,z),$$

$$(PDF) \quad 1 = \int_{\underline{a}}^{\infty}\int_{\underline{z}}^{\overline{z}} g_{j,t}(z,a)dzda,$$

$$(Assets) \quad \begin{aligned} 0 = \alpha\int_{\underline{a}}^{\infty}\int_{\underline{z}}^{\overline{z}} ag_{FF,t}(z,a)dzda \\ +(1-\alpha)\int_{\underline{a}}^{\infty}\int_{\underline{z}}^{\overline{z}} ag_{CF,t}(z,a)dzda. \end{aligned}$$

The above system of equations is solved numerically with a solution method introduced by Achdou *et al*. (2020) and its companion website (Moll, 2021).

C. *Calibration*

Baseline parameters are calibrated to match the Korean economy before the COVID-19 pandemic and are presented in Table 1. Time is discretized by a half quarter, 0.125 year. The borrowing constraint $\underline{a}$ is arbitrarily set to -0.5, which is slightly larger than the average yearly labor income in the initial steady state. The

TABLE 1—PARAMETER VALUES

Parameter	Explanation	Value	Target
$\underline{a}$	Borrowing constraint	-0.5	Arbitrary choice, slightly larger than the average yearly labor income
ρ	Time discounting rate	0.073	Interest rate r = 2.5%
γ	Curvature of the consumption utility function	2.0	Within the standard values in the literature
η	Curvature of the leisure utility function	1.47	Weighted average of Frisch elasticity = 1
ψ_n	Coefficient of leisure preference	2.45	The share of hours worked of the time endowment = 42.3%
θ	Coefficient of the idiosyncratic labor productivity process governing autocorrelation	0.09	Persistence of wage process in Floden and Linde (2001)
μ	Coefficient of the idiosyncratic labor productivity process governing the average value	0	Mean value of productivity normalized to 1
σ	Coefficient of the idiosyncratic labor productivity process governing the standard deviation	0.22	Variance of wage process in Floden and Linde (2001)
α	Share of the FF sector households	0.34	The share of employed persons in the FF sector in 2019

time discounting rate ρ is chosen to yield a yearly interest rate of 2.5% in the initial steady state. The relative risk aversion parameter γ is assumed to be 2.0, which is within the standard choices in the macroeconomics literature. The curvature of the leisure utility function η is 1.47, which matches the weighted average of Frisch elasticity to 1.0.[6] The coefficient of consumption preference is normalized to 1 in the initial steady state,[7] and that of leisure preference is 2.45 to match the average hours worked for households as 42.3% of their time endowment.[8] The labor supply constraint $\overline{n}_j$ for all sectors is set to 1 in the initial steady state,[9] at which no households are constrained. The continuous-time Ornstein-Uhlenbeck process parameters, θ and μ, are calibrated by matching the wage process in Floden and Linde (2001).[10] Lastly, the share of FF sector households is chosen to be 0.34 given that the share of those employed in the FF sector was 34% in 2019 in South Korea (Statistics Korea).[11]

Figure 2 presents households' policy functions in the initial steady state economy. The horizontal axes indicate household asset holdings a. Solid lines and dashed lines refer to the policy functions of households with high labor productivity ($z = 1.5$) and those with low labor productivity ($z = 0.5$), respectively.[12] The optimal labor supply functions are presented in the panel on the left in Figure 2. Thin and thick lines represent the labor supply (the share of time endowment) and the effective labor supply (the labor supply multiplied by labor productivity), respectively. Note that the effective labor supply is equal to labor income given the linear technology assumption in the model.

Longer hours for work are supplied either by households with insufficient assets due to an income effect or by households with greater labor productivity due to a substitution effect. For most values of a, the substitution effect dominates, and high-productivity households supply longer hours for work. As a is low enough, however, the income effect dominates and low-productivity households supply longer hours for work than high-productivity households. As households approach the borrowing constraint, borrowing for them becomes more restricted, and they depend more on labor income to smooth consumption. While high-productivity

[6]Given that labor supply elasticity has substantial heterogeneity in both the cross-section and over the business cycle (e.g., Attanasio *et al.*, 2018), I arbitrarily set the value to 1.0, which is within the range widely used in the literature.

[7]The coefficient of consumption preference changes over time due to the constrained consumption demand in Section 4.

[8]Time for sleep and personal care per week is assumed to be 70 hours. The average hours worked for those employed is 41.5 hours per week in 2019 in South Korea according to Statistics Korea. Thus, the share of hours worked of the time endowment is $41.5/(168-70) = 0.423$.

[9]The labor supply constraint changes over time due to the social distancing measures in Sections 3 and 4.

[10]Although Floden and Linde (2001) report idiosyncratic risks of the U.S. and Sweden, I follow their estimates because I cannot find reliable estimates of households' idiosyncratic risks for South Korea. The S80/S20 income quintile share in the model in the initial steady state, which is the share of all income received by the top quintile divided by the share of the first, is 5.9. Because the observed S80/S20 disposable income quintile share of South Korea in 2018 is 6.5 (OECD income distribution database; https://stats.oecd.org), the model seems to have lower levels of idiosyncratic risk than in the targeted Korean economy before the COVID-19.

[11]The face-to-face sector as defined here includes (1) wholesale and retail trade; (2) transportation and storage; (3) accommodation and food service activities; (4) arts, sports, and recreation related services; and (5) membership organizations, repair and other personal services.

[12]Two productivity levels are presented among others for expositional purposes. The model has a continuous labor productivity space, which is discretized into 16 grid points from $z_{min} = 0.37$ to $z_{max} = 2.72$ for the numerical computation.

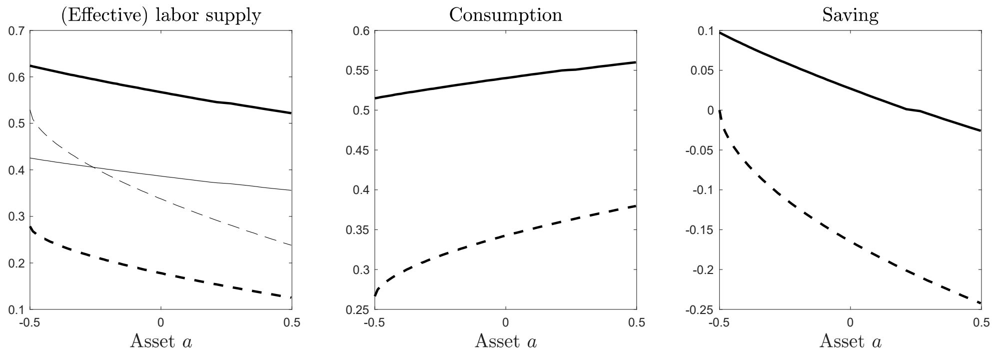


FIGURE 2. POLICY FUNCTIONS IN THE INITIAL STEADY STATE

households can earn sufficient labor income and even save the remaining income after consumption, low-productivity households cannot earn sufficient labor income to smooth consumption and need to increase their labor supply steeply. Note that the low-productivity households' consumption policy function shows steeper concavity for low values of a in the middle panel.

In the model, a household with low labor productivity successively for a long enough time hits the borrowing constraint because this household always chooses to borrow to consume. With this finite probability of hitting the borrowing constraint, the marginal distribution of asset holdings is bimodal, one peak at the borrowing constraint and another peak around at $a = 1$ due to precautionary savings. Figure A4 in the Appendix presents the endogenous marginal distributions of assets and labor productivities in the initial steady state. A sizable share of households can be found on the left side of the marginal asset distribution in the initial steady state. These households could be more susceptible to the labor supply constraint limiting the maximum hours for work, as discussed in the following section.

III. Constrained Labor Supply

Among the major social distancing measures implemented by the South Korean government to counteract COVID-19 are restrictions on business hours in the face-to-face (FF) sector. Depending on the level of the corresponding social distancing scheme, the government forces business sites with a high risk of infection to shut down or close at night. The government also imposes bans on gathering, which can decrease the maximum amount of effective labor supply and production in the FF sector. These restrictions are captured in the model by lowering the labor supply constraint in the FF sector, $\overline{n}_{FF,t}$.

To examine the effects of tightening the labor supply constraint, we assume that $\overline{n}_{FF,t}$ is reduced to 0.4 at $t = 0.125$, which is 68% of the largest optimal labor supply (0.584) in the initial steady state at $t = 0$.[13] This shock decreases the output

[13]A household's optimal labor supply does not exceed 0.584 in the initial steady state and thus $\overline{n}_{FF} > 0.584$ is not binding in the initial steady state.

of the FF sector by 8.8% for the first year after the arrival of the shock in the model, which is comparable to a 9.3% (YoY) decrease in the FF sector service production for the period from February of 2020 to December of 2020 in South Korea. We assume that the labor supply constraint shock is unanticipated at $t=0$, but the sequence of shocks is fully anticipated from $t=0.125$. Given the fact that production in the other sectors have remained intact or recovered rapidly in 2020, as shown in Figure A3 in the Appendix, we assume that the labor supply constraint for the contact-free (CF) sector never binds over time such that $\overline{n}_{CF,t}=1$ for all t.

In South Korea, employment and production in the FF sector fell sharply on February of 2020 and has remained stagnant since then without a sign of recovery,[14] which makes the persistent labor constraint shock a plausible assumption for the long-lasting social distancing measures. Specifically, the following labor constraint shock process is assumed:

$$\overline{n}_{FF,t}=0.584-(0.584-0.4)\cdot\frac{\exp\left(\dfrac{(T-t)}{\tau}\right)}{\exp\left(\dfrac{(T-1)}{\tau}\right)}\quad \textit{for}\ t\geq 0.125,$$

where $\tau>0$ is a parameter governing the mean lifetime of the shock and T is the last period that is long enough for $\overline{n}_{FF,t}$ to converge to the initial level. As households expect the social distancing measures will last longer, τ becomes larger. In the next section, a permanent shock with $\tau=\infty$ is examined as an extreme case, after which a transitory shock with $\tau=2$ is investigated.

A. *Case of a Permanent Shock*

Suppose that the labor supply constraint lasts forever ($\tau=\infty$). Figure 3 shows how households' optimal policy functions change with the permanent labor supply constraint. Dashed lines correspond to the policy functions in the initial steady state ($t=0$). Solid lines show the values immediately after the arrival of the shock ($t=0.25$), in which thick and thin solid lines refer to FF and CF sector households, respectively. Both a low ($z=0.5$, bottom lines) and a high ($z=1.5$, top lines) level of labor productivity are presented.

The effective labor supply of households who hold insufficient assets is binding to $\overline{n}_{FF,t}$, as indicated by the flattened thick solid lines in the left panel of Figure 3. Given the expectation that the labor supply of FF sector households is binding to $\overline{n}_{FF,t}$ over time, these households choose to supply longer hours for work and increase their precautionary savings when their labor supply constraint is not binding.

The expected permanent income of the FF sector households decreases with the constraint and these households are therefore forced to cut their average consumption

[14]See Figures A1 and A2 in the Appendix.

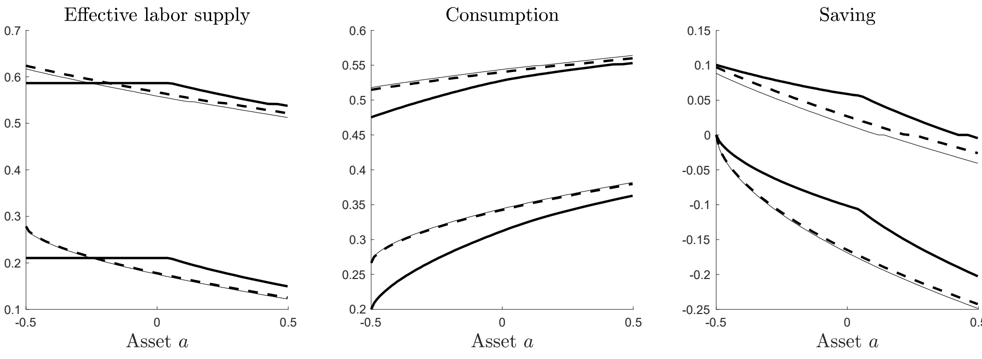


FIGURE 3. POLICY FUNCTIONS WITH A PERMANENT LABOR CONSTRAINT SHOCK

level, which can be seen in the middle panel. Their optimal consumption decisions become more concave. This implies that their consumption volatility over time increases given the idiosyncratic productivity shocks, causing their precautionary saving motive also to rise. The savings of FF sector households, thus, increase for all a in the right panel.

In contrast to FF sector households, CF sector households enjoy the fall of the equilibrium interest rate due to the increased savings of the FF sector households. Thus, the CF sector households, as indicated by thin solid lines, slightly decrease their labor supply in the left panel, increase consumption in the middle panel, and decrease savings in the right panel.

Changes in aggregate variables over time are presented in Figure 4. Units of the vertical axes are the percentage deviations from the initial steady state, except for the right panel of the interest rate, where units of the vertical axis are the percentage-point interest rate level. Note that the aggregate consumption in this economy is equal to the aggregate output (GDP) because the net aggregate saving is zero.

We can observe that both the GDP in the left panel and interest rates in the right panel fall immediately when the shock to $\overline{n}_{FF,t}$ arrives at $t = 0.125$. The labor supply constraint shock decreases the expected permanent income of FF sector households and hence aggregate consumption plunges. As explained above, FF sector households, who hold insufficient assets, cannot supply their optimal hours

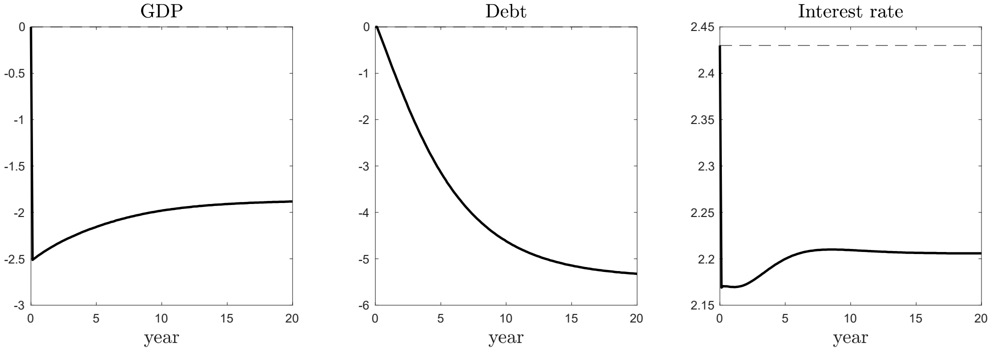


FIGURE 4. AGGREGATE VARIABLES WITH A PERMANENT LABOR CONSTRAINT SHOCK

for work due to the social distancing measures; they decrease their consumption steeply and hence save more or borrow less to prepare for the rising consumption volatility. Other FF sector households, who hold sufficient assets, also anticipate binding to the constraint over time and save more in order to smooth consumption. These increased savings of FF sector households push down the equilibrium interest rate. Note that consumption by FF sector households decreases more than their income due to the rising precautionary saving motive and that the aggregate debt continues to fall over time until FF sector households accumulate their optimal levels of precautionary savings. GDP is also suppressed until that time.

Distributional effects of the social distancing measures can be observed in Figure 5. Similar to the figures above, dashed lines represent the initial steady state distribution, and thick and thin solid lines refer to the distributions of the FF sector households and those of the CF sector households immediately after the shock at $t = 0.25$, respectively.

The labor income distribution of the FF sector households, indicated by the thick solid line in the left panel, shifts to the left while its right tail remains mostly intact. This leftward shift mainly derives from households whose labor supply levels are constrained by the social distancing shock. Note that in Figure 3, FF sector households whose labor supply is not restricted indeed increase their labor supply due to a precautionary saving motive. The capital income distributions for all households in the middle panel barely changes, but the right tails of the distributions are slightly pushed down due to the decline in the interest rate. Overall, the total income distribution of FF sector households in the right panel shows a leftward shift, while the corresponding right tail remains mostly unchanged.

This increase in income inequality indicated by the thickening of the left tail of the household income distribution in the model is in line with observations in South Korea in 2020. Figure 6 shows the changes in household income by income decile. Incomes of the first and the second deciles decrease by 13.8% and 9.8%, respectively, comparable to that in the first quintile (-9.1%) in Figure 1. The model also generates uneven decreases in income; the lower the decile is, the more the income decreases. The two highest income deciles in Figure 6 show significantly smaller changes, -1.2% for the ninth decile and -2.2% for the tenth decile. In sum, given the labor supply constraint, the model can generate quantitatively plausible numbers indicating the rising income inequality.

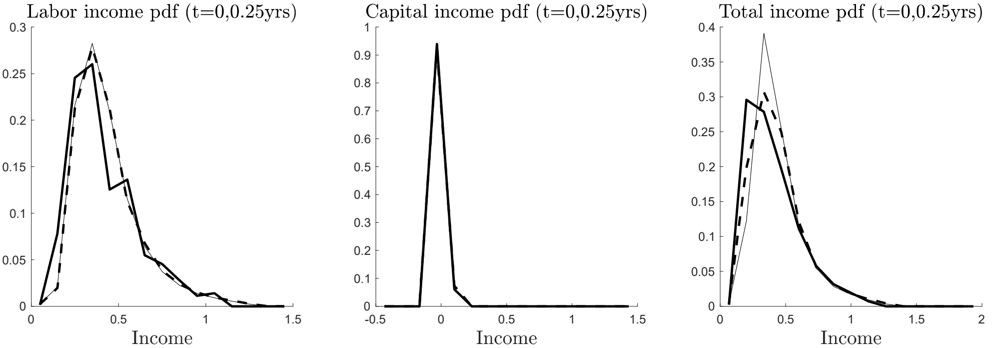


FIGURE 5. INCOME DISTRIBUTIONS WITH A PERMANENT LABOR CONSTRAINT SHOCK

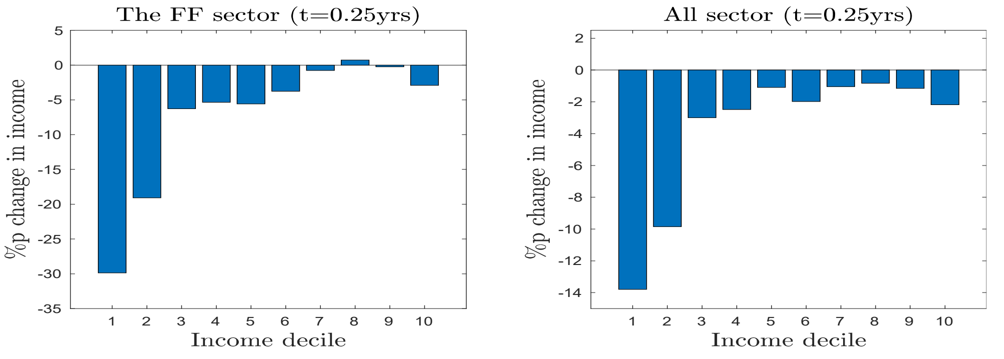


FIGURE 6. CHANGES IN INCOME BY INCOME DECILE WITH A PERMANENT LABOR CONSTRAINT SHOCK

B. *Case of a Transitory Shock*

In this section, we consider the case of a transitory shock. Here, we assume that the labor supply constraint in the FF sector $\overline{n}_{FF,t}$ is reduced to 0.4 at $t = 0.125$ and that $\overline{n}_{FF,t}$ recovers to its initial level exponentially past that point with $\tau = 2$.

Changes in households' policy functions are presented in Figure 7. Dashed lines, thick solid lines, and thin solid lines refer to the initial steady state policy functions, the FF sector households' policy functions immediately after the arrival of the shock at $t = 0.25$, and the CF sector households' policy function at $t = 0.25$, respectively. The bottom and top lines represent households with low labor productivity ($z = 0.5$) and high labor productivity ($z = 1.5$), respectively.

Because the shock is transitory, the expected permanent income of households changes little. Only low-productivity FF sector households holding insufficient assets are forced to cut their consumption sizably, as they cannot earn sufficient labor income due to the labor supply constraint shock, as indicated in the bottom left of the middle panel in Figure 7. High-productivity FF sector households with insufficient assets, however, do not reduce their consumption despite the fact that they are also binding to the labor supply constraint, as they can earn sufficient labor income to smooth consumption. The panel on the right shows that these households save less and smooth consumption given the expectation that the shock is transitory.

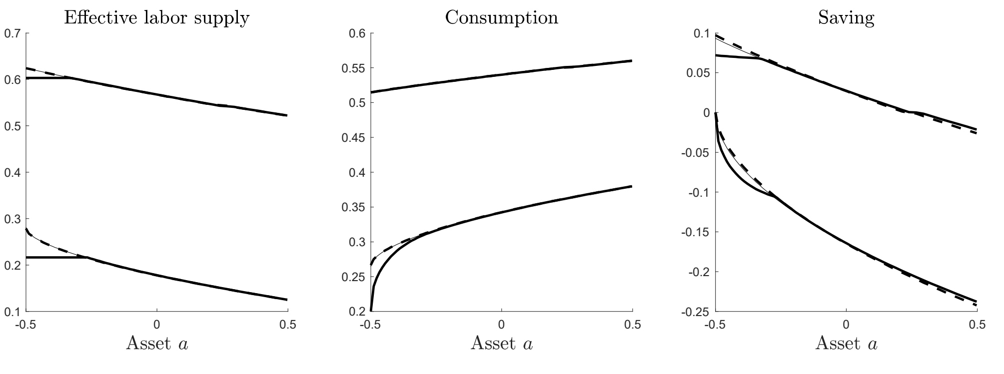


FIGURE 7. POLICY FUNCTIONS WITH A TRANSITORY LABOR CONSTRAINT SHOCK

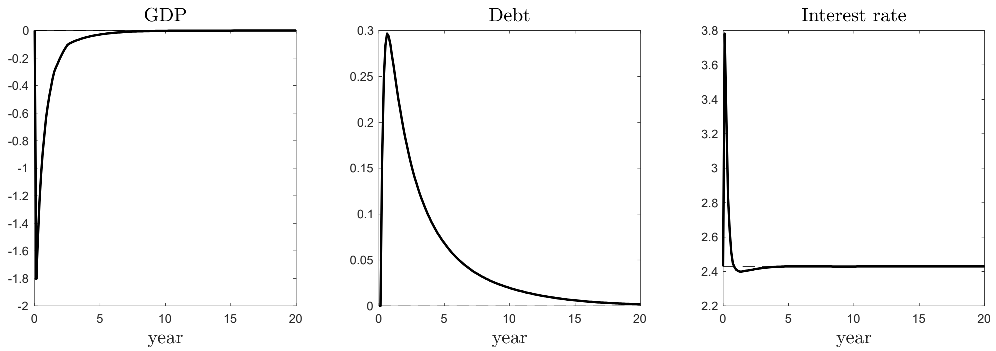


FIGURE 8. AGGREGATE VARIABLES WITH A TRANSITORY LABOR CONSTRAINT SHOCK

In contrast, FF sector households with sufficient assets, whose labor supply is not binding, increase their savings slightly due to a rising precautionary saving motive as well as the increased equilibrium interest rate, which will be explained below.

Figure 8 shows the changes in aggregate variables over time. Units of the vertical axes are the percentage deviations from the initial steady state, except for the right panel of interest rates, where units of the vertical axis are the interest rate level. When the shock hits the economy at $t = 0.125$, GDP falls and the interest rate increases. Given the sizable population of households who are net debtors or have small levels of assets in equilibrium,[15] the main driver of the change in the interest rate is the decrease in savings or increase in borrowing by households with insufficient assets. This rising demand for borrowing increases the aggregate debt in the middle panel and pushes up the equilibrium interest rate in the right panel.[16] Note that the rising aggregate debt level is deleveraged and converges to the initial level much more slowly than other aggregate variables, such as the GDP and interest rate, which implies that the distributional impacts of the social distancing shock can last longer even after the shock itself is dissipated.

Similar to the previous permanent labor supply constraint shock, the transitory labor constraint shock also increases the dispersion of income distributions. In Figure 9, dashed lines indicate the income distributions in the initial steady state, and thick and thin solid lines refer to the income distributions of the FF and the CF sector households, respectively, at $t = 0.25$. The thick solid line in the panel on the left shifts to the left with its right tail fixed because low-income households in the FF sector cannot increase their labor supply due to the constraint. In contrast to the previous case, however, the right tails of the capital income distributions in the middle panel are inflated owing to the rising interest rate.

Figure 10 shows that the lower the income decile is, the greater the decrease in households' income becomes, similar to the previous case of the permanent shock. The only qualitative difference between the permanent and transitory cases is that the highest income quantile households benefit from the rising capital income in the

[15]Figure A4 in the Appendix shows the marginal distributions of the initial steady state.

[16]See Figure A5 in the Appendix for the impact of the shock on interest rates with different values of τ. The responses of the interest rate converge from that with a transitory labor supply constraint shock to that with a permanent shock as τ increases.

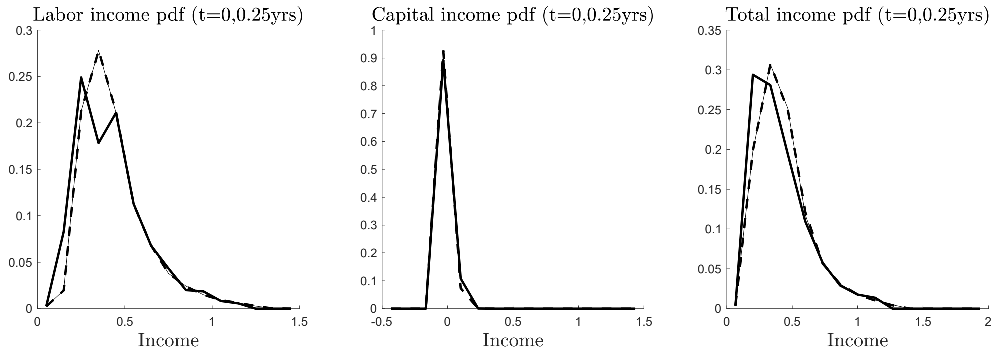


FIGURE 9. INCOME DISTRIBUTIONS WITH A TRANSITORY LABOR CONSTRAINT SHOCK

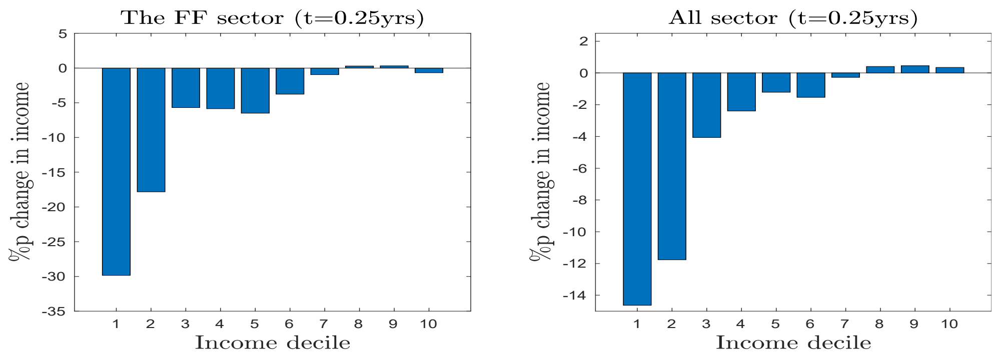


FIGURE 10. CHANGES IN INCOME BY INCOME DECILE WITH A TRANSITORY LABOR CONSTRAINT SHOCK

transitory case, as indicated by the increases in income of the eighth, ninth, and tenth income deciles in Figure 10.

IV. Sectoral Asymmetry and Constrained Consumption Demand

In the previous section, the labor supply constraint is applied only to FF sector households, whose population share α is 34% in the baseline calibration. Although the rising income inequality in the model derives from changes in income within the FF sector households, a part of the result still may stem from the sectoral asymmetry of the labor supply constraint in the model. To address this issue, we examine the effects of symmetric shocks by assuming that both $\overline{n}_{CF,t}$ and $\overline{n}_{FF,t}$ are reduced to 0.4 at $t = 0.125$ and then converge exponentially to the initial level with $\tau = 2$.

Figures 11 and 12 present changes in households' optimal behaviors and changes in households' total income by income decile, respectively. As shown in these figures, every result with the symmetric constraint ($\overline{n}_{CF,t} = \overline{n}_{FF,t} = 0.4$ at $t = 0.125$) is nearly identical to that with the asymmetric constraint ($\overline{n}_{CF,t} = 1$ for all t), which can be seen in Figures 7 and 10. The only prominent difference between the two

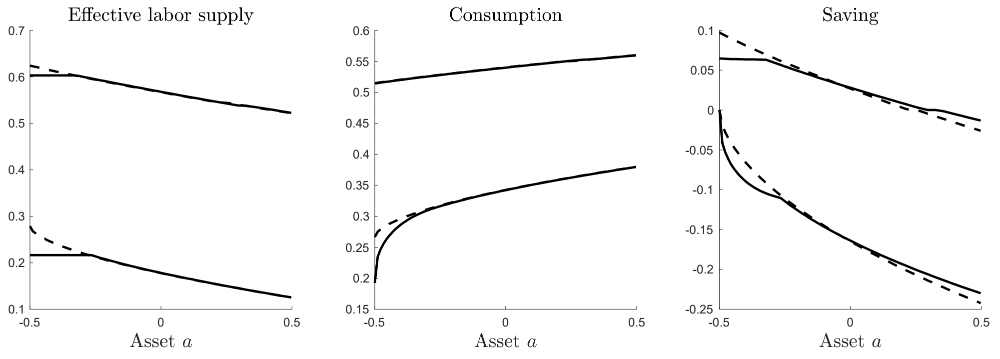


FIGURE 11. POLICY FUNCTIONS WITH A SYMMETRIC, TRANSITORY LABOR CONSTRAINT SHOCK

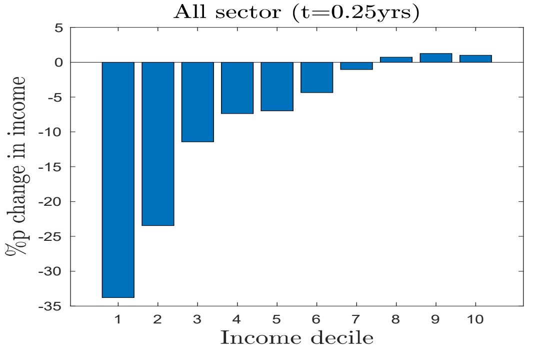


FIGURE 12. CHANGES IN INCOME BY INCOME DECILE WITH A SYMMETRIC, TRANSITORY LABOR CONSTRAINT SHOCK

cases is the size of the responses; this stems from the differences in how many households are subject to the constraint.

Lastly, we consider another prominent feature of social distancing shocks: distorted consumption demand. As households have decreased outdoor activities and avoided face-to-face interactions, their sectoral consumption changed abruptly in 2020.[17] These changes in consumption behaviors imply that households cannot optimize their consumption basket as before and are thus likely to experience a decline in the marginal utility of consumption with the shrinking feasible consumption set (Carroll *et al.*, 2020). In this case, the social distancing measures could be understood as a demand shock.

To capture this consumption demand shock, we assume that the consumption preference coefficient, $\psi_{c,t}$, is decreased by 8% at $t = 0.125$ and is recovered

[17]The left panel of Figure A3 in the Appendix shows that monthly sales index of semi-durable goods, mostly apparels, decreased by 32% due to restricted outings in March of 2020 compared to the corresponding month of the previous year, while sales of durable goods increased in 2020. The composite consumer sentiment index (CCSI) also decreased sharply right after the outbreak of COVID-19 and has shown a slow recovery thus far as of February of 2021. The panel on the right in Figure A3 shows that the shares of households' nominal consumption expenditures changed abruptly in 2020. Expenditures of the face-to-face sector include households' consumption abroad. Note that households have been effectively prohibited from traveling abroad since March of 2020, and their overseas consumption fell sharply; this represents one of the sizable components of household consumption in South Korea.

exponentially with $\tau = 2$ past that point.[18] We also assume that the shock is unanticipated at $t = 0$ but is fully anticipated from $t = 0.125$. The size of the shock is chosen to match the observed difference of -2.4%p (YoY) in the growth rate of the monthly retail sales index for the period from February of 2020 to December of 2020.[19]

With this transitory consumption demand shock, every household reduces its consumption, saves more with unused income, and supplies shorter hours for work to enjoy more leisure. As can be seen in Figure 13, households who hold sufficient assets decrease their consumption more than households who hold insufficient assets, as rich households have a lower marginal utility of consumption and are more sensitive to the diminishing marginal utility of consumption. This is in stark contrast to the results from the labor supply constraint shocks observed in Figures 3 and 7. As households consume less and save more, aggregate consumption (GDP) falls, aggregate debt shrinks, and the interest rate falls, which can be seen in Figure A6 in the Appendix.

The effects of the constrained consumption demand shock on labor income distributions are not asymmetric in that every household reacts to the demand shock in the same way. Figure 14 shows that the demand shock decreases income for every

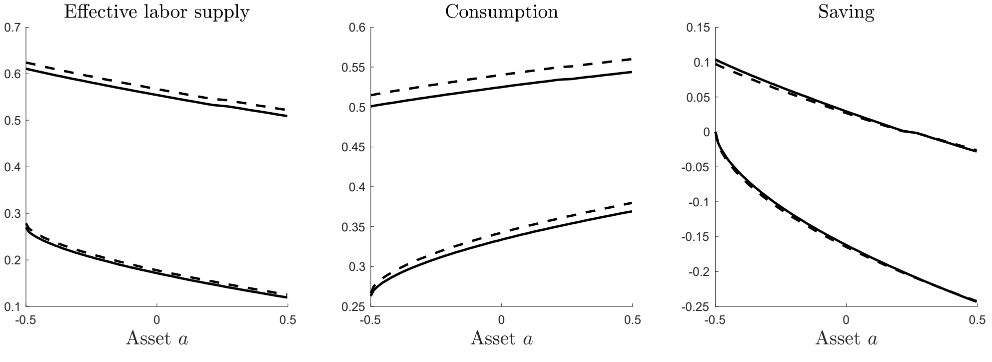


FIGURE 13. POLICY FUNCTIONS WITH A CONSTRAINED CONSUMPTION DEMAND

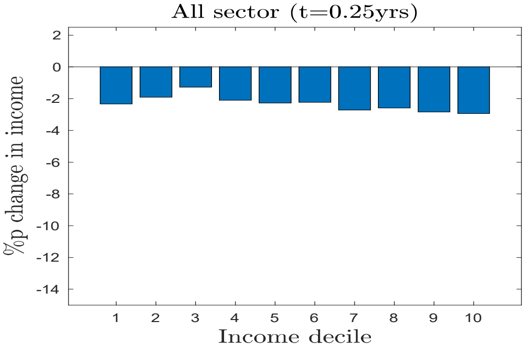


FIGURE 14. CHANGES IN INCOME BY INCOME DECILE WITH A CONSTRAINED CONSUMPTION DEMAND

[18]The shock process of $\psi_{c,t}$ is defined as follows: $\psi_{c,t} = 1 - 0.08 \cdot \frac{\exp\left(-\frac{(t-T)}{\tau}\right)}{\exp\left(-\frac{(1-T)}{\tau}\right)}$ for $t \geq 0.125$.

[19]This preference shock lowers aggregate consumption by 2.45% in the model for the first year after the shock, comparable to observed data.

income decile. This implies that the constrained consumption demand by itself cannot readily explain the observed rise in income inequality during the COVID-19 pandemic, which features larger decreases in incomes of poor households.

V. Conclusion

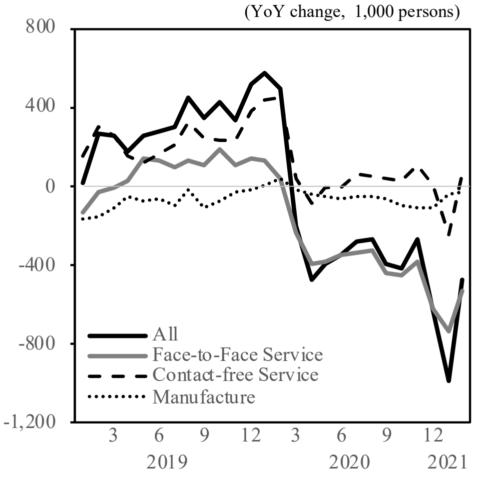
This paper sheds light on how the constrained labor supply imposed by social distancing measures can increase households' income inequality despite the fact that social distancing per se is not directly related to households' income levels. An off-the-shelf heterogeneous-agent incomplete-market model is used to show that the labor supply constraint can increase the income inequality of households by mainly restricting the labor supply of low-income households, who need income the most due to their insufficient asset holdings given a borrowing constraint. The rising income inequality in the model derives from changes in the income distribution within the face-to-face sector, in which households are subject to the constraint.

The model also shows that households' expectations about the longevity of the social distancing measures affect the responses of aggregate variables such as the equilibrium interest rate. If households expect a persistent labor constraint shock, they cut their consumption and save more in order to prepare for the increased consumption volatility in the long run, and the interest rate can tumble. In contrast, when a labor constraint shock is expected to be transitory, households smooth their consumption by borrowing more, and the interest rate can shoot up due to the growing aggregate debt in the short run. This implies that we can observe an interest rate hike with a recovery of consumption at the time when the expectation that social distancing measures will end forms.

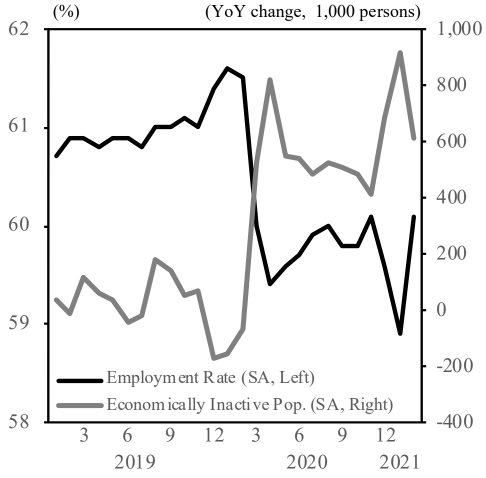
Given the observation that poor households asymmetrically suffer from decreases in income due to social distancing measures, a government transfer scheme could be an effective complementary measure. In future research, several policies could be examined with the model to find an optimal transfer scheme that alleviates the side effects of social distancing measures.

To focus on the direct effects of labor supply shocks due to mandatory social distancing measures, this paper abstracts from sectoral differences in consumption goods. This parsimonious modeling choice leaves many questions unanswered. For instance, voluntary social distancing due to the fear of infection can asymmetrically decrease consumption demand in the face-to-face sector and result in a collapse in the labor demand level in this sector. This demand shock channel could be quantitatively important and potentially intertwined with the labor supply shock channel. Krueger *et al*. (2020) argue that the COVID-19 shocks concentrated in the face-to-face sector could be substantially mitigated if households elastically shift their consumption across sectors. On the other hand, Guerrieri *et al*. (2020) show that sectoral supply shocks concentrated in the face-to-face sector can trigger an extra aggregate demand shortage given that the degree of substitution across sectors is low enough or that the intertemporal elasticity of substitution is high enough.

APPENDIX



(a) Changes in the number of employed

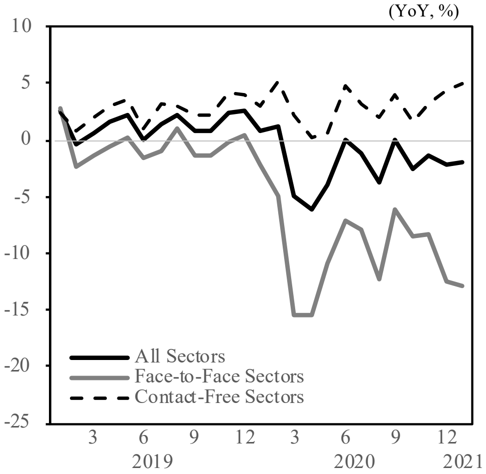


(b) Employment rate and the Econ. Inactive Pop.

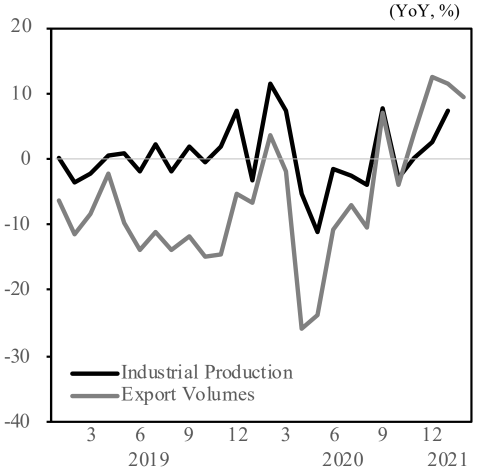
FIGURE A1. EMPLOYMENT VARIABLES

Note: The face-to-face sector includes (1) wholesale and retail trade; (2) transportation and storage; (3) accommodation and food service activities; (4) arts, sports, and recreation related services; and (5) membership organizations, repair and other personal services. The contact-free sector includes all other categories.

Source: KOSIS (Last Access Date: 2021. 3. 19). All employment variables are monthly and were acquired from the Economically Active Population Survey, Statistics Korea.



(a) Service production by sector

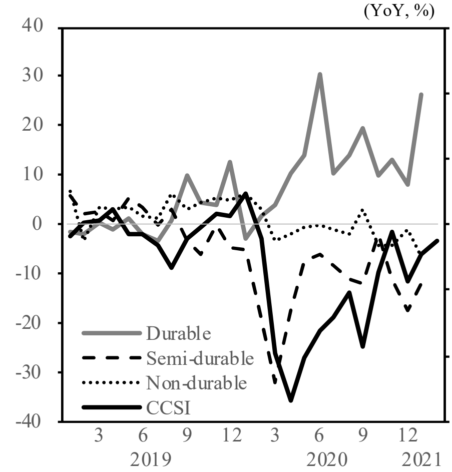


(b) Industrial production and export volumes

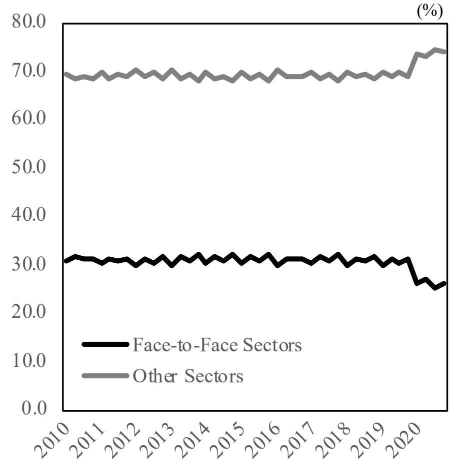
FIGURE A2. SERVICE AND INDUSTRIAL PRODUCTION

Note: The face-to-face sector includes (1) wholesale and retail trade; (2) transportation and storage; (3) accommodation and food service activities; (4) arts, sports, and recreation related services; and (5) membership organizations, repair and other personal services. The contact-free sector indicates all other categories.

Source: KOSIS; KITA (Last Access Date: 2021. 3. 19). Monthly indices of service productions by sector in the left panel are acquired from the Monthly Service Industry Survey, Statistics Korea. Monthly industrial production index and export volumes in the panel on the right are acquired from Monthly Survey of Mining and Manufacturing, Statistics Korea and from KITA, respectively.



(a) Retail sales indices and CCSI

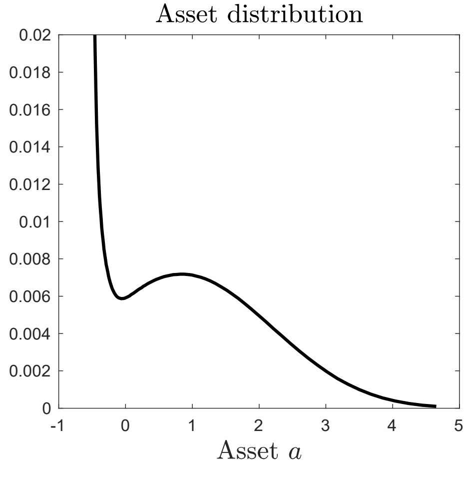


(b) Share of HH's sectoral nominal consumption expenditure

FIGURE A3. RETAIL SALES, COMPOSITE CONSUMER SENTIMENT INDEX (CCSI), AND THE SHARE OF HOUSEHOLDS' SECTORAL NOMINAL CONSUMPTION EXPENDITURES

Note: Face-to-face sectors are defined by the sum of sectors experiencing decreases in 2020 exceeding a standard deviation of one and a half.

Source: KOSIS; ECOS (Last Access Date: 2021. 3. 19). Monthly retail sales indices and CCSI data in the left panel are acquired from the Monthly Service Industry Survey, Statistics Korea and from the Consumer Survey Index, Bank of Korea, respectively. The share of households' sectoral nominal consumption expenditures in the panel on the right is calculated with data acquired from Final Consumption Expenditure of Household by Purpose, Bank of Korea.



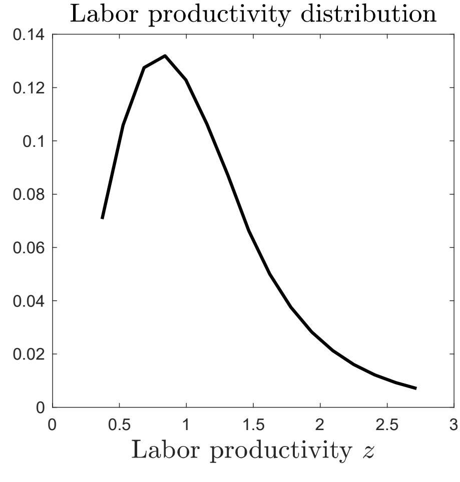


FIGURE A4. MARGINAL DISTRIBUTIONS IN THE INITIAL STEADY STATE

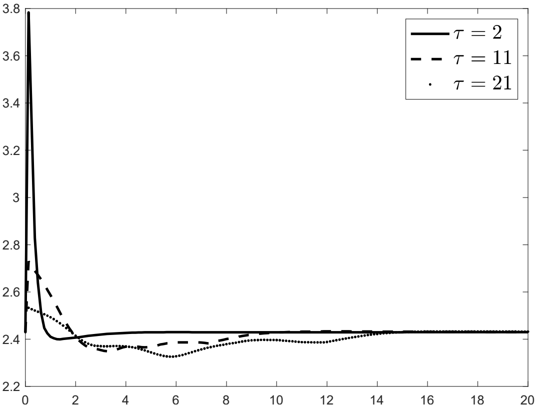


FIGURE A5. CHANGES IN INTEREST RATE RESPONSES FROM TRANSITORY TO PERMANENT SHOCKS WITH MEAN LIFETIME τ

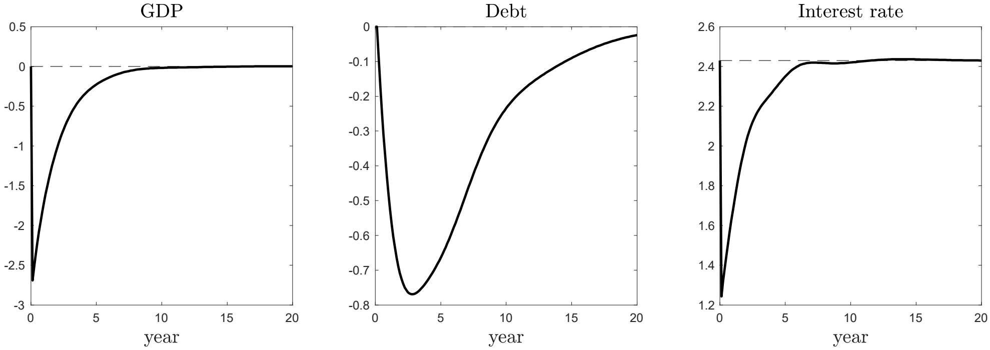


FIGURE A6. AGGREGATE VARIABLES WITH A CONSTRAINED CONSUMPTION DEMAND

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