Macroeconomic Impacts of COVID-19 and Policy Responses: The Case of Korea

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Motivation

- COVID-19 critically damaged global economy...
  - Macro aggregates: output, consumption and export have declined
  - Labor market: employment and wages decreased
  - Inequality: Reported that income and wealth distribution worsened
- However, difficult to analyze the propagation of the pandemic shock due to various channels that interact with each other
  - consumption shortage due to 'fear of infection'
  - decline in labor supply due to infection and lockdown
  - work from home (WFH)
  - various policy tools simultaneously target quarantine and stimulus

This Paper

- Question
  - What are the macroeconomic impacts of the pandemic?
    - consumption, labor market...
    - inequality
  - What are the impacts of government's COVID-19 relief policies?
    - Roles of transfers
- How?
  - New Keynesian model with many households
    - unique situation in Korea allows such method
    - allows adding various features and estimating the model

Main Takeaways

- model matches key features of epidemiological and macroeconomic dynamics
  - endogenous rise in the confirmed cases in the second half of 2020
  - sharp decline in economic activity followed by a temporary recovery caused by KEIP program
- modest consumption multiplier of KEIP
  - stimulated economic activity
  - did not disturb prevention of the pandemic

Model
Households

- five families of households that are ex-ante heterogeneous
  - steady state asset holdings, labor types (regular(permanent) and irregular(temporary) jobs)

- differentiate families $i \in \{1, 2, 3, 4, 5\}$ based on their net asset position

  - family $i = 1$ consists of the households belong to the first quintile in the net asset position across the entire households (Survey of Household Finances and Living Conditions)

Model

Households

- maximizes their life-time utility

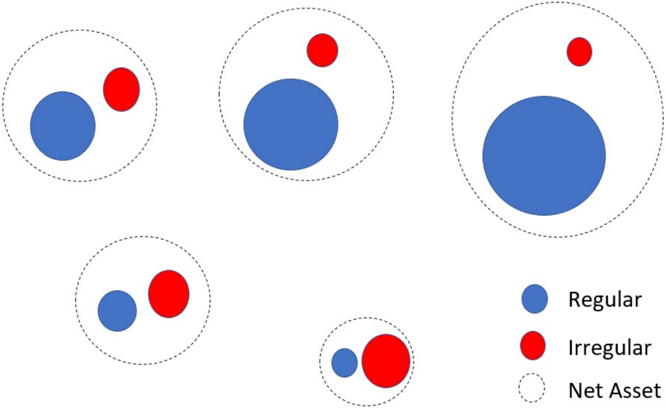
$$\max E \sum_{t=0}^{\infty} \beta^t \psi_t' [\ln(c_{it} - hc_{it-1}) - \chi N_{it}] \tag{1}$$

- subject to the budget constraint:

$$c_{it} + \frac{B_{it}}{P_t R_t} = \frac{B_{it-1}}{P_t} + w_t^r (1-\tau_t) N_{it}^r + w_t^{ir} (1-\tau_t) N_{it}^{ir} + \phi(1 - N_{it}^r - N_{it}^{ir}) + d_{it} + T_{it} \tag{2}$$

- assume that the first quintile family is hand-to-mouth

$$c_{1t} = \frac{b_{1t-1}}{\pi_t} - \frac{b_t}{R_t} + w_t^r (1-\tau_t) N_{1t}^r + w_t^{ir} (1-\tau_t) N_{1t}^{ir} + \phi(1 - N_{1t}^r - N_{1t}^{ir}) + d_{1t} + T_{1t} \tag{3}$$


Regular
Irregular
Net Asset

Model

Aggregate goods producer

- From the aggregate goods producer's problem:

$$Y_t = \left(\int_0^1 Y_t(j)^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \tag{4}$$

- Resulting aggregate price index:

$$P_t = \left(\int_0^1 P_t(j)^{\frac{1}{1-\eta}} \right)^{1-\eta} \tag{5}$$

Model

Retail goods producers

- continuum of retailers produce a differentiated goods using a homogeneous intermediate good

$$Y_t(j) = X_t(j) \tag{6}$$

- subject to the quadratic adjustment cost:

$$Ad_t(j) = \frac{\Omega_p}{2}\left(\frac{P_t(j)}{\pi P_{t-1}(j)} - 1\right)^2 Y_t \tag{7}$$

- maximizes her expected discounted profit shown below

$$\max_{P_t(j)} E_t \sum_{i=0}^{\infty} \frac{\beta^i \Lambda_{t+i}}{\Lambda_t}\left[\left(\frac{P_{t+i(j)}}{P_{t+i}} - q_{t+i}\right) Y_{t+i}(j) - Ad_{t+i}(j)\right] \tag{8}$$

Model

Labor market and Intermediate goods producers

- two types of intermediate goods producers: producers employing a regular worker (denoted by superscript r) and those employing an irregular one (denoted by superscript ir)

$$x_t = x_t^r + x_t^{ir} \tag{9}$$

  - differs by their separation ratio
  - separation ratio is larger for irregular workers

- The intermediate goods producers hire a worker to produce the intermediate goods

$$x_t^j = z_t^j, \quad j \in [r, ir] \tag{10}$$

Model

Labor market and Intermediate goods producers

- exists a matching friction

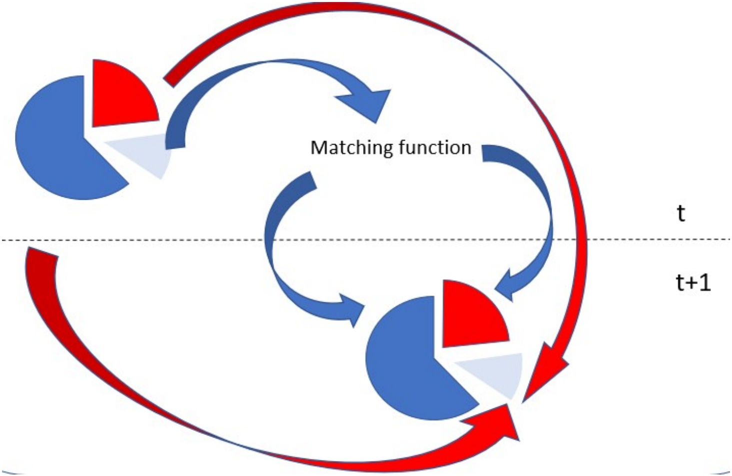
$$m_t^j = \mu u_t^\alpha (v_t^j)^{1-\alpha} \tag{11}$$

$$q_t^{v,j} = \frac{m_t^j}{v_t^j} \tag{12}$$

$$q_t^{u,j} = \frac{m_t^j}{u_t} \tag{13}$$

$$N_t^j = (1 - \rho^j) N_{t-1}^j + m_t^j, \quad j \in \{r, ir\} \tag{14}$$

$$u_t = 1 - (1 - \rho^r) N_{t-1}^r - (1 - \rho^{ir}) N_{t-1}^{ir} \tag{15}$$


Matching function
t
t+1

Model

Policies

- Monetary policy rule

$$R_t = r\pi \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_y} \tag{16}$$

- Government budget constraint

$$\phi(1 - N_t) + T_t + G_t + \frac{B_{t-1}}{P_t} = \frac{B_t}{P_t R_t} + \tau_t w_t^r N_t^r + \tau_t w_t^{ir} N_t^{ir} \tag{17}$$

- tax policy

$$\tau_t = \tau \left(\frac{b_{t-1}}{b}\right)^{\delta^b} \tag{18}$$

Model
Market clearing

aggregate resource constraint

$$c_t + G_t + \kappa v_t + \frac{\Omega_p}{2}\left(\frac{\pi_t}{\pi} - 1\right)^2 Y_t = Y_t \tag{19}$$

$$c_t = \sum_i c_{it} \tag{20}$$

bond market clearing

$$B_t = \sum_i B_{it} \tag{21}$$

aggregate production function

$$Y_t = \sum_j z_t^j N_t^j \tag{22}$$

COVID-19
Epidemiological block

- introduce additional features into the above benchmark model to analyze the impact of COVID-19 pandemic
  1. plug a version of Susceptible-Infectious-Recovered (SIR) framework in the benchmark model
  2. add a number of interactions between epidemic and economic variables

SIR framework

- A period corresponds to a month
- assume that the recovered immediately becomes susceptible...
  1. multiple reports that a person who is recovered from COVID-19 gets infected again (WHO, 2020)
  2. rely on a usual first-order approximation $\rightarrow$ steady state should remain unchanged
  3. confirmed cases in South Korea very small (approximately less than 0.2% of the population) $\rightarrow$ strict distinction between the recovered from the susceptible is not essential in terms of quantitative evaluations

SIR framework (2)

- The laws of motion for susceptible and infectious

$$I_{t+1} = I_t(1 - rc) + \iota_t S_t \tag{23}$$

$$S_t = 1 - I_t \tag{24}$$

- rc, I_t, S_t and ι_t: recovery rate, the number of infectious and susceptible people and transmission rate
- transmission rate determined by the basic transmission rate and economic variables, such as aggregate consumption and effective labor supplies

$$\iota_t = \tilde{\iota}_t \left(\frac{c_{t-1}}{c}\right)^{\nu} \left(\frac{\tilde{N}^r_{t-1}}{N^r}\right)^{\nu'_r} \left(\frac{\tilde{N}^{ir}_{t-1}}{N^{ir}}\right)^{\nu'_{ir}} \tag{25}$$

$$\tilde{\iota}_t = \rho^{\iota}\tilde{\iota}_{t-1} + \varepsilon_t \tag{26}$$

- $\tilde{\iota}$: basic transmission rate

$$\tilde{N}^j_t = (1 - \omega^j_t)N^j_t \tag{27}$$

SIR framework (3)

- COVID-19 pandemic begins $\rightarrow$ basic transmission rate jumps due to the epidemic shock ε_t
- ω_t^j: ratio of employees of type j who work from home
- share of workers who stay at home $\uparrow$ $\rightarrow$ transmission rate $\downarrow$
- basic transmission rate $\tilde{\iota}_t$ $\rightarrow$ transmission rate when the interactions between the spread of pandemic and economic activities are ignored
    - Following Kaplan et al. (2020), basic transmission rate varies $\rightarrow$ capture transmission rate $\downarrow$ through learning about best-practice behavior such as wearing a face mask etc

Interactions between Epidemic and Economic Variables

- Besides SIR framework, impose a number of interactions between epidemic and economic dynamics
- productivities z^r and z^{ir} drops immediately when epidemic shock arrives
  - firms were not ready to implement work-from-home effectively at the beginning of the pandemic
  - previous studies introduce similar mechanisms that result in a drop in labor productivity (e.g., Kaplan et al., 2020)
- consumer taste for consumption ψ_t drops either
  - explain the consumption dynamics that is caused by behaviors of consumers (fear of infection)

$$z_t^j = \rho^{z,j} z_{t-1}^j + \varepsilon_t^{z,j} - \delta^{z,j}\varepsilon_t \tag{28}$$

$$\psi_t = \rho^{\psi}\psi_{t-1} + \varepsilon_t^{\psi} + \delta^{e}\varepsilon_t \tag{29}$$

- productivity loss from work-from-home (Aum et al., 2021)
  - proportion of employees who work from home (ω_t^j)
  - efficiency loss compared to on-site work (δ_j^{ω})

Interactions between Epidemic and Economic Variables (2)

- proportion of employees work remotely → react to transmission rate

$$\omega_t^j = \delta_j \hat{\iota}_t, \quad j \in \{r, ir\} \tag{30}$$

$$z_t^{j,e} = z_t^j (1 - \delta_j^\omega \omega_t^j) \tag{31}$$

- number of infectious ↑ → numbers of effective labor supplies for both types of jobs and effective number of households seeking a job ↓ (e.g., Eichenbaum et al., 2020; Bayer et al., 2020; Kaplan et al., 2020)

$$N_t^{j,e} = N_t^j - N^j I_t, \quad j \in \{r, ir\} \tag{32}$$

$$u_t^e = u_t - (1 - N^r - N^{ir}) I_t \tag{33}$$

$$Y_t = \sum_j z_t^{j,e} N_t^{j,e}, \quad j \in \{r, ir\} \tag{34}$$

$$m_t^j = \mu (u_t^e)^\alpha (v_t^j)^{1-\alpha} \tag{35}$$

Estimation

- examine the impacts of COVID-19 outbreak and of fiscal measures $\rightarrow$ require estimation of the model
- estimate the parameters through three steps
  1. calibrated some of parameters related to long-run properties
  2. estimate the model without the epidemiological block using quarterly data
  3. fixing the parameters obtained in the previous step, parameters associated with the epidemiological block are estimated based on monthly data after February of 2020

First Step (1)

Parameter	Description	Value
β	Households' discount factor	0.99
ρ^r	job separation rate for regular jobs	0.0464
ρ^{ir}	job separation rate for irregular jobs	0.1014
c_1	consumption of 1st quintile family to output ratio	0.73×0.11
c_2	consumption of 2nd quintile family to output ratio	0.73×0.15
c_3	consumption of 3rd quintile family to output ratio	0.73×0.19
c_4	consumption of 4th quintile family to output ratio	0.73×0.23
c_5	consumption of 5th quintile family to output ratio	0.73×0.32
ξ_1	wealth share of 1st quintile family	-0.01
ξ_2	wealth share of 2nd quintile family	0.07
ξ_3	wealth share of 3rd quintile family	0.10
ξ_4	wealth share of 4th quintile family	0.20
ξ_5	wealth share of 5th quintile family	0.64

Table: Calibrated Parameters (1)

First Step (2)

Parameter	Description	Value
z^r	productivity of regular workers	1.1
z^{ir}	productivity of irregular workers	0.9
N	total number of employed workers	0.94
N^r	number of regular workers	0.77
N^{ir}	number of irregular workers	0.17
N_1^r	number of regular workers in 1st quintile family	0.108
N_2^r	number of regular workers in 2nd quintile family	0.140
N_3^r	number of regular workers in 3rd quintile family	0.162
N_4^r	number of regular workers in 4th quintile family	0.178
N_5^r	number of regular workers in 5th quintile family	0.184
N_1^{ir}	number of irregular workers in 1st quintile family	0.068
N_2^{ir}	number of irregular workers in 2nd quintile family	0.046
N_3^{ir}	number of irregular workers in 3rd quintile family	0.028
N_4^{ir}	number of irregular workers in 4th quintile family	0.014
N_5^{ir}	number of irregular workers in 5th quintile family	0.010

Table: Calibrated Parameters (2)

Second Step

- estimate the model without epidemiological block based on Bayesian technique
- using the quarterly data from 2000Q1 to 2019Q4 (consumption, government spending, consumer price index, unemployment rate, employment rate and government primary surplus)

Parameter	Prior			Posterior	
	Distribution	Mean	Stan. Dev.	Mean	90% CI
h	beta	0.5	0.2	0.18	[0.15, 0.22]
Ω_p	normal	112	10	114.41	[112.20, 116.49]
γ^r	beta	0.5	0.2	0.44	[0.42, 0.46]
γ^{ir}	beta	0.5	0.2	0.69	[0.62, 0.70]
$b^{r,n}$	beta	0.5	0.2	0.07	[0.03, 0.11]
$b^{ir,n}$	beta	0.5	0.2	0.23	[0.20, 0.26]
ϕ_π	gamma	1.5	0.2	1.68	[1.64, 1.73]
ϕ_y	gamma	0.25	0.1	0.07	[0.05, 0.09]

Table: Estimated Parameters

Third Step (1)

- Similar to the execution above for macroeconomic parameters, some of parameters are calibrated first before estimating the model
- estimate the model based on Bayesian technique using the monthly data from February 2020 to December 2020
- some of parameters discussed above which are related to persistence are re-calibrated accordingly
- use Google Mobility Report and the number of newly confirmed cases

Parameter	Description	Value
δ_r	response of share of regular WFH to transmission rate	228
δ_{ir}	response of share of irregular WFH to transmission rate	228
ν	response of transmission rate to consumption	0.0004
ν_r	response of transmission rate to regular labor supply	0.0009
ν_{ir}	response of transmission rate to irregular labor supply	0.0009
rc	recovery rate	2/3

Table: Calibrated Epidemic Parameters

Third Step (2)

Parameter	Prior			Posterior	
	Distribution	Mean	Stan. Dev.	Mean	90% CI
δ_r^ω	beta	0.3	0.2	0.02	[0.00, 0.05]
δ_{ir}^ω	beta	0.3	0.2	0.32	[0.31, 0.34]
ρ^ι	beta	0.7	0.1	0.71	[0.69, 0.73]
δ^e	normal	0	0.1	0.04	[0.03, 0.05]
δ^{zr}	gamma	0.01	0.1	0.06	[0.05, 0.07]
δ^{zir}	gamma	0.01	0.1	0.00	[0.00, 0.01]

Table: Estimated Epidemic Parameters

Simulation

- simulate the model to analyze the impact of the pandemic outbreak
- To do so, we feed a series of epidemic shocks

Month	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ε	x	0.06x	0.07x	0.06x	0.1x	0.26x	0.13x	0.13x	0.17x	0.28x	0.26x

Table: Epidemic shocks: x=0.00006

- inject a government transfer shock that represents Korean Economic Impact Payment (KEIP) program

Month	May	Jun	Jul	Aug
T_{1t}/Y	0.0045	0.0045	0.0045	0.0045
T_{2t}/Y	0.0045	0.0045	0.0045	0.0045
T_{3t}/Y	0.0045	0.0045	0.0045	0.0045
T_{4t}/Y	0.0045	0.0045	0.0045	0.0045
T_{5t}/Y	0.0045	0.0045	0.0045	0.0045

Table: Transfer shocks

Results

Macro impacts of COVID-19 (1)

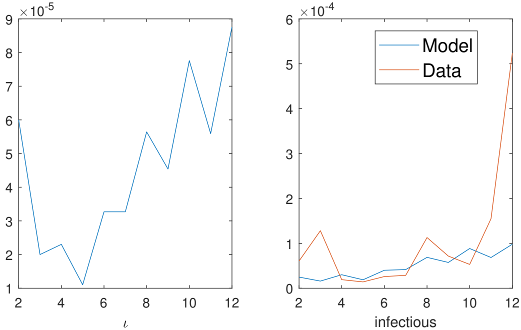


Figure: Dynamics of Epidemiological Variables

- closely related to economic activities
- simulated number of infectious captures the underlying movement of the actual observations
  - explains about 50% of confirmed cases in 2020 (65% except Dec.)

Results

Macro impacts of COVID-19 (2)

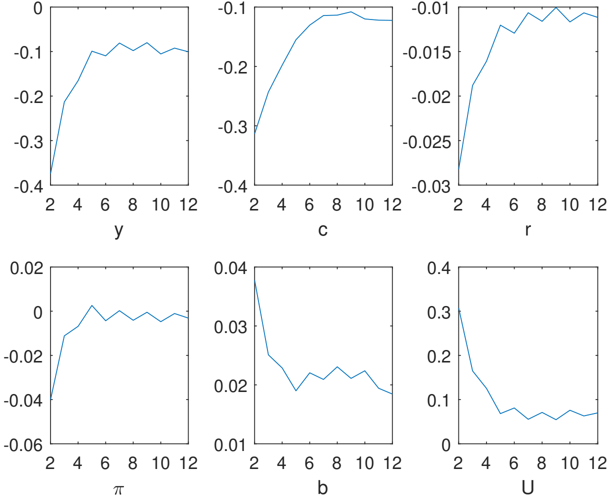


Figure: Dynamics of Macroeconomic Variables

Results

Labor market impacts of COVID-19

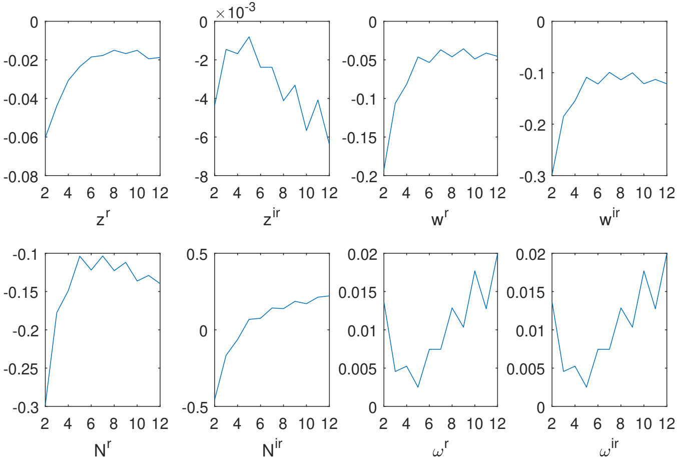


Figure: Dynamics of Labor Market Variables

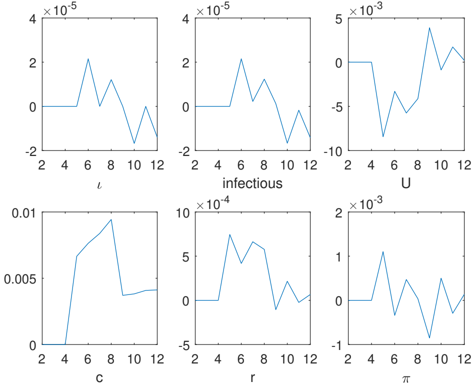
Distributional Impact

Type	Steady State	2020 (Model)	Change
Earnings Gini	0.0259	0.0036	-0.0223
Income Gini	0.1124	0.1698	0.0574
Wealth Gini	0.5720	0.5452	-0.0268

Table: Changes in Gini coefficients

Results

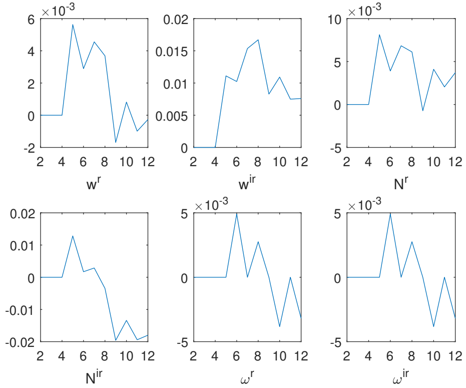
Effects of KEIP transfer (1)



- increased the number of confirmed cases by 249 (appox., in 2020)
- substantial stimulating effect
- cumulative output multiplier: 0.22 (during 2020)
- cumulative consumption multiplier: 0.75 (during 2020)

Results

Effects of KEIP transfer (2)



- Increase wages
- encourage employment of regular workers but not irregular

Distributional Impact

Type	Model w transfer (A)	Model wo transfer (B)	(A)-(B)
Earnings Gini	0.0036	0.0039	-0.0003
Income Gini	0.1698	0.1695	0.0003
Wealth Gini	0.5452	0.5504	-0.0052

Table: Changes in Gini coefficients

Conclusion

- analyze the impacts of COVID-19 and a policy response to it on epidemiological and economic variables based on a version of Macro-SIR model
- model matches key features of epidemiological and macroeconomic variables
    - predicts an endogenous rise in the confirmed cases in the second half of 2020
    - sharp decline in economic activity followed by a temporary recovery caused by KEIP program
- modest consumption multiplier of KEIP
    - stimulated economic activity
    - did not disturb prevention of the pandemic