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COVID-19 and the Korean Economy: When, How, and What Changes?

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Abstract Under the on-going evolution of the COVID-19 pandemic, estimating the economic impact of the pandemic is highly uncertain and challenging. This situation makes it difficult for policymakers, governors, and economic entities to formulate appropriate responses and decision makings. To provide useful information about the effect of the COVID-19 pandemic on the Korean economy, this study examined macroeconomic impact analysis stemming from the pandemic shocks with different scenarios for the Korean economy. Based on three scenarios using the growth rate of 2020 GDP and consumer expenditure patterns, the 2021 GDP by industry sector was forecast with two new approaches. First, the recovering process of the Korean economy from the shock was analyzed by applying a Flex-IO method. Second, a new forecasting approach combined with an IO coefficient matrix was applied to forecast the future GDP changes. The findings of this study are summarized as follows: First, the total GDP growth rate under the Pessimistic Scenario demonstrates less rebound from the shock than that of the Base Scenario. Second, agriculture, culture, and tourism-related sectors that are suffering from the severe losses of COVID-19 showed lower resilience than other different industries. Third, information and communications technology (ICT) industry maintains a stable growth trend and is expected to take the leading role for the Korean economy in the post-COVID-19 and the Industry 4.0 eras. The findings deliver that it needs to analyze how government expenditure responding the shock into the forecasting model, which can be more useful and reliable to simulate the resilience from the pandemic.

Keywords COVID-19 and pandemic, economic impact and recovery, Flex-IO, IO-based forecasting model

I. Introduction

The COVID-19 pandemic has been spreading out as not only the most severe health crisis but also an economically costly pandemic in recent history (Boissy

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and Rungcharoenkitkul, 2020). The global experience of COVID-19 has led to closing the border of each country, generating a high rate of unemployment, reducing economic activities within each country, and hence, blocking international trades that induce a new economic recession. The new phenomenon could be more critical to the Korean economy due to the high degree of dependence upon foreign trade.

The past global crises have caused structural changes in world economies, affecting the economic cycles in most of countries. The World Health Organization (WHO) declared the H1NI outbreak a pandemic on June 12, 2009, to avoid possible mutations of the virus of which situation negatively affected the economic activities of each country. For example, Gordon et al. (2009a) discussed the economic consequences of temporarily closing the U.S. border with Mexico to protect the spread of H1N1 and found that a one-year border shut-down reaches $1.425 trillion of an overall GDP loss in the U.S. with the most optimistic scenario. Even though WHO warned about the possibility of a severe second wave, surprisingly, CDC (2009) already expected upwards of 100,000 U.S. cases that are already more than the current COVID-19 level in the U.S as of the end of May 2020. Also, Fraser et al. (2009) estimated case fatality ratio of 0.4%, but the current COVID-19 showed the ratio higher than 5% in the U.S. Under the situation of the COVID-19 pandemic, it is highly expecting that the world economy will converge quickly on the new normal state, which is entirely different from the past (BOK, 2020).

According to the Bank of Korea (BOK, 2020), it is required to assessing the significant changes in the economic environments of Korea; indeed, it is highly expected to experience dramatic changes in behaviors of economic entities in the post-COVID-19 era. The post-COVID-19 era will accelerate transitioning to the deglobalization, digital, and low-carbon economies. Since the changes in the economic environment can affect the entire structure of the national economy, we also have to assess the effect of the changes in the real economy of Korea during the mid- and long-term periods to keep the economic growth sustainable.

Understanding and evaluating the economic consequences of a pandemic such as the COVID-19 thoroughly, several studies explored economic impacts mostly by assuming economic damages in several industries and behavioral changes. For the COVID-19 impact analysis, however, the impacts are still not much reported. Therefore, this situation makes difficult policymakers or governors to formulate appropriate responses and decision makings to protect the economic system of Korea.

Hence, it is critical to provide useful information about the economic effect of the COVID-19 pandemic on the Korean economy for the purpose of preparing future economic strategies. This study examined the economic impact of the pandemic shocks on macroeconomic outcomes with some different scenarios after collecting Korea's economic outlook information until the first quarter of

2020. Based on the KDI economic outlook (KDI, 2020), three scenarios of the 2020 gross domestic product (GDP) and final expenditure growth rate of Korea. Under these scenarios, we forecast the 2021 GDP of 30 industry sectors and analyzed how the national economy would be recovering from the shock in the short term according to the previous year's GDP and final expenditure growth rate.

To carry out the GDP forecasting work of each industry sector, we applied the Flexible input-output (Flex-IO) methodology and a newly developed IO weighted forecasting model. The estimation processes are demonstrated in Figure 1. In the next section, the literature review was summarized, focusing on the economic impacts of historical diseases. Chapter 3 explained the methodologies adopted in this paper and related data. In Section 4, we suggested the results. Conclusions are followed in Section 5.

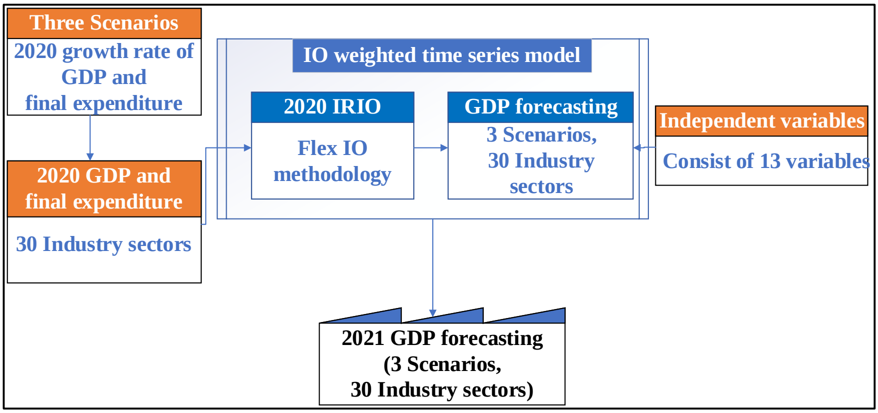

Figure 1. The Korea GDP forecasting processes by industry sector

II. Economic impacts of historical diseases

The conventional approach estimating the economic impact of an infectious disease outbreak has used the valuation of human life and injury. Based on death and illness rates information, Zimmerman et al. (2007) suggested that the valuation includes estimates on loss of income, assessments of 'willingness to pay' to risk one's life, and observations of actual payment on protecting against loss of life and injury. The analogy using fatalities dollar estimates is widely applied to economic impact studies (US EPA, 1999; Dixon and Stern, 2004; National Safety Council, 2017; Viscusi and Aldy, 2003; Levi et al., 2007). For example, the previous World Bank study about the H1N1 pandemic estimated the loss of the global economy as $2 trillion (World Bank, 2008). Another study published in The Lancet by the Harvard Initiative for Global Health Group (Murray et al., 2006) reported that an estimated range of U.S. fatalities that would result from 114,483 to 744,226. Based on the current U.S. fatalities from the COVID-19 pandemic is reaching the lower range and the valuation of a statistical life that was estimated by the U.S. Environmental Protection Agency, which is $5.8 million, the lower dollar amount of facilities imputed is estimated to $664 billion while the median $1.728 trillion.

In 2007, Gordon et al. (2009) conducted an economic impact study for the case of temporarily closing all U.S. borders to respond to a worst-case disease outbreak. Based on five categories of border closure that include 1) exports and imports; 2) air travel; 3) legal immigration; 4) illegal immigration; and 5) cross-border shopping, various simulations combined with possible and alternate scenarios have been conducted. They used a 2001 input-output model from IMPLAN to develop the national version USIO (a 47-sector aggregation of the national IMPLAN model) and NIEMO (the National Interstate Economic Model; Park et al., 2007), a 47-sector, 50-state plus D.C. for the simulation purposes. Demand- and supply-side versions of both models were applied (Park, 2009; Park et al., 2017). The year targeted for which they collected all input data is 2007. While this approach has its limitations, for example, assuming that only minor changes in the technical relationships of U.S. economy have occurred since 2001, it has provided essential guidelines for various economic impact studies stemming from an extreme disease outbreak (Dixon et al., 2011; Kazimi and MacKenzie, 2016; and more). The technical relationships represent sector relationships captured by the input-output model. However, relevant inputs have changed in terms of nominal values expressed as 2007 current dollar values, to be consistently applied for the 2001 models, they targeted the year of 2001 for the analysis. Their results of the short-term economic effects from the border shut-down are summarized as follows. According to the most optimistic scenario is that a one-year border shut-down reaches $1.425 trillion of an overall GDP loss. This is approximately 14 % of 2001 U.S. GDP. According to the study by Gordon et al. (2009), the cost magnitude is close to the cited median dollar value of expected loss of life. The significance of the result is that the total costs associated with the potential U.S. border closure policy may match the magnitude of the cost of the life loss.

While it should be noted that the estimates by Gordon et al. (2009) ignored various treatment costs needed for confirmed cases who get sick but do not die, quarantine costs, other disaster management costs, other insurance costs, and government administration costs to substitute job losses. Also, they revealed that they could not know the enforcement costs of border closures and avoided adding them. Further, economic losses by switching consumer choices or behaviors due to the limitation of available goods and/or due to consumers' preference and context changes are not accounted for in the study, which can be understood as unnecessary reductions in consumer choice as Broda and Weinstein (2004) estimated. While The Lancet study expected that the current medical management system, including antivirals, quarantine, and vaccination, would be much improved and save fatalities than in 1918-20. However, as at the end of May of 2020, the current COVID-19 pandemic is even worse than the previous pandemic due to no vaccination. In this situation, as The Lancet study suggested, much higher border closure costs could be justifiable, doubling the 14% economic damage of 2001 U.S. GDP.

Comparing to other macroeconomic impact studies on HIV/AIDS (Cuddington, 1993a; Cuddington, 1993b; Cuddington et al., 1994; Cuddington and Hancock, 1994), studies of Haacker (2002a; 2002b; 2004) emphasized how HIV/AIDS affects society and economic sectors (especially public health and education) combined with the increase in mortality rates, affects the welfare of individuals and households. Other studies (Arndt and Lewis, 2001; Bell et al., 2004) have analyzed the macroeconomic impact of AIDS with a computable general equilibrium (CGE) model.

In the case of the 2003 SARS epidemic, Lee and Mckibbin (2004) applied the CGE model and estimated that the GDP of the world decreased by 0.1% in 2003. Hai et al. (2004) surveyed in Beijing to examine the impact of SARS on several service sectors in China. They predicted that SARS would cause a total loss of 25.3 billion US $, including tourism industry loss. The World Bank Group (2014) responded to the 2014 outbreak of the Ebola virus disease by presenting macroeconomic and fiscal effects of the disease. The World Bank provided the preliminary estimates of the short-term (2014) and medium-term (2015) impacts using on-the-ground data in West Africa.

Several studies estimated economic losses of hypothetical influenza pandemics such as a 1918-type pandemic and an H1N1 pandemic. For example, Global Preparedness Monitoring Board (2019) indicated that the world is confronted by increasing infectious disease outbreaks, thus requiring urgent actions to prepare for health threats at national and global levels. They suggested that a worldwide influenza pandemic similar to the scale and virulence of the 1918 pandemic would cost up to 4.8% of global GDP (US$ 3 trillion); the cost would be 2.2% of GDP for even a moderately virulent epidemic. Another study by Fan et al. (2016) estimated the expected annual cost of 1918-type pandemic influenza lies in the range of 0.4% ~ 1% of global gross national income (GNI). For moderately severe pandemics, almost 40% of inclusive cost resulted from income loss with 12% of the cost in case of severe pandemics. Finally, they suggested that the estimates of mortality cost as a % of GNI ranged from 1.6% (lower-middle-income countries) to 0.3% (high-income counties) with higher pandemic death rates in lower-income countries.

Under the HINI and potential H5N1 flu pandemics, Keogh-Brown et al. (2010) examined the possible economic cost of a hypothetical pandemic using a multisector single country (the UK, France, Belgium, and The Netherlands) CGE models with disease scenarios of varying severity. GDP impacts were most significant for the Netherlands, followed by Belgium, France, and the UK in the range of 0.5% to 2% of GDP losses.

Recently, studies on the economic impact of COVID-19 dealing with rapidly changing circumstances have been undertaken, and Mckibbin and Fernando (2020) explored seven different scenarios of COVID-19 evolving phases to understand possible economic outcomes. They examined the impacts of different scenarios on macroeconomic outcomes and financial markets with a global hybrid DSGE/CGE general equilibrium model. The results showed that the worldwide economy could significantly be affected by a moderate severity of COVID-19 in the short run. Using mortality and economic contraction information of the 1918 Influenza pandemic, Barro et al. (2020) estimated plausible outcomes of COVID-19 with cross-country regression analysis. They suggested that the COVID-19 pandemic would decline the typical country's GDP and private consumption by 6% and 8%, respectively, with a 2% death rate. Finally, based on the estimates in the study of Gordon et al. (2009a), Park (2020) estimated the Korean GDP loss stemming from the COVID-19 shock. Referring to the Park (2020)'s study, 15% and 30% of GDP losses are applied for the 2019 Korean economy. Since the 2019 nominal GDP of Korea was approximately $2 trillion, the total losses stemming from COVID-19 may reach $0.3 trillion to $0.6 trillion for one year. If considering induced impacts that are associated with income losses arising from industrial layoffs that take approximately 50% off additionally, one-year GDP losses may reach $0.45 trillion to $0.9 trillion. On average, per month loss falls into the range of $37.5 billion to $75 billion. While the economic losses may have a range, to simplify the calculation, $50 billion per month loss was assumed. Because COVID-19 severely affected global trade in February of 2020, the simple calculation of economic damages for Korea until the end of May may reach $200 billion loss with a variation. Note that Korea's economic structure is even different from that of the U.S. Also, Korea did not shut-down its borders due to its export-oriented economic structure, which is also different from the U.S. as assumed in the study of Gordon et al. (2009). However, many countries closed their borders, and hence, global trade would be significantly shrunk where Korea may experience a similar effect of border shut-down. Even though the economic impact studies could deliver both overestimation and underestimation due to multiple adaptations processes that cannot be predicted, COVID-19 is still vivid, and no vaccine has been come out as of June 7, 2020. However, considering all the aspects, the four-month economic losses that may reach $200 are possible because the areas of underestimation and overestimation roughly balance out. Therefore, the Korean government may consider a short-term strategy that revitalizes the current, potential economic losses in the domestic market via stimulating domestic consumptions. Also, the Korean government needs to analyze industrial structures to understand what economic sectors would be competitively stronger or weaker in the global market as mid-term and long-term strategies under the border shut-down period. Based on the analysis of the export strategies, furthermore, the Korean government should provide more active strategies that restore trade and economic relations because Korea has successfully handled the COVID-19 cases without border closures.

III. Methods and data

Based on supply-side input data for the analysis, this study used GDP by annual economic activities from the Korean Statistical Information Service (KOSIS). For demand-side data, 'Household Income and Expenditure Survey' data from KOSIS were applied as a final expenditure. Using the matching bridge for industry classification, the industry classification of GDP by economic activity and household expenditure data were converged to 30 industry sectors that were the basis of the current input-output model and of which base year is 2010. Applying the 2019 GDP and final expenditure of 30 industry sectors, the 2020 GDP and final expenditure by industry sector were estimated along with scenarios for the 2020 GDP and final expenditure growth rate of Korea.

We also set up weights reflecting the COVID-19 impacts to each industry sector, where the 2020 GDP and final expenditure could represent the COVID-19 impacts differently to each industry sector. The weights were made using the 2020 first-quarter GDP and government's press releases on the COVID-19 effects. Therefore, the results of analyses in this study can suggest more realistic insights to policymakers and governors when they prepare appropriate countermeasures against the COVID-19 shock on both supply and demand sides.

1. Scenarios for the 2020 GDP and final expenditure growth rate of Korea

The Korea Development Institute (KDI) published the 2020 first-half outlook of the Korean economy in May 2020, where KDI suggested the 2020 and 2021 GDP and final expenditure growth rates of Korea about the effect of the COVID-19 shock on both supply and demand sides and forecast macroeconomic paths with scenarios of the COVID-19 spreading. Based on the 2020 first-quarter GDP and final expenditure data from Bank of Korea and KDI outlook information, three scenarios of 2020 Korea GDP and final expenditure growth rates used for the analyses in this study were developed. Table 1 presents them.

Table 1 Three scenarios for the 2020 GDP and Final expenditure growth rate of Korea

Scenarios	Supply (GDP)	Demand (Expenditure)
Base	0.2	-2
Optimistic	1.2	-1
Pessimistic	-1	-3.2

Note: Negative sign means a decrease in growth rate. Unit: %

2. Flex-IO methodology

As shown in Figure 1, the first step forecasting the 2021 GDP by industry sector is to construct a 2020 Inter-Regional Input-Output (IRIO) model of Korea. Applying the Flex-IO approach, we estimated it based on the 2013 IRIO model that is available from the Bank of Korea. As a quasi-dynamic model based on the Bayesian analysis, the Flex-IO approach has been first applied in the studies of Gordon et al. (2009b) and Park and Richardson (2015), where they proved how the approach could improve the limitation of the current IO model that only uses fixed technical coefficients. Since the conventional IO analysis could not be applied for the analysis where it requires estimating new effects expecting in the future due to the fixed coefficients, Gordon et al. (2009b) proposed a simple calculation process of estimating new IO coefficients as a new method to update the fixed coefficients. Recently, the detail of the Flex-IO method was presented in the study of Park et al. (2019). This study briefs the basic structure of the method, as shown in Equations 1 and 2.

$$A(t) = R_t[C^s(t)] \quad (1)$$

$$B(t) = S_t[C^d(t)] \quad (2)$$

where, A(t) is the target year' s demand-driven IO coefficients,
B(t) is the target year's supply-driven IO coefficients,
R_t and S_t are the matrix functions updating both IO coefficients of the base year,
$C^s(t)$ is the base year's demand-driven IO coefficients, and
$C^d(t)$ is the base year's supply-driven IO coefficients.

Since the external variables in the Flex-IO method are changes in final demand and value-added factors at the target year, the input data of IO coefficients updating the functions of R_t and S_t are the value ratios of the target year to the base year of GDP and final expenditure by industry sector. Using the ratios between two periods of both demand and supply sides instead of real value changes in the traditional RAS method, the Flex-IO method could more effectively and dynamically update the coefficients matrix overcoming numerous limitations in the RAS method. Indeed, the Flex-IO method is in updating both demand- and supply-driven IO coefficients matrices that will efficiently reflect changes in the economic structure for the target year.

3. An IO weighted forecasting method

Applying the inter-industry relationship, which is represented by the IO technical coefficients, to a forecasting model as the weight, a new GDP by industry sector was forecast in this study. Traditional time-series models such as Vector Autoregression (VAR), Bayesian VAR, and Dynamic Factor models are widely applied to forecaster GDP or final expenditure (Armeanu et al., 2017; Dees and Brinca, 2013), where the GDP or final expenditure at the national level are forecast for the short term.

Our new approach allows us to construct industry and regional specific models by adopting locally disaggregated independent variables. The main framework of the model is similar to an autoregression model, but a lagged dependent variable with a weighting term that consists of IO coefficients are added. Since the weighting term represents regional and inter-industrial relationships, the forecasting model could present GDP or final expenditure of specific region and industry sector for a target year.

The model description for the new forecasting model, including the IO weighting term, is suggested in Equation 3, where variables are listed in Table 2.

$$\mathrm{ln\_y}^{r}_{n,t} = \alpha + \beta \mathrm{ln\_y}^{r}_{n,t-1} + \gamma \mathrm{ln\_x}^{r}_{t} + \delta W_{t-1} \mathrm{ln\_y}^{r}_{n,t-1} + z^{r}_{n,t} \qquad (3)$$

where, y = dependent variables (GDP or final expenditure of industry sectors),
x = independent variables listed in Table 2,
ln = observations transformed into the natural logarithm form,
r = a region,
n = industry classification consisting of 30 sectors,
t = time periods from1992 to 2016,
W = weighting matrices of IO coefficients, and
$z^{r}_{n,t} = \eta W_{t-1} z^{r}_{n,t-1} + \varepsilon^{r}_{n,t}$.

Study areas of this model consist of 16 metropolitan cities and provinces of Korea, and time-periods of both dependent and independent variables range from 1992 to 2016. To set up the best model of each industry sector, we selected the appropriate independent variables from Table 2 through the trial and error process on the basis of the Akaike Information Criterion (AIC) and Schwarz criteria.

Table 2 List of dependent and independent variables of the forecasting model

Variables	Supply-side	Demand-side
Dependent	GDP	Final expenditure
Common Independent	Economic Leading Index	
	Economic Coincident Index	
	Economic Lagging Index	
	Short Term Interest Rate	
	Stock Market Index	
	Population by region	
	Unemployment rate by region	
	Current Balance of Trade	
	Equipment Investment Index	
Specific Independent	Producer Price Index	Consumer Price Index
	-	Consumer Survey Index
	-	Consumer Sentiment Index
	-	Disposable Income by region

IV. Results

The forecasting results for the 2021 GDP estimates by industry sectors are presented by each scenario in Tables 3, 4, and 5, respectively. Identifying the recovering process of the Korean economy from the COVID-19 pandemic shock by industry sectors, the 2020 GDP data also presented next to the 2021 GDP forecasting results.

Table 3 2021 GDP forecasting results by industry sector: base scenario

Code	Industry Sector Name	2020 GDP	2021 GDP	Growth Rate
1	Agriculture, forestry and fishing	29,771.72	30,732.82	3.23%
2	Mining and quarrying	2,457.06	2,534.95	3.17%
3	Food, beverages and tobacco product manufacturing	17,586.22	18,175.12	3.35%
4	Textile and leather product manufacturing	19,629.59	20,176.49	2.79%
5	Wood and paper product manufacturing, printing and reproduction of recorded media	10,986.95	11,342.46	3.24%
6	Petroleum and coal product manufacturing	18,598.76	19,124.95	2.83%
7	Chemical product manufacturing	57,362.60	59,285.53	3.35%
8	Non-metallic mineral product manufacturing	11,579.73	11,979.95	3.46%
9	Basic metal product manufacturing	44,212.11	45,689.20	3.34%
10	Fabricated metal product manufacturing, except machinery and furniture	24,330.49	25,165.50	3.43%
11	Machinery and equipment manufacturing	29,643.77	30,710.18	3.60%
12	Electronic and electrical equipment manufacturing	149,733.07	155,075.40	3.57%
13	Precision instrument manufacturing	12,243.15	12,703.58	3.76%
14	Transportation equipment manufacturing	64,640.74	67,128.26	3.85%
15	Other manufacturing	10,192.49	10,564.29	3.65%
16	Electricity, gas, and steam supply	18,686.37	19,315.84	3.37%
17	Water supply, sewage, and waste management	6,461.81	6,661.45	3.09%
18	Construction	76,434.37	78,720.29	2.99%
19	Wholesale and retail trade	136,114.29	140,994.48	3.59%
20	Transportation	54,144.38	55,978.26	3.39%
21	Food services and accommodation	32,140.33	33,278.07	3.54%
22	Communications and broadcasting	62,244.54	64,347.01	3.38%
23	Finance and insurance	98,566.94	101,809.79	3.29%
24	Real estate and leasing	104,779.84	108,206.31	3.27%
25	Professional, scientific, and technical services	73,223.61	75,826.67	3.55%
26	Business support services	33,000.48	34,178.94	3.57%
27	Public administration and defense	99,248.13	102,515.66	3.29%
28	Educational services	68,239.23	70,533.44	3.36%
29	Health and social work	73,182.92	75,811.58	3.59%
30	Cultural and other services	40,632.93	42,002.76	3.37%
Total		1,480,068.66	1,530,569.25	3.41%

Note: The GDP value of each sector excludes net taxes on production and products.
Unit: billion won.

Table 4 2021 GDP forecasting results by industry sector: optimistic scenario

Code	Industry Sector Name	2020 GDP	2021 GDP	Growth Rate
1	Agriculture, forestry and fishing	30,246.65	31,293.25	3.46%
2	Mining and quarrying	2,486.00	2,570.18	3.39%
3	Food, beverages and tobacco product manufacturing	17,742.34	18,384.09	3.62%
4	Textile and leather product manufacturing	19,801.43	20,399.95	3.02%
5	Wood and paper product manufacturing, printing and reproduction of recorded media	11,084.60	11,472.53	3.50%
6	Petroleum and coal product manufacturing	18,761.81	19,338.27	3.07%
7	Chemical product manufacturing	57,865.62	59,969.31	3.64%
8	Non-metallic mineral product manufacturing	11,681.42	12,115.33	3.71%
9	Basic metal product manufacturing	44,606.67	46,214.60	3.60%
10	Fabricated metal product manufacturing, except machinery and furniture	24,546.52	25,450.65	3.68%
11	Machinery and equipment manufacturing	29,905.31	31,072.06	3.90%
12	Electronic and electrical equipment manufacturing	151,050.13	156,896.34	3.87%
13	Precision instrument manufacturing	12,351.19	12,855.31	4.08%
14	Transportation equipment manufacturing	65,213.25	67,945.46	4.19%
15	Other manufacturing	10,283.20	10,689.64	3.95%
16	Electricity, gas, and steam supply	23,697.05	24,450.13	3.18%
17	Water supply, sewage, and waste management	8,193.46	8,440.19	3.01%
18	Construction	79,546.22	82,046.72	3.14%
19	Wholesale and retail trade	136,154.58	141,484.91	3.91%
20	Transportation	54,160.49	56,157.81	3.69%
21	Food services and accommodation	32,149.94	33,387.46	3.85%
22	Communications and broadcasting	62,263.09	64,545.25	3.67%
23	Finance and insurance	98,596.24	102,130.26	3.58%
24	Real estate and leasing	104,810.97	108,534.16	3.55%
25	Professional, scientific, and technical services	73,245.33	76,079.55	3.87%
26	Business support services	33,010.34	34,293.69	3.89%
27	Public administration and defense	99,277.33	102,824.73	3.57%
28	Educational services	68,259.57	70,753.59	3.65%
29	Health and social work	73,204.03	76,058.80	3.90%
30	Cultural and other services	40,645.04	42,134.11	3.66%
Total		1,494,839.81	1,549,988.30	3.69%

Note: The GDP value of each sector excludes net taxes on production and products.
Unit: billion won.

Table 5 2021 GDP forecasting results by industry sector: pessimistic scenario

Code	Industry Sector Name	2020 GDP	2021 GDP	Growth Rate
1	Agriculture, forestry and fishing	29,509.13	30,332.68	2.79%
2	Mining and quarrying	2,424.42	2,491.60	2.77%
3	Food, beverages and tobacco product manufacturing	17,395.78	17,899.30	2.89%
4	Textile and leather product manufacturing	19,419.96	19,885.52	2.40%
5	Wood and paper product manufacturing, printing and reproduction of recorded media	10,867.83	11,171.43	2.79%
6	Petroleum and coal product manufacturing	18,399.86	18,847.61	2.43%
7	Chemical product manufacturing	56,748.96	58,386.10	2.88%
8	Non-metallic mineral product manufacturing	11,455.67	11,799.65	3.00%
9	Basic metal product manufacturing	43,730.79	44,994.85	2.89%
10	Fabricated metal product manufacturing, except machinery and furniture	24,066.96	24,785.57	2.99%
11	Machinery and equipment manufacturing	29,324.73	30,233.16	3.10%
12	Electronic and electrical equipment manufacturing	148,126.37	152,672.17	3.07%
13	Precision instrument manufacturing	12,111.36	12,504.53	3.25%
14	Transportation equipment manufacturing	63,942.32	66,052.25	3.30%
15	Other manufacturing	10,081.83	10,398.83	3.14%
16	Electricity, gas, and steam supply	12,561.25	13,028.59	3.72%
17	Water supply, sewage, and waste management	4,345.02	4,485.54	3.23%
18	Construction	72,630.42	74,572.58	2.67%
19	Wholesale and retail trade	136,065.05	140,230.26	3.06%
20	Transportation	54,124.70	55,694.54	2.90%
21	Food services and accommodation	32,128.57	33,103.74	3.04%
22	Communications and broadcasting	62,221.87	64,027.34	2.90%
23	Finance and insurance	98,531.12	101,304.93	2.82%
24	Real estate and leasing	104,741.78	107,681.24	2.81%
25	Professional, scientific, and technical services	73,197.07	75,425.60	3.04%
26	Business support services	32,988.42	33,997.30	3.06%
27	Public administration and defense	99,212.42	102,018.32	2.83%
28	Educational services	68,214.37	70,182.45	2.89%
29	Health and social work	73,157.12	75,413.24	3.08%
30	Cultural and other services	40,618.14	41,793.04	2.89%
Total		1,462,343.29	1,505,413.95	2.95%

Note: The GDP value of each sector excludes net taxes on production and products.
Unit: billion won.

Under the base scenario that includes a 0.2% increase in 2020 GDP and a 2% decrease in 2020 final expenditure, the total GDP of 2021 will reach 1,480 trillion won, and the growth rate of the total GDP is estimated as 3.4% compared to that of 2020 total GDP. Since the GDP growth rate of each industry represents the degree of restoring from the pandemic shock, we can check which industry has relatively high resilient power from the shock in the short term. The growth rate of the 'Transportation equipment manufacturing' sector (Code 14) locates in the top list as 3.85%, and the 'Precision instrument manufacturing' (Code 13) and 'Other manufacturing' (Code 15) sectors are followed as 3.76% and 3.65%, respectively.

In the case of the optimistic scenario that assumes a 1.2% increase of 2020 GDP and a 1% decrease of 2020 final expenditure, the growth rate of the total GDP in 2021 will be 3.69% as shown in relatively high growth rates in 'Transportation equipment manufacturing,' 'Precision instrument manufacturing,' and 'Other manufacturing sectors' that are recorded as 4.19%, 4.08%, and 3.95%, respectively. Especially, 'Wholesale and retail trade' (Code 19, 3.91%), 'Machinery and equipment manufacturing' (Code 11, 3.9%), 'Health and social work' (Code 29, 3.9%), and 'Business support services' (Code 26, 3.89%) sectors would lead economic recovery together under the optimistic scenario.

Finally, the 2021 growth rate of total GDP in the pessimistic scenario (1% decrease of 2020 GDP and 3.2% decrease of 2020 final expenditure) was estimated to increase by 2.95%. In the order of the 'Electricity, gas, and steam supply' (Code 16, 3.72%), 'Transportation equipment manufacturing' (3.3%), and 'Precision instrument manufacturing' (3.25%) sectors, the growth rates were relatively high.

In contrast to the recovery power, as shown in the base scenario as expressed in the growth rate, the growth rate of the total GDP in the pessimistic scenario represents less power in recovering from the shock. This means that the degree of resilience from the shock under the pessimistic scenario (2.95%) is weaker than that of the base scenario (3.41%). Figure 2 confirms this implication with clarity.

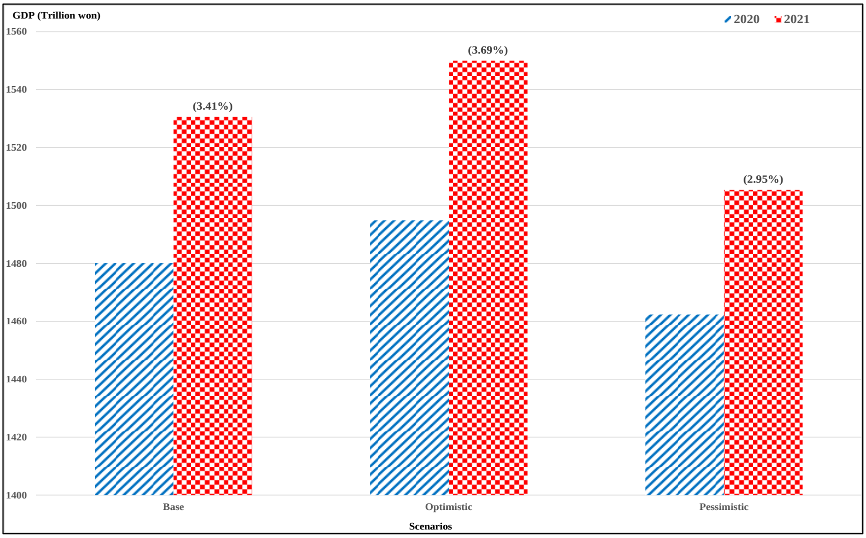

Figure 2 Comparing 2020 and 2021 total GDP by scenario

Note: The value in parenthesis is the growth rate of total GDP.

The result of comparing GDP growth rates of industry sectors by each scenario is expressed in Figure 3, where we could verify the pattern of the growth rates by scenario and identify the distinction of the GDP growth trend at the sector-level among scenarios. The main findings from the trend comparison of the growth rate by scenario could be summarized as follows: First, the overall changing pattern by scenario is similar; however, the 'Electricity, gas, and steam supply' sector shows dominant resilience from the shock in the pessimistic scenario. The second finding is that agriculture, culture, and tourism related sectors affected with relatively high impacts showed lower resilient power than the other sectors. For third finding, the order among scenarios in the GDP growth rates of all industry sectors is optimistic, base, pessimistic scenarios except for the 'Electricity, gas, and steam supply' (Code 16) and 'Water supply, sewage, and waste management' (Code 17) sectors. The order of both industry sectors is completely inverted to pessimistic, base, optimistic scenarios. Because these sectors were not severely affected by the shock, the relative importance among industry sectors under given scenarios has changed in both industries. The same trend is found in the 2020 first-quarter GDP by the industry of the U.S. Finally, information and communications technology (ICT) industry, including 'Electronic and electrical equipment manufacturing' and 'Communications and broadcasting' sectors, maintains a stable growth trend and is expected to take the leading role for the Korean economy in the post-COVID-19 and the Industry 4.0 eras.

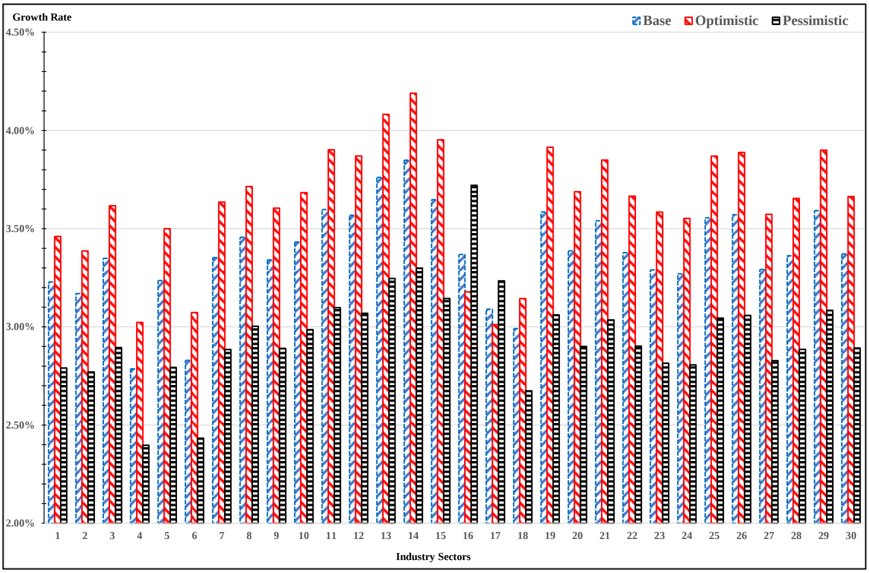

Figure 3 2021 GDP and the growth rate of an industry sector by scenarios

V. Conclusions

Grave concerns over the negative effect of the COVID-19 pandemic on the global economy have been raised since March of 2020 due to the experiences from the previous pandemics. As advanced in science and technology, the increasing linkages in the global supply chain system and the connectivity of the global economy that has been accelerated, but the current global economy has been more vulnerable to a pandemic shock than the past at the same time.

Under the on-going situation of the COVID-19 pandemic, estimating the economic impact of the pandemic is highly uncertain and challenging due to the limited empirical data and rapidly changing trade conditions. This makes difficult policymakers, governors, and economic entities to formulate appropriate responses and decision makings when protecting the economic system and maintaining sustainable economic activities.

For the purpose of providing useful information about the effect of the COVID-19 pandemic on the Korean economy, this study examined the macroeconomic impact of the pandemic shocks using three scenarios constructed for the Korean economy. By using the 2020 GDP and final expenditure growth rate, 2021 GDPs by industry sector were forecast, and the recovering process of the Korean economy from the shock in the short term was analyzed, where we applied the Flex-IO method and IO weighted time-series forecasting model.

The findings of this study are summarized as follows: First, the total GDP growth rate under the pessimistic scenario represents less rebound from the shock than that of the base scenario. The degree of resilience from the shock is weaker in the pessimistic scenario than even in the base scenario. Second, agriculture, culture, and tourism related sectors suffering from severe losses of the COVID-19 shock presented lower resilient power than the other sectors. Third, the order of GDP growth rates in 'Electricity, gas, and steam supply' and 'Water supply, sewage, and waste management' sectors are completely inverted to the order of pessimistic, base, and optimistic scenarios, while all the other sectors' order was optimistic, base, and pessimistic scenarios. This implies that the impact of the shock on utility sectors has changed due to the relative importance of them in the economic structure according to the three scenarios. Finally, ICT industry maintains a stable growth trend and is expected to take the leading role for the Korean economy in the post-COVID-19 and the Industry 4.0 eras.

Based on the assumptions about the macroeconomic situation of the COVID-19 impact on the 2020 GDP of Korea, this study tried to provide some basic estimates which are helpful to reveal how the Korean economy can recover from the shock in the short term. With a high uncertainty on the Korean economy, several improvements are needed to suggest realistic estimates on the effect of the pandemic. First, if the forecasting process includes government expenditure coping with the negative impact of the shock, then the estimates would better and reliably imply to diverse stakeholders. Second, it is necessary to analyze regionally detailed estimates to be useful for local governors or economic entities. Finally, if it is possible to conduct this type of analysis on the global level, the impact of the COVID-19 pandemic will be mitigated when international cooperation and collaboration were made. These limitations are expected to overcome with future research.

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