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Article

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ABSTRACT

This study examines the relationship between COVID-19 shocks and GDP loss of different countries worldwide based on the seven scenarios of the epidemiological DSGE/CGE model of [*McKibbin, W., & Fernando, R. (2020). The Global Macroeconomic Impacts of COVID-19: Seven Scenarios. Asian Economic Papers, 20(2): 1-30, MIT Press*]. We implemented a panel data approach for 24 cross-sectional units with three periods and a general regression neural network. The economic and financial shocks consist of labor supply, equity risk premium, consumption demand, and government expenditure. The findings show that the consumption demand and equity risk premium shocks on GDP are more influential than the other shocks. Moreover, the results reveal that the most significant GDP loss is associated with Japan, Germany, and the US, respectively, which are industrialized countries with the most prominent automobile manufacturers. The lowest GDP loss is linked to Saudi Arabia, one of the world's biggest oil producer countries.

KEYWORDS

COVID-19, Economic Shocks, GDP Loss, Global Business

JEL classification: C33, C53, C63, F47

INTRODUCTION

Severe Acute Respiratory Syndrome (SARS) was identified in China's Guangdong province in 2003, and it affected 26 countries with more than 8,000 cases (Şenol et al., 2020). A few days before the New Year of 2020, a highly contagious disease from the family of SARS virus originated from Wuhan, Hubei Province in China, COVID-19 affected the whole world (Huang et al., 2020; Tan et al., 2020; Zhu et al., 2020), and accordingly, World Health Organization (WHO) declared a state of emergency on March 11, 2020 (World Health Organization, 2021; Wang et al., 2020). The number of confirmed cases and deaths of COVID-19 surpassed 555 million and 6.3 million as of July 15, 2022 (World Health Organization, 2022).

COVID-19 has several economic, psychological, political, and sociological shocks (Amjad et al., 2020; Hitt et al., 2021). COVID-19 is probably the biggest shock to the economy after the great depression in the 1930s (Sahoo & Ashwani, 2020). Some researchers also believe that COVID-19 can be one of the worst pandemics in the world (Ferguson et al., 2020). COVID-19 has created some challenges to globalizations (Delios et al., 2021), caused a deep recession and loss of millions of jobs globally (Colbourn, 2020), and it takes time for all economic activities to return to a level before the COVID-19 pandemic (Guerrieri et al., 2020; McKibbin & Fernando, 2020).

In this study, we focus on the economic shock. The global economy faced a massive COVID-19 pandemic-related shock due to shut down and interruption of different business sectors. According to

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the International Monetary Fund (IMF), the global economy contracted by 4.9% in 2020, which is worse than the financial crisis of 2008 (IMF, 2020). Moreover, the COVID-19 pandemic is called the worst global crisis after the Second World War by International Labor Organization, and around 34% of the workforce had trouble working remotely after being hit hard by COVID-19 (ILO, 2020). The US Federal Reserve (FED) announced a zero percent interest rate in April 2020. Also, the central banks in other countries followed the FED in reducing the interest rate. The IMF's borrowing rate rose from 3.7% in 2019 to around 10% in 2020 (Akhtaruzzaman et al., 2020).

COVID-19 caused severe shocks to many fragments of financial markets worldwide, in which the magnitude and duration of the economic and financial crisis are still ambiguous. During the last week of February 2020, the stock market experienced a sharp decline in its indexes, especially when the WHO announced the COVID-19 as a global pandemic on March 11, 2020 (Eachempati et al., 2021). The largest drop is related to airlines, which faced the most significant decline in their services (Akhtaruzzaman et al., 2020; Şenol et al., 2020). During the period between the first day of 2020 and the first week of April, the decline in major stock market indexes is shocking: Dow Jones -26%, S&P500 -24%, FTSI100 -29%, DAX -29%, NIKKEI225 -23%, NASDAQ -18%, and Shanghai -10%. Moreover, the effect of COVID-19 on oil stock price is shocking (Salisu et al., 2020), and the crude oil price decline was around -53% during this time (Şenol et al., 2020).

There are several ongoing studies to find the impact of COVID-19 on the economy, but it is difficult to find a particular solution with the uncertainties surrounding the world (Martin et al., 2020). Most researchers seek to find appropriate models for economic shocks caused by COVID-19 that can help policymakers make the proper economic decisions. Some studies investigated the effect of COVID-19 pandemic on the economy and financial markets all around the world at the macroeconomic level (See, Baker et al., 2020a; Conlon & McGee, 2020; Corbet et al., 2021a; Klona, 2021; Kristoufek, 2020; McKibbin & Fernando, 2020; Pandey & Kumari, 2020; Ramelli & Wagner, 2020; Zhang et al., 2020).

There have been several studies about the effect of COVID-19 on the economy and financial markets. To our best knowledge, none of these studies examined various economic and financial types of COVID-19 shocks to find the relationship between the shocks and the amount of Gross Domestic Product (GDP) loss. This research study fills this gap and contributes to the economic literature by studying how the shocks in four different areas of the economy affect GDP through the various scenarios proposed by McKibbin & Fernando (2020). We find that boosting consumption demand can reduce GDP loss. Financial agencies and policymakers can use the findings to manage different financial and economic shocks appropriately.

The rest of the paper proceeds as follows. In Section 2, the prior research works, and different types of shocks are presented. In Section 3, the research methodology and data collection are explained. In Section 4, the mathematical structures of different models are described. Section 5 provides the descriptive analysis. The results of the different models are provided in Sections 6 and 7. Discussion and conclusion are presented in Section 8. Lastly, Section 9 is given limitations and future research directions.

COVID-19 SHOCKS

The social distancing, the stay home order, and the lockdown during the COVID-19 pandemic are the main reasons for the loss of jobs and economic shock worldwide (Loayza & Pennings, 2020; Yilmazkuday, 2020). The COVID-19 shocks first hit the Chinese economy and then spread worldwide through the supply chain networks. The first and most hit province in China, Wuhan, is one of China's leading economic centers and has been closed from the last week of January to the last week of March 2020. For instance, the Japanese automobile company Honda reduced its production in Japan due to the lack of materials imported from China (Inoue & Todo, 2020).

Some recent studies investigate the effect of the COVID-19 pandemic on the economy. For instance, Fornaro & Wolf (2020) studied the supply disruption; Faria-Castro (2020) investigated the utility of human capital services; Eichenbaum et al. (2020) examined the shock related to consumptions; Jordà et al. (2020) scanned the rates of return on assets during the pandemic; Guerrieri et al. (2020) investigated the changes in aggregate demand; Baker et al. (2020a) examined the effect of shock on household spending; McKibbin & Fernando (2020) examined the COVID-19 shock on health care system; Ozili (2020) addressed the impact of the COVID-19 shock on stock market indexes; Zaremba et al. (2020) investigated stock market volatility; especially, Corbet et al. (2021b) examined the effect of COVID-19 on financial market volatility spillovers; Al-Awadhi et al. (2020) studied stock market return; Corbet et al. (2020) and Conlon & McGee (2020) examined the effect of COVID-19 on gold and cryptocurrencies hedges; Dietrich et al. (2020) investigated the impact of COVID-19 on household expectations; and Yu and Aviso (2020) show a relationship between pandemic and economic dynamics.

In all the studies mentioned above, the magnitude of shocks caused by the COVID-19 is significant. The impact of the current shock is more remarkable than almost all previous shocks in the present century. Our study examines several shocks related to COVID-19 in more detail.

SHOCK TO THE LABOR SUPPLY

The main reason for the recession of the global economy is maybe the disruption in the global supply networks (Fornaro & Wolfe, 2020). Most of the supply shock comes from the labor market due to sickness and deaths which COVID-19 caused (McKibbin & Sidorenko, 2006; McKibbin & Fernando, 2020; Rio-Chanona et al., 2020; Santos et al., 2013). Also, due to the stay home or lockdown order, while some laborers can work remotely, some essential workers cannot perform their activities at home. Therefore, this causes a shortage in the labor supply market, especially for crucial industries (Rio-Chanona et al., 2020). Some other studies also examined the supply shock caused by COVID-19 in the labor market (Dingel & Neiman, 2020; Hicks, 2020; Koren & Pető, 2020).

Rio-Chanona et al. (2020) revealed that supply and demand shocks caused around 17% loss of the total wage income in the US, in which the weight of supply shock is the main reason for most of the reduction. Another study shows that the economy faces the most massive fall in supply for two to five weeks after starting the COVID-19 pandemic (Haren & Simchi-Levi, 2020). Therefore, such labor supply shock in our study represents a sudden change in primary factors of labor in McKibbin & Fernando (2020) study that reduces the labor supply in each country due to mortality and morbidity.

SHOCK TO THE EQUITY RISK PREMIUM

Due to the COVID-19 pandemic, some workers lost their income because they could not work remotely, and consequently, the amount of saving in those household budgets has been reduced. This contributed to volatility in the stock market's investment, and the risk of equity increased. Uncertainty due to the volatility of stock markets raises the opportunity cost of the investments and associated risks.

Global Financial Stability, in its report, declared that the equity market experienced the fastest drop in history due to the impact of the COVID-19 pandemic on the financial markets (Khan et al., 2020). During mid-February through the end of March of 2020, most stock indexes became volatile. They lost approximately 35% of their values, and the drop in indexes due to COVID-19 shock was faster than the shock related to the Great Depression of the Global Financial Crisis (Roubini, 2020).

Some studies show there is a short-term negative effect of the COVID-19 pandemic on stock markets, which increases the risk of equity (Okorie & Lin, 2020; Sansa, 2020; He et al., 2020; Ammy-

Driss et al., 2020; Ali et al., 2020; Ashraf 2020). Topcu & Gulal (2020) show that Asian emerging markets suffer more negative returns than European countries. Also, Gormsen & Koijen (2020) examined the aggregate equity market and found a drop of 28% and 22% for the US and European Union GDP, respectively. Therefore, the equity risk premium shock in our study highlights the sudden changes in equity risk premia in different sectors of countries in McKibbin & Fernando (2020) study due to an exposure to COVID-19. This increases the risk of macroeconomic conditions in each country.

SHOCK TO THE CONSUMPTION DEMAND

Any epidemic influences the consumption pattern because consumers usually try to reduce the risk of exposure to the virus. They avoid close contact with other people by reducing demand for products and services (Rio-Chanona et al., 2020; Baker et al., 2020a).

Economists believe that the shocks caused by the COVID-19 pandemic can be dramatic (Baldwin & Mauro 2020; Bullard, 2020). In a study, Muellbauer (2020) estimated a 20% fall in consumption and, consequently, a loss in annual GDP if the lockdown lasted for the whole year of 2020. The Organization for Economic Cooperation and Development (OECD) (OECD, 2020b) also estimated an approximately 25% drop in GDP. In their study, Barrot et al. (2020) evaluated a 5.6% drop in GDP due to several weeks of social distancing and lockdown of industry sectors.

One factor related to demand shock is the shock to the investment, which can reduce cash flow and its impact on imports and exports (Baldwin & Mauro, 2020; Boone, 2020), and consequently disrupt the demand chains. For example, the reduction of oil demand is the most considerable amount since the Gulf War. Baldwin (2020) explains that COVID-19 causes a decrease in households' consumption because some households do not get paid. Also, it reduces the investment due to a lack of cash flow and concludes with a reduction in capital stock. Moreover, the demand and supply shocks created by the COVID-19 pandemic disrupt the global supply chains. In addition, all the shocks together cause a tremendous drop in consumption demand.

Transportation, hotels, restaurants, and some retail manufacturing experienced the consumption demand shock more than the other sectors (Rio-Chanona et al., 2020). The results of an online survey about household expectations showed a 6% decline in GDP by the end of 2020 (Dietrich et al., 2020). Coibion et al. (2020), in their study of more than 10,000 households, find that aggregate consumer spending, especially in the travel and clothing sectors, declined significantly. Therefore, the consumption demand shock in our study shows the consumption reduction in McKibbin & Fernando (2020) study for each county due to changes in consumer preferences. This would be related with changes in consumer income and the prices of goods and services during the COVID-19 pandemic.

SHOCK TO THE GOVERNMENT EXPENDITURE

Governments' reaction to any pandemic needs to be quick and coherent. In most cases, they face a situation that they have never experienced before. In any outbreak, especially COVID-19, the health sector is the first and directly affected by pandemics (OECD, 2020b).

Therefore, governments spend a significant amount of their budgets on preventing the spread of the outbreak. It causes a shock to government expenditure and disrupts the balance between health and other sectors such as the military or education. An OECD report shows that more than 40% of the subnational governments allocated their budget to the health expenditure among the OECD countries in controlling the COVID-19 pandemic (OECD, 2020a).

Atems (2019) study shows that expenditure shocks with a positive innovation can boost the outputs and employment rate. Also, they find a heterogeneity effect of government spending shocks which can be more effective during a recession than an expansion.

The COVID-19 shock is an exogenous shock to government expenditures, and it has a direct effect on income and employment (Shoang, 2019; Ramey, 2009). Some previous studies (Caldara & Kamps 2006; Gali et al., 2007; Perotti, 2005) examined the impact of government expenditure on employment and income levels and found a positive effect of government expenditure on employment and GDP.

In the US, Congress passed the CARES Act, which was designed to help local governments, medical sectors, firms, and households with more than two trillion dollars. Also, the FED expanded the balance sheet to around three trillion dollars to provide enough liquidity to the market. In addition, the Paycheck Protection Program was set up to help households and the labor market for a faster recovery.

Most of the above government expenditures are for the recovery of employment and aim to maintain the output levels by allowing firms to retain their workers. However, the government has a challenge: the shortfall in the budget when the output and production sectors are not at the optimal level. For example, in the US, the state budget shortfalls for 2021 are estimated at 290 billion dollars (McNichol & Leachman, 2020). Therefore, the government expenditure shock in our study illustrates the money that was suddenly injected to market by government in McKibbin & Fernando (2020) study.

SHOCK TO THE COST OF PRODUCTION & GDP

Wren-Lewis (2020) shows that COVID-19 shocks significantly affected the GDP by reducing consumer demand and production. Baker et al. (2020b) predicted a decline of 11% in GDP by the end of 2020. Barro et al. (2020) show that the effect of the Spanish Flu in 1918-1920 on the reduction of GDP and consumption is 6% and 8.1%, respectively; and in a pessimistic view, they estimated a 6 to 8% drop in GDP caused by COVID-19. None of the previous pandemics, even the Spanish Flu, had the magnitude of the COVID-19 shock on the US stock market (Baker et al., 2020a). The OECD announced around a 25% reduction in outputs and a 30% reduction in consumer expenditures. The negative magnitude of decline caused by the current pandemic is much bigger than the magnitude of reduction in outputs and expenditures in the 2008 financial crisis (OECD, 2020b). This reduction increases the cost of production due to the fixed costs.

It is noteworthy that only 37% of the jobs in the US can be performed remotely, and this number is lower in low-income countries (Dingel & Neiman 2020). A study by Fernandes (2020) shows that the GDP is genuinely affected by COVID-19 related shocks. He demonstrates that the impact of the COVID-19 shocks on global GDP is around 2.5%, and some types of jobs like tourism hurt the GDP by more than 15%. It is worth noting that China contributes approximately 16.3% to the global GDP, and Wuhan is a province in China with more than 300 companies, including some largest companies (e.g., Microsoft) in the world (Ayittey et al., 2020).

Some studies (Fernandes, 2020; McKibbin & Fernando, 2020) estimated that the GDP of the US economy falls into recession with a 5% contraction, and the statistics released by the US Bureau of Labor reported a 14.7% unemployment rate in the US in April, and it is predicted that this number will increase to 20% by the end of 2020 (Bick & Blandin, 2020). The European Commission estimated a fall of 7.25% in the GDP in 2020 (Directorate-General for Economic and Financial Affairs, 2022).

Across sectors, the leisure and hospitality sectors are the most affected, where their employees lost their jobs (Burns, 2020). In their study, McKibbin & Fernando (2020) computed that the loss of GDP would be about $2.4 trillion in the world. This number can extend to $9 trillion in a case similar to the Spanish flu (Sahoo & Ashwani, 2020). In its estimates in June 2020, the IMF projected a 4.9% shrink for the global economy, which is three times bigger than the Great Financial Crisis (IMF, 2020). Therefore, the production or GDP shock in our study is indicated by the amount of GDP loss in McKibbin & Fernando (2020) due to rising cost of production in business sector.

METHODOLOGY AND DATA

This study explores three scenarios in the McKibbin & Fernando (2020) paper to examine how each of COVID-19 related shocks can affect the growth rates of countries based on the GDP loss. The three scenarios are based on their hybrid Dynamic Stochastic General Equilibrium (DSGE) and Computable General Equilibrium (CGE) models, and it is a version of G-Cubed of McKibbin & Triggs (2018) model. We describe their G-Cubed model here briefly.

1- A firm's output is a function of energy (E), materials (M), capital (C), and labor (L); we can write the equation as follows:

$$Q_i = A_i^O \left(\sum_{j=E,M,C,L} (\delta_{ij}^O)^{\frac{1}{\sigma_i^O}} X_{ij}{}^{\frac{\sigma_i^O - 1}{\sigma_i^O}} \right)^{\frac{\sigma_i^O}{\sigma_i^O - 1}} \tag{1}$$

where Q_i is the output of firm *i*, and *Xij* is the firm *i's* input *j*. A_i^O shows the level of technology, δ_{ij}^O represents the input weights, and σ_i^O denotes the elasticity of substitution.

2- The household behavior utility function is in this form:

$$U_t = \int_t^{\infty} (ln\, C_s + ln\, G_s) e^{-\theta(s-t)} d_s \tag{2}$$

where C_s represents aggregate consumption of services & goods of households at time *s*, G_s shows the government consumption at time *s*, and θ is the parameter in the above equation.

3- The government budget equation is an expression of the accumulation of public debt, and it is as follows:

$$D_t = r_t B_t + G_t + TR_t - T_t \tag{3}$$

where *D* represents budget deficit, *B* represents debt, *G* is government spending on services and goods, *TR* shows the payment transferred to households, and *T* is tax revenue.

4- Balance of payments in financial markets follows the following equation:

$$i_k + \mu_k = i_j + \mu_j + \frac{\dot{E}_k^j}{E_k^j} \tag{4}$$

where the interest rates in countries *k* and *j* are i_k and i_j, respectively. μ_k and μ_j show the risk premium by investors in countries *k* and *j*. E_k^j defines as the exchange rate of the currencies of countries *k* and *j.*

5- There is a balance between demand for real money and the value of aggregate output and short-term nominal interest rate:

$$MON = PYi^{\varepsilon} \tag{5}$$

where *MON* is the money, *P* is the price index of output, *Y* represents the aggregate output, *i* shows the interest rate, and ε represents the interest elasticity of money demand.

There are some highlights for G-Cubed McKibbin & Fernando (2020) model: First, the model is for stocks and flows of physical and financial assets. Second, the households should use money that central banks issue for all transactions. Third, nominal wages will adjust according to the specific labor contract assumptions over time. Fourth, it is not easy for the economy to move quickly from one equilibrium to another. Fifth, the model incorporates heterogeneous households and firms.

With above assumptions, McKibbin & Fernando (2020) simulated seven different scenarios in which the first three scenarios assume that the spread of COVID-19 is isolated to China, and the next three scenarios are based on the epidemiological shocks occurring in all countries to differing degrees. A portion of data in McKibbin & Fernando (2020) study were collected from GTAP database (Aguiar et al., 2019). These scenarios assume that the shocks are temporary. We use the second three scenarios (fourth, fifth, and sixth) in our study. The rigorousness of the shocks on the economy is spatially heterogeneous, and it could take a long time to recover the economy. To evaluate the effect of macroeconomic level shocks on the economy, we consider a model with country-specific random and fixed effects to estimate the impact of labor supply, equity risk premium, consumption demand, and government expenditure shocks on the loss of GDP.

This study has 24 countries and regions which are selected from McKibbin & Fernando's (2020) fourth, fifth and sixth scenarios. The countries faced with minimal shock at the beginning are grouped together (e.g., rest of the world), including some African and South American countries that were affected less by COVID-19 at the initial time of the shock period. The three different scenarios are the three distinct periods in our panel data model: the fourth scenario is the first period, the fifth scenario is the second period, and the sixth scenario is the last period.

MATHEMATICAL STRUCTURE OF THE MODELS

Let the dependent variable be the GDP loss and x_{it} be a $1 \times k$ vector of labor supply shock, equity risk shock, consumption demand shock, and government expenditure shock. We set up a model for the GDP loss using the panel data structure, for $i = 1,2, \dots, N$, and $t = 1,2, \dots, T$,

$$y_{it} = x_{it}\beta + v_{it} = x_{it}\beta + (c_i + d_t + u_{it}) \tag{6}$$

where the second equality defines v_{it} as the sum of three terms, this makes it possible to sort out factors in the composite error term that may cause a correlation between the composite error term and the regressor.

With the correlation between the composite error term and the regressor, the least-squares estimator of the coefficients on the regressor is not consistent. We use the panel data setup to decompose the composite error term into the sum of three factors: time-invariant country-specific factors, time-varying macro factors, and the idiosyncratic error term. c_i is the time-invariant country-specific fixed effects that could be related to the regressors, d_t is the time period dummy capturing macro effects that affect countries together in the same time period, and u_{it} is the idiosyncratic error term.

We consider three estimators: the random effects (RE), fixed effects (FE), and first-differencing (FD) estimators (Wooldridge, 2010). The RE estimator assumes the zero correlation between the regressors and the composite error term. In contrast, the FE and FD estimators allow the possibility of correlation between the regressors and the unobserved heterogeneity terms. Time-invariant country fixed effects like political culture or economic system may be correlated with the regressors, which is allowed under the FE and FD estimation.

FIXED EFFECTS ESTIMATOR

The FE estimator is a pooled OLS estimator applied to the within transformed equation (6). The within transformation eliminates the time-invariant fixed effects in the composite error term, which is done by subtracting the time-averaged equation from equation (6): for example, the time-averaged dependent variable is

$$\bar{y}_i = T^{-1} \sum_{t=1}^{T} y_{it} \tag{7}$$

and $\bar{x}_i$, $\bar{d}$, $\bar{u}_i$ are similarly defined. The time-averaged equation is

$$\bar{y}_i = \bar{x}_i \beta + c_i + \bar{d} + \bar{u}_i \tag{8}$$

where the time average of c_i is the same as c_i. By subtracting equation (8) from (6), we have

$$y_{it} - \bar{y}_i = (x_{it} - \bar{x}_i)\beta + \left(d_t - \bar{d}\right) + (u_{it} - \bar{u}_i) \tag{9}$$

so that the time-invariant fixed effects are eliminated, and the correlation between the time-invariant fixed effects and the regressors does not affect the consistency of the pooled OLS estimator applied to the above equation. With the OLS estimator applied to the demeaned equation, we obtain the FE estimator.

$$\hat{\beta}_{FE} = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \ddot{x}_{it}{}' \ddot{x}_{it}\right)^{-1} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \ddot{x}_{it}{}' \ddot{y}_{it}\right) \tag{10}$$

where $\ddot{x}_{it} = (x_{it} - \bar{x}_i)$, $\ddot{y}_{it} = (y_{it} - \bar{y}_i)$ and the demeaned time effects are included as the demeaned time dummies in the demeaned regressors. The FE estimator is consistent if the time-demeaned regressors are not correlated with the time-demeaned idiosyncratic error term, and this no correlation is implied under the strict exogeneity assumption:

$$E(u_{it} | x_{i1}, \dots, x_{iT}, c_i) = 0 \tag{11}$$

This FE estimator is efficient with the constant variance and no serial correlation assumption. However, when any of the two assumptions is violated, the robust standard errors clustered at the country level can be used for valid inference.

RANDOM EFFECTS ESTIMATOR

The RE estimation method is a feasible Generalized Least Squares (FGLS) estimator that assumes c_i is uncorrelated with the regressors and imposes a special restriction on the composite error term whose components are not correlated with each other. The RE estimator is

$$\hat{\beta}_{RE} = \left(\sum_i X_i' \widehat{\Omega}^{-1} X_i\right)^{-1} \sum_i X_i' \widehat{\Omega}^{-1} y_i \tag{12}$$

where X_i is $N \times k$ regressor matrix, $\widehat{\Omega}$ is the estimated variance-covariance matrix of the composite error term with c and u. For robust standard errors that are valid under heteroskedasticity and/or serial correlation in u, we use

$$\left(\sum_i X_i'\widehat{\Omega}^{-1}X_i\right)^{-1}\sum_i X_i'\widehat{\Omega}^{-1}\hat{v}_i\hat{v}_i'\widehat{\Omega}^{-1}X_i\,\left(\sum_i X_i'\widehat{\Omega}^{-1}X_i\right) \tag{13}$$

where $\hat{v}$ is the residual vector after RE estimation.

To test if the time-invariant unobserved heterogeneity is correlated with the regressors, we use the Hausman test with the following statistic:

$$\left(\hat{\beta}_{FE}-\hat{\beta}_{RE}\right)'\left[\widehat{Avar}(\hat{\beta}_{FE})-\widehat{Avar}(\hat{\beta}_{RE})\right]^{-1}\left(\hat{\beta}_{FE}-\hat{\beta}_{RE}\right) \tag{14}$$

where $Avar$ is the asymptotic variance.

As the RE estimates under no correlation between c and the regressors are efficient relative to the FE estimates, the non-rejection of the null in the Hausman test indicates that the RE estimates would be preferred to FE.

GENERAL REGRESSION NEURAL NETWORK

The mathematical structure of the general regression neural network (GRNN) is described as follows. Equation (15) represents the conditional mean of *Y* given *X* in which f(X, Y) is the joint continuous probability density function, *X* represents the vector, and *Y* refers to its scalar random variables.

$$E[Y|\,X]=\frac{\int_{-\infty}^{\infty}Yf(X,Y)dy}{\int_{-\infty}^{\infty}f(X,Y)dy} \tag{15}$$

We can estimate the density f(X, Y) through a sample of observations *x* and *y*. With some consistent estimators in nonparametric statistics (Cacoullos, 1966; Parzen, 1962), we can estimate the probability estimator f(X, Y) as follows.

$$\hat{f}(X,Y)=\frac{1}{(2\pi)^{(p+1)}/_{2}\,\sigma^{(p+1)}}\cdot\frac{1}{n}\sum_{i=1}^{n}\exp\left[-\frac{\left(X-X^i\right)^T\left(X-X^i\right)}{2\sigma^2}\right]\cdot\exp\left[-\frac{\left(Y-Y^i\right)^2}{2\sigma^2}\right] \tag{16}$$

where *n* represents the sample size, *p* is the dimension of the vector variable X, and *σ* indicates the width of the sample probability for each sample of $X^i and\ Y^i$ (Specht, 1991).

Then, we can find the desired conditional mean estimator by combining and reordering equations (15) and (16) as follows.

$$\hat{Y}(X)=\frac{\sum_{i=1}^{n}\exp\left[-\frac{\left(X-X^i\right)^T\left(X-X^i\right)}{2\sigma^2}\right]\int_{-\infty}^{\infty}y\exp\left[-\frac{\left(y-Y^i\right)^2}{2\sigma^2}\right]dy}{\sum_{i=1}^{n}\exp\left[-\frac{\left(X-X^i\right)^T\left(X-X^i\right)}{2\sigma^2}\right]\int_{-\infty}^{\infty}\exp\left[-\frac{\left(y-Y^i\right)^2}{2\sigma^2}\right]dy} \tag{17}$$

and by substituting the scalar function in equation (18) into equation (17), we get the consistent estimator in another format.

$$D_i^2=\left(X-X^i\right)^T\left(X-X^i\right) \tag{18}$$

This consistent estimator is called the summations over the observations and is as follows.

$$\hat{Y}(X) = \frac{\sum_{i=1}^{n} Y^i \exp\left(-\frac{D_i^2}{2\sigma^2}\right)}{\sum_{i=1}^{n} \exp\left(-\frac{D_i^2}{2\sigma^2}\right)} \tag{19}$$

In the next step, after the normalization of variables with further simplification, we find the probability density function with the same dimension (Specht, 1991).

$$\hat{Y}(X) = \frac{\sum_{i=1}^{n} Y^i \exp\left(-\frac{C_i}{\sigma}\right)}{\sum_{i=1}^{n} \exp\left(-\frac{C_i}{\sigma}\right)}$$

where (20)

$$C_i = \sum_{j=1}^{p} |X_j - X_j^i|$$

We can use the obtained estimator in equation (20) when the number of observations (X, Y) is small. Therefore, this can be a good estimator for our study with 72 observations and no need to use the clustering technique which is appropriate for a large sample. The proposed GRNN algorithm is as follows.

Figure 1 represents the pseudo-code of the proposed GRNN model with four explanatory variables as the input variables and the GDP loss as its output.

Algorithm: Proposed GRNN

Procedure
begin
initialize the GDP loss (Y), variables (X) and algorithm schemes (ID);
input:
X_1: Input Labor Supply Shock
X_2: Input Equity Risk Shock
X_3: Input Consumption Demand Shock
X_4: Input Government Expenditure Shock
output:
Y: Output GDP loss
function:
f = GRNN (inputs = X_1, X_2, X_3, X_4), Y=output, weight = w^n, ε: Threshold parameter, di = $|f(x_i) - y_i|$ for i= 1 to n
*Apply robust fitting and find unit vector * size*
Update the f_{best}
Repeat the steps for the iteration n from 0
$\boldsymbol{if}\left|\boldsymbol{w_i^n} - \boldsymbol{w_i^{n+1}}\right| < \boldsymbol{\varepsilon}$ *then*
end of the iteration and then
break
else
Apply all the above processes
until the end of the iterations
end

Figure 1. The Overall Structure of Proposed GRNN Algorithm

DESCRIPTIVE STATISTICS

Table 1 shows the summary statistics of the variables in the model. The mean of Labor Supply Shock (LSS), Equity Risk Shock (ERS), Consumption Demand Shock (CDS), and Government Expenditure Shock (GES) are “-1.50”, “1.78”, “-2.45”, and “1.02”, respectively. It indicates that, on average, a shock to consumption demand, “-2.45”, is greater than other types of shocks. The maximum of shocks related to the equity risk premium is 3.18. It shows that financial market shock can be greater than other shocks.

The lowest amount of shock (in absolute value) is related to the government expenditure. The GDP loss (GDPL) is “-4.1” on average for all countries globally, in which the maximum and minimum losses are “-9.9” and “-0.7”, respectively.

Table 1. Descriptive Statistics

Variables	LSS	ERS	CDS	GES	GDPL
Mean	-1.50	1.78	-2.45	1.02	-4.10
Std. Dev	0.96	0.50	1.34	0.63	2.36
Minimum	-4.56	1.07	-4.78	0.22	-9.90
Maximum	-0.40	3.18	-0.74	2.67	-0.70

Note: LSS is Labor Supply Shock, ERS is Equity Risk Shock, CDS is the Consumption Demand Shock, GES is the Government Expenditure Shock, and GDPL is the GDP loss. Sample size is 72.

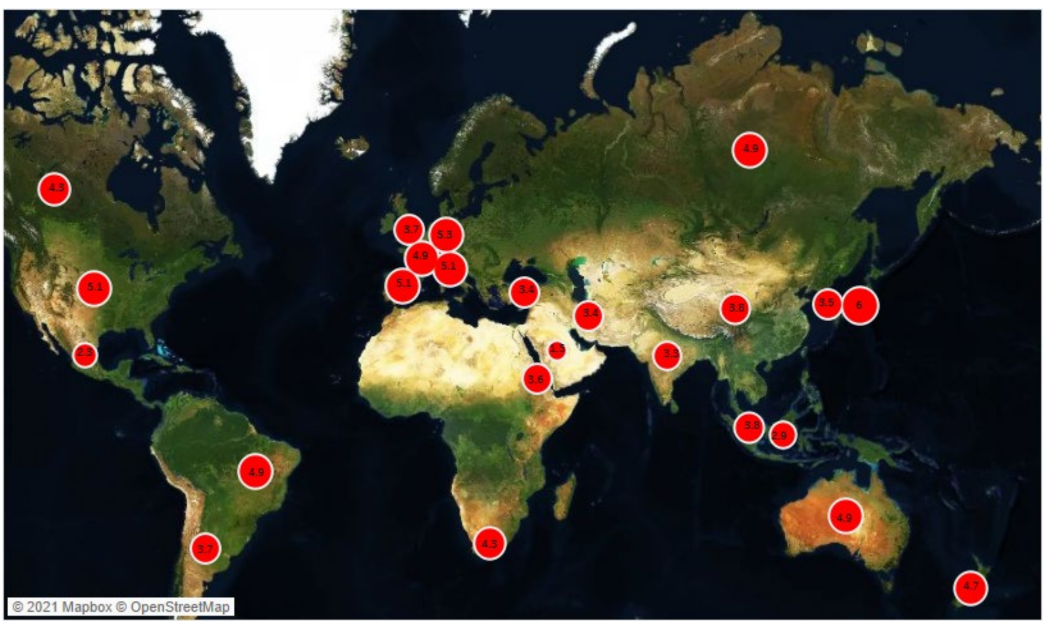


Figure 2. The Average of GDP Loss of Countries and Regions in the World

Figure 2 illustrates the GDP loss of different countries and regions in the world on average. Japan, with a GDP loss of six, has the highest amount of GDP loss on average, and on the other hand, Saudi Arabia, with a GDP loss of one and a half, has the lowest amount. Figure 2 demonstrates that the large amounts of GDP loss are more related to Western Europe on average.

Table 2 shows more details on the GDP loss for each country and region in our data. Japan, on average, experienced the highest amount of shock of “-6.03” to GDP. The maximum amount of GDP loss in Japan is “-9.9”: after that, Germany “-5.3”, Rest of Euro Zone “-5.1”, the US “-5.06”, and Italy “-

5.06". It reveals that, on average, the European countries experienced high GDP losses due to the COVID-19 pandemic compared to other countries in the world.

We observe that Saudi Arabia experienced the lowest average GDP loss, "-1.5" among the countries in the world, and the minimum amount of the GDP loss is "-0.7". Other oil producing countries also had a low GDP loss compared to other countries in the world. Therefore, natural resources like oil and gas might help a country experience a low GDP loss in a pandemic situation. The median of GDP loss is "-3.6", and as the median GDP losses by industrialized countries are mostly more than 3.6, the industrialized countries might be at a higher risk of GDP loss.

Table 2. Descriptive Statistics of the GDP Loss for Each Country and Region

Country	Mean	Median	Minimum	Maximum
Argentina	-3.7	-3.5	-6	-1.6
Australia	-4.9	-4.6	-7.9	-2.1
Brazil	-4.9	-4.7	-8	-2.1
Canada	-4.3	-4.1	-7.1	-1.8
China	-3.8	-3.6	-6.2	-1.6
France	-4.9	-4.6	-8	-2
Germany	-5.3	-5	-8.7	-2.2
India	-3.3	-3.1	-5.3	-1.4
Indonesia	-2.9	-2.8	-4.7	-1.3
Italy	-5.1	-4.8	-8.3	-2.1
Japan	-6.0	-5.7	-9.9	-2.5
Mexico	-2.3	-2.2	-3.8	-0.9
Republic Korea	-3.5	-3.3	-5.8	-1.4
Russia	-4.9	-4.6	-8	-2
Saudi Arabia	-1.5	-1.4	-2.4	-0.7
South Africa	-4.3	-4	-7	-1.8
Turkey	-3.4	-3.2	-5.5	-1.4
United Kingdom	-3.7	-3.5	-6	-1.5
United States	-5.1	-4.8	-8.4	-2
Other Asia	-3.8	-3.6	-6.3	-1.6
Other Oil country	-3.4	-3.2	-5.5	-1.4
Rest of Euro Zone	-5.1	-4.8	-8.4	-2.1
Rest of OECD	-4.7	-4.4	-7.7	-2
Rest of the World	-3.6	-3.5	-5.9	-1.5

Note: Rest of Euro Zone: Belgium, Cyprus, Estonia, Finland, Greece, Ireland, Luxemburg, Malta, Netherlands, Portugal, Slovakia, Slovenia, and Spain. Rest of OECD: Denmark, Iceland, Liechtenstein, New Zealand, Norway, Sweden, Switzerland. Oil-exporting and the Middle East: Ecuador, Nigeria, Angola, Congo, Iran, Venezuela, Algeria, Libya, Bahrain, Iraq, Israel, Jordan, Kuwait, Lebanon, Palestinian Territory, Oman, Qatar, Syrian Arab Republic, United, Arab Emirates, and Yemen. Other Asia: Hong Kong, Malaysia, Philippines, Singapore, Taiwan, Thailand, and Vietnam. Rest of World: All countries not included in other groups (McKibbin & Fernando, 2020).

The GDP loss ranges for Japan, Germany, and the US are "-7.4", "-6.5", and "-6.4", respectively. Interestingly, these countries are the biggest car manufactures in the world. Therefore, a pandemic might have a more negative effect on the GDP of car producers compared to other industrialized countries in the world.

Table 3 shows the Pearson correlation coefficients between variables. We observe that GDP loss is positively correlated with LSS and CDS; therefore, the higher labor supply and consumption demand shocks, the more GDP loss. The correlations of GDP loss with LSS and CDS are statistically significant at the 5 percent statistical level; however, the correlation between GDP loss and CDS is larger than the correlation between GDP loss and LSS. Alternatively, ERS and GES are negatively correlated with GDP loss; therefore, an increase in government expenditure is significantly associated with a lower GDP loss. However, the correlation between ERS and GDP loss is not statistically significant.

Table 3. Pearson Correlation Between Variables

	GDP loss	**LSS**	**ERS**	**CDS**	**GES**
GDP loss	*1*				
LSS	*0.4455***	*1*			
ERS	*-0.1067*	*-0.8637***	*1*		
CDS	*0.9067***	*0.6768***	*-0.3522***	*1*	
GES	*-0.6397***	*-0.8992***	*0.7305***	*-0.8493***	*1*

Note: ** indicates a statistical significance at the 5 percent statistical level. LSS is Labor Supply Shock, ERS is Equity Risk Shock, CDS is the Consumption Demand Shock, GES is the Government Expenditure Shock. Sample size is 72.

ESTIMATION RESULTS

In this section, we present two sets of results in our panel data model. In the first set, we include the time dummies, columns (1) and (2) in Table 4, and in the second set, we exclude the time dummies, columns (3) and (4) in Table 4. Time dummies allow us to control time-specific fixed effects that cannot be controlled by other explanatory variables in each period. We find that the time dummies are individually insignificant in both columns (1) and (2); however, they are jointly significant at the 5% level in column (1) but not in column (2).

As we find evidence of serial correlation in the idiosyncratic error term, we report the cluster-robust standard errors. Given this, we carried out the Hausman test in two different ways: one under the ideal RE assumptions of homoskedasticity and no serial correlation, and the other in a regression-based test which allows the use of robust variance-covariance matrix. In both cases, we find the RE estimator is preferred to the FE estimator. We also report the FE results for comparison.

Table 4 shows the RE and FE estimation results with the four explanatory variables: LSS, ERS, CDS, and GES. Although the estimated coefficients on ERS, CDS, and GES are positive, only consumption demand shock is statistically significant in the RE results with and without the time dummies. It indicates that if the consumption demand shock increases by one unit in column (1), the GDP loss will increase by around "3.48", on average; without the time dummies, the partial effect decreases to "2.22." We also find that the equity risk shock is statistically significant in the FE results without the time dummies, which indicates that equity risk premium could be another factor in explaining GDP loss of countries.

We also estimated the model with a FD estimator which eliminates the time-invariant unobserved heterogeneity but imposes a serial correlation assumption different from the assumption in FE estimation. As we find the FD results are similar to the FE results, the FD results are not reported.

Table 4. Estimation Results with GDP Loss as the Dependent Variable

	(1) RE	(2) FE	(3) RE	(4) FE
LSS	*-0.5208*	*0.2520*	*-0.2083*	*0.6759*
	(0.3941)	*(0.8771)*	*(0.5434)*	*(0.7848)*
ERS	*0.0212*	*2.8553*	*0.1511*	*3.7034***
	(0.1811)	*(2.4504)*	*(0.1403)*	*(1.7154)*
CDS	*3.4795****	*3.3569****	*2.2220****	*2.2844****
	(1.1160)	*(1.0718)*	*(0.2296)*	*(0.2218)*
GES	*0.5528*	*0.6937*	*1.3013*	*1.2914*
	(0.8419)	*(0.9076)*	*(1.1577)*	*(1.1035)*
Dummy for 2nd period	*1.9084*	*1.6988*		
	(1.5669)	*(1.5195)*		
Dummy for 3rd period	*4.6198*	*3.9736*		
	(3.6448)	*(3.5673)*		
Constant	*0.8731*	*-3.1838*	*-0.5548***	*-5.4050***
	(1.1594)	*(3.6794)*	*(0.2182)*	*(2.3193)*
Country fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
Time fixed effects	*Yes*	*Yes*	*No*	*No*
R squared	*0.896*	*0.793*	*0.884*	*0.733*
Test of overall significance	*1217****	*190****	*1232****	*276****

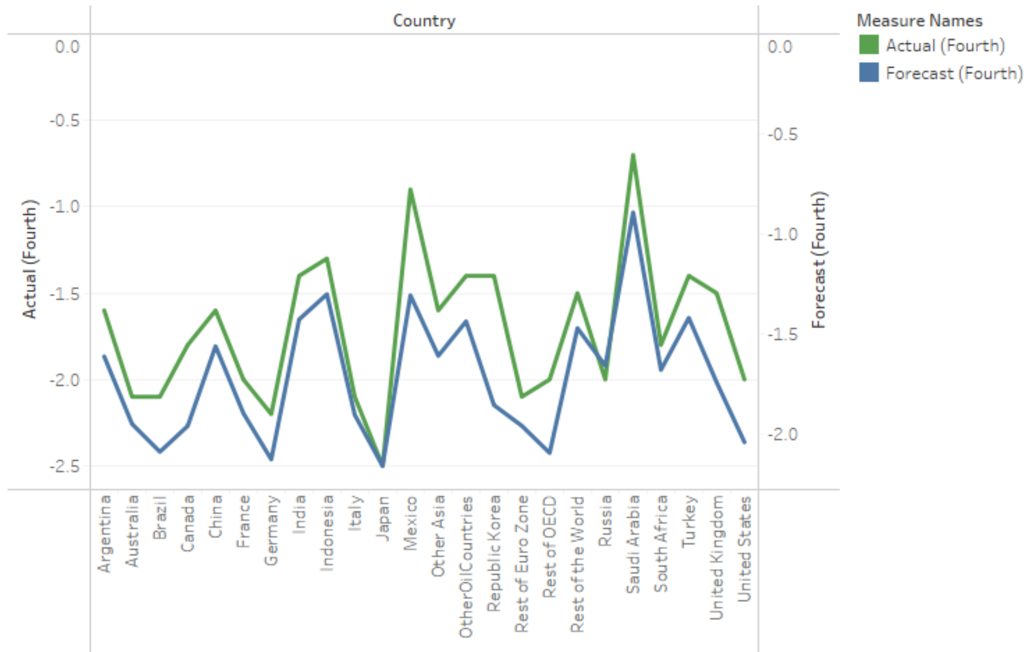
Note: sample size of 72; RE in columns (1) and (3) are random effects estimation results, and FE in columns (2) and (4) are fixed effects estimation results; cluster-robust standard errors in parenthesis; *** for p value < 0.01; ** for 0.05; * for 0.10; LSS is Labor Supply Shock, ERS is Equity Risk Shock, CDS is the Consumption Demand Shock, and GES is the Government Expenditure Shock.; R squared is the square of correlation coefficient between the dependent variable and the fitted dependent variable.; chi-squared statistics in RE overall significance, and F statistic in FE overall significance.

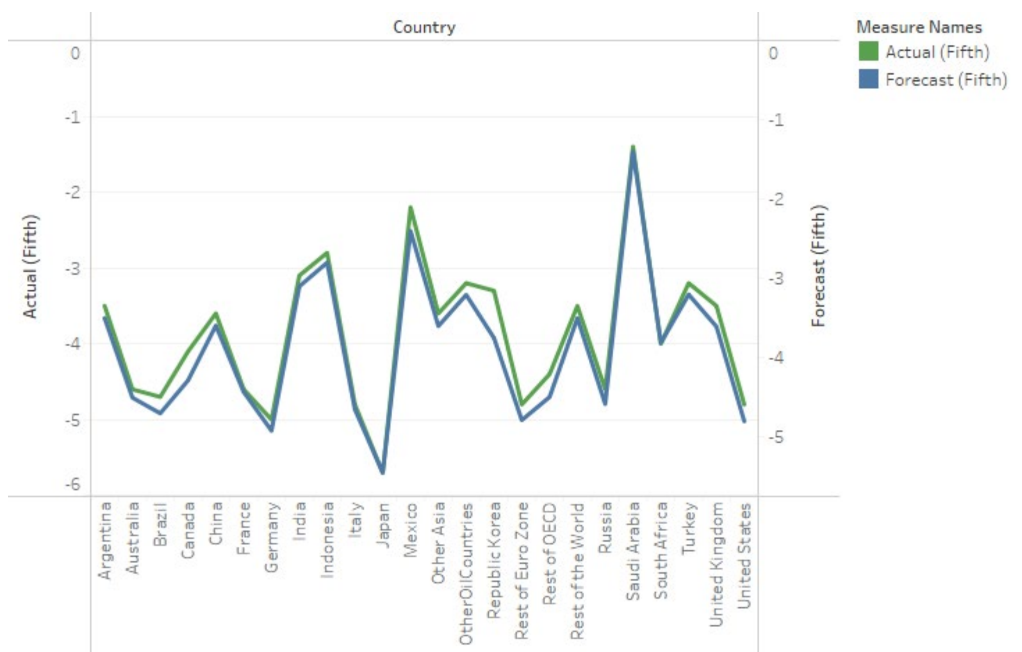
NEURAL NETWORK ANALYSIS

In this section, after estimating the panel data model and finding the associated coefficients, we forecast the GDP loss of each country by our proposed neural network method. The neural network method we implement in our study is the GRNN, which uses a feedforward network with fast training ability (Ahangar et al., 2020; Bărbulescu, 2018; Majumder & Maity, 2018).

The proposed GRNN model in our study uses a Gaussian activation function in the hidden layer, which some earlier studies about SARS-CoV-1 confirmed that the SARS family virus follows the Gaussian or Exponential distribution (Bai & Jin, 2005; Hsieh et al., 2004; Lai, 2005; Wang & Ruan 2004). The trend of the COVID-19 pandemic is like a discrete function with particular daily cases and follows the Poison function (Ahangar et al., 2020). Therefore, the GRNN with a feedforward neural network can be a good procedure.

Figure 3 demonstrates the GDP loss of the mentioned countries in this study for the fourth, fifth, and sixth scenarios of McKibbin and Fernando (2020). The sixth scenario or the third graph in Figure 3, shows that Japan faces the highest GDP loss. Germany and the US are the next countries.


Country
Measure Names
Actual (Fourth)
Forecast (Fourth)
Actual (Fourth)
Forecast (Fourth)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
Argentina
Australia
Brazil
Canada
China
France
Germany
India
Indonesia
Italy
Japan
Mexico
Other Asia
OtherOilCountries
Republic Korea
Rest of Euro Zone
Rest of OECD
Rest of the World
Russia
Saudi Arabia
South Africa
Turkey
United Kingdom
United States


Country
Measure Names
Actual (Fifth)
Forecast (Fifth)
Actual (Fifth)
Forecast (Fifth)
0
-1
-2
-3
-4
-5
-6
Argentina
Australia
Brazil
Canada
China
France
Germany
India
Indonesia
Italy
Japan
Mexico
Other Asia
OtherOilCountries
Republic Korea
Rest of Euro Zone
Rest of OECD
Rest of the World
Russia
Saudi Arabia
South Africa
Turkey
United Kingdom
United States

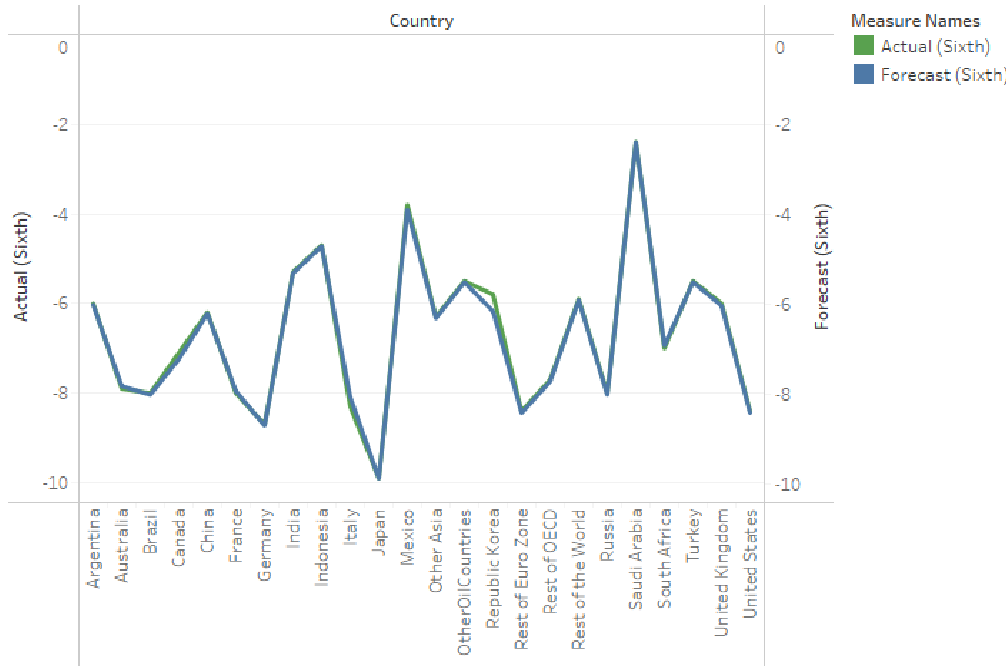


Figure 3. The Actual and Predicted GDP Loss per Country for Fourth, Fifth, and Sixth Scenarios

In the proposed GRNN forecast model, we observe that the forecast power is increasing from the fourth to sixth scenario since the forecast numbers get closer to the actual data, which shows the strength of the proposed GRNN model after a learning pattern.

VALIDITY OF THE GRNN MODEL

Table 5 shows the actual and predicted number of GDP losses for the countries in our study. In this step, we illustrate the actual and predicted GDP loss numbers of the proposed GRNN model for the fourth, fifth, and sixth scenarios of McKibbin and Fernando (2020) for each country.

Table 5. Actual and Forecast GDP Loss of GRNN Model with Fourth, Fifth, and Sixth Scenarios

Country	Actual (fourth)	Forecast	Actual (fifth)	Forecast	Actual (sixth)	Forecast
Argentina	-1.6	-1.6128	-3.5	-3.4999	-6	-6.0000
Australia	-2.1	-1.9502	-4.6	-4.5028	-7.9	-7.8079
Brazil	-2.1	-2.0894	-4.7	-4.6990	-8	-8.0000
Canada	-1.8	-1.9599	-4.1	-4.2849	-7.1	-7.2086
China	-1.6	-1.5614	-3.6	-3.5936	-6.2	-6.2000
France	-2	-1.8967	-4.6	-4.4302	-8	-7.9201
Germany	-2.2	-2.1272	-5	-4.9187	-8.7	-8.6832
India	-1.4	-1.4277	-3.1	-3.1000	-5.3	-5.3000
Indonesia	-1.3	-1.3013	-2.8	-2.8000	-4.7	-4.7000
Italy	-2.1	-1.9046	-4.8	-4.6515	-8.3	-8.0477
Japan	-2.5	-2.1598	-5.7	-5.4488	-9.9	-9.8562
Mexico	-0.9	-1.3070	-2.2	-2.4019	-3.8	-3.8930
Republic Korea	-1.4	-1.8559	-3.3	-3.7493	-5.8	-6.1460
Russia	-2	-1.6588	-4.6	-4.5825	-8	-8.0000
Saudi Arabia	-0.7	-0.8923	-1.4	-1.4004	-2.4	-2.4000
South Africa	-1.8	-1.6796	-4	-3.8113	-7	-6.9060
Turkey	-1.4	-1.4198	-3.2	-3.2023	-5.5	-5.5000
United Kingdom	-1.5	-1.7420	-3.5	-3.6063	-6	-6.0221
United States	-2	-2.0414	-4.8	-4.7998	-8.4	-8.4000
Other Asia	-1.6	-1.6093	-3.6	-3.6000	-6.3	-6.3000
Other Oil Countries	-1.4	-1.4370	-3.2	-3.2065	-5.5	-5.5000
Rest of Euro Zone	-2.1	-1.9590	-4.8	-4.7856	-8.4	-8.4025
Rest of OECD	-2	-2.0950	-4.4	-4.4939	-7.7	-7.7052
Rest of the World	-1.5	-1.4712	-3.5	-3.4990	-5.9	-5.9000

Note: Rest of Euro Zone: Belgium, Cyprus, Estonia, Finland, Greece, Ireland, Luxemburg, Malta, Netherlands, Portugal, Slovakia, Slovenia, and Spain. Rest of OECD: Denmark, Iceland, Liechtenstein, New Zealand, Norway, Sweden, Switzerland. Oil-exporting and the Middle East: Ecuador, Nigeria, Angola, Congo, Iran, Venezuela, Algeria, Libya, Bahrain, Iraq, Israel, Jordan, Kuwait, Lebanon, Palestinian Territory, Oman, Qatar, Syrian Arab Republic, United, Arab Emirates, and Yemen. Other Asia: Hong Kong, Malaysia, Philippines, Singapore, Taiwan, Thailand, and Vietnam. Rest of World: All countries not included in other groups (McKibbin & Fernando, 2020).

As shown in Table 5, the proposed GRNN model shows an excellent fit in the prediction of GDP loss. In the next step, we calculate the average forecast errors of the model.

Table 6. Average Forecast Errors of the Fourth, Fifth, and Sixth Scenarios for Proposed GRNN Model

Country	(%MAPE)
Argentina	*0.0370*
Australia	*0. 7745*
Brazil	*0. 0239*
Canada	*1. 16231*
China	*0. 1317*
France	*0. 8059*
Germany	*0. 3582*
India	*0. 0944*
Indonesia	*0.0050*
Italy	*1.3074*
Japan	*1. 1699*
Mexico	*3. 39575*
Korea	*3. 9740*
Russia	*0. 8190*
S-Arabia	*1. 4271*
S-Africa	*1. 0496*
Turkey	*0. 0726*
UK	*1. 1227*
US	*0. 0902*
O-Asia	*0. 0270*
Oil Country	*0. 1435*
R-Euro	*0. 3320*
R-OECD	*0. 4588*
R-World	*0. 0883*

Note: (%MAPE) is Mean Absolute Percentage Error

Table 6 represents the average forecast error of the GDP loss for the fourth, fifth, and sixth scenarios. A rough rule of thumb specifies if %MAPE < 10%, then the forecast is ideal. The above table demonstrates that all forecast errors are smaller than 10%; therefore, the proposed GRNN model is a good fit model with high accuracy for all countries.

DISCUSSION AND CONCLUSION

This study is based on the recently published paper of McKibbin and Fernando (2020) that proposed seven COVID-19 scenarios where the first three scenarios, at the initial stage of COVID-19 shocks, are related to China. The last four scenarios are related to the global economy when the COVID-19 virus spreads worldwide and affects almost all countries. We use the data from the simulation model of McKibbin and Fernando (2020) that a portion of data were collected from GTAP database (Aguiar et al., 2019) to find how the loss in GDP is related to shocks in various areas of the economy.

In this paper, we look at fourth, fifth, and sixth scenarios from a different view. We assume each of the scenarios is a different time period and analyze how shocks to labor supply, equity risk, consumption demand, and government expenditure affect the GDP loss.

The findings show that Japan experienced the highest amount of GDP loss among all countries in the world. Also, Japan faced the most extensive range of GDP loss. Literature reviews show that the COVID-19 pandemic originated from Wuhan in China (Huang et al., 2020; Tan et al., 2020; Zhu et al., 2020), and this province consists of more than 300 companies, including some largest companies in the world, which contributes nearly 16.3% of global GDP (Ayittey et al., 2020). In addition, the Japanese Honda car company has several branches in Wuhan and also reduced its production in Japan due to a reduction of imported materials from China (Inoue & Todo, 2020).

Our analysis reveals that Japan, Germany, and the US, respectively, experienced the highest range of GDP loss among all countries in the world. We can also add France and Italy to this list of the countries with the significant GDP loss. An interesting finding is that the countries with considerable GDP loss have a large automobile manufacturing industry that is part of the durable goods sector. The COVID shock has a more significant effect on durable goods because the change in risk premia sharply reduces the discounted present value of durable goods as risk rises. Therefore, countries that export such goods could face a large negative external consumption demand shock. On the other hand, we see Saudi Arabia and other oil producer countries have the lowest GDP loss. Thus, we can see the oil industry as a counterpart of the automobile industry during a pandemic.

The literature review shows that the equity market faced the fastest decline in history (Khan et al., 2020). Our analysis finds that the equity risk shock along with the consumption demand shock is an important and significant factor explaining GDP loss. Policies designed to boost consumption demand and stabilize equity market can reduce shocks to GDP. For example, the US policy of sending stimulus checks to selected households who will spend the money almost immediately can increase consumption demand and reduce GDP loss.

The COVID-19 pandemic followed by lockdown affected the global economy, including the financial markets and the demand-supply networks. The restrictions on the movement of the products enforce the supply-side shock, and consequently, the supply shock reduces the wage income and the amount of saving, creating the demand-side shock (Sahoo & Ashwani, 2020). Therefore, it has a negative impact on the growth rate and leads to a massive GDP loss.

It is noteworthy that some supply and demand shocks are more concentrated on specific occupations that face more risk of unemployment in the industry. For example, some types of job, such as mining, roofing, and floor layering, are almost impossible to work at home (Rio-Chanona et al., 2020). Therefore, during the COVID-19 pandemic, for such occupations, the supply shock is bigger than the demand shock because COVID-19 is considered an immediate shock.

Indeed, the aggregate shocks of demand and supply depend on each occupation's prevalence in its relevant industry. Some studies stated that the employment and wage shocks related to demand and supply volatilities are around 24% and 17%, respectively (Rio-Chanona et al., 2020; Adams-Prassl et al., 2020).

Moreover, we need to consider that the COVID-19 pandemic may hit developing countries with low-income populations. In a report, the World Bank estimated that poverty reaches 11 million people in East Asia and the Pacific (World Bank, 2020). In another study, Buheji et al. (2020) estimated that 49 million people worldwide would suffer from poverty in 2021.

The weekly number of unemployment insurance claims in the US before the COVID-19 pandemic was reported at 695,000. After COVID-19, from March 14 through March 21, 2020, it jumped to 3,307,000. It was as high as 6,867,000 in the last week of March. This number is expected to increase by the end of the year (U.S. Employment and Training Administration, 2020). In a study of 5,800 small and medium-sized enterprises in the US, Bartik et al. (2020) found a 40% decline in employment. Therefore, for recovery, the increase in employment is an essential factor. Also, some unemployment might occur if workers choose to quit their current positions for fear of being infected by COVID-19 at work and seek alternative jobs.

History shows a V-shape recovery for the Spanish flu, Asian flu, and SARS pandemic in 1918, 1958, and 2002, respectively, when the aggregate output recovered fast to the pre-pandemic level (Carlsson-Szlezak et al., 2020). For such a fast recovery, each government can increase direct income assistance to households who spend such aid, and as a result, consumption demand could increase. Indirectly, consumption demand can also rise with government's efforts to limit the spread of the virus by offering vaccines so that people can return to their pre-pandemic life and increase consumption without being worried about the COVID-19. With such direct and indirect methods, the GDP loss can be mitigated, and international entrepreneurship will grow at a great pace, and this leads to a transformation of the global business environment in post COVID-19 era.

LIMITATIONS AND FUTURE RESEARCH

Due to the nature of our research, this study has some limitations. First, unlike the other units, five cross-sectional units in our sample are a group of countries. Second, as we mentioned earlier, COVID-19 also created psychological, political, and sociological shocks in addition to the economic shocks. Those shocks are not covered in our study. Third, this study examined a short-term shock at the beginning of the COVID-19 pandemic; however, the effects of the shocks on GDP could change over time.

With the limitations in mind, future studies can include more detailed economic and non-economic shocks such as psychological, political, and sociological shocks in the model. In addition, it will be interesting to know how government expenditure and equity risk premium shocks affect GDP loss in the long run. With an ongoing supply chain disruption and high inflation, especially in the US, studying the long-term impact of such shocks on the GDP loss can give us a more comprehensive understanding of how COVID-19 affected the world economy.

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