Economic Analysis of COVID-19 Non-Pharmaceutical Interventions in the Context of World Trade

Yeh, Chun-Hsien[1] Liou, Je-Liang[2] Yang, Chin-Wen[3] Chang, Hsuan-Yu[4]

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Abstract

In 2020, the COVID-19 pandemic spread rapidly across the world. Before the vaccine coverage increases effectively, Non-Pharmaceutical Interventions (NPIs) implementation become crucial for preventing epidemic spread. However, these measures inevitably affected production and consumption, thereby negatively impacting the economy. And these impacts on individual economy or region will deliver to other region through international trade. Our study proposes an analytical framework to evaluate the effectiveness of NPIs mixes in various regions/countries under considering world trade effects. Furthermore, we explore how adopting a relatively appropriate mix of NPIs can mitigate the negative economic impacts of such worldwide infectious diseases. Our findings show that region groups responding faster to the epidemic experienced smaller negative impacts from their own NPIs mix. This indicates the importance of early implementation of border controls. Secondly, facial coverings result in smaller negative impacts compared to workplace closures. Finally, considering the world trade context, if regions/countries with higher bilateral trade volumes implement relatively appropriate NPIs mixes (border controls, workplace closures, and facial coverings) collectively, they can mitigate the negative economic impacts while also generating positive spillover effects for other regions/countries.

Keywords: COVID-19; non-pharmaceutical interventions; trade effect

[1] The President of Chung-Hua Institution for Economic Research. Email: chyeh@cier.edu.tw
[2] Deputy Director, The Center for Green Economy, CIER. Email: jlliou@cier.edu.tw
[3] Deputy Director, The Center for Economic Forecasting, CIER. Email: cwyang@cier.edu.tw
[4] Assistant Research Fellow, The Center for Green Economy, CIER. Email: hychang@cier.edu.tw

Introduction

The COVID-19 pandemic had a significant negative impact on the world in 2020. According to estimates by the United Nations Department of Economic and Social Affairs (UN DESA) and the World Health Organization, global trade volumes in goods and services fell by 7.6%, and the death toll from COVID-19 surpassed 3 million people. Before effective medications were developed, governments primarily implemented various Non-Pharmaceutical Interventions (NPIs) to address the outbreak, such as border controls, workplace closures, mandatory mask-wearing, and various domestic containment and quarantine measures. Although these measures helped suppress the spread of the pandemic to some extent, they also negatively impacted the economy.

In response to the impacts of the COVID-19 pandemic, existing literature primarily follows two research directions: (1) from a public health perspective, using actual observational data to analyze the effects of preventive measures on confirmed cases and/or death counts; and (2) from an economic perspective, assuming specific infection rates to analyze their impacts on the economy.

In the first type literature, Worby and Chang (2020) investigated the impact of mask-wearing on epidemics and found that this NPI can effectively reduce the total number of infections and deaths, as well as delay the peak of the pandemic. Regarding the effectiveness of various NPIs, Haug et al. (2020) ranked the effectiveness of government NPIs during COVID-19. This study highlighted that border controls have a significantly positive effect on reducing infections, followed by closing and restricting places where people gather for extended periods, such as businesses, bars, and schools. Therefore, the study suggests that governments prioritize these types of NPIs (border controls, closing, and restricting places). Brauner et al. (2021) also found similar results, indicating that banning gatherings was more effective than closing non-essential face-to-face businesses.

In the second type literature, the focus is largely on assessing how the pandemic shock, assuming specific infection rates, impacts the overall economy through transmission within economic systems. For instance, Santos (2020) utilized a single-country Input-Output (IO) model to explore the pros and cons of various pandemic measures under different settings on days to the peak of the epidemic curve. Guan et al. (2020) applied a multi-country IO model considering different durations and strictness of lockdown scenarios, exploring the impact of lockdown intensities on supply chains globally and for different industries in various regions and countries. In terms of methodology, due to the IO model and the Computable General Equilibrium (CGE) model both incorporating inter-industrial interactions into their analysis, researchers frequently employ these two models to examine the economic impacts of pandemic measures. For example, Haddad et al. (2021) used a single-country IO model to study which regions within Brazil were most affected by pandemic measures. Keogh-Brown et al. (2020) used a single-country CGE model to demonstrate how the duration of school and business closures affects the economy.

Under the existing global trade structure, the impact of the pandemic or the implementation of an NPI mix by one country is transmitted through trade relations. Therefore, incorporating trade relations and effects into the analytical framework will also make the results more realistic. The impact of the pandemic and the implementation of various NPI mixes on the economy should integrate two different research perspectives: public health and economics.

Based on this background, this study proposes an analytical framework from economic and public health perspectives under the international trade context to measure the transnational impacts of NPIs. This framework conducts simulation analyses through different scenarios to assess how appropriate NPIs can mitigate the economic impact caused by such large-scale infectious diseases, particularly during the year 2020. This is the period before effective vaccines were introduced and while effective medications were still under development.

Methodology and Research Framework

This study aims to explore the impact of various NPI mixes implemented during 2020. These NPI mixes affect the economy through two main pathways (see Figure 1). Firstly, confirmed cases and deaths lead to a shortage of labor available for production. Secondly, the impact on production is due to the closure of workplaces.

To elaborate on these pathways, we use the Oxford COVID-19 Government Response Tracker (OxCGRT) database to determine the response speed of border controls, classifying the world into five groups from slowest to fastest. We then employ panel data models to estimate the impact of each country's NPI mix on daily confirmed cases by group. Finally, we convert the numbers of confirmed cases and deaths under the NPI mix into reductions in labor supply for each country. In the second pathway, the number of workplace-closure days is accounted for annual output reductions in the corresponding industries. The reductions in labor supply and output are then input into the Global Trade Analysis Project (GTAP) model to assess their economic impact.

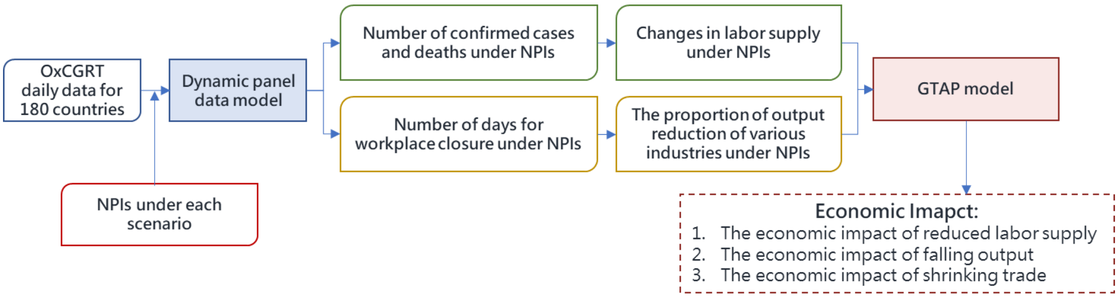


Figure 1: Research Framework

Panel data model

Pandemic Response Speed Grouping

In this study, the intensity of border control implemented when the first confirmed case was reported gauges the response speed of various regions or countries to the pandemic. For example, Taiwan's border control measures were at level 3 when the first confirmed case was reported, indicating that relatively strong border controls were already in place before the virus could spread widely within Taiwan. By extension, Group 0 represents regions that had not yet implemented any border control when their first confirmed cases were reported, thereby exhibiting the slowest response speed. This classification helps us assess how the timing and intensity of border control might correlate with the spread and control of the pandemic within different regions or countries.

As shown in figure 2, Group 0 includes 64 regions which collectively have a larger population than the other groups and Taiwan belongs to group 3. Figure 3 presents the number of confirmed cases in Group 0 also constitutes a major portion of the global confirmed cases.

Data Source and Variable Selection

This study adopts the Oxford COVID-19 Government Response Tracker (OxCGRT) dataset, which covers daily data from 180 regions and countries. The study period is set from the first reported international case in January 2020 to the initial vaccine administration in mid-December 2020. This timeframe almost covers the entire year of 2020 and focuses on the early stages of the pandemic to the period before effective medications were developed, examining the economic impacts of various NPI mixes.

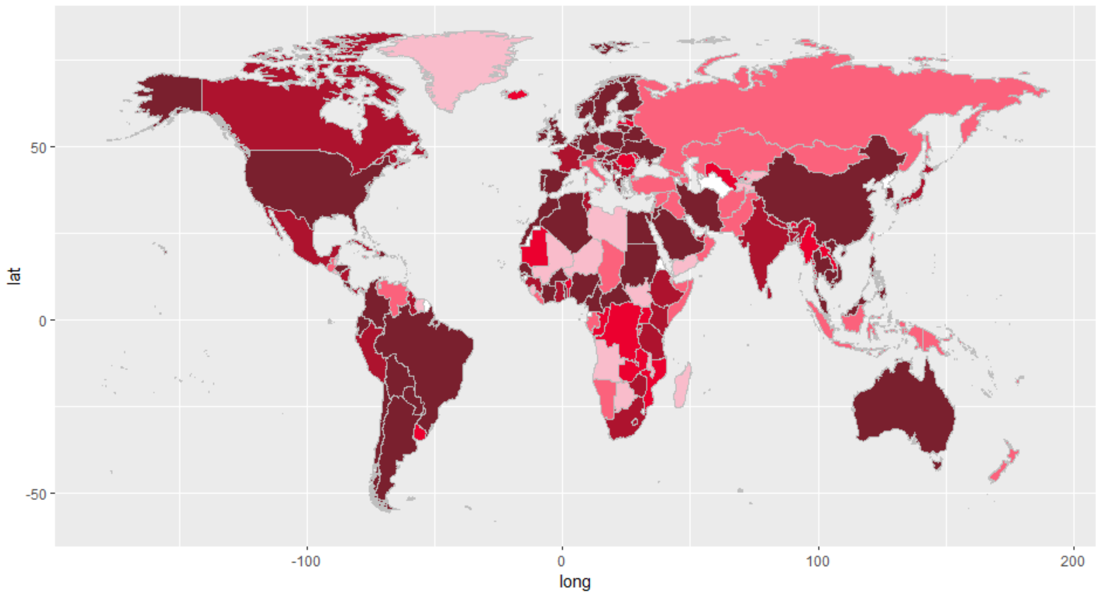


Figure 2: Distributions of Group 0 to Group 4

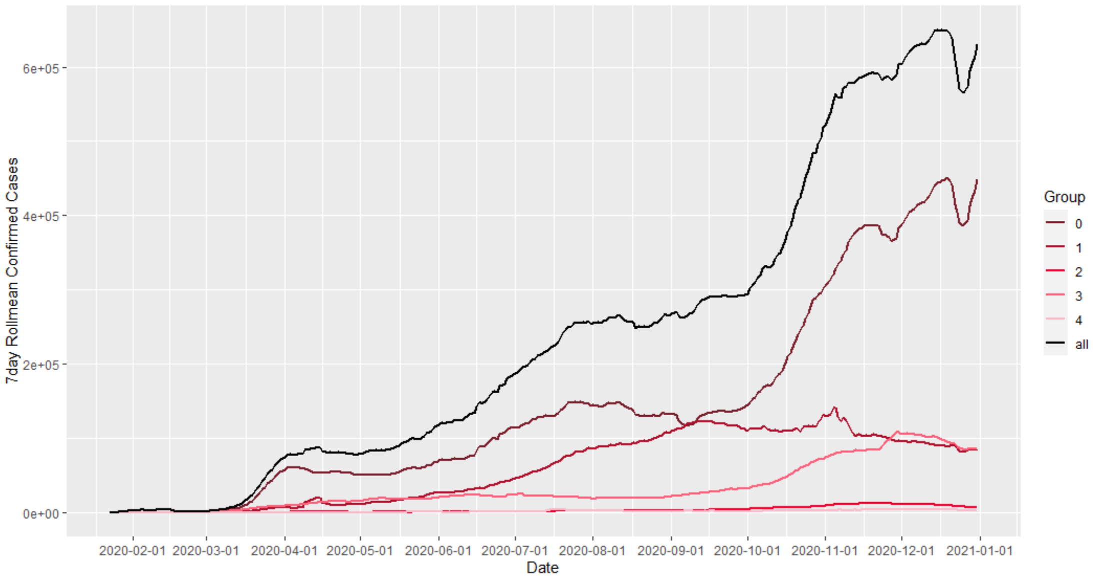


Figure 3: Global Daily Confirmed Cases in 2020

A stepwise backward elimination algorithm was employed for variable selection to perform econometric analysis. This technique helps reduce model complexity and avoid overfitting by removing the least significant variables based on specific statistical criteria. We use the Number of Confirmed Cases (mar_case) to measures the daily number of confirmed cases in each region or country, and other selected variables include:

- Workplace Closures (C2): Records whether and to what extent workplaces were closed in response to the pandemic.

- Restrictions on Gatherings (C4): Indicates the restrictions imposed on the number of people allowed to gather.
- Public Transport Closures (C5): Documents the closure of public transportation systems.
- Domestic Movement Restrictions (C7): Details restrictions on movement between cities or regions within regions and countries.
- Travel Restrictions on Foreign Travelers (C8): Reflects the extent of restrictions on international travelers entering the country.
- Regulations on Mask Wearing (H6): Indicates whether masks were mandated and the circumstances of their required use.

Variable descriptions and data handling specifics can be found in Appendix 1.

Estimation Results

This paper employs a dynamic panel model with two-way (individual and time) fixed effects to analyze the data. The two-way fixed effects allow the individual characteristics of each country to be reflected through individual fixed effects, while time fixed effects can account for phenomena such as the weekend effect. For example, some laboratories close over the weekend, leading to zero cases reported on Monday and a small peak in reported cases on Tuesday.

Two-way panel model is applied with 180 regions pooled data and groups data separately. The results from pooled data, shown in Table 2, indicate that mask-wearing (h6) significantly reduces the spread of the pandemic and that the faster the implementation of such measures, the more effective they are in controlling the spread (Respond speed:h6).

The analysis of different response speed groups shows how preventive measures affect confirmed cases in each group. Our findings (Table 1) reveal: (i) For each group, the number of confirmed cases on any given day is significantly influenced by the number of cases from the previous day, mainly due to the high transmissibility of the disease. (ii) The R-squared coefficients of each model indicate that groups with faster responses have a higher explanatory power for the number of confirmed cases. This is because prompt border controls at the start of the pandemic effectively block the virus from entering the country, preventing a large-scale domestic spread. Other domestic control measures manage those viruses entering from borders.

Table 1: The Results of Two-way Panel Model

	Dependent variable: mar_case					
	Pooled	Group 0	Group 1	Group 2	Group 3	Group 4
lag(mar_case)	0.958***	0.963***	0.929***	0.936***	0.973***	0.491***
	(0.001)	(0.002)	(0.004)	(0.004)	(0.002)	(0.010)
c2	18.326		-163.890*	-13.348	4.864	17.573***
	(13.705)		(92.469)	(11.326)	(10.893)	(3.199)
c4				-3.821	7.592	16.313**
				(4.201)	(9.307)	(7.733)
c5	26.483	27.512	56.899	35.807**		-0.531
	(17.411)	(42.174)	(42.868)	(16.213)		(14.267)
c7	-27.408	-40.879			-22.76	15.919***
	(22.792)	(55.893)			(17.410)	(3.537)
c8	-37.456	-78.847	-111.045	-9.104*	-25.622	16.803**
	(31.275)	(83.417)	(88.127)	(5.207)	(25.227)	(7.743)
h6	-108.935***	-280.229***	-239.724***	-10.588	-28.329**	-26.500***
	(30.213)	(74.282)	(83.385)	(6.883)	(12.983)	(9.392)
c22			51.070*	6.064		
			(29.212)	(3.822)		
c42						-3.524*
						(1.900)
c52				-16.352**		-21.981***
				(7.450)		(6.107)
c82	11.052*	21.93	30.416*		5.972	-7.253***
	(6.688)	(18.191)	(18.489)		(5.260)	(1.716)
h62	33.732***	70.079***	48.420**			-4.930**
	(7.194)	(18.414)	(19.527)			(1.935)
c2:h6			46.527***			
			(17.256)			
c4:h6				3.052**	5.277	2.189
				(1.547)	(3.679)	(1.544)
c5:h6				-6.878**		21.211***
				(2.920)		(2.427)
c7:h6	14.632*	33.352			6.544	
	(8.018)	(22.066)			(6.270)	
c8:h6				5.803***		7.591***
				(2.061)		(1.305)
Respond speed:h6	-16.394***					
	(4.192)					
Observations	61,740	21,952	11,319	7,203	12,691	8,575
R^2	0.893	0.894	0.877	0.892	0.943	0.323
Adjusted R^2	0.892	0.891	0.873	0.886	0.941	0.291
F Statistic	51,112.260*** (df = 10; 61208)	22,591.340*** (df = 8; 21538)	8,673.918*** (df = 9;10935)	5,101.163*** (df = 11; 6829)	22,638.120*** (df = 9; 12303)	278.983*** (df = 14;8194)
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$					

The dynamic panel model used in this research emphasizes two key aspects. Firstly, the model estimates the number of confirmed cases under different simulated scenarios, reflecting the impact of various NPI mixes on the labor supply. This helps generate accurate simulations from the GTAP model. By quantifying how NPIs reduce workforce availability due to illness, quarantine, or preventive measures, the model helps assess the economic impacts more precisely. These estimates are crucial for simulating the economic dynamics during the pandemic and provide insights into how labor supply disruptions can ripple through economies. Secondly, the model reveals that the response speed indeed influences the effectiveness of NPI mixes on the number of confirmed cases.

Our findings highlight that while prompt response is critical, the specific combination and execution of NPIs are equally important in managing the pandemic's spread. Policymakers need to consider not only the timing but also the appropriateness and integration of various interventions to achieve the best possible outcomes in mitigating their economic impacts.

GTAP model

We now integrate the above estimation results from the dynamic panel model into the GTAP model to simulate the numbers of deaths and confirmed cases under different NPI mixes and assess the economic impacts of implementing these NPI mixes within the context of trade structure.

Brief Introduction of GTAP

This study utilizes the Computable General Equilibrium (CGE) model from the Global Trade Analysis Project (GTAP), which is a multi-country global trade analysis model. Developed by Purdue University in the United States, the GTAP model is widely accepted in assessing various environmental and trade-related issues. As the GTAP model is based on the neoclassical general equilibrium theory and represents an open economy market model, it describes the relations among production, consumption, government expenditure, and trade in each country and region. Consequently, it can depict varies in economic activities across multiple regions and industries, as well as overall macroeconomic performance.

By exploiting the GTAP model to assess the impact of the pandemic, this study can evaluate and compare the economic shocks caused by the spread of the pandemic and the implementation of NPIs mix across different regions and countries. Additionally, it can encompass the indirect economic impacts caused by the trade disruptions and increment of transaction costs between countries due to the pandemic.

This trade impact effect is particularly obvious during the COVID-19 pandemic, as there are not only geographical differences in the spread of the pandemic but also geographical linkages in trade partnerships and supply chain relationships.

Regarding the data, this study adopts the GTAP 10th edition database, dividing the world into 37 regions and 37 commodities. To analyze various scenarios based on Taiwan's NPIs mix, the study retains Southeast Asian countries, the United States, Japan, South Korea, China, and the United Kingdom as individual regions due to their close trade relationships with Taiwan, rather than as an agglomeration. For commodities, industries affected by different levels of domestic restrictions are treated separately. For example, during level 2 restrictions, the food and beverage, leisure, and personal services industries are closed, while during level 3 restrictions, all industries except for essential services such as agriculture, utilities, and gas are closed.

Simulation Scenario

Given that the response speed of regions and countries has been considered in the dynamic panel model estimates, the GTAP model scenario designs primarily focus on the combinations of mask-wearing and workplace closures. Furthermore, aside from the previously discussed significant impact of mask-wearing (h6) on confirmed case numbers, workplace closure (c2) is identified as having a more direct economic impact. Other NPIs, such as restrictions on gatherings (c4), public transportation controls (c5), and movement restrictions (c7), have fewer correlations with production. Therefore, the scenarios are based primarily on mask-wearing (h6) and workplace closure (c2).

This study designs five scenarios to evaluate the impact of NPIs on the economy under mask-wearing and workplace closures. Scenario 1 reflects the impact of the current NPI mix for each region and country. Scenarios S2 to S5 are designed to examine the impact of the NPI mix of trade partner regions and countries on each country's economic performance. By doing so, the study aims to better understand how trade relationships amplify or mitigate the economic impacts of pandemics. This is critical, as global supply chains often transmit economic shocks across borders, which can exacerbate or alleviate the local impacts of NPIs, depending on the nature of the trade dependencies and economic structures involved. The details of each scenario are listed in Table 2.

Table 2: Scenario Description

ID	Scenario Assumptions
S1	**Baseline**: This scenario evaluates the economic impact of the actual situation where the pandemic occurred and NPIs were adopted in 2020, which is versus a scenario where the pandemic did not occur and no NPIs were implemented. This scenario serves as a baseline for comparison with other scenarios.
S2	**Global Adoption of Taiwan's Workplace Closure**: Assuming all regions and countries adopt Taiwan's duration and intensity of workplace closure and comparing the economic impact relative to a scenario where the pandemic did not occur and no NPIs were implemented. The purpose is to evaluate the economic impact if the rest of the world had implemented workplace closures as stringently as Taiwan.
S3	**Global Adoption of Taiwan's Mask Wearing**: Assuming all regions and countries adopt Taiwan's duration and intensity of mask-wearing and comparing the economic impact relative to a scenario where the pandemic did not occur and no NPIs were implemented. The purpose is to assess how widespread adoption of mask wearing at Taiwan's level could have moderated the economic impact.
S4	**Global Adoption of Taiwan's Mask Wearing and Workplace Closure**: Assuming all regions and countries adopt Taiwan's duration and intensity of workplace closures and mask-wearing and comparing the economic impact relative to a scenario where the pandemic did not occur and no NPIs were implemented. The purpose is to evaluate the combined effects of both types of NPIs.
S5	**Trade Partners' Adoption of Taiwan's Mask Wearing and Workplace Closure**: Assuming that only Taiwan's major trade partners (Including China, the United States, Japan, South Korea, Southeast Asian regions and countries, and the European Union) adopt Taiwan's duration and intensity of mask-wearing and workplace closures and comparing the economic impact relative to a scenario where the pandemic did not occur and no NPIs were implemented. The purpose is to analyze the economic impact of Taiwan's NPIs on its major trade partners.

From Panel Model to GTAP

- Conversion of Confirmed Cases and Deaths to Labor Supply Reduction

Since this study focuses on the early stages of the pandemic, prior to widespread vaccination, it examines the impact of NPIs. Thus, the simulation is set for the single year of 2020. Adopting a fixed-effects model, the number of confirmed cases for each country under the seven scenarios mentioned can be estimated. It is assumed that each confirmed case, in the absence of death, results in a 10-day work absence for home recovery. Assuming the infection rate is the same among employed and non-employed populations, the employment rate can be calculated using World Bank statistics on population and employment data for each country. This allows the conversion of the number of confirmed cases into the number of workdays lost by employed individuals and the corresponding percentage reduction in labor supply relative to the standard 245 annual workdays per person.

Furthermore, utilizing the OxCGRT database, the cumulative number of deaths and confirmed cases for each country in 2020 can be used to calculate the mortality rate. The number of confirmed cases among the employed population in each scenario is then multiplied by the mortality rate to estimate the number of deaths among employed individuals in 2020. Assuming that deceased individuals cannot work for the entire 245 annual workdays, the total number of workdays lost due to deaths can be calculated, along with the percentage reduction in labor supply relative to the non-deceased working population.

- Conversion of Workplace Closure Days to Industry Output Reduction

The OxCGRT database categorizes workplace closures into four levels (see Appendix 1). At level 2, we assume that closures affect the food and beverage, leisure, and personal services industries. At level 3, all industries except for essential services such as agriculture, utilities, and gas are closed. First, the proportion of days at level 2 relative to the 245 annual workdays is calculated. Then, the proportion of the output of the food and beverage, leisure, and personal services industries within the broader personal services industries (as these three industries are aggregated under personal services in the model) is determined. Assuming that the annual output of each industry is evenly distributed over the 245 workdays, multiplying these two proportions yields the percentage reduction in annual output for the personal services industries in the model.

For the impact of level 3 closures, it is assumed that all industries except for agriculture, food, utilities, gas, and wholesale and retail must close their workplaces.

Therefore, based on the proportion of days at level 3 relative to the 245 annual workdays, the percentage reduction in annual output for these industries can be calculated.

- Simulation Procedure

Since each scenario results in both a reduction in labor supply and a decrease in industry output, the simulation is conducted in two stages. First, the impact of the reduction in labor supply is considered. This involves adjusting the economic model to account for the reduced number of available workdays, as derived from the calculations of workdays lost due to confirmed cases and deaths. This step simulates the direct impact of a decreased labor force on the economy. Next, based on the new economic state post-labor supply adjustment, the impact of the reduction in industry output is simulated. This involves incorporating the calculated percentage reductions in output for various industries due to workplace closures. By applying these output reductions to the adjusted economic model, the combined effects of decreased labor supply and industry output can be assessed, providing a comprehensive understanding of the economic impacts under each scenario.

Simulation Results

- Impacts of Response Speed on Confirmed Cases and Workplace Closures on Production

Generally, in the current NPI mix scenario, regions and countries with faster response speeds (Group 3) experienced relatively fewer confirmed cases, leading to a less severe impact on labor supply (as shown in the blue bars of S1 in Figure 4). The primary reason is that a region's or country's response speed at the onset of the pandemic effectively prevented the virus from entering and spreading within the region. Consequently, the impact on the labor supply was less severe, resulting in a relatively lower negative economic impact compared to regions and countries with slower response speeds. This finding emphasizes the importance of prompt response in pandemic management. By preventing the virus from entering society, domestic NPIs considered in the regression can significantly reduce the spread of the disease, thereby preserving health safety and economic stability. Faster response speed leads to a less severe impact on labor supply. This, in turn, exempts regions from implementing stronger domestic workplace restrictions (as illustrated in the brown bars of S1, Figure 4). Thus, fewer days of workplace closure result in a less negative impact on production.

- Impact on Economy if Adoption of Taiwan’s NPI Mix

All regions and countries will benefit if adopting Taiwan’s NPI mix altogether, as shown in S2-S1 and S4-S1 in Figure 5. Due to the close supply chain relationships between China, some Southeast Asian regions and countries, and Taiwan, Taiwan benefits more relative to Japan and Korea.

If Taiwan's trade partners adopt Taiwan's NPI mix, as shown in S5-S1 in Figure 5, it would further mitigate the economic impacts on Taiwan's trade partners while also benefit most other non-partner regions and countries.

Overall, these analyses underscore the interconnected nature of global economies and highlight the significance of international coordination, especially in tightly knit trade networks. The simulation results reveal that while adopting Taiwan's NPI mix can curb the pandemic and lessen economic downturns, international trade dynamics can shift these outcomes, necessitating careful consideration of global economic interdependencies in pandemic response strategies.

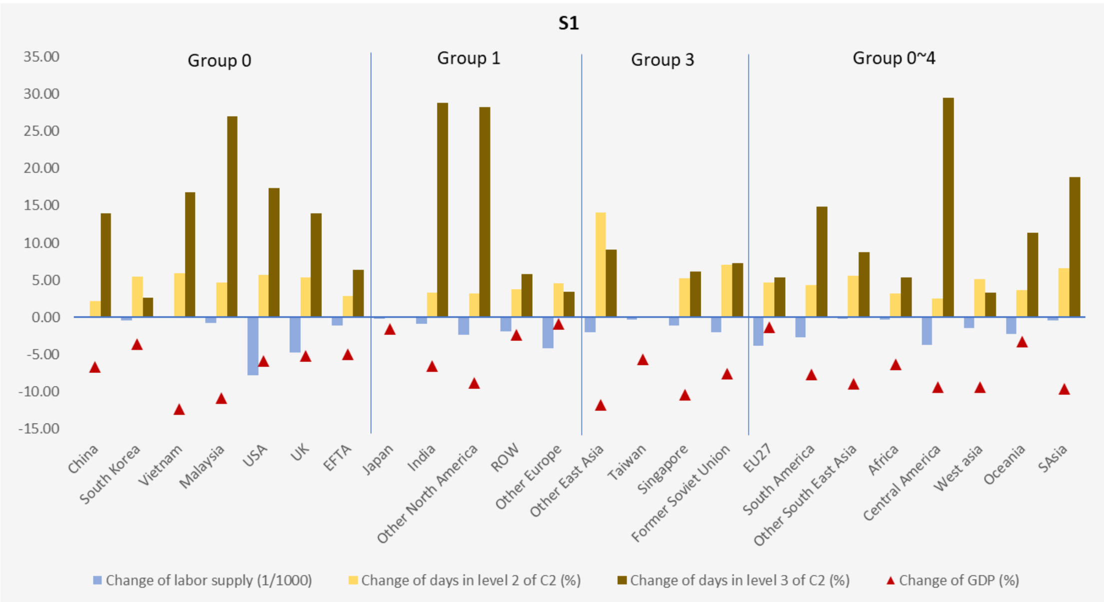
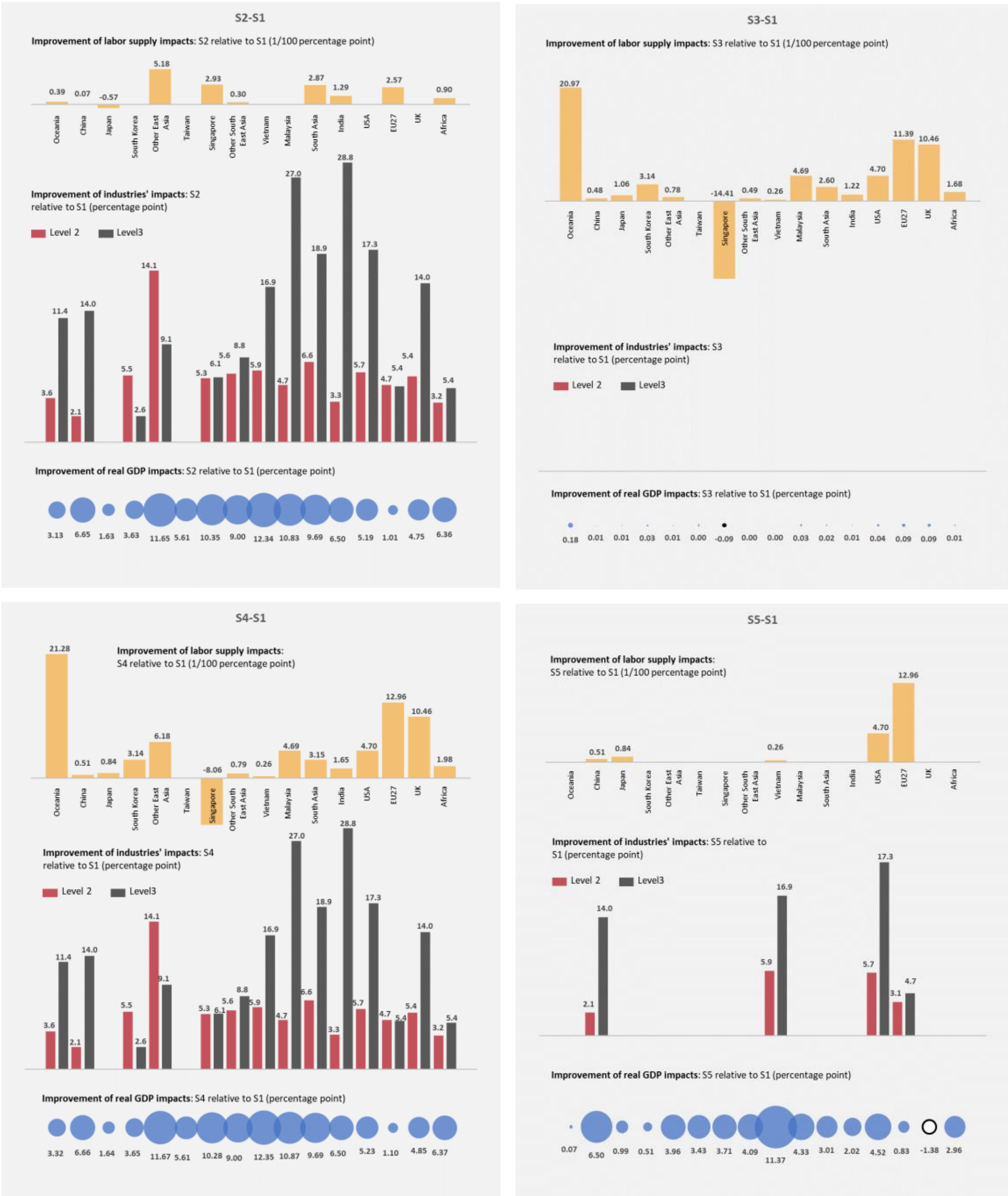


Figure 4: The Impacts of Response Speed in the current NPI mix scenario



Notice: The data in the graph show the improvement or mitigation in economic impacts relative to the baseline scenario (S1), with changes expressed in percentage points. For example, "S2-S1" indicates the percentage change in impact from S2 relative to S1. The size of each bubble corresponds to the absolute change in real GDP percentage points. Larger bubbles indicate a greater impact on the economy, whether positive or negative. Solid Bubbles: Represent scenarios where the change in real GDP is positive. These scenarios show an economic improvement or a lesser economic decline than the baseline. Hollow Bubbles: Indicate scenarios where the change in real GDP is negative compared to the baseline, representing a worsening economic situation.

Figure 5: The Impacts of NPI Mixes in Various Scenarios

Discussion

Throughout the year 2020, regions and countries implemented various NPI mixes, resulting in different economic impacts. Additionally, under the global trade structure, any NPI mix through trade and supply chains will influence the world economy.

The simulation results from this study indicate that if all regions and countries were to adopt Taiwan's NPI mix, it would mitigate the economic impact on each region and country. If Taiwan's trade partner regions and countries also adopted Taiwan’s NPI mix, it would not only benefit those regions and countries but also have a positive effect on most other non-partner regions and countries.

Additionally, this study shows that for a given region or country, the faster the response to the pandemic, the more effective its NPI mix is, leading to a smaller economic impact. Prompt responses to the pandemic are critical for the effectiveness of mask-wearing and workplace controls. This explains why Taiwan's NPI mix was effective throughout the year 2020 and led to a relatively lower economic downturn. However, a key factor influencing the prompt response is the availability and transparency of information about the outbreak of the pandemic. If the relevant authorities do not have a good grasp of the outbreak early on and fail to disseminate information timely, it inevitably leads to a delayed response, adversely affecting the global economy.

In conclusion, this study highlights the importance of a prompt response to a pandemic before effective medications are developed and the economic advantage of mask-wearing compared to workplace closures. Moreover, the analytical framework introduced by this study could serve as a reference for assessing the economic impacts of NPIs against large-scale infectious diseases in the future.

Reference

[1] United Nations Department of Economic and Social Affairs. (2021). *World economic situation and prospects 2021*. UN.

[2] Who. (n.d.). *The True Death Toll of COVID-19: Estimating Global Excess Mortality*. https://www.who.int/data/stories/the-true-death-toll-of-covid-19-estimating-global-excess-mortality

[3] Worby, C. J., & Chang, H. H. (2020). Face mask use in the general population and optimal resource allocation during the COVID-19 pandemic. *Nature communications*, *11*(1), 4049.

[4] Haug, N., Geyrhofer, L., Londei, A., Dervic, E., Desvars-Larrive, A., Loreto, V., ... & Klimek, P. (2020). Ranking the effectiveness of worldwide COVID-19 government interventions. *Nature human behaviour*, *4*(12), 1303-1312.

[5] Brauner, J. M., Mindermann, S., Sharma, M., Johnston, D., Salvatier, J., Gavenčiak, T., ... & Kulveit, J. (2021). Inferring the effectiveness of government interventions against COVID-19. *Science*, *371*(6531), eabd9338.

[6] Santos, J. (2020). Using input-output analysis to model the impact of pandemic mitigation and suppression measures on the workforce. *Sustainable Production and Consumption*, *23*, 249-255.

[7] Haddad, E. A., Perobelli, F. S., Araújo, I. F., & Bugarin, K. S. (2021). Structural propagation of pandemic shocks: an input–output analysis of the economic costs of COVID-19. *Spatial Economic Analysis*, *16*(3), 252-270.

[8] Guan, D., Wang, D., Hallegatte, S., Davis, S. J., Huo, J., Li, S., ... & Gong, P. (2020). Global supply-chain effects of COVID-19 control measures. *Nature human behaviour*, *4*(6), 577-587.

[9] Keogh-Brown, M. R., Jensen, H. T., Edmunds, W. J., & Smith, R. D. (2020). The impact of Covid-19, associated behaviours and policies on the UK economy: A computable general equilibrium model. *SSM-population health*, *12*, 100651.

[10] McKibbin, W. and R. Fernando (2023). The global economic impacts of the COVID-19 pandemic. *Economic Modelling*, 129, https://doi.org/10.1016/j.econmod.2023.106551.

[11] Hale, T., Angrist, N., Goldszmidt, R., Kira, B., Petherick, A., Phillips, T., ... & Tatlow, H. (2021). A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). *Nature human behaviour*, *5*(4), 529-538.

[12] Hsu, W. T., Lin, H. C. L., & Yang, H. (2023). Between lives and economy: COVID-19 containment policy in open economies. *European Economic Review*, 104512.

Appendix 1. Variable Description and Coding

ID	Description	Coding
C2	Record closings of workplaces	0 - no measures 1 - recommend closing (or recommend work from home) or all businesses open with alterations resulting in significant differences compared to non-Covid-19 operation 2 - require closing (or work from home) for some sectors or categories of workers – 3 - require closing (or work from home) for all-but-essential workplaces (eg grocery stores, doctors)
C4	Record limits on gatherings	0 - no restrictions 1 - restrictions on very large gatherings (the limit is above 1000 people) 2 - restrictions on gatherings between 101-1000 people 3 - restrictions on gatherings between 11-100 people 4 - restrictions on gatherings of 10 people or less
C5	Record closing of public transport	0 - no measures 1 - recommend closing (or significantly reduce volume/route/means of transport available) 2 - require closing (or prohibit most citizens from using it)
C7	Record restrictions on internal movement between cities/regions	0 - no measures 1 - recommend not to travel between regions/cities 2 - internal movement restrictions in place
C8	Record restrictions on international travel for foreign travellers	0 - no restrictions 1 - screening arrivals 2 - quarantine arrivals from some or all regions 3 - ban arrivals from some regions 4 - ban on all regions or total border closure
H6	Record policies on the use of facial coverings outside the home	0 - No policy 1 - Recommended 2 - Required in some specified shared/public spaces outside the home with other people present, or some situations when social distancing not possible 3 - Required in all shared/public spaces outside the home with other people present or all situations when social distancing not possible 4 - Required outside the home at all times regardless of location or presence of other people