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Article

Lives and livelihoods trade-offs: Which COVID-19 strategies for which countries?

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GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

Lives and livelihoods trade-offs: Which COVID-19 strategies for which countries?

Vu Minh Ngo^{1*}, Huan Huu Nguyen², Hien Thu Phan² and Phương Thanh Thi Tran²

Abstract: Are COVID-19 non-pharmaceutical interventions (NPIs) at the expense of economic outcomes? Furthermore, given the heterogeneities in macroeconomic conditions, should countries follow a unified COVID-19 strategy such as “No-COVID”? This study provides cross-country evidence that attempts to address these critical questions during the pandemic era. Given the substantial heterogeneity in unemployment rates of OECD countries, it is necessary to understand the effects of NPIs’ implementation, which could vary widely across conditional quantiles of unemployment rates. Using monthly data from OECD countries from February 2020 to June 2021 and quantile regression analysis for panel data (QRPD), we explore the impacts of NPIs on economic outcomes. The results indicate that NPIs effectively contained the pandemic and had substantial positive impacts on low quantiles of unemployment rates. However, at high quantiles of unemployment rates, the trade-off is viable and significant. In addition, countries’ vaccination policies and scales also predict their economic outlooks, especially when combined with non-pharmaceutical interventions. Based on these findings, this study suggests different COVID-19 strategies for different groups of countries according to their macroeconomic settings. The trade-off between lives and livelihoods is much more troublesome and prevalent

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Dr. Vu Ngo is a lecturer at University of Economics Ho Chi Minh City (UEH), Vietnam. He is greatly interested in the areas of Financial Economics, International Finance, Financial Stability, Financial Technology, and Digital transformation. Dr. Huan Nguyen is the head of the Financial Market Department at UEH, Vietnam, specializing in macroeconomics, finance research for twelve years. Dr. Hien Phan is a senior lecturer at UEH, Vietnam. Her research interests are International Finance, Financial Stability, and Bank efficiency. Dr. Phuong Tran is the head of the Healthcare management division at UEH. She is actively pursuing research in public health economics and the management of public hospitals in the era of digitalization. This paper is one of the outputs of joined research projects between School of Banking and School of Management in UEH to suggest appropriate policies for governments to deal effectively with the COVID-19 pandemic, especially for developing countries such as Vietnam.

PUBLIC INTEREST STATEMENT

This research explores the impacts of Non-pharmaceutical interventions (NPI) policies on economic outcomes. Our findings suggest that NPIs effectively contained the outbreak of the pandemic and have substantial positive impacts on future outcomes of economic activities at the lower quantile of unemployment rates. However, countries with worse macroeconomic conditions, such as higher unemployment rates, could experience severe economic impacts due to stricter NPIs for the COVID-19 pandemic. Therefore, strategies to contain the COVID-19 pandemic should be applied differently to groups of countries according to their macroeconomic contexts. Some countries such as Germany, Australia, and New Zealand have the resources and developed economic systems to support businesses and individuals. They can adjust to the new normal at a lower cost than other countries. Thus, a “No Covid” strategy might be possible for such countries, as they can apply strong and long-lasting NPIs from the start of the pandemic to reduce cases to near zero, then reopen the structure of economic activity in green zones.

in countries with unfavorable macroeconomic conditions and hinders them from pursuing strategies such as “No-COVID”.

Subjects: Economics; Political Economy; Hazards & Disasters

Keywords: non-pharmaceutical interventions; vaccination campaign; COVID-19; trade-offs; public health; unemployment rate

1. Introduction

The COVID-19 pandemic has created a worldwide dual crisis in both peoples' lives and livelihoods. More than 4.5 million COVID-19 deaths have been confirmed globally (CSSE, 2021). Compared to other major pandemics in human history, the COVID-19 pandemic has not been the worst pandemic there has ever been (Feehan & Apostolopoulos, 2021), it has been one of the deadliest pandemics since the Spanish flu in the early 20th century. In addition to the enormous challenges to people's lives, the COVID-19 pandemic has caused a profound global economic slowdown due to local and global lockdown policies, which cause severe disruptions in the global supply chain and economic activities (Kumar & Sharma, 2021). According to (Gourinchas, 2020), the exceptionally high degrees of interconnectedness and specialization in production and the disruption in global supply chains created cascading effects. (Carlsson-Szlezak et al., 2020) suggested three main economic shocks that could occur during the COVID-19 pandemic. The first shock is related to the sudden reduction in consumer spending on goods and services due to behavioral restrictions and social distancing measures. The second is the indirect impact of financial market shocks, which probably reduces household wealth, and spending will fall further. The third shock is directly related to supply-side disruptions, as pandemic containment measures negatively impact labor demand, workforce, and employment. These tremendous shocks, if prolonged, cause global economic slowdowns, high unemployment rates, and severely affect peoples' livelihoods (Tandon et al., 2020). Nevertheless, facing tremendous impacts on public health, governments have been required to have appropriate policies to respond to the pandemic and protect people's lives. In the absence of an effective and safe treatment or vaccine, non-pharmaceutical interventions (NPIs) as public health policies are the most critical measures to prevent and control the transmission and spread of COVID-19 adopted by many governments (Iezadi et al., 2020). Popular NPIs include personal protection protocols, social distancing, lockdown, school closure, public events banned and travel-related restriction measures (Lai et al., 2020). Italy was the first European nation to initiate major NPIs such as city lockdown, school and workplace closures, and other countries such as France, Spain and the UK quickly followed (Flaxman et al., 2020). Public mobilities were expected to be significantly reduced when applying NPIs such as lockdown, then, in turn, contain the level of COVID-19 infection rate in public (Davies et al., 2020). Many governments, however, have refrained from implementing significant social distance and other NPIs because to the possible damage to economic development (Kane). Numerous anti-social-distancing demonstrations have occurred worldwide in response to fears of unemployment and business insolvency (Li et al., 2020). Even though implementing NPIs could potentially harm the economy in the short term. However, governments who implement NPIs sooner could mitigate these negative economic impacts and lower cumulative mortality (Demirgüç-Kunt et al., 2021). In contrast, countries that implement NPIs in the later stages of the COVID-19 pandemic or stop it prematurely could confront a twofold crisis affecting both people's lives and livelihoods (Ruktanonchai et al., 2020). Thus, the trade-off between public health and economic consequences has become a heated debate among academicians in the COVID-19 period (Nisa et al., 2021; Schneider, 2021). Theoretically, the trade-off between economic outcomes and public health could be explained using the production possibility frontier (PPF) theory and the assumption of limited resources in public policies (Peroff & Podolak-Warren, 1979). According to the PPF theory, governments are required to give up a portion of public health goods to improve economic goods (Figure 1).

However, this trade-off could be significantly modified in the pandemic condition compared to normal conditions. As suggested by Gans (Gans, 2020), such as in a war or natural disaster, if the pandemic is allowed to spread uncontrollably without significant NPIs, a country's resources could be severely damaged, and the ability and health of the workforce are substantially reduced, which could result in severely dampened labor productivity. In this case, significantly reducing public health goods could not significantly improve the economic situation, as in normal conditions (Figure 2). In fact, by analyzing differences in non-pharmaceutical interventions among different cities of the United States during the 1918 influenza pandemic, economists found that those cities that implemented NPI earlier and stronger ended up bouncing back and had better economic growth thereafter (Gans, 2020).

Regarding empirical investigations, initially, some studies have found evidence to support that stringent NPIs significantly reduce economic activities globally. For example, in India, in the most severely restricted regions, economic activities were estimated to drop by about 9% and GDP levels were 12% to 18% lower (Beyer et al., 2021). At the global scale, (Boissay & Rungcharoenkitkul, 2020) found that future global GDP growth could drop significantly (about 4% for 2020) under the impact of the COVID-19 pandemic. (Deb et al., 2021) found that containment measures have created a massive loss of approximately 15% in industrial production after 30 days of implementation. However, some studies have recently discovered that the relationship between NPIs and economics could be much more complex, and the usual trade-off could not capture the whole interactions between them (Nisa et al., 2021; Schneider, 2021). (Nisa et al., 2021) found that, globally, people did not perceive saving lives and saving the economy as a binary choice. (Kochańczyk & Lipniacki, 2021) also found that the trade-offs were illusory as lighter containment measures at the beginning of the pandemic could create a higher death toll, which leads to long-lasting lockdown later on and cause a severe economic downturn.

European countries were among the first to be severely affected by the COVID-19 pandemic, and very soon after China, they became the largest COVID-19 epicenter in the world in March and April 2020 (Sohrabi et al., 2020). As a result, the majority of Europe established stringent lockdown measures to prevent disease spread, which have been demonstrated to be successful at reducing transmission (Flaxman et al., 2020; Ruktanonchai et al., 2020). In terms of the economic and public health trade-off, mixed results have also been found in the European area. Fezzi and Fanghella (2020) looked at the Italian power market data and estimated that the three weeks of the most

Figure 1. The production possibility frontier (PPF) of Economic goods and Public health. Source: adapted from (Gans, 2020). **Panel A** is the PPF between economic outcomes and public health in normal conditions given the assumption of scarce resources in government budget for public policies. **Panel B** is the modified version of this PPF in pandemic conditions when the trade-off between economic outcomes and public health if the pandemic is allowed to spread uncontrollably and countries's resources could be severely damaged.

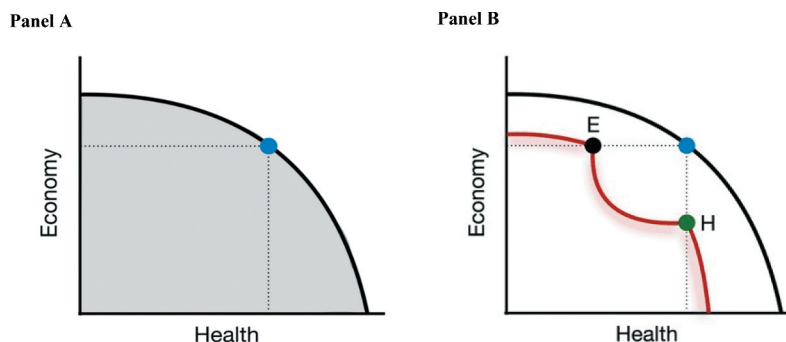
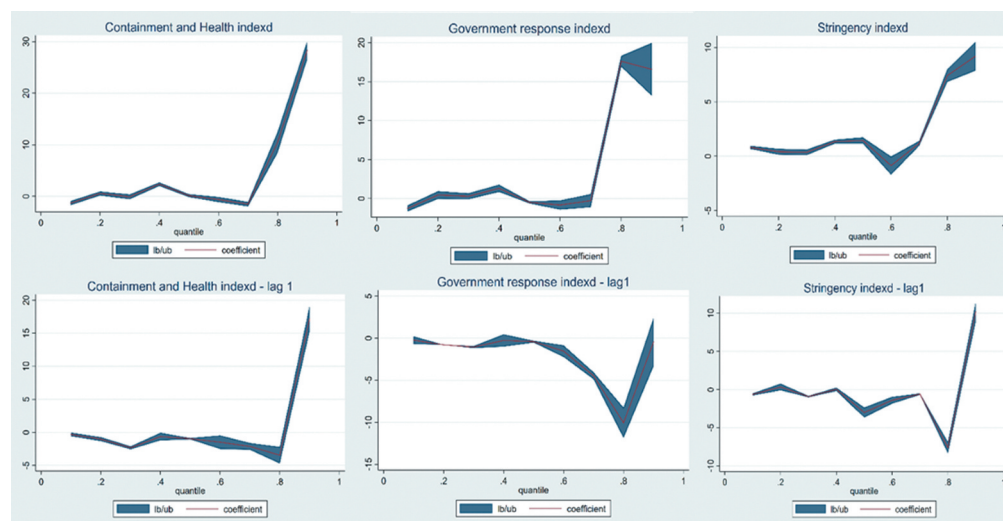


Figure 2.



severe lockdown cut Italy's GDP by about 30%. So far, these adverse effects have been getting less and less, but by the end of June 2020, GDP will still be about 8.5% less than it would have been had the outbreak not happened. This study shows that high-frequency electricity market data can be used to figure out how COVID-19 will affect the economy in the short term, which is important for planning future lockdown policies. In contrast, (Demirgüç-Kunt et al., 2021) found that the level of economic impacts of NPIs in European countries depends on how fast countries react to the pandemic. NPIs in the early pandemic appear to be less strict and have better short-term economic outcomes and lower cumulative mortality than non-pharmaceutical interventions in the later stages of a pandemic. In this way, the results show that the sooner non-pharmaceutical interventions are put into place, the better the economic and health outcomes are going to be. However, another study from (Chen et al., 2020) that examined the economic effect of COVID-19 in Europe and the United States during the early stages of the epidemic using high-frequency data showed that the majority of variance across states or nations is explained by observable variations in individual mobility, but the timing of NPIs has no discernible influence on economic results between March and mid-April 2020. Indeed, the drop in economic activity or migration occurs before implementing such mitigating initiatives, not after.

Given the mixed empirical evidence from different contexts such as the US, India, or European countries (Aum et al., 2020; Gori et al., 2021), this study aims to provide up-to-date evidence on the trade-off between NPIs implementation and economic outcomes in one of the most important economic powerhouses of the world economy, the OECD countries. The following questions are posed. First, is the COVID-19 pandemic a common shock, or do countries or areas with different levels of pandemic breakouts and macroeconomics situations differ in their economic suffering; and in which case, what makes an economy more sensitive to the COVID-19 shock? In addition to the NPIs measure, the ongoing COVID-19 vaccination campaign also plays a crucial role in controlling the pandemic and reopening economies (Dave et al., 2021). As countries have started to reopen their economies in the midst of mass vaccination efforts, very few studies have investigated the impacts of mass vaccination campaigns and economic activities. Thus, in this study, we also investigate the effectiveness of vaccination efforts on economic outcomes. Given the essential roles of NPIs in fighting with COVID-19 pandemic and the vital roles of OECD countries in the world economy, this study could provide insights on how NPIs impact economic

outcomes under different conditions and provide useful policy implications for future NPIs implementations in different contexts.

We found that, on average, there is no trade-off between public health and economic activities in OECD countries. Instead, implementing a higher level of pandemic containment measures has a positive impact on employment rates over the next one or two months. Moreover, trade-offs between public health and economic activities are local rather than global phenomena. The trade-off magnitudes depend on countries-specific macroeconomic conditions. Specifically, countries with higher unemployment rates are impacted the most in terms of economic losses when implementing stringent restrictions. However, when combining vaccination efforts with NPIs measures, these countries are the most beneficial compared to countries with more stable macroeconomic conditions. These findings suggest that groups of countries with stronger macroeconomic situations, such as Germany, Australia, and New Zealand, may implement the “No-COVID” strategy. The strategy requires countries to use strong and long-lasting NPIs from the pandemic to reduce infection cases to near zero. Only then could they gradually and structurally reopen economic activities in green zones, where covid-transmission is completely controlled. Additionally, if the epidemic recurs, it must be dealt with aggressively.

The remainder of the study is organized as follows: we begin by introducing the data and methodologies that were employed in the analysis (Section 2). The impact of NPIs on economic activity in OECD is next discussed (Section 3). Finally, we conclude with a discussion, a few drawbacks to our study, and future research direction (Section 4).

2. Methodology

2.1. Data

To track the changes in government NPIs, we use the Covid-19 Government Response Tracker dataset from the Blavatnik School of Government, University of Oxford (Hale et al., 2021). The dataset provides daily updates on the composite indexes, including the overall government response index, containment, and health index, and the stringency index (rated from 0-weakest to 100-strongest). These indexes are aggregated numbers that are calculated from indicators measuring lockdown and closure restrictions, social distancing, mask-wearing, testing policy, contact tracing or investment in healthcare, income support, and debt relief.

The unemployment rate is used as a proxy for the overall economy. The measures and other macroeconomic variables as control variables were collected from the OECD data. Controlling for the effects of population, we used the number of COVID-19 cases per million and vaccinated cases per hundred collected from the Our World in Data project for pandemic-related data. All the data are presented in monthly values from February 2020 to June 2021, which forms the final panel dataset for the investigation. The descriptive statistics of the dataset are presented in Table 1.

The average monthly unemployment rate in OECD countries is about 6.7% during the period from February 2020 to June 2021. More importantly, unemployment rates were dramatically varied from country to country (see Appendix 2). The average monthly confirmed COVID-19 case growth is about 63% in OECD countries. The Containment Health index/Stringency index/Government Response index measuring the level of NPIs implemented in a country have the monthly growth rates of 8.2%/7.9%/8.9% accordingly. The Economic support index has a lower monthly average growth rate of 5.7%. In terms of control variables, the average GDP of countries in the sample is 49.1 thousand dollars, and the percentage of population over 65 is 17.7% on average. The average share of digital intensive jobs in sample countries is about 49.5%, and jobs related to the service sector account for more than 61% of total employment in these countries.

Table 1. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Unemployment rate (%)	467	6.752	3.348	2.000	17.60
Shareprice (%)	491	1.257	6.709	-33.14	18.07
ContainmentAndHealth	490	0.082	0.336	-0.366	3.209
Stringency	485	0.079	0.430	-0.653	3.984
GovernmentResponse	487	0.089	0.348	-0.361	3.209
EconomicSupport	454	0.058	0.296	-0.762	2.263
Vaccinationsperhundred_g	491	0.294	0.698	0.000	5.687
Cases_g	490	0.636	1.438	-0.011	9.459
GDP per capita (thousand \$)	522	49.18	19.54	19.12	118.5
Aged_65_older	522	17.78	3.821	6.857	27.04
Hospitalbedper1000	522	4.711	2.690	1.380	13.05
Population_density	522	156.9	143.2	3.202	527.9
HDI	522	0.911	0.038	0.779	0.957
Physicianper1000	522	3.551	0.861	2.361	5.479
Shareofdigitintensive (%)	522	49.58	3.346	42.54	56.51
Shareinserv (%)	488	61.05	8.280	44.79	73.88
CPI (%)	491	0.003	5.119	-15.06	28.50
Interest rate (%)	514	1.074	1.518	-5.685	6.085
BCI	505	0.653	1.233	-0.832	7.370
CCI	509	98.96	2.484	90.16	106.3

Note: ContainmentAndHealth/Stringency/GovernmentResponse/EconomicSupport: relative monthly changes in Containment and Health index/Stringency index/ Government response/Economic support index of COVID-19 NPIs; Shareprice:monthly changes in Share prices index of OECD countries calculated from the prices of common shares of companies traded on national or foreign stock exchanges. HDI_education: human development index for each countries in 2020; Population_density: population density index; Aged_65_older: share of populations with age 65 and over; Hospitalbedper1000: Hospitalbedper1000: number of hospital bed per 1000 people; Physicianper1000: number of physician per 1000 people; CPI: monthly consumer price index changes from the previous year (2015 = 100); BCI: monthly business confidence index (long term average = 100); CCI: monthly consumer confidence index (long term average = 100). Vaccinationsperhundred_g: monthly relative changes in the total number of people who received the COVID-19 vaccination. Cases_g: monthly relative changes in total confirmed COVID-19 cases

Appendix A provides a detailed explanation of the data and sources.

2.2. Methodologies

2.2.1. Feasible generalized least squares

Autocorrelation and heteroskedasticity in panel data could create biases in formulating the sample variance of the within-groups and generalized least square estimators (Arellano, 1993). In this study, Wooldridge's autocorrelation test (Wooldridge, 1991) and Wald's heteroskedasticity test (Arellano, 1993) were conducted. In most cases, feasible generalized least squares (FGLS) are used instead of fixed- or random-effects models if both autocorrelation and heteroskedasticity exist in the sample (Yaffee, 2003). In general, the FGLS model used to assess the impact of NPIs on economic outcomes is as follows:

$$Unemployment_{it} = \alpha_0 + \sum_{j=0}^n \beta_j NPI_{i,t-j} + \sum_{l=n+1}^m \beta_l COVID_{i,t} + \sum_{k=m+1}^h \beta_k X_{kit} + \sum_{p=h+1}^q \beta_p Z_{pi} + \gamma_i + \epsilon_{it}$$

$Unemployment_{it}$ is the unemployment rate of country i for month t . $NPI_{i,t-j}$ is the main independent variable consisting of the monthly changes in month t and their lag effects of containment and health/overall government response/stringency/economic support indexes. $COVID_{i,t}$ is the related COVID-19 variables of country i for month t . X_{kit} and Z_{pi} denote any panel and cross-sectional data control variables. Robust standard errors were used to account for heteroscedasticity in the sample.

Similarly, the FGLS model used to assess the impact of NPIs on pandemic-related variables is as follows:

$$Case_{it} = \alpha_0 + \sum_{j=0}^n \beta_j NPI_{i,t-j} + \sum_{l=n+1}^m \beta_l COVID_{i,t} + \sum_{k=m+1}^h \beta_k X_{kit} + \sum_{p=h+1}^q \beta_p Z_{pi} + \gamma_i + \epsilon_{it}$$

$Case_{it}$ is confirmed COVID-19 cases growth of country i for month t . $NPI_{i,t-j}$ is the main independent variable consisting of the monthly changes in month t and their lag effects of containment and health/ government response/stringency/economic support indexes. $COVID_{i,t}$ is the related COVID-19 variables of country i for month t including the lag of confirmed COVID-19 cases growth and Vaccination variables. X_{kit} and Z_{pi} denote any panel and cross-sectional data control variables, respectively. Robust standard errors were used to account for heteroscedasticity in the sample.

2.2.2. Quantile regression panel data (QRPD)

The trade-off between life and livelihood could vary largely across different levels of economic outcome distributions. Given the substantial heterogeneity in unemployment rates of OECD countries (see Appendix B), it is necessary to understand the effects of NPI implementations on economic outcomes across conditional quantiles of unemployment rates. This study employed the quantile panel data (QRPD) estimator to address this issue.

Introduced by (Koenker & Bassett, 1978), quantile regression is known for its ability to provide complete conditional distribution details. Owing to the inherent robustness of quantile regression, outliers and extreme data are usually less influential (Waldmann et al., 2013). The frequently used method for quantile panel data estimators, such as fixed-effect quantile regression (FEQR), uses the additive fixed effect to account for unobserved variables. However, FEQR estimators suffer from biased issues when the time dimension is small in the sample because of the incidental parameter problem (Graham et al., 2009). QRPD is much more consistent, even for small-time

dimensions in the sample. The use of a Bayesian additive approach such as MCMC in the estimation of QRPD to supply the entire posterior distribution of the parameters also takes into account the uncertainties of the parameters when making predictions (Yu & Moyeed, 2001). The QRPD approach followed by (Powell, 2014) and (Powell, 2016) are presented as follows:

$$y_{it} = D_{it}\mu'(U_{it}^*)$$

where y_{it} is the economic outcome variable (unemployment rate). D_{it} is the vector for the independent and control variables for country i in time t , including NPI variables and macroeconomic variables. where μ is the coefficient vector to be estimated. U_{it} is a vector of error terms that includes several disturbances. It is usually assumed to be uniformly distributed and uncorrelated with outcome variables. In the conventional quantile regression, U^* and D are assumed to be independent. However, in the QRPD approach, this assumption could be relaxed, and U^* and D are not necessarily independent. The inclusion of time effects in the model could help QRPD to be more comparable to cross-sectional quantile analysis. Several recent studies have successfully applied the QRPD approach (Dogan et al., 2021; Tansel et al., 2020).

3. Results

3.1. The effectiveness of NPIs policies

In Table 2, we control for countries' socio-economic conditions, pandemic size, and event time effects (i.e., the delta variant) in the model to investigate the effects of government NPIs and vaccination efforts on the number of average monthly new COVID-19 confirmed cases per million. We use lag variables as NPIs, and vaccination efforts need time to be effective and expressed in the pandemic cases growth (lag variables of the previous one and two months are used). As the results in Table 2 suggest that the tighter the NPIs (measured by containmentAndHealth/ GovernmentRespond/ Stringency) are implemented last month, the lower are the growth rates of COVID-19 new confirmed cases (p-value = 0.019, 95% C.I. -0.332 to -0.0294 for Stringency index). This finding suggests that the government's NPIs in OECD countries have been effective in slowing down the spread of the COVID-19 pandemic at the country level. Notably, although vaccination campaigns have recently started in OECD countries (from February 2021), it also shows strong associations with lower growth rates of COVID-19 confirmed cases in the following month (p-value = 0.026, 95% C.I. -0.332 to -0.029). These results support the effectiveness of the OECD government's vaccination policies in fighting the COVID-19 pandemic. However, these policies are at the cost of economic outcomes.

3.2. NPIs policies and economic outcomes

Controlling for macroeconomics, pandemic size, and vaccination efforts, the results in Table 3 suggest that a higher level of NPI policies is not associated with a higher level of unemployment rate. In fact, tighter policies in all three NPIs could significantly lower the unemployment rate of the next month (p = 0.019, 95% C.I. -0.645 to -0.057 for ContainmentAndHealth; p-value = 0.026, 95% C.I. -0.699 to -0.0442 for GovernmentResponse; and p-value = 0.03, 95% C.I. -0.431 to -0.018 for Stringency). In contrast, the government's economic support policies do not achieve their expected impact in reducing unemployment (p-value = 0.723, 95% C.I. -0.465 to 0.327 for EconomicSupport). OECD governments have attempted to mitigate the effects of lockdown and restriction behavior measures using several economic support policies, such as income support to individuals and financial support to firms. More than 80% of OECD countries have issued economic support programs since June 2020 (OECD, 2020). However, the effects of economic-related responses on employment are limited. Only 20% of OECD countries directly change their regulation of dismissal to curb the unemployment rate (OECD, 2020). This finding favors governments' policy

Table 2. The effects of non-pharmaceutical interventions (NPIs) on growth rates of COVID-19 confirmed cases in OECD countries

	(1)	(2)	(3)
	Cases_g	Cases_g	Cases_g
L1.ContainmentAndHealth	-0.203* (0.106)		
L1.GovernmentResponse		-0.219* (0.115)	
L1.Stringencyindex			-0.181** (0.077)
L1.Vaccinationsperhundred_g	-0.033** (0.015)	-0.033** (0.015)	-0.033** (0.015)
L1.Cases_g	0.478*** (0.040)	0.478*** (0.040)	0.483*** (0.040)
L2.Cases_g	-0.059*** (0.016)	-0.056*** (0.017)	-0.062*** (0.017)
Time	0.114*** (0.024)	0.112*** (0.024)	0.119*** (0.024)
Time ²	-0.005*** (0.001)	-0.005*** (0.001)	-0.006*** (0.001)
GDPpercapita	-0.000 (0.001)	-0.000 (0.001)	-0.000 (0.001)
Aged_65_older	0.000 (0.004)	0.000 (0.004)	0.000 (0.004)
Hospitalbedper1000	0.005 (0.005)	0.005 (0.005)	0.005 (0.005)
Population_density	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)

(Continued)

Table2. (Continued)

	(1)	(2)	(3)
	Cases_g	Cases_g	Cases_g
HDI	-0.354 (0.411)	-0.359 (0.412)	-0.340 (0.410)
Physicianper1000	0.019 (0.013)	0.019 (0.013)	0.019 (0.013)
Constant	-0.117 (0.358)	-0.102 (0.357)	-0.163 (0.358)
N	424	424	425
Hausman's test	9.77	10.00	10.68
Prob > χ^2	0.281	0.2648	0.153
Wald's test	854.69	884.55	756.75
Prob > χ^2	0.000	0.000	0.000
Wooldridge's test	226.795	169.770	149.523
Prob > F	0.000	0.000	0.000

Note: Case_g: monthly growth rate of number of confirmed COVID-19 cases per million; ContainmentAndHealth: relative changes in monthly Containment and Health index of COVID-19 NPIs; GovernmentResponse: relative changes in monthly Government response index of COVID-19 NPIs; Stringencyindex: relative changes in monthly stringency index of COVID-19 NPIs; HDI_education: human development index for each country in 2020; Population_density: population density index; Aged_65_older: share of populations with age 65 and over; Hospitalbedper1000: Hospitalbedper1000: number of hospital bed per 1000 people; Physicianper1000: number of physician per 1000 people; Time is the variables accounting for specific month-effects in the model; Vaccinationsperhundred_g: monthly relative changes in the total number of people which received the COVID-19 vaccination. Cases_g: monthly relative changes in total confirmed COVID-19. L1.index: the one-period lagged variables of the index (ContainmentAndHealth/ GovernmentResponse/ Stringency/ EconomicsSupport); L2.Case_g: the two-period lagged variables of the Case_g. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3. The effects of non-pharmaceutical interventions (NPIs) on the unemployment rate in OECD countries			
	(1) Unemployment	(2) Unemployment	(3) Unemployment
Containment index	-0.190 (0.218)		
L1.ContainmentAndHealth	-0.353** (0.153)		
L2.ContainmentAndHealth	-0.126* (0.076)		
GovernmentResponse		-0.208 (0.248)	
L1.GovernmentResponse		-0.377** (0.170)	
L2.GovernmentResponse		-0.123 (0.079)	
Stringency			-0.111 (0.138)
L1.Stringency			-0.229** (0.108)
L2.Stringency			-0.138** (0.058)
EconomicSupport			-0.042 (0.212)
L.EconomicSupport			-0.097 (0.204)
L2.EconomicSupport			-0.041 (0.108)

(Continued)

Table3. (Continued)

	(1) Unemployment	(2) Unemployment	(3) Unemployment	(4) Unemployment
Cases_g	-0.129 (0.092)	-0.128 (0.091)	-0.132 (0.093)	-0.143 (0.091)
Vaccinationsperhundred_g	0.041 (0.030)	0.040 (0.030)	0.042 (0.029)	0.041 (0.032)
GDPpercapital	-0.010* (0.006)	-0.010* (0.006)	-0.010* (0.006)	-0.010* (0.006)
CPI	-0.109* (0.060)	-0.114* (0.060)	-0.093 (0.058)	-0.126* (0.065)
Interest rate	-0.206* (0.106)	-0.204* (0.106)	-0.212** (0.105)	-0.166 (0.133)
BCI	0.057 (0.035)	0.055 (0.035)	0.054 (0.035)	0.051 (0.038)
CCI	-0.067 (0.065)	-0.067 (0.065)	-0.072 (0.064)	-0.070 (0.069)
Constant	8.334 (5.109)	8.475* (5.140)	9.019* (5.002)	9.248 (5.642)
N	343	343	344	319
Hausman's test	9.91	9.93	6.90	8.96
Prob > χ^2	0.358	0.355	0.647	0.441
Wald's test	795.62	819.15	780.32	1095.21
Prob > χ^2	0.000	0.000	0.000	0.000
Wooldridge's test	153.86	156.02	152.33	15.772
Prob > F	0.000	0.000	0.000	0.000
Containment index	-0.192			

(Continued)

Table3. (Continued)

	(1) Unemployment	(2) Unemployment	(3) Unemployment	(4) Unemployment
L1.ContainmentAndHealth	(0.176) -0.303** (0.142)			
L2.ContainmentAndHealth	-0.100 (0.076)			
GovernmentResponse		-0.202 (0.201)		
L1.GovernmentResponse		-0.325** (0.152)		
L2.GovernmentResponse		-0.096 (0.076)		
Stringency			-0.156 (0.122)	
L1.Stringency			-0.185* (0.106)	
L2.Stringency			-0.129** (0.059)	
EconomicSupport				0.021 (0.147)
L.EconomicSupport				0.039 (0.145)

Note: Unemployment: monthly unemployment rate of OECD countries; ContainmentAndHealth: relative changes in monthly Containment and Health index of COVID-19 NPIs; GovernmentResponse: relative changes in monthly Government response index of COVID-19 NPIs; Stringencyindex: relative changes in monthly stringency index of COVID-19 NPIs; EconomicSupport index: relative monthly changes in Economic support index of OCVID-19 NPIs Vaccinationsperhundred_g: monthly relative changes in total population vaccinated per hundred. Cases_g: monthly relative changes in total confirmed COVID-19. CPI: monthly consumer price index changes from the previous year (2015 = 100); BCI: monthly business confidence index (long term average = 100); CCI: monthly consumer confidence index (long term average = 100). L1.index: the one-period lagged variables of the index (ContainmentAndHealth/ GovernmentResponse/ Stringency/ EconomicSupport); L2.index: the two-period lagged variables of the index (ContainmentAndHealth/ GovernmentResponse/ Stringency/ EconomicSupport); Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4. The effects of non-pharmaceutical interventions (NPIs) on unemployment rate in OECD countries with labor markets control variables			
	(1) Unemployment	(2) Unemployment	(3) Unemployment
Containment index	-0.192 (0.176)		
L1.ContainmentAndHealth	-0.303** (0.142)		
L2.ContainmentAndHealth	-0.100 (0.076)		
GovernmentResponse		-0.202 (0.201)	
L1.GovernmentResponse		-0.325** (0.152)	
L2.GovernmentResponse		-0.096 (0.076)	
Stringency			-0.156 (0.122)
L1.Stringency			-0.185* (0.106)
L2.Stringency			-0.129** (0.059)
EconomicSupport			0.021 (0.147)
L.EconomicSupport			0.039 (0.145)
L2.EconomicSupport			0.001

(Continued)

Table 4. (Continued)

Shareofdigintensive	-0.282*** (0.049)	-0.282*** (0.049)	-0.280*** (0.049)	(0.080)
Shareinserv	0.154*** (0.019)	0.154*** (0.019)	0.153*** (0.019)	0.168*** (0.017)
Cases_g	-0.035 (0.069)	-0.032 (0.070)	-0.024 (0.070)	-0.036 (0.084)
Vaccinationsperhundred_g	0.016 (0.024)	0.015 (0.024)	0.020 (0.024)	0.024 (0.028)
GDPpercapital	-0.090*** (0.017)	-0.089*** (0.017)	-0.090*** (0.017)	-0.094*** (0.016)
CPI	-0.058 (0.042)	-0.058 (0.042)	-0.055 (0.042)	-0.074 (0.051)
Interest rate	-0.116 (0.152)	-0.107 (0.151)	-0.110 (0.152)	-0.129 (0.151)
BCI	-0.001 (0.030)	-0.004 (0.030)	-0.006 (0.030)	-0.024 (0.031)
CCI	-0.023 (0.052)	-0.025 (0.052)	-0.023 (0.052)	0.031 (0.057)
Constant	17.885*** (4.614)	18.193*** (4.647)	18.295*** (4.636)	14.738*** (5.231)
N	322	322	323	304
Hausman's test	9.91	9.93	6.90	8.96
Prob > χ^2	0.358	0.355	0.647	0.441
Wald's test	795.62	819.15	780.32	1095.21

(Continued)

Table 4. (Continued)					
Prob > χ^2	0.000	0.000	0.000	0.000	0.000
Wooldridge's test	153.86	156.02	152.33	15.772	
Prob > F	0.000	0.000	0.000	0.000	0.000

Note: Unemployment rate; ContainmentAndHealth: relative changes in monthly Containment and Health index of COVID-19 NPIs; GovernmentResponse: relative changes in monthly Government response index of COVID-19 NPIs; StringencyIndex: relative changes in monthly stringency index of COVID-19 NPIs; EconomicSupport index: relative monthly changes in Economic support index of COVID-19 NPIs Vaccinationsperhundred_g: monthly relative changes in total population vaccinated per hundred. Cases_g: monthly relative changes in total confirmed COVID-19; CPI: monthly consumer price index changes from the previous year (2015=100); BCI: monthly business confidence index (long term average = 100); CCI: monthly consumer confidence index (long term average = 100); Shareofdigitalintensive: share of digital intensive job in total employments in OECD countries; Shareinserv: share of employments in service industry in total employments; L1.index: the one-period lagged variables of the index (ContainmentAndHealth/ GovernmentResponse/ Stringency/ EconomicSupport); L2.index: the two-period lagged variables of the index (ContainmentAndHealth/ GovernmentResponse/ Stringency/ EconomicSupport); Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 3. Coefficients and confidence intervals of NPIs indexes across quantiles of unemployment rates.

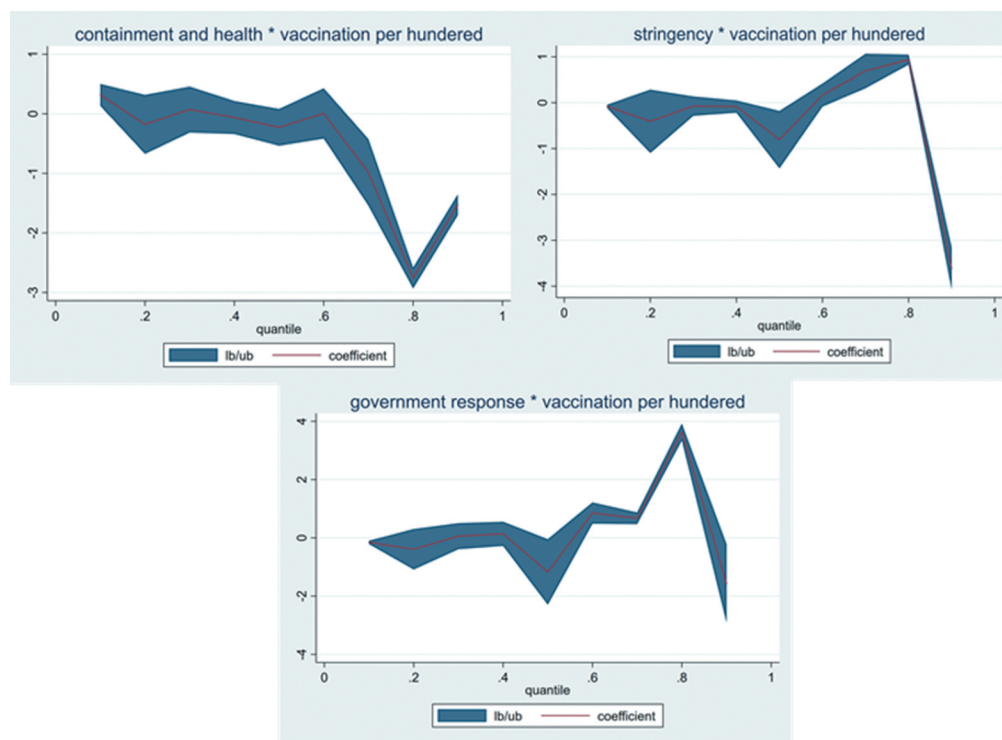


Table 5. Quantile regression for the impacts of NPIs on the unemployment rate

	Unemployment rate	Unemployment rate	Unemployment rate
	25th quantile	50th quantile	75th quantile
<i>ContainmentAndHealth</i>	−0.545*** (0.150)	1.324*** (0.280)	1.765*** (0.171)
<i>L1. ContainmentAndHealth</i>	−0.970*** (0.250)	−0.283* (0.155)	−0.724*** (0.206)
<i>GovernmentResponse</i>	−0.846*** (0.041)	0.539*** (0.166)	3.316*** (0.467)
<i>L1.GovernmentResponse</i>	−0.925*** (0.008)	−0.088 (0.079)	−3.330*** (0.314)
<i>Stringency</i>	−0.400** (0.183)	0.530*** (0.199)	1.788*** (0.224)
<i>L1.Stringency</i>	−0.917*** (0.075)	−0.545*** (0.149)	3.020*** (0.332)
<i>N</i>	372	372	372
<i>MCMC mean acceptance rate</i>			
<i>ContainmentAndHealth</i>	0.313	0.324	0.470
<i>GovernmentResponse</i>	0.310	0.592	0.464
<i>Stringency</i>	0.654	0.449	0.480

Exogenous explanatory variables include *L2.GovernmentResponse*, *Cases_g*, *Vaccinationsperhundred_g*, *GDPpercapital*, *CPI*, *Interest rate*, *BCI*, *CCI*

Table 6. Quantile regression for the interactive impacts of NPIs and COVID-19 vaccination campaign on the unemployment rate

	Unemployment rate	Unemployment rate	Unemployment rate
	25th quantile	50th quantile	75th quantile
<i>ContainmentAndHealth</i>	1.186*	1.020	0.350**
	(0.561)	(0.610)	(0.134)
<i>Vaccinationsperhundred_g</i>		0.308**	0.375***
−0.797***			
	(0.116)	(0.087)	(0.135)
<i>ContainmentAndHealth* Vaccinationperhundred_g</i>	−0.066	−1.575*	−0.597**
	(0.145)	(0.751)	(0.211)
<i>GovernmentResponse</i>	−0.606***	−4.449***	−1.635***
	(0.162)	(0.365)	(0.147)
<i>Vaccinationsperhundred_g</i>		0.262**	−0.398*
−0.585***			
	(0.117)	(0.226)	(0.043)
<i>GovernmentResponse * Vaccinationperhundred_g</i>	0.097	−1.183***	−0.481***
	(0.171)	(0.351)	(0.121)
<i>Stringency</i>	0.002	−0.979***	1.708***
	(0.157)	(0.226)	(0.036)
<i>Vaccinationsperhundred_g</i>		0.271**	0.223
0.076**			
	(0.135)	(0.140)	(0.035)
<i>Stringency * Vaccinationperhundred_g</i>	−0.195	−0.760**	−0.950***
	(0.167)	(0.382)	(0.018)
<i>N</i>	372	372	372
<i>MCMC mean acceptance rate</i>			
<i>ContainmentAndHealth</i>	0.342	0.378	0.249
<i>GovernmentResponse</i>	0.421	0.370	0.226
<i>Stringency</i>	0.294	0.346	0.245

of acting strongly to contain the spread of COVID-19 viruses using strict NPIs. As tighter NPIs could quickly reduce newly infected cases (see, [Table 1](#)), in turn, the low number of newly infected cases could allow countries to gradually reopen their economy at “green zone” regions and allow newly created employment (Beyer et al., 2021).

These results remain robust when we add control variables for countries’ labor market characteristics with the share of digital intensive jobs (*Shareofdigiintensive*) and share of employment in service industries (*Shareinserv*) in [Table 4](#). Moreover, the share of digital intensive jobs has a strong negative effect on the unemployment rate (p-value < 0.000, 95% C.I. −0.379 to −0.185). In contrast, the share of employment in service industries is positively related to the unemployment

Table 7. The effects of non-pharmaceutical interventions (NPIs) on growths of Share Price indexes in OECD countries			
	(1) Shareprice	(2) Shareprice	(3) Shareprice
Containment index	0.018 (0.017)		
L1.ContainmentAndHealth	0.017 (0.012)		
L2.ContainmentAndHealth	0.021*** (0.006)		
GovernmentResponse		0.028 (0.020)	
L1.GovernmentResponse		0.008 (0.013)	
L2.GovernmentResponse		0.023*** (0.006)	
Stringency			0.012 (0.011)
L1.Stringency			0.014 (0.009)
L2.Stringency			0.016*** (0.004)
EconomicSupport			0.018* (0.011)
L.EconomicSupport			0.023** (0.011)
L2.EconomicSupport			0.040*** (0.005)

(Continued)

Table 7. (Continued)

	(1) Shareprice	(2) Shareprice	(3) Shareprice	(4) Shareprice
Shareofdiintensive	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.000 (0.001)
Shareinserv	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Cases_g	-0.023*** (0.007)	-0.024*** (0.007)	-0.024*** (0.007)	-0.016** (0.006)
Vaccinationsperhundred_g	-0.001 (0.002)	-0.001 (0.002)	-0.001 (0.002)	0.000 (0.002)
GDPpercapital	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)
CPI	0.001 (0.002)	0.001 (0.002)	0.001 (0.002)	-0.001 (0.002)
Interest rate	-0.002 (0.003)	-0.001 (0.003)	-0.001 (0.003)	-0.000 (0.003)
BCI	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	0.001 (0.001)
CCI	0.000 (0.001)	0.000 (0.001)	-0.000 (0.001)	0.000 (0.001)
Constant	0.184 (0.135)	0.157 (0.136)	0.199 (0.134)	-0.101 (0.150)
N	355	355	356	336
Hausman's test	16.11	15.80	13.76	15.74
Prob > χ^2	0.064	0.071	0.131	0.072
Wald's test	519.74	502.74	527.42	779.87

(Continued)

Table 7. (Continued)			
	(1)	(2)	(3)
	Shareprice	Shareprice	Shareprice
Prob > χ^2	0.000	0.000	0.000
Wooldridge's test	113.34	113.24	113.31
Prob > F	0.000	0.000	0.000

Note: Shareprice: monthly changes in Shareprice index of OECD countries; ContainmentAndHealth: relative changes in monthly Containment and Health index of COVID-19 NPIs; GovernmentResponse: relative changes in monthly Government response index of COVID-19 NPIs; StringencyIndex: relative changes in monthly stringency index of COVID-19 NPIs; EconomicSupport: index: relative monthly changes in Economic support index of OCVID-19 NPIs Vaccinationsperhundred_g: monthly relative changes in total population vaccinated per hundred. Cases_g: monthly relative changes in total confirmed COVID-19. CPI: monthly consumer price index changes from the previous year (2015 = 100); BCI: monthly business confidence index (long term average = 100); CCI: monthly consumer confidence index (long term average = 100); Shareofdigitintensive: share of digital intensive jobs in total employment in OECD countries; Shareinserv: share of employment in service industry in total employments; L1.index: the one-period lagged variables of the index (ContainmentAndHealth/ GovernmentResponse/ Stringency/ EconomicSupport); L2.index: the two-period lagged variables of the index (ContainmentAndHealth/ GovernmentResponse/ Stringency/ EconomicSupport); Standard errors in parentheses.
* p < 0.10, ** p < 0.05, *** p < 0.01

rate (p -value < 0.000, 95% C.I. 0.116 to 0.190). These findings are expected, as digital intensive jobs could be largely worked from home, and employment in these sectors is marginally affected by the restriction measures. As major service industry employment is required to perform tasks directly at sites, employment rates in service industries could be severely affected by the restriction measures (i.e., hospitality industry, transportation). As control variables, GDP per capita and inflation (CPI) have expected adverse effects on unemployment rates.

In Table 5, we use quantile regression for panel data with MCMC optimizations to examine the focal effects at different conditional quantiles of unemployment rates. We executed three models at the 25th, 50th, and 75th quantiles of unemployment rates. In general, the results in Table 5 provide similar conclusions about the impacts of NPIs on the unemployment rate, as shown in Tables 3 and 4. However, in detail, there are significant differences in the patterns of public health-economic trade-offs across quantiles of unemployment rates. Specifically, unlike the results in Tables 3 and 4, at a higher quantile level of the unemployment rate (at the 50th and 75th quantile), these relationships turn around, and the trade-offs between public health and economic outcomes are practical (at the 75th quantile: p -value < 0.000, 95% CI 1.429 to 2.099 for ContainmentAndHealth; p -value < 0.000, 95% C.I. 2.400 to 4.231 for Government Response; and p -value < 0.000, 95% C.I. 1.349 to 2.226 for Stringency). At lower quantiles of the unemployment rate (at the 25th quantile), a higher level of NPIs could lead to a lower unemployment rate, as suggested in the previous analysis (at 25th quantile: p -value < 0.000, 95% CI -0.838 to -0.250 for ContainmentAndHealth; p -value < 0.000, 95% C.I. -0.925 to -0.765 for GovernmentResponse; and p -value < 0.000, 95% C.I. -0.758 to -0.041 for Stringency). These results explain the complex relationships between public health policies and economic outcomes and why these relationships could differ between countries with different macroeconomic conditions. Figure 3 shows the coefficients and their confidence interval of containment and health index in the relationships with unemployment rate across quantiles of unemployment rates. In general, the coefficients increase and remain positive at higher quantiles of unemployment.

*ContainmentAndHealth: relative changes in monthly Containment and Health index of COVID-19 NPIs; GovernmentResponse: relative changes in monthly Government response index of COVID-19 NPIs; Stringencyindex: relative changes in monthly stringency index of COVID-19 NPIs; Vaccinationsperhundred_g: monthly relative changes in total population vaccinated per hundred, Cases_g: monthly relative changes in total confirmed COVID-19. CPI: monthly consumer price index changes from the previous year (2015 = 100); BCI: monthly business confidence index (long term average = 100); CCI: monthly consumer confidence index (long term average = 100). L1.index: the one-period lagged variables of the index; L2.index: the two-period lagged variables of the index; Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.*

Table 6 shows the results of the quantile regression of the interactive impacts of NPIs and COVID-19 vaccination campaigns on the unemployment rate. The results suggest that countries' COVID-19 vaccination campaign growth rates, when combined with NPIs, could considerably impact their future economic outlook. According to the results in Table 6, the interactive effects of NPIs and countries' vaccination growth rates are more crucial in reducing unemployment rates when unemployment is at higher quantiles. Specifically, the interactions with NPIs show negative impacts on unemployment rates at the 50th and 75th quantile levels of the unemployment rate (at 75th: p -value < 0.000, 95% C.I. -0.945 to -0.248 for ContainmentAndHealth; p -value < 0.000, 95% C.I. -0.680 to -0.281 for government response; and p -value < 0.000, 95% C.I. -0.979 to -0.920 for Stringency). Figure 3 also illustrates the same conclusion as Table 6 that the interactions between NPIs and vaccination growth rates reduce unemployment rates to a larger extent at higher quantiles of unemployment rates.

Exogenous explanatory variables include: Daystoaccses, Daysto50%, GDPpercapital, CPI, Interest rate, BCI, CCI.

*ContainmentAndHealth: relative changes in monthly Containment and Health index of COVID-19 NPIs; GovernmentResponse: relative changes in monthly Government response index of COVID-19 NPIs; Stringencyindex: relative changes in monthly stringency index of COVID-19 NPIs; Daystoaccses: number of days from the first 500 COVID-19 cases per million to the first vaccinated case; Daysto50%: number of days needed to get to 50% of the population vaccinated from the first vaccinated case; Vaccinationsperhundred_g: monthly relative changes in the population vaccinated per hundred, CPI: monthly consumer price index changes from the previous year (2015 = 100); BCI: monthly business confidence index (long term average = 100); CCI: monthly consumer confidence index (long term average = 100). L1.index: the one-period lagged variables of the index; L2.index: the two-period lagged variables of the index; Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

3.3. Robustness tests

As a robustness test, we use the monthly changes in the share price indexes from OECD countries as the economic outcomes instead of unemployment rates in Table 7. The link between macro-economics and the stock market has been widely examined in the past (Jansen & Nahuis, 2003). Additionally, scholars such as (Hooker, 2004), (Chiarella & Gao, 2004) have shown that macro-economic measures such as GDP, productivity, employment, and interest rates have an effect on stock market returns. Increased stock prices have the potential to promote consumption through the confidence channel for two reasons. The first is that rising stock prices imply more wealth and, thus, increased optimism. The second argument is that economic actors may take increased stock prices as an indication of future good economic circumstances. Stock prices' leading indicator feature creates a pathway for equity prices to affect the behavior of all customers, regardless of whether they have a direct investment in the stock market. Thus, besides using direct economic outcomes such as unemployment rates, the share price index is also chosen as a proxy for future economic outcomes in the short term. The results in Table 7 show that the results give similar conclusions to previous results, with unemployment rates as economic outcomes. Governments' NPIs are positively related to changes in Share price indexes two months later. These results suggest that more stringent NPIs for containing the COVID-19 pandemic could lead to a raise in OECD countries' share price indexes in the future in short term. This could be because investors are more positive about the future macroeconomic conditions and outcomes given the lower COVID-19 infection and mortality rates as a result of stricter NPIs.

4. Conclusion

Using cross-country evidence, we found that the NPI policies implemented by OECD countries effectively contain the COVID-19 pandemic. We found that NPI implementations have substantial positive impacts on future outcomes of economic activities at the lower quantile of unemployment rates. However, countries with deteriorated macroeconomic conditions (higher unemployment rates) could suffer severe economic impacts from stricter NPIs fighting the COVID-19 pandemic. Some countries hit worse than others, and some countries with solid macroeconomic conditions could stabilize their labor markets quickly in the future by controlling the spread of COVID-19 with tighter government NPIs such as whole city lockdown, workplace, and school closing. These countries have available resources and developed economic systems (rooms for major monetary and fiscal policies) to support firms and individuals and preserve jobs. They can then adjust to the new normal at a lower cost than other countries. This finding suggests that the "No-COVID" strategy could be feasible for countries such as Germany, Australia, and New Zealand, as they could apply strong and long-lasting NPIs from the beginning of the pandemic to reduce the infection case to near zero, then structurally reopen the economic activities in green zones.

On the other hand, the practical trade-off between public health and economic activities suggests that implementing tight NPIs could impose severe damages to the economies and societies of countries with unfavorable macroeconomic conditions (higher unemployment rates). If tight NPIs are applied for a considerably long time, it could lead to severe foreign direct investment withdrawals, higher costs to reopen economic activities, and social unrest in these countries. Nevertheless, we also find that combining NPIs and high growth rates in vaccination could be very beneficial at higher quantiles of unemployment rates. This finding encourages countries with limited macroeconomic resources to urgently combine their NPI measures with COVID-19 vaccination efforts to be able to reopen their economy sooner. Instead of pursuing the “No-COVID” strategy, these countries should focus on speeding up their vaccination campaign to achieve larger COVID-19 immune population shares. They can then gradually reopen economies and tolerate the viruses to some extent. The key to this strategy is the speed at which a country can scale up its vaccination campaign to achieve the community’s immune level. Nevertheless, the “vaccine nationalism” could hinder this strategy for low-income economies and could slow down global economic recovery significantly. This vaccine nationalism poses a critical question of how developed and developing countries could effectively cooperate in fighting vaccine nationalism and quickly recover the global economy and people’s lives from the aftermath of the COVID-19 pandemic. Further research should pay more attention to this cooperation issue between countries with different socio-economic conditions, given its critical role in the fight against the COVID-19 pandemic.

This study suffers from some limitations. First, because of macroeconomic and COVID-19 data limitations, we only test the trade-off between NPIs and economic outcomes using monthly data from February 2020 to June 2021. This short timeframe of the COVID-19 pandemic could be considered the early stage of the pandemic. Thus, more research should be conducted at the later pandemic stages when the trade-off is more mature and with more data to test the robustness of this study’s findings. Second, this study uses panel data and quantile panel regression to explore the heterogeneities of trade-offs in different macroeconomic conditions. More methodologies, especially causal inference ones, could be used to define the focal factors in the trade-offs. Finally, the trade-off between public health and economic outcomes is an important and complex topic. It needs more attention from scholars in different fields of knowledge to enrich our understanding of how governments could improve their public policies to deal with pandemics in the future.

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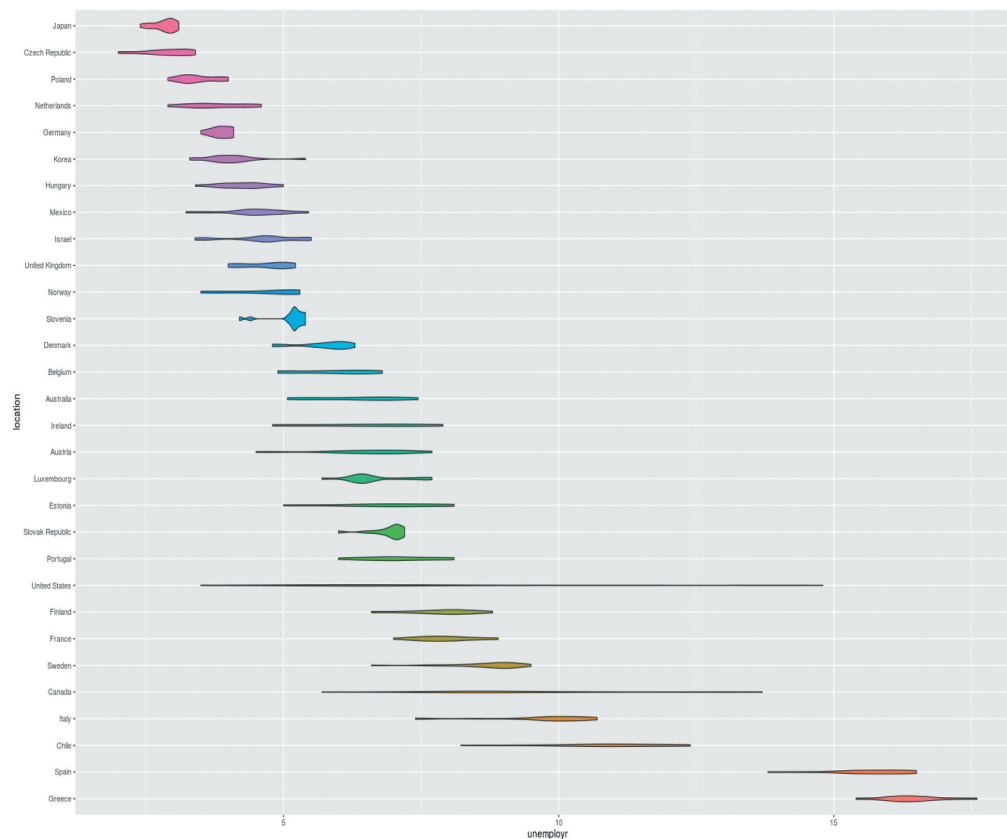
Appendix A Data and sources

Variables	Description	Sources
Unemployment	Monthly unemployment rate from OECD countries	OECD (2021), Employment rate (indicator). doi: 10.1787/1de68a9b-en (Accessed on 24 September 2021)
Shareprice	Monthly changes in Share prices index of OECD countries calculated from the prices of common shares of companies traded on national or foreign stock exchanges.	OECD (2021), Share prices (indicator). doi: 10.1787/6ad82f42-en (Accessed on 24 September 2021)
Cases_g	Monthly growth rate of number of confirmed COVID-19 cases per million	Ritchie et al.(2020)
ContainmentAndHealthStringency GovernmentResponse EconomicSupport	Relative monthly changes in Containment and Health index/ Government Response index/ Stringency index/ Economic Support index. Containment and Health index: combines “lockdown” restrictions and closures with measures such as testing policy and contact tracing, short-term investment in healthcare, as well investments in vaccines. Government response index: records how the response of governments has varied over all indicators in the database, becoming stronger or weaker over the course of the outbreak. Stringency index: records the strictness of “lockdown style” policies that primarily restrict people’s behaviour. Economic support index: records measures such as income support and debt relief.	Hale et al. (2021)
GDPpercapita (\$)	Gross domestic product per capita	World Bank national accounts data
CCI	Monthly consumer confidence index (long term average = 100)	OECD (2021), Consumer confidence index (CCI) (indicator). doi: 10.1787/46434d78-en (Accessed on 24 September 2021)
BCI	Monthly business confidence index (long term average = 100)	OECD (2021), Business confidence index (BCI) (indicator). doi: 10.1787/3092dc4f-en (Accessed on 24 September 2021)
CPI	Monthly consumer price index changes from the previous year which is used to measure inflation (base year 2015 = 100)	OECD (2021), Inflation (CPI) (indicator). doi: 10.1787/eee82e6e-en (Accessed on 24 September 2021)

(Continued)

(Continued)		
Variables	Description	Sources
Interest rate	Monthly basic interest rate of the economy which is long-term interest rates refer to government bonds maturing in ten years.	OECD (2021), Long-term interest rates (indicator). doi: 10.1787/662d712c-en (Accessed on 24 September 2021)
Hospitalbedper1000	Number of hospital beds per 1000 population	World Health Organization, World Health Statistics (2020)
Physicianper1000	Number of medical doctors per 1000 population	World Health Organization, World Health Statistics (2020)
HDI	Human Development Index in 2020 collected from United Nation Development Program database	UNDP (2020)
Population_density (people/km2)	Population density index	World Bank national accounts data
Aged_65_older (%)	Share of populations with age 65 and over	World Bank national accounts data (2020)
Time	Variable accounting for specific month-effects in the model	
Shareofdigiintensive	Share of digital intensive jobs in total employments in OECD countries	OECDGoingDigitalToolkit (2021). Digital-intensive sectors' share in total employment. http://goingdigital.oecd.org/indicator/41
Shareinserv	Share of employments in service industry in total employments	OECD, 2020 Employment by activity (indicator). doi: 10.1787/a258bb52-en.

Appendix B. Distribution of unemployment rates across OECD countries





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