Estimating the Global Effects of the Covid-19 Pandemic on GDP Growth Rate

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Contents

1 Introduction

The COVID-19 pandemic, an unprecedented global crisis, has left an indelible mark on economies worldwide. As nations grappled with the multifaceted challenges posed by the pandemic, questions arose about its impact on economic indicators, particularly GDP growth. This paper delves into the intricate relationship between the COVID-19 pandemic and the real GDP growth rate across 217 countries. Employing a comprehensive dataset and advanced statistical modeling techniques, we aim to discern patterns, draw insights, and provide a nuanced understanding of how the pandemic has influenced economic trajectories.

The investigation begins with the preprocessing of a diverse dataset, encompassing variables such as GDP growth rate, GDP per capita, unemployment rates, exchange rates, and more. Utilizing the R programming language and various packages, the data is meticulously curated and transformed to facilitate a rigorous analysis.

The exploration phase involves visualizing trends in real GDP growth rates across all countries, categorizing them by income levels, and scrutinizing the impact on high, upper-middle, lower-middle, and low-income nations. By employing exploratory data analysis (EDA) techniques and generating insightful visualizations, we lay the groundwork for understanding the macroeconomic landscape during and after the onset of the pandemic.

Subsequently, a series of fixed effects panel models are constructed to assess the relationships between the real GDP growth rate and key economic variables. These models are designed to capture the nuanced effects of factors such as unemployment, exchange rates, technological exports, and health expenditures while considering the potential influence of COVID-19. A careful examination of the models, including diagnostic tests for heteroskedasticity and normality of residuals, provides a robust framework for evaluating the reliability of the results.

The paper concludes with a nuanced interpretation of the findings, shedding light on the varying degrees of impact experienced by countries of different income levels. Additionally, recommendations for further research and policy implications are discussed, aiming to contribute valuable insights to the ongoing discourse on the economic aftermath of the COVID-19 pandemic.

Through this endeavor, we strive to enhance our understanding of the complex interplay between global health crises and economic performance, providing valuable insights for policymakers, economists, and researchers alike.

2 Data and Methodology

2.1 Data

The data used in this study encompass annual economic indicators spanning from 1973 to 2022 for a total of 217 countries. This comprehensive dataset was meticulously curated from the World Bank, providing an extensive collection of economic metrics that forms the foundation for our analysis.

The selected variables for examination are as follows:

2.1.1 GDP Growth (Annual %) (Dependent Variable)

This variable signifies the annual percentage change in Gross Domestic Product (GDP) and serves as the dependent variable in our study. It stands as a key indicator of a country's economic performance and growth.

2.1.2 GDP Per Capita (Current USD)

Measuring the current US dollar value of a country's GDP per capita, this variable plays a pivotal role in categorizing countries into income groups. It is instrumental in classifying countries into one of four groups based on income levels: high income, upper-middle income, lower-middle income, and low income. This categorization aligns with the guidelines suggested by the World Bank in 2022:

- Low-income countries: GNI per capita of $1,045 or less.
- Lower-middle-income countries: GNI per capita between $1,046 and $4,095.
- Upper-middle-income countries: GNI per capita between $4,096 and $12,695.
- High-income countries: GNI per capita of $12,696 or more.

In light of insufficient data availability pertaining to Gross National Income per capita, the Gross Domestic Product per capita was employed as a replacement to facilitate the classification of countries into distinct income groups within the analytical framework of this study.

2.1.3 Unemployment, Total (% of Total Labor Force)

This variable represents the percentage of the total labor force that is unemployed, offering a crucial measure of labor market dynamics. It holds particular significance in the context of examining GDP, as the unemployment rate is integral to understanding the efficiency and productivity of the workforce. A higher unemployment rate may indicate underutilization of labor resources, potentially impacting overall economic output and growth. Therefore, close monitoring of this variable is essential for comprehensive assessments of the economic landscape, especially in relation to GDP fluctuations.

2.1.4 Real Effective Exchange Rate Index

This index reflects the relative value of a country's currency against a basket of other currencies while accounting for inflation and trade balances It offers valuable insights into currency dynamics. The choice of the base year, 2010 in this case, provides a benchmark for comparison and analysis. The index is crucial in discerning a country's global competitiveness, particularly in terms of net exports. By considering inflation-adjusted and trade-balanced values, it provides a more nuanced understanding of currency strength or weakness. Examining this index allows for the identification of trends that may impact a nation's position on international trade, influencing its economic performance.

2.1.5 Tariff Rate

The tariff rate, a key aspect of trade policy, significantly shapes a country's net exports by acting as a trade barrier that discourages international trade. Higher tariffs increase the cost of imported goods, leading to a reduction in imports. This reduction positively influences the trade balance by limiting the outflow of funds for imports.

2.1.6 High Technology Exports

Representing the percentage of manufactured exports classified as high-technology products, this variable highlights a country's involvement in advanced technological industries. It also serves as an indirect indicator of the overall level of technology within the country. The higher the percentage of high-tech exports, the more technologically advanced a country's manufacturing sector is likely to be, reflecting its production capabilities.

2.1.7 Curent Health Expenditure (% GDP)

Indicating the proportion of a country's GDP spent on health expenditures, this variable offers insights into healthcare prioritization. Countries with higher health expenditure percentages often exhibit greater emphasis on healthcare infrastructure and well-being. This focus on health can contribute to mitigating the adverse economic effects of a pandemic by fostering a healthier population and potentially reducing the severity and duration of health crises. Therefore, analyzing this variable becomes instrumental in comprehending the intertwined dynamics of health and economic resilience in the face of global crises.

2.1.8 Population Ages 15-64 (% of Total Population)

Representing the percentage of the population aged between 15 and 64 years, this variable provides information about the demographic structure. Given the observed pattern that the virus, such as COVID-19, tends to impact older citizens more severely than younger individuals, countries with a higher proportion of elderly populations may experience greater health and societal impacts. Analyzing this demographic aspect becomes essential in understanding the potential variations in the severity and nature of the challenges posed by the pandemic across different countries. It adds a nuanced layer to the exploration of the interconnected dynamics between demographics and the economic repercussions of the COVID-19 crisis.

2.1.9 Labor Force Participation Rate (% of Total Population Ages 15-64)

Measuring the percentage of the total population aged 15-64 that is economically active, this variable provides insights into workforce participation. As previously discussed, the working-age demographic holds particular significance in the context of the COVID-19 pandemic as a young working population could experience less impact from the virus.

The graph depicts the average growth rates of countries categorized by income groups from 1973 to 2022. Notably, there is a significant dip in 2020, indicating the widespread impact of the COVID-19 pandemic on global economies. This unique occurrence serves as a focal point for our analysis, exploring the specific dynamics influencing economic trends during this pivotal year.

2.1.10 Method

Model Specification:

The analysis employs fixed effects panel models, with country-level fixed effects to account for unobservable heterogeneity. Two base models are constructed, both including all independent variables. One of the base models introduces an interactive term between the dummy variable for COVID-19 and income categories, allowing for an exploration of how the pandemic's impact varies based on income levels.

Refined Models:

Building upon the base models, 3 refined models include an interactive term between COVID-19 and income categories, providing nuanced insights into the differential effects of the pandemic. Simultaneously, 3 models omit this interactive term, allowing for a comparative analysis.

3 Results

3.1 Baseline Models

Referring to Table 2
Base Model (1):

The base model, examining the relationship between GDP growth rate and various economic indicators, reveals insightful findings. Notably, the unemployment rate exhibits a statistically significant negative relationship with GDP growth rate, with a coefficient of -0.181. This suggests that higher unemployment rates are associated with lower GDP growth. Health expenditure also demonstrates a statistically significant negative impact, contrary to the expected positive correlation. The coefficient for COVID-19 is highly significant, indicating a substantial negative correlation with GDP growth rate, aligning with expectations.

Base Model with Interaction Term (2):

The model with an interaction term between COVID-19 and income categories adds a layer of complexity. The unemployment rate remains statistically significant with a negative impact on GDP growth rate (-0.178). Health expenditure retains its negative correlation, suggesting that increased spending in healthcare is associated with lower GDP growth, which warrants further investigation.

The interactive term provides nuanced insights into the differential effects of COVID-19 across income categories. The negative coefficient for COVID-19 in low-income countries (2.002) suggests low-income countries experienced on average a 3.774% decrease in their GDP growth rate. In contrast, the significant negative coefficient for COVID-19 in high-income countries (-5.776) suggests a slightly smaller impact of only 5.776% reduction in growth rate. The magnitude increases for lower-middle-income countries with an 8.32% decrease and upper-middle-income countries with an 7.826% decrease. The interaction terms (covid:incomeLow, covid:incomeLower mid, covid:incomeUpper mid) underscore the varying strength of the pandemic's impact based on income levels.

In summary, both models highlight the crucial role of the unemployment rate and the unexpected negative correlation of health expenditure with GDP growth. The interaction term in the second model emphasizes the differentiated impact of COVID-19 across income categories, providing valuable insights for policymakers and researchers.

Model Comparison: Adjusted R-squared Analysis:

Comparing the adjusted R-squared values of both models sheds light on potential omitted variable bias. Both models exhibit adjusted R-squared values around 0.45, indicating that a substantial portion of the variation in GDP growth rate is captured by the included variables. The similarity in these values suggests that there might be unaccounted factors influencing the dependent variable.

However, a notable distinction emerges when evaluating the models' effectiveness. The model with the interactive term (2) displays a slightly higher adjusted R-squared compared to the base model (1). This suggests that the inclusion of the interaction term contributes to a better fit, capturing additional nuances in the relationship between the independent and dependent variables.

While both models provide valuable insights, the modest improvement in adjusted R-squared in the model with the interactive term underscores its superiority in explaining variations in GDP growth rate. This finding reinforces the importance of considering the differential impact of COVID-19 across income categories for a more comprehensive understanding of the economic landscape.

3.2 Restricted Models with no Interactive Term

Referring to Table 3:
The unemployment rate is consistent with previous analyses, the unemployment rate remains statistically significant and negatively associated with GDP growth rate across all models.

Tariff Rate and Exchange Rate show little significance across models (1) and (2), it's noteworthy that Model 3 excludes them.

Despite variability in high-Tech export rate, high-tech exports exhibit significance in Model 1 and Model 3, highlighting their nuanced impact on GDP growth as their coefficients are 0.001, indicating a 0.001% increase in GDP growth rate as it increases by 1%.

Model 3 omits labor force participation Rate, due to possible multicollinearity.

Covid Impact: Regardless of model specifications, the negative impact of COVID-19 on GDP growth is evident. Model 3, despite having a slightly lower adjusted R-squared, stands out as the most comprehensive, considering the statistical significance of all regressors and the largest number of observations.

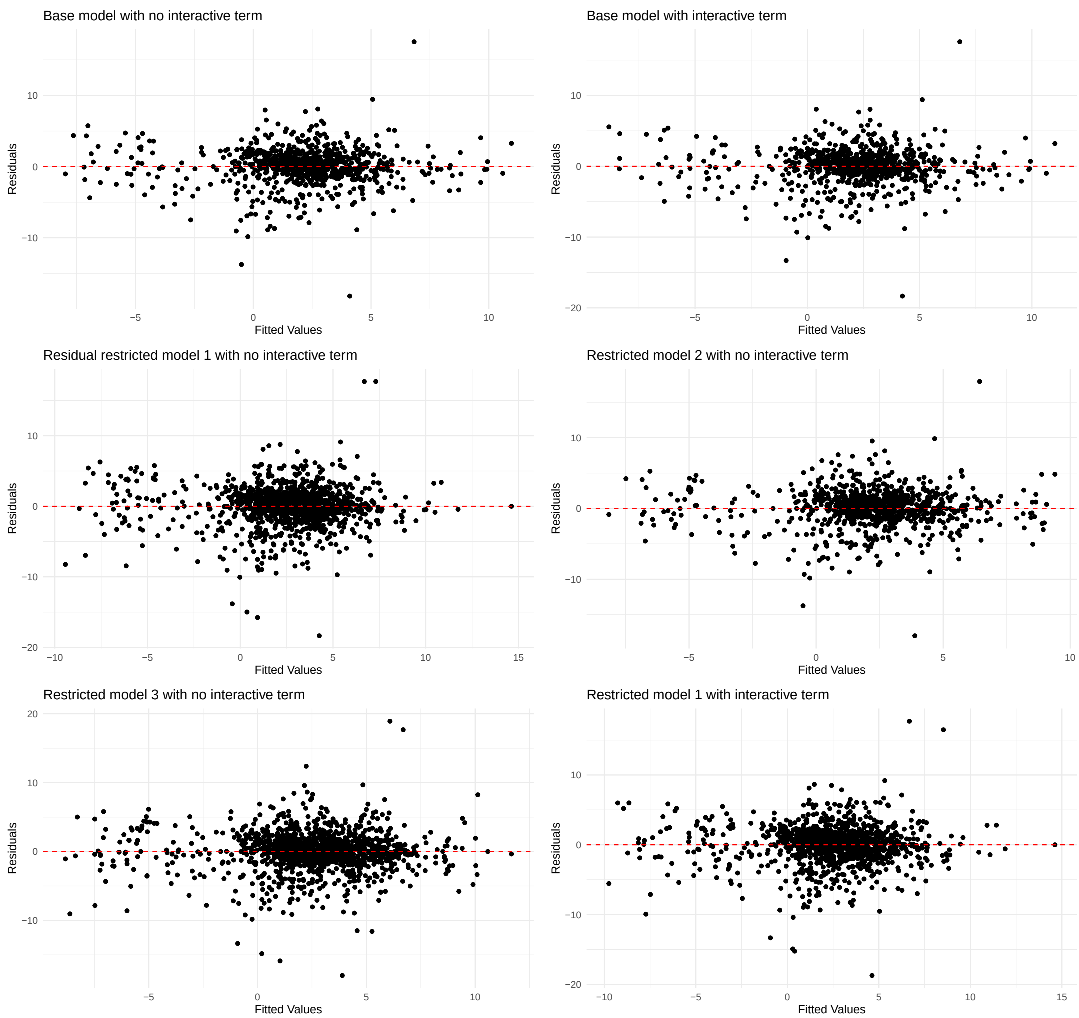
To summarize, Model 1, despite having some insignificantly related regressors, emerges as the most favorable with the highest adjusted R-squared. The consistent significance of COVID-19 emphasizes its substantial negative influence, with an average reduction of 6.608

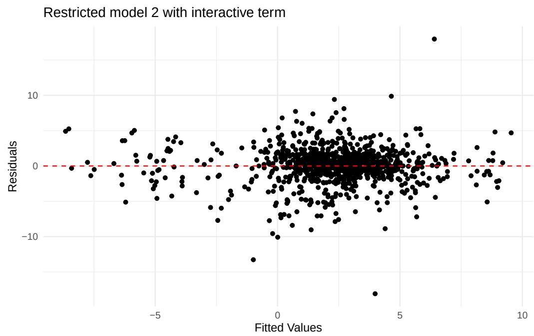
3.3 Restricted Models with Interactive Term

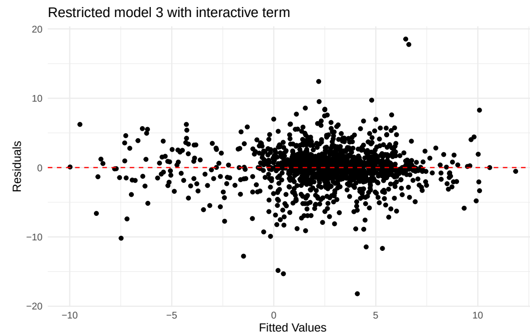
Referring to Table 4:
In evaluating the restricted models with an interactive term, Model 1 emerges as the most robust. It boasts the highest adjusted R-squared, indicating a better fit to the data compared to Models 2 and 3. While all models share common significant variables like unemployment rate, health expenditure, and population, Model 1 stands out with additional significant interaction terms between COVID-19 and income categories.

High-Income Countries: Experience a relatively moderate decrease of -4.941% in GDP growth. Low-Income Countries: Face a substantial decline, with a 7.7% decrease in GDP growth. Lower-Middle-Income Countries: Exhibit the most significant negative impact, with a -8.764% decrease in GDP growth. Upper-Middle-Income Countries: Also experience a notable decline, with a 7.948% decrease in GDP growth.

3.4 Residuals







Brusch Pagan Test for Homoskedasticity:

Model	BP Statistic	Df	P-value
1 (Base model with no int term)	19.016	9	0.02505
2 (Restricted model 1 with no int term)	16.818	6	0.009978
3 (Restricted model 2 with no int term)	14.541	6	0.02415
4 (Restricted model 3 with no int term)	17.972	5	0.002981
5 (Base model with int term)	32.482	15	0.005532
6 (Restricted model 1 with int term)	18.108	12	0.1125
7 (Restricted model 2 with int term)	26.675	12	0.008605
8 (Restricted model 3 with int term)	22.285	11	0.02225

The Breusch-Pagan test results presented above indicate that, with the exception of the first restricted model with interaction term, the null hypothesis of homoskedasticity is rejected for the remaining models. This inference is drawn from the statistically significant p-values, suggesting evidence of heteroskedasticity in the residuals across various model specifications apart from restricted model 1 with interactive term.

Shapiro-Walk normality test:

Table 1: Shapiro-Wilk Normality Test Results for Residuals

Model	W Statistic	P-Value
Base model with no int term	0.92178	$< 2.2 \times 10^{-16}$
Restricted model 1 with no int term	0.92063	$< 2.2 \times 10^{-16}$
Restricted model 2 with no int term	0.93327	$< 2.2 \times 10^{-16}$
Restricted model 3 with no int term	0.92552	$< 2.2 \times 10^{-16}$
Base model with int term	0.92029	$< 2.2 \times 10^{-16}$
Restricted model 1 with int term	0.92093	$< 2.2 \times 10^{-16}$
Restricted model 2 with int term	0.93222	$< 2.2 \times 10^{-16}$
Restricted model 3 with int term	0.92607	$< 2.2 \times 10^{-16}$

Given that all p-values from the tests are below the 1

4 Discussion

The findings of our analysis reveal a striking consistency across all models, indicating a significant negative impact of the COVID-19 pandemic on the growth rates of GDP across diverse countries. Regardless of the specific model specifications employed, the evidence strongly supports the notion that the global economic landscape has been markedly affected by the ongoing health crisis.

Interestingly, models incorporating interactive terms shed light on a nuanced dimension of the pandemic's economic repercussions. Notably, high-income countries appear to experience relatively milder declines in GDP growth rates compared to their lower-income counterparts. This observation suggests that economic resilience in the face of the pandemic is, to some extent, correlated with a nation's income level. These results align with existing literature that posits varying economic vulnerabilities among countries based on their income strata.

However, it is imperative to acknowledge the potential limitations identified in our analysis. The values of R-squared and the presence of homoskedastic residuals suggest the existence of omitted variable bias in our models. This implies that there are additional factors influencing GDP growth rates that were not considered in our current framework.

To address this limitation, we propose the inclusion of other relevant variables in future iterations of the model. One potential candidate is the lagged variable of GDP growth rate, which could capture temporal dependencies and account for historical trends. By incorporating such variables, we aim to enhance the robustness and explanatory power of our models, thereby providing a more comprehensive understanding of the factors influencing GDP dynamics in the wake of the COVID-19 pandemic.

In conclusion, our analysis underscores the pervasive negative impact of COVID-19 on global economic growth, while also highlighting the nuanced role of income levels in shaping countries' economic resilience. The identified limitations pave the way for future research endeavors, emphasizing the need for more intricate modeling that considers additional variables to refine our understanding of the complex interplay between the pandemic and economic outcomes.

5 Appendix

Table 2:

	income	gdp_gr	gdp_per_cap	urate	exrate	tar_rate	HT_export	health_exp	pop	labpart_r
1	High	2.5	35909.4	6.7	102.9	4.3	15.6	7.4	67.8	62.1
2	Low	3.7	511.5	6.4	157.6	14.1	5.5	5.4	53.6	60.9
3	Lower mid	3.8	2232.2	9.6	109.9	10.4	6.5	5.7	59.3	57.8
4	Upper mid	3.4	7431.5	9.3	101.6	8.1	24.3	6.1	64.8	58.7

Table 3: Base Models

	Dependent variable:	
	gdpgr	
	(1)	(2)
urate	-0.181^{***}	-0.178^{***}
	(0.057)	(0.051)
exrate	-0.004	-0.007
	(0.023)	(0.025)
tarrate	0.082	0.084
	(0.093)	(0.092)
hightechexpr	-0.052	-0.052
	(0.042)	(0.041)
healthexp	-1.157^{***}	-1.152^{***}
	(0.218)	(0.210)
pop	-2.488	-2.861
	(1.776)	(1.763)
pop_sq	0.015	0.018
	(0.014)	(0.014)
labpartr	0.031	0.028
	(0.050)	(0.052)
covid	-6.405^{***}	-5.776^{***}
	(0.509)	(0.531)
incomeLow		-3.875^{**}
		(1.716)
incomeLower mid		-0.431
		(1.542)
incomeUpper mid		-0.490
		(1.235)
covid:incomeLow		2.002
		(1.226)
covid:incomeLower mid		-2.544
		(2.579)
covid:incomeUpper mid		-2.050^{*}
		(1.206)
Observations	809	809
R^2	0.503	0.511
Adjusted R^2	0.441	0.445
Residual Std. Error	2.822 (df = 718)	2.812 (df = 712)

Table 4: Restricted models with no interactive term

	Dependent variable:		
	gdpgr		
	(1)	(2)	(3)
urate	-0.282^{***}	-0.205^{***}	-0.257^{***}
	(0.058)	(0.057)	(0.053)
tarrate	0.033		
	(0.071)		
exrate		-0.009	
		(0.021)	
hightechexpr	0.001^{***}	-0.044	0.001^{***}
	(0.0001)	(0.039)	(0.00004)
healthexp	-1.225^{***}	-0.811^{***}	-0.940^{***}
	(0.216)	(0.217)	(0.221)
labpartr	-0.023		
	(0.036)		
pop		-0.477^{***}	-0.406^{***}
		(0.123)	(0.111)
covid	-6.608^{***}	-6.973^{***}	-7.126^{***}
	(0.488)	(0.488)	(0.444)
Observations	1,206	908	1,401
R^2	0.514	0.481	0.498
Adjusted R^2	0.444	0.424	0.434
Residual Std. Error	3.023 (df = 1055)	2.845 (df = 817)	3.018 (df = 1240)
Note:			*p<0.1; **p<0.05; ***p<0.01

Table 5: Restricted models with interactive term

	Dependent variable:		
	gdpgr		
	(1)	(2)	(3)
urate	-0.270^{***}	-0.198^{***}	-0.251^{***}
	(0.057)	(0.052)	(0.052)
tarrate	0.030		
	(0.068)		
exrate		-0.012	
		(0.022)	
hightechexpr	0.002^{***}	-0.044	0.002^{***}
	(0.0001)	(0.038)	(0.0002)
healthexp	-1.296^{***}	-0.807^{***}	-0.952^{***}
	(0.209)	(0.215)	(0.220)
labpartr	-0.024		
	(0.037)		
pop		-0.463^{***}	-0.382^{***}
		(0.124)	(0.113)
covid	-4.941^{***}	-6.394^{***}	-6.185^{***}
	(0.532)	(0.541)	(0.553)
incomeLow	-0.346	-3.748^{**}	-1.173
	(1.585)	(1.586)	(1.310)
incomeLower mid	0.588	-0.596	-0.325
	(1.335)	(1.451)	(1.035)
incomeUpper mid	-0.519	-0.561	-0.674
	(0.961)	(1.241)	(0.868)
covid:incomeLow	-2.760^{***}	1.788^{***}	-0.187
	(1.030)	(0.632)	(1.012)
covid:incomeLower mid	-3.823^{***}	-2.730	-1.307
	(1.122)	(2.666)	(1.158)
covid:incomeUpper mid	-3.007^{***}	-1.796^{*}	-2.232^{**}
	(0.960)	(1.013)	(0.889)
Observations	1,206	908	1,401
R^2	0.526	0.487	0.503
Adjusted R^2	0.456	0.426	0.437
Residual Std. Error	2.992 (df = 1049)	2.838 (df = 811)	3.010 (df = 1234)
Note:			*p<0.1; **p<0.05; ***p<0.01

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