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Effect of the COVID-19 Pandemic on CO_2 Emissions in India

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We assess the effect of the COVID-19 pandemic on CO_2 emissions in India. We study the impact of COVID-19–induced control measures on the major contributors of CO_2 emissions by using a difference-in-differences model and eliminating the lockdown effect. We find that all the major contributors except for industrial emissions were significantly reduced due to the COVID-19 pandemic.

I. INTRODUCTION

The COVID-19 was declared a global pandemic by the World Health Organization on March 11, 2020, after it was first identified in December of the previous year. In a short span of time, it spread globally in huge proportions, and governments placed stringent control measures to prevent the transmission of the disease. The pandemic shook the world and led to a huge economic crisis. The gross domestic product (GDP) in India contracted by 7% in 2020–2021 due to reduced economic activity and led to the loss of income and employment.

Various studies have been conducted on the economic, social, financial, environmental, and psychological effects of the COVID-19 pandemic, including several on energy prices amid the pandemic (e.g., Kartal, 2021; Narayan, 2020) and the effect of the pandemic on emissions (e.g., Le et al., 2020; Mahato et al., 2020; Sarfraz et al., 2021; Smith et al., 2021; J. Wang et al., 2021). This note adds to the literature on the effect of the COVID-19 pandemic on CO_2 emissions. These emissions are tracked globally to control climate change, which is important for sustainable development.

We hypothesize that COVID-19 control measures reduce CO_2 emissions in India. This note differs from the previous literature for the following reasons. First, it examines the effect of the pandemic on the various contributors of CO_2 emissions. The major contributors of CO_2 emissions are power, industry, transport, residential buildings, and aviation. Second, a nationwide lockdown, a rigorous temporary preventive and control measure, was announced during the initial stages of the pandemic, bringing the economy to a halt. We eliminate the lockdown effect and determine whether the overall control measures enforced due to the pandemic had reduced CO_2 emissions. We find that, even after removal of the lockdown effect, all the major contributors, except for industrial emissions, showed reduced CO_2 emissions.

The disease spread was first identified in India in March, and several measures were subsequently taken to reduce its spread. Shortly thereafter, a nationwide lockdown of more than two months was announced on the evening of March 24, 2020, as a severe countermeasure to reduce the spread of COVID-19. Several controls were in place during this lockdown, such as school closures, workplace closures, public event cancellations, restrictions on gatherings, public transport closures, stay-at-home requirements, restrictions on internal movement, and international travel controls.

The lockdown was an extraordinary situation and intuitively it meant that CO_2 emissions were extremely low during that period. Studies have assessed the effect of the pandemic on the emissions. Smith, Tarui and Yamagata (2021) forecasted the recovery of CO_2 emissions to pre-crisis levels within a year. Sarfraz et al. (2021) modeled CO_2 emissions using the number of COVID-19 cases and found that the lockdown significantly reduced them. However, none of the studies specifically eliminated the effect of the intense lockdown on CO_2 emissions. We use a difference-in-differences (DID) model (Jiménez & Perdiguero, 2017) to determine the effect of pandemic-induced government regulations on CO_2 emissions, separating the influences of the nationwide lockdown. Wan et al. (2019) and Wang and Watanabe (2019) used a DID model to study the effect of environmental policy on pollution and risk. Wang et al. (2021) used a DID model to determine the effect of COVID-19 on air quality. We differentiate our study by

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specifically eliminating the effect of the lockdown on various CO_2 emissions.

This note makes the following contributions to the literature. First it evaluates the effect of the pandemic lockdown on various CO_2 emissions. It uses a DID design model to evaluate the effect of the lockdown on CO_2 emissions. This note is the first to evaluate the impact of pandemic control policy measures on CO_2 emissions in India after eliminating the lockdown effect. The results can be extended to other major countries through the same experimental design, which defines the future scope of work. There is also a question of whether the impact of pandemic control measures on CO_2 emissions is momentary, since the course of the pandemic has altered various economic activities, and the effect of such measures on sustainability also has a future scope of study.

II. DATA AND RESULTS

A. Data

This study uses daily emissions data for the sample period from January 1, 2019, to April 30, 2021. The outcome variable, data on various CO_2 emissions data (*lnCO*$_2$) were obtained from Carbon Monitor (see https://carbonmonitor.org/). The CO_2 emission data represent total CO_2 emissions arising from major contributing factors such as ground transport, industry, power, residential buildings, and aviation. The variable CO_2gt represents CO_2 emissions due to ground transport, which includes passenger and freight vehicles; CO_2ind denotes CO_2 emissions from industry, due to the burning of fossil fuels for energy; CO_2res denotes CO_2 emissions from residential buildings, primarily from fossil fuels burned for heat, the use of certain products containing greenhouse gases, and the handling of waste; CO_2pwr denotes CO_2 emissions arising from power generation, which is mainly due to the burning of fossil fuels, mostly coal and natural gas; and CO_2avi represents CO_2 emissions from the aviation sector.

The variables were converted to a logarithmic scale to address the issue of heteroskedasticity. The spread of the COVID-19 pandemic was countered by the announcement of the lockdown from March 24, 2020, to May 31, 2020. This external intervention led to the nationwide shutdown of most economic activities. The effect of the lockdown as an external intervention is evaluated by creating two groups, namely, a control group and an experimental group. To address the lockdown effect, we set the dummy variable *Lockdown,* indicating the lockdown period, equal to zero for that period (March 24, 2020, to May 31, 2020), and equal to one otherwise days. The dummy variable *Treat*, for the treatment period, equals one for the period from March 2020 to April 2021, since several control measures were undertaken since the identification of the first case in March, and zero otherwise.

Table 1 summarizes descriptive statistics on the data. The nature of the emissions data can be understood using the mean, standard deviation (SD), minimum, maximum, skewness, and kurtosis. The statistics are reported for CO_2 emissions on both the pre–COVID-19 sample (from January 1, 2019, to February 29, 2021) and the COVID-19 sample (from March 1, 2020, to April 30, 2021) for the complete sample of 851 observations.

India announced several control measures from March 2020 on, since the first active COVID-19 case. The pre-COVID-19 sample is thus taken from January 2019 to February 2020, accounting for 425 observations. The COVID-19 sample is taken from March 2020 to April 2021, for a total of 426 observations. We find that the mean of all CO_2 emissions (CO_2, CO_2gt, CO_2ind, CO_2pwr, CO_2res, and CO_2avi) are lower for the COVID-19 sample than for the pre–COVID-19 sample. CO_2 emissions could have been lower during the COVID-19 pandemic due to reduced economic activity. Variance is also found to be large for the COVID-19 sample, particularly for transport and industrial CO_2 emissions.

All the emissions data are checked for a unit root using the augmented Dickey–Fuller test, and the null hypothesis is found to be rejected at the 1% level in the first difference for $\ln CO_2$ and $\ln CO_2$ind. It is rejected at the 1% level in the second difference for $\ln CO_2$gt, $\ln CO_2$pwr, $\ln CO_2$res, and $\ln CO_2$avi. Therefore all the variables are stationary at I(2). The data can be utilized for a DID regression model.

B. Results

We use a DID model to determine the causal effect of pandemic-induced preventive and control policy measures on CO_2 emissions, by eliminating the effect of the major influencing factor, namely, the lockdown, which included the closure of the majority of activities, with restrictions on movement. After the lockdown, the controls were slightly more relaxed and, depending upon the disease spread, other restrictions were imposed. The differences in CO_2 emissions due to the lockdown and general restrictions due to COVID-19 are shown for the following DID model:

$$\begin{aligned} \ln CO_{2t} = {} & \beta_0 + \beta_1 Lockdown + \beta_2 Treat \\ & + \beta_{12}(Lockdown * Treat) + \beta_3 X_t + \varepsilon_t \end{aligned} \quad (1)$$

where $\ln CO_{2t}$ is the natural logarithm of all the major contributors of daily CO_2 emissions, *Lockdown* is a dummy variable that takes the value of zero during the lockdown period, and one otherwise; *Treat* is a dummy variable that groups both the pandemic and non-pandemic periods; and the interaction term $Lockdown * Treat$ represents pandemic measures excluding those during the lockdown period. The CO_2 emissions data before the pandemic period are used as the control group, and the CO_2 emissions data during the pandemic period are used as the experimental group. Year and month of the year effects are also addressed in this model and are denoted by X_t.

Table 2 reports the results of the DID analysis. We can infer that CO_2 emissions were significantly reduced because of the pandemic-induced control measures. It is found that $lnCO_2gt$, $lnCO_2pwr$, and $lnCO_2avi$ show reduced CO_2 emissions at the 1% level of significance, and $lnCO_2$ and $lnCO_2res$ show reduced emissions at the 5% level. We can infer that overall CO_2 emissions were reduced by 9.8% due to the COVID-19 control measures, a figure that is followed by CO_2 emissions due to power, which were reduced by 13.5%. CO_2 emissions due to ground transport and resi-

Table 1. Summary of descriptive statistics

Emissions		Mean	SD	Min	Max	Skewness	Kurtosis	ADF test
CO_2	Pre-covid	6.907	0.779	4.997	9.78	0.568	0.742	3.597* (1)
	covid	6.271	1.153	3.503	9.064	-0.188	0.027	
CO_2gt	Pre-covid	0.824	0.048	0.239	0.870	-5.279	52.144	-4.197* (2)
	covid	0.702	0.185	0.116	0.865	-1.666	1.671	
CO_2ind	Pre-covid	2.071	0.133	1.571	2.393	-0.657	0.655	-3.691* (1)
	covid	1.766	0.455	0.62	2.300	-1.159	0.330	
CO_2pwr	Pre-covid	3.304	0.306	2.339	3.96	-0.425	-0.233	-3.983* (2)
	covid	3.281	0.447	2.316	4.200	0.447	-0.682	
CO_2res	Pre-covid	0.655	0.588	0.258	2.257	1.825	3.110	-3.981* (2)
	covid	0.499	0.444	0.256	2.302	2.545	5.436	
CO_2avi	Pre-covid	0.053	0.003	0.031	0.059	-0.808	3.628	-3.981* (2)
	covid	0.023	0.012	0.001	0.057	-0.043	-0.066	

The table reports the statistics for various contributors of CO_2 emissions including both pre-covid and covid sample. CO_2 denotes total CO_2 emissions of the country; CO_{2gt} is emissions from ground transport; CO_{2ind} is emissions from industry; CO_{2pwr} is emissions from power; CO_{2res} is emissions from residential; CO_{2avi} is emissions from aviation.

Table 2. Regression Analysis of the DID model

Variables	$lnCO_2$	$lnCO_2gt$	$lnCO_2ind$	$lnCO_2pwr$	$lnCO_2res$	$lnCO_2avi$
Intercept	1.381** (0.047)	-1.267** (0.088)	0.419** (0.066)	0.823** (0.035)	-1.944** (0.246)	-6.556** (0.096)
Did	-0.098* (0.043)	-0.377** (0.081)	0.358** (0.061)	-0.135** (0.032)	-0.581* (0.227)	-1.410** (0.089)
Treat	-0.018 (0.040)	0.330** (0.0753)	-0.394** (0.056)	0.103** (0.030)	-0.111 (0.210)	0.232** (0.082)
Lockdown	0.491** (0.038)	1.095** (0.073)	0.365** (0.055)	0.358** (0.029)	0.726** (0.202)	3.089** (0.079)
Year	0.073** (0.013)	-0.029 (0.024)	-0.042* (0.018)	0.060** (0.009)	0.478** (0.066)	0.342** (0.026)
Month	-0.006** (0.001)	0.0001 (0.002)	-0.002 (0.002)	-0.011** (0.001)	-0.011 (0.008)	0.020** (0.003)
R^2	0.567	0.5341	0.6193	0.4995	0.1604	0.9118
F-statistic	221.7	193.7	274.9	168.7	32.29	1747

The table represents the result from regression analysis of DID model which is of the following form:

$$\ln CO_{2t} = \beta_0 + \beta_1 Lockdown + \beta_2 Treat + \beta_{12}(Lockdown * Treat) + \beta_3 X_t + \varepsilon_t$$

In this model, $lnCO_{2t}$ is the natural logarithm of all the major contributors of the daily carbon dioxide emissions. $lnCO_2$ is natural logarithm of total CO_2 emissions, $lnCO_2gt$ is natural logarithm of CO_2 emissions from ground transport, $lnCO_2ind$ is natural logarithm of CO_2 emissions from industry, $lnCO_2pwr$ is natural logarithm of CO_2 emissions from energy production and $lnCO_2avi$ is natural logarithm of CO_2 emissions from aviation. DID is Difference-in-difference interaction term of $Lockdown * Treat$. $Lockdown$ and $Treat$ are the dummy variables. Value inside the parenthesis is Newey-west standard error which addresses for heteroscedasticity and autocorrelation. Year and month are fixed effects variables. **1%, * 5% level of significance.

dential were reduced by 37.7% and 58.1%, respectively. CO_2 emissions due to aviation were reduced by 1.4 times due to pandemic-induced control measures. On the contrary, industrial emissions are found to have increased by 35.8% during the pandemic.

Except for industrial emissions, all the other contributors reduced CO_2 emissions, after we eliminate the lockdown effect. This result is similar to other research findings that showed reductions in CO_2 emissions during the COVID-19 pandemic (Sarfraz et al., 2021; Smith et al., 2021).

III. CONCLUSION

CO_2 emissions play a pivotal role in global climate change and have several far-reaching implications for sustainability and environment. The COVID-19 pandemic brought about various preventive measures, from a rigorous lockdown to less severe travel restrictions as countermeasures to reduce the disease spread. The impact of the pandemic has been one of a kind and has had a positive impact on environment. The economy came to a standstill during the lockdown, and it is intuitively understood that CO_2 emissions were reduced as rigorous control measures were in place, such as public closures and travel bans. There are

various major contributors to CO_2 emissions, and the impact of preventive control measures and lockdowns were studied for each of the categories of CO_2 emissions. The results show that CO_2 emissions were reduced across all major contributors, except industrial emissions, even after the lockdown effect was eliminated. The rigorous lockdown had a significant impact on CO_2 emissions in India. The pandemic and lockdown momentarily altered economic activities, which is evident from the reduction in CO_2 emissions.

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