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Estimation of economic benefits associated with the reduction in the CO₂ emission due to COVID-19

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A B S T R A C T

Since World War-II, the COVID-19 pandemic is considered the most serious challenge faced by the mankind. This pandemic has not only adversely affected the health systems but has also disrupted the manufacturing and industrial sectors and thus leading to low CO₂ emissions. Reduction in the carbon dioxide (CO₂) gas emission has been noticed nearly everywhere in the world due to shutdown of industries and lockdown imposed by governments as a consequence of the COVID-19 pandemic. In the year 2019, around 37 billion tons of CO₂ emitted globally that has been reduced by 9% in the same period (January to July) for the year 2020 as consequence of COVID-19 pandemic. The Social Cost of Carbon (SCC) of a country reflects the economic damages caused by per ton increase in the CO₂ emissions. Economic and environmental benefits are associated with the reduction of CO₂ emissions as a result of COVID-19 and their estimation is the main theme of the study. Coupling reduction in the CO₂ emissions to the Social Cost of Carbon gives economic benefit for a country. The research presented investigates the long term economic and environmental benefits associated with the reduction in the CO₂ emissions for various regions of the world. The economic benefit due to the reduction in the of the CO₂ emissions as consequence of the COVID-19 to global economy is estimated as 650 billion US Dollars for the period of 6 months (from January to July). The study mainly focuses on the countries that contribute the high percentage of CO₂ emissions to the atmosphere. The first half of year 2020 (from January 2020 to July 2020) is taken into consideration because lockdown was mainly followed in that period. Further, within the country the sectors that contribute the high percentage of CO₂ emissions are also taken into account.

Introduction

Since the mid-20th century, the emission of greenhouse gases from the human activities is observed as the most significant driver that has adversely affected the climate and environment (Matthews et al., 2009). Climate change due to CO₂ emissions is one of the challenges the world faces in current times and a prime focus for the researchers. The emissions of greenhouse gases have increased the global temperature by 1 °C in 2017 and 1.1 °C in 2019 since the pre-industrial times. According to the global carbon project report, 2.7% increase in the CO₂ emission has been observed in the year 2018 and 2019 (Safarian et al., 2020).

Sectors like power generation, industrial, housing or transport play a major role for emitting CO₂ into the atmosphere. Investigations reported reduction in the CO₂ emission would prevent more than 150 million premature deaths worldwide by taking meaningful steps (Shindel et al., 2018). A strategy can be beneficial if it is significant for meeting the climate targets; lower the emission of CO₂ etc. Researchers need to understand and use the evidence to support action for the reduction of CO₂ emissions. In simple words, if a strategy that is beneficial for any country in-terms of reduction in the CO₂ emissions can be used by researchers or policy makers as an evidence to make a strategy or policy that would help in reduction of CO₂ emissions in the future (Quere et al., 2020).

Every society pays damages to their economy that is referred as Social Cost of Carbon (SCC) by emitting CO₂ into the atmosphere. As emitting CO₂ leads towards global warming and flooding, droughts, melting of glaciers are the consequences that damage economy of a country. SCC is an estimate, in dollars, of the economic loss as a result from emitting additional tons of CO₂ into the atmosphere or benefit by the reduction of CO₂ emissions in tons (Mandell, 2011). Social cost of carbon varies from country to country and region to region. Over the past years, the research community of climate change has established five “Shared Socioeconomic Pathways (SSPs) from SSP1 to SSP5 (Yang et al., 2018). Among these five pathways (SSP1 to SSP5), SSP2 is the center case which describes the world with intermediate challenges for both adaption and mitigation due to which it is also narrated as “Middle of the Road Pathway” (Neill et al., 2017). SSP2 is widely applicable and

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relevant to the proposed study. A specific value of SCC that is obtained from the SSPs is required for the Cost Benefit Analysis (CBA) to estimate the benefit or loss as a consequence of a strategy such as lockdown.

COVID-19 has challenged the world public health security since December 2019. World Health Organization (WHO) has declared it as a global pandemic. In-order to reduce the spread (transmission) of the virus millions of people around the globe has been limited to their houses and strict lockdown was imposed (Zowalaty et al., 2020). Overall, the activities those are associated with the income of the people have been stopped almost and the stock markets dropped downward. However, the reduction in the human activities due to lockdown improve the air quality by reducing greenhouse gas emissions specifically CO2. Industrial production and energy consumption in some countries were reported to decline nearly by 30% in just few weeks as lockdowns were imposed to protect public health (Wang and Su, 2020). Globally there has been 5.8% decrease in the CO2 emissions (Liu et al., 2020).

Almost in every country of the world, reduction in the CO2 emission has been noticed as a result of COVID-19 lockdown (Chakraborty and Maiti, 2020; Mitra et al., 2020; Wang et al., 2020). However, a significant decrease in the CO2 emission has been observed in China, India, United States (US) and Brazil (Dang and Trinh, 2021). China is the largest CO2 emitter and around 14 billion metric tons of CO2 was produced in 2019. When the lockdown was imposed in China because of the COVID-19 pandemic, 10.3% reduction in the CO2 emission in the first quarter of 2020 was observed as compared to same period of 2019 (Liu et al., 2020). The United States is the 2nd largest CO2 emitter with approximately 5.3 billion metric tons of carbon dioxide emissions in 2017. The great cause of CO2 emissions in the United States is power generation, transportation and industry (Zhu et al., 2018). After the lockdown due to covid-19, there is 4.2% decrease in the emission of CO2 in the United States in first quarter of 2020 (Liu et al., 2020). India is the world 3rd biggest emitter of CO2, produced around 2.5 billion metric tons of CO2 in 2017 (Zhu et al., 2018). Due to COVID in the first quarter of 2020, 1.6% decrease in the CO2 emission is noticed as a result of the shutdown imposed by the federal government (Liu et al., 2020). Brazil emissions of greenhouse gases specifically CO2 reached to 1.93 billion tons in 2018 which is 0.3% more than in 2017. About 44% more CO2 in 2019 as compared to the previous years was emitted in Brazil as a result of the Amazon forest fire (Pereira et al., 2019).

In Brazil, the emission of CO2 after COVID-19 lockdown is reduced by 4.1% during the first quarter of 2020 (Liu et al., 2020).

The objective of the study is to investigate the economic benefits associated with the reduction in the CO2 emissions to the atmosphere. Per ton increase in CO2 emission bring damages to an economy in the form global warming that leads to flooding, droughts and forest fires etc. Similarly, per ton reduction in the CO2 is fruitful to an economy. The study investigates the benefits to the global economy as a result of CO2 reduction due to COVID-19 lockdown. Also, estimation of country wise economic benefits as a consequence of reduction in the CO2 emissions due to COVID-19 is a prime focus of the study. Further, economic benefit as result of sector wise reduction in the CO2 emission is taken into account. The study presented has a great importance for countries like Pakistan that contributes very little to the global CO2 emission but affected the most because of the CO2 emission of neighboring countries.

Methodology

The following Eq. (1) would be used for the estimation of CO2 emissions (Liu et al., 2015).

\[
\text{Emission} = \sum \sum \sum (\text{Energy consumption data}_{i,j,k} \times \text{EF}_{i,j,k}) \tag{1}
\]

Where, \(i, j, k\) represents the regions, sectors and fuel types respectively. Energy consumption is the total amount of energy used. EF is the Emission Factor which is the representative value that allows converting activity data into greenhouse gas emissions.

The estimation of Social Cost of Carbon (SCC) is based on Integrated Assessment Models (IAMs) which consist of Socio-Economic projection and damage function (Metcalfe and Stock, 2017). For the Socio-Economic projection, the shared Socio-Economic pathway 2 (SSP2) also narrated as “Middle of the road” is used because it is the center case which consists of intermediate challenges compared to other SSPs.

From the combination of CO2 and SCC estimation benefits from the reduced emission under COVID-19 lockdown can be calculated by using the following equation given as follows (Rennert and Kington, 2019):

\[
\text{Economic Benefit} = \left( \text{reduction in CO}_2 \text{ emission in tons} \right) \times \left( \text{social cost of CO}_2 \text{ per ton} \right) \tag{2}
\]
Eq. (2) is the main equation that will be used in the study for the estimation of benefit.

Results and discussion

Increase in the CO$_2$ emissions in the atmosphere leads to the global warming that is a serious threat to the man kind and the environment in the coming decays and therefore lots of resources being allocated to mitigate its adverse effects in the current times. Severe flooding, melting of glaciers, droughts, wildfires, increase in sea levels and depletion in Oxygen are the adverse consequences of the global warming that directly affect the economies of various countries. The emitted CO$_2$ remains in the atmosphere for number of years and per ton increase in the CO$_2$ emission further complicate the situation. Similarly, per ton decrease in the CO$_2$ not only has a positive impact on the global warming but also safe guard the economy of a country from the adverse effects of the global warming.

Wuhan China was the city where COVID-19 was detected and announced officially by the end of 2019. As reporting of the COVID-19 cases started, a strict lock down was imposed in Wuhan city for a couple of months that leads to a drastic decrease in the CO$_2$ emissions that could be visualized in available images by comparing the images before and after the lockdown. Fig. 1 is the clear representation of the difference in the CO$_2$ emissions before and after lockdown.

After China, the COVID-19 virus spread to the other parts of the world and to control its harmful effects lockdown was imposed in various parts of the world. After China, Europe and Iran was the epicenter of the COVID-19 virus and then spread in almost every country of the world. Flights were canceled, industries were shutdown and people were limited to their houses in order to control the spread of the COVID-19 virus. As a result reduction in the CO$_2$ emissions was noticed in different parts of the world. Fig. 2 shows reduction in the CO$_2$ emissions globally for the first 6 months of 2020. It can be seen in Fig. 2 that in the month of May 2020, maximum decrease in the CO$_2$ reduction has been noticed.

On the other hand, Social Cost of Carbon (SSC) is the economic damages caused by per ton increase in the CO$_2$ to the atmosphere. Similarly, per ton reduction in the CO$_2$ is assumed as a benefit for the economy of any country. The value of SSC is different for different countries as per ton increase in the CO$_2$ emission damages every country differently. Negative SSC means that a country emits less CO$_2$ to the atmosphere as compared to absorbing the CO$_2$. Values of SSC for different countries are provided in Table 1.

Economic benefit as a result of reduction in the CO$_2$ emissions to the global economy could be estimated by multiplying the total reduction of CO$_2$ in tons to the global Social Cost of Carbon. For the period from 1 January 2020 to 1 July 2020, the total global reduction in the CO$_2$ emission has been reported as 1551 Million tons of CO$_2$. The value of global SCC is 418, therefore, the due to the reduction in the CO$_2$ emission the global economy has been benefited by 648 Billion US dollars.

Fig. 3 is the representation of the country wise reduction in the CO$_2$ emissions during the first half year period of 2020. Also, Table 2 shows Social Cost of Carbon of the respective countries; therefore, economic benefit associated with the reduction in the CO$_2$ emission could be estimated. 205.2 million tons of CO$_2$ reduction was recorded for India, and the Social Cost of Carbon of India is 86 Dollars per ton. Therefore, economic benefit for the Indian economy is 17.65 billion US Dollars for the proposed period as a result of reduction in the CO$_2$ emission. Similarly, reduction in the CO$_2$ emission for China, US, Brazil, Japan, Italy and Spain are 187.2, 338.3, 25.9, 43.1, 22.9 and 23.1 million tons, respectively. Also, Social Cost of Carbon for China, US, Brazil, Japan, Italy

![Image](image_url)

Fig. 2. Global reduction in the CO$_2$ emissions for the first half of 2020 as compared 2019 (Liu et al., 2020).

| Country Name | SCC per ton increase in the CO$_2$ emission (US Dollars) |
|--------------|--------------------------------------------------------|
| India        | 86                                                     |
| USA          | 48                                                     |
| China        | 24                                                     |
| Brazil       | 24                                                     |
| Japan        | 5.48                                                   |
| Russia       | -11                                                    |
| UK           | -3.8                                                   |
| France       | -1.10                                                  |
| Germany      | -5.05                                                  |
| Italy        | 1.64                                                   |
| Spain        | 3.42                                                   |
| Pakistan     | 9.05                                                   |
| Global       | 418                                                    |

Table 1: Social Cost of Carbon (SSC) per ton increase in the CO$_2$ emission to the atmosphere of different countries.
Fig. 3. Country wise reduction in the CO$_2$ emission (Liu et al., 2020).

and Spain are 24, 48, 24, 5.48, 1.64 and 3.42, respectively. Estimated benefit for China, US and Brazil, Japan, Italy and Spain economies are 4.5, 16.23 and 0.621, 0.2361, 0.038, 0.079, respectively as shown in Table 2. Further, benefit for Japan Italy and Spain could also be estimated by multiplying reduction in the CO$_2$ emissions to the Social Cost of Carbon. Counties like Russia, UK and Germany have negative Social Cost of Carbon; it means these countries absorb more CO$_2$ than their emissions. The countries with positive Social Cost of Carbon would benefit the economy of the respective country in-case of per ton reduction in the CO$_2$ emissions. Countries like Pakistan contributes very little amount of CO$_2$ emissions to the atmosphere, but because of the huge CO$_2$ emissions of the surrounding countries like China and India.
Pakistan is among the top 5 counties to be adversely effected by the global warming. This implies that environment of a country or region can be affected by CO$_2$ emissions in the nearby countries. Therefore, CO$_2$ emission to the atmosphere is an international issue and every country of the world needs to contribute in the reduction of greenhouse gases. 

Fig. 4 shows the sector wise reduction in the CO$_2$ emissions globally as a consequence of the shutdown imposed during the first half year period of 2020. Power, Industry, Ground Transport, Domestic aviation and International aviation are the sectors taken into account. Among all the sectors, reduction in the CO$_2$ emission was higher in the International aviation sector. Globally reduction in the CO$_2$ emission due to power sector was 341.4 million tons. Social Cost of Carbon per ton increase is 418 US Dollars. Therefore, the global economy has been benefitted by 142.7 billion US Dollars by the Power sector. Similarly, global reduction in CO$_2$ emissions from Industry, Ground Transport and Aviation (Domestic and International) are 212.6, 613 and 200.8 million tons, respectively. Now, the global economic benefit obtained from reduction
Table 2
Global and country wise economic benefits obtained as a result of reduction in the CO$_2$ emissions.

| Region     | Economic benefit in Billions (US Dollars) |
|------------|------------------------------------------|
| Global     | 648                                      |
| India      | 17.65                                    |
| China      | 4.5                                      |
| US         | 16.23                                    |
| Brazil     | 0.621                                    |
| Japan      | 0.2361                                   |
| Italy      | 0.038                                    |
| Spain      | 0.079                                    |

Table 3
Global economic benefit obtained as result of reduction in the CO$_2$ emissions in various sectors.

| Sectors       | Global economic benefit in Billion (US Dollars) |
|---------------|-------------------------------------------------|
| Power         | 142.7                                           |
| Industry      | 88.9                                            |
| Ground Transport | 256.2                                         |
| Aviation      | 94                                             |

in the CO$_2$ emission from Industry, Ground Transport and Aviation respectively are 88.9, 256.2, 84 billion US dollars as provided in Table 3.

Conclusions

Since the 2nd World War, COVID-19 is the most serious challenge faced by the mankind. Nearly every country and every sector is adversely affected by the COVID-19 pandemic. To control the spread of the virus, a complete and a partial lock down was imposed in various regions of the world. Because of the lockdown human activities were minimal and therefore the emission of CO$_2$ gasses reduced considerably in different regions of the world. According to the literature the emitted CO$_2$ remains for many years in the atmosphere. Increase per ton in the CO$_2$ emission further complicate the situation and cause damages the economy of a country. The damage caused to the economy of a country by per ton increase in the CO$_2$ emission is referred as Social Cost of Carbon (SCC). Similarly, economic benefits are associated with per ton reduction in the CO$_2$ emissions. Economic benefit was estimated by coupling Social Cost of Carbon to the reduction in the CO$_2$ emission due to COVID-19 lockdown. The strick lockdown was followed in the first half of the 2020 therefore that period was taken into account. Due to COVID-19 pandemic, for the first half year of 2020, overall CO$_2$ emissions were reduced by 1551 million tons globally. Global economy was benefitted by 648 Billion US dollars for the specific time period (first half of 2020). Further, Estimated economic benefit for India, China, US and Brazil are 17.65 4.5, 16.23 and 0.621, billion US Dollars, respectively. Various sectors (Power, Industry, Ground Transport and Aviation) were also taken into account. The global economy was benefitted by 142.7, 86.9, 256.2, 84 billion US Dollars, respectively as result of reduction CO$_2$ emissions from Power, Industry, Ground Transport and Aviation.

Declaration of Competing Interest

None.

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