ASSESSING SPATIOTEMPORAL CO2 EMISSION DYNAMICS IN CHINA'S ROAD TRANSPORT SECTOR DURING THE PANDEMIC

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Overview

The outbreak of COVID-19 that commenced in late December 2019 has rapidly spread worldwide, becoming one of the worst disasters in human history. The pandemic poses a formidable threat to public health and has had a severe impact on both society and the economy. Since the lockdown imposed in Wuhan on January 23, 2020, the Chinese government has adopted strict measures to halt the spread of COVID-19, such as travel restrictions, closing public transport, school closures, quarantines, social distancing, and community containment. These measures have had a significant impact on the national economy and consequently on the transportation of goods and passengers. The changes in transport turnover have been accompanied by a lower consumption of fossil fuel. While the prevalence of COVID-19 has presented a serious challenge to China in terms of economic growth, it has had a strong and immediate impact on carbon dioxide (CO_2) emissions. The slowdown in manufacturing, construction, transportation, and overall economic activity has reduced China's greenhouse gas emissions temporarily. However, few studies have analyzed the transport-related CO_2 emission reductions associated with COVID-19. Thus, understanding the impact of COVID-19 on the CO_2 emission dynamics from the transport sector is an important task.

The main purpose of this study was to achieve a better understanding of how transport emissions changed at the provincial level during the COVID-19 pandemic in China. Specifically, this study addressed four key research questions. (1) How can the changes in CO_2 emissions from the road transport sector during the COVID-19 pandemic be estimated in China? (2) How did the COVID-19 crisis affect transport emissions? (3) What are the spatiotemporal characteristics of the changes in the transport emissions? (4) What policy implications can be drawn from the changing features of transport emissions? This study constructed a research framework that integrated transport and energy studies to provide information for future low-carbon transport planning and policymaking based on emission conditions during the COVID-19 pandemic.

Methods

Given the lack of real-time CO_2 emission data from the road transport sector, we developed an alternative approach to estimate provincial-level time-series emissions based on monthly transport demand data that included both passenger and freight transport demand in China's 31 provinces, as well as mode share, technology mix, energy intensity, and emission factor data obtained from an energy system model. The estimation of CO_2 emissions from the road transport sector can be represented as a function of passenger or freight transport demand, modal structure, technology share, energy intensity, and emission factors.

A spatial autocorrelation approach was then used to detect the spatial structure and spatial dependence of changes in CO_2 emissions from road transport. Moran's I is one of the most classical measures of spatial autocorrelation that was first proposed by Patrick Alfred Pierce Moran. When the global Moran's I has a positive value, the geographic feature is statistically autocorrelated and suitable for cluster analysis (hot spot and cold spot analyses). The hot spot analysis assesses whether high or low values cluster spatially. Here, the Getis-Ord Gi* statistic was used to detect the hot and cold spots of geographic features. Given a set of weighted data, the Getis-Ord Gi* statistic identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots).

The study area includes 31 provincial-level administrative regions in Mainland China but excludes Hong Kong Special Administrative Region, Macau Special Administrative Region, and Taiwan Province. The provincial-level divisions of China were grouped into seven regions: north, northeast, east, central, south, southwest, and northwest. The monthly transport demand data in China's 31 regions during the 24 months from January 2019 to December 2020 were obtained from the transport statistics released by the Ministry of Transport of the People's Republic of China. Mode shares, technology shares, energy intensities, and emission factors for the transport sector in 2019 and 2020 were obtained from a bottom–up energy system model developed for China's provincial transport sector.

Results

During the 24 months from January 2019 to December 2020, there were substantial changes in the CO_2 emissions from the road transport sector in China's 31 provincial-level regions. CO_2 emissions from passenger transport changed only slightly or remained almost constant in most provinces from January to December in 2019, but CO_2 emissions dropped sharply in February 2020 compared with January 2020. The substantial decreases in CO_2 emissions in February were consistent with the outbreak and spread of COVID-19, with Hubei being the most affected province in China and having the highest number of cases in February. Starting from March 2020, CO_2 emissions displayed fluctuant increases in all 31 provinces but did not return to the levels recorded in 2019. Overall, passenger transport emissions have been reduced substantially due to the COVID-19 pandemic and have not yet increased to the levels observed pre-COVID. Similar to the changing patterns of passenger transport emissions, significant decreases in CO_2 emissions from freight transport also occurred in February 2020. The CO_2 emissions displayed quick rebounding trends in all 31 provinces from March to December 2020. Beijing, Tianjin, Shanghai, and Jiangsu experienced substantial increases in CO_2 emissions, with much higher levels compared with those in January 2020 and earlier in 2019, which might be due to the effects of the drastic increase of online shopping accelerated to prevent COVID-19 in populated areas. Although provincial emissions from freight transport decreased significantly in February 2020, they later reverted to the pre-COVID level and even increased substantially in some developed regions such as Beijing, Tianjin, and Shanghai.

Regardless of whether COVID-19 influenced the transport emissions, the provinces located in northern and eastern China produced enormous emissions from road transport. In contrast, the CO_2 emissions in western and particularly northwestern provinces were relatively low. According to the emission reduction percentages for each province, Shanghai had the highest emission growth rate, with CO_2 emissions increasing by 78% in 2020, while the eastern coastal provinces experienced only moderate emission reductions. The most notable emission reductions occurred in northwestern and southwestern regions, indicating that transport-related CO_2 emissions were significantly influenced by the prevalence of COVID-19 in western China. Furthermore, the global Moran's I of annual emission reduction percentages for 2020 compared with 2019 were measured to examine the effect of the recent COVID-19 pandemic on spatial features. The Moran's I values during the four quarters were 0.2066, 0.2774, 0.2171, and 0.1970, respectively. This indicates that the emission changes during all four quarters also had a significant spatial autocorrelation, and the spatial autocorrelation was most pronounced during the second quarter and weakest during the fourth quarter. Because the global Moran's I had a positive value for the changes in CO_2 emissions during the whole year and each quarter, a spatial clustering effect on emission reductions was detected. The Getis-Ord-Gi* statistic for the whole year of 2020 shows that, the changes in emissions in 2020 presented a northeast–southwest pattern. Provinces in northern and eastern China were the hot spot of annual changes in CO_2 emissions, while the cold spot was located in the southwestern region, indicating that the most significant emission reductions were concentrated in developing regions.

Conclusions

Using provincial monthly transport demand data and a bottom–up approach to represent the technology mix over the period from January 2019 to December 2020, an analysis of transport-related CO_2 emission changes associated with the COVID-19 outbreak was conducted. The main outcomes of this study were (1) the quantification of CO_2 emissions from passenger and freight transport based on provincial monthly data from 2019 to 2020 and (2) a deeper understanding of the spatiotemporal dynamics of transport emissions across Chinese provinces during the COVID-19 pandemic. The national decrease in CO_2 emissions was clearly due to the impact of COVID-19 on China's provincial CO_2 emissions, and an understanding of how the situation has arisen will be useful for policymakers when proposing low-carbon transport development strategies in the post-pandemic era.

There are several implications of these findings. First, due to the increasing role of teleworking and online shopping, the future decrease in passenger transport will contribute to the reduction of CO_2 emissions from the transport sector. To ensure the decarbonization of the transport sector, more attention should be given to freight transport. Second, eastern developed regions should be the focus for reducing the CO_2 emissions because they experienced the lowest emission reductions during the COVID-19 pandemic. The deep decarbonization of the transport sector might require region-specific policies. Third, it is likely that the emission reductions generated by the pandemic will only be temporary and may lead to a quick rebound in the post-COVID-19 world, which would not assist with the transition towards a carbon neutral transport sector. To prevent further increases in CO_2 emissions and meet the carbon neutral target by 2060, revolutionary technological improvements in the transport sector and the adoption of renewable energy must be achieved.