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Impact of COVID-19 pandemic on energy consumption and carbon dioxide emissions in China’s transportation sector

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\begin{abstract}
The COVID-19 pandemic has put the whole world in a great lockdown and greatly changed our lives. The lockdown caused by the COVID-19 pandemic has greatly affected the transportation industry in China. In this paper, energy consumption and carbon dioxide emissions of fuel vehicles and battery electric vehicles in China during the COVID-19 pandemic was estimated and analyzed. The impact of COVID-19 pandemic was analyzed. The study period is taken from September 2019 to April 2020, and the period from September 2018 to August 2019 is taken for comparison. Moreover, energy consumption and CO\textsubscript{2} emissions of fuel vehicles during SARS epidemic was also analyzed. The related study period is taken from January 2003 to August 2003. The results show COVID-19 has a much larger impact on transportation energy consumption and CO\textsubscript{2} emissions than SARS. After the COVID-19 pandemic, energy conservation and emission reduction still have a long way to go. Determining the energy consumption and emissions in transportation sector during the COVID-19 pandemic will provide the government with a reference for future energy conservation and emission reduction in transportation sector and the further promotion of battery electric vehicles.
\end{abstract}

1. Introduction

Coronavirus Disease (COVID-19), which emerged in Wuhan, China in December 2019 \cite{1}, has been expanding since the beginning of 2020 and was declared a pandemic on March 11th, 2020 by World Health Organization (WHO). The COVID-19 pandemic has triggered an unprecedented global health and economic crisis which has changed our lives. It has put the whole world in a great lockdown. The COVID-19 pandemic and the lockdown it caused have had a more negative impact on economic activity in the first half of 2020 than anticipated. Global growth is projected at \(-4.9\%\) in 2020, 1.9\% points below the April 2020 World Economic Outlook (WEO) forecast. Its recovery is projected to be more gradual than previously forecast \cite{2}. The global economy is under pressure in ways not seen since the Great Depression in the 1930s.

As material basis, energy is very important for human survival and development. It is the indispensable force driving all economic activities. Continuous development of the world economy has driven the growth of energy consumption. The severe decline of the global economy caused by the COVID-19 pandemic will inevitably lead to a decline in energy consumption. Therefore, the energy sector is affected by the crisis caused by the COVID-19 pandemic. According to the IEA Oil Market Report (OMR)-April 2020 issued by...
International Energy Agency (IEA), activity in the transportation sector has fallen dramatically almost everywhere due to the confinement measures taken in 187 countries and territories. Global oil demand in 2020 will fall by 9.3 million barrels a day (mb/d) versus 2019, erasing almost a decade of growth [3]. Also due to city lockdown, the daily energy demand has a significant drop. Suehiro and Koyama, from The Institute of Energy Economics, Japan, estimated that the demand for oil, mainly for transportation in particular, would decrease by as much as 20% [4]. In addition to its impact on economic activity and energy consumption, COVID-19 pandemic has greatly contributed to the environmental improvement, especially in the countries and territories which have taken lockdown and confinement measures strictly [5]. Quéré et al. estimated daily global CO₂ emissions decreased by –17% by early April 2020 compared with the mean 2019 levels and emissions in individual countries decreased by –26% on average. They also thought the impact on 2020 annual emissions depends on the duration of the confinement, with a low estimate of –4% (–2 to –7%) if prepandemic conditions return by mid-June, and a high estimate of –7% (–3 to –13%) if some restrictions remain worldwide until the end of 2020 [6].

It has been mentioned that energy is the main driving force for the development of human society. To a certain extent, the history of human society development is a history of energy exploration and utilization. In turn, human behavior also greatly affects energy consumption. A number of major events in the history of mankind have caused earth-shaking changes in global energy landscape. The famous examples are two oil shocks during the last 30 years. The first occurred in 1973 following the Arab-Israel war. The second took place in 1979 following the Shah of Iran’s fall from power. As a major event in the history of mankind this year, the COVID-19 pandemic will also have a major impact on the world’s economic activity and energy consumption. Bahmanyar et al. compared the impact of different confinement measures adopted by European countries for responding to COVID-19 pandemic on their electricity consumption profiles. The results show that lockdown changed the consumption profiles which reflect the impacts of different measures to dealing with the pandemic on people’s activities [7]. Naderipour et al. studied the potential positive effects of COVID-19, including the reduction of greenhouse gases emission and pollutant gases and the increase of renewable energy generated by more sunlight reaching photovoltaic panels [8]. Aruga et al. investigated the impact of COVID-19 cases on Indian energy consumption. They found energy consumption started to recover with relaxed lockdown. However, such a positive impact was not apparent in the poorest regions [9].

COVID-19 emerged in Wuhan, China in December 2019 and Wuhan shut down all inbound and outbound transportation and went into lockdown at 10 a.m. on January 23rd, 2020, hoping to stop the new virus from spreading further across the nation. The lockdown was conducted one day before Chinese New Year’s Eve, a major travel day for people planning to return home for the holidays. This has greatly affected the transportation industry in China. At present, the global energy consumption of transport sectors is about one third of the total energy consumption of the world, such a proportion in China accounts for about 20% [10]. In the past few decades, fuel vehicles have been dominant in transportation energy consumption and emissions, but in recent years, with the gradual maturity of new energy vehicle technology and government financial subsidies, new energy vehicles on the road have gradually increased. Many countries and regions in the world have announced a timetable for the ban on the sale of fuel vehicles, and gradually promote new energy vehicles. Among the new energy vehicles, battery electric vehicles are very representative. Therefore, in this paper, energy consumption (EC) and carbon dioxide emissions (CDE) of fuel vehicles (FV) and Battery electric vehicles (BEV) in China during the COVID-19 pandemic are calculated and analyzed. The impact of COVID-19 pandemic on EC and CDE of FV and BEV in China are analyzed. Moreover, EC and CDE of FV in China during severe acute respiratory syndrome (SARS) epidemic in 2003 are also calculated and analyzed. On this basis, EC and CDE during COVID-19 and SARS epidemic are compared and analyzed.

2. Energy consumption and carbon dioxide emissions of fuel vehicles and battery electric vehicles in China during the COVID-19 pandemic

2.1. Energy consumption and carbon dioxide emissions of fuel vehicles

2.1.1. Calculation method

Bottom-up and top-down estimating are two of the most common estimation methods. Bottom-up estimates rely on aggregating all the individual costs of a project to build up to the total for the job. Top-down estimating begins with some form of overall result and applies it to a new set of tasks.

These two estimation methods were adopted by the Intergovernmental Panel on Climate Change (IPCC) and used in 2006 IPCC Guidelines for National Greenhouse Gas Inventories [11]. Bottom-up estimation method calculates the fuel consumption from the data of vehicle types, vehicle ownership, driving mileage, and fuel consumption per unit driving mileage, and then calculates CO₂ emissions. Top-down estimation method is to obtain the calculation result by multiplying the total fuel consumed by transportation by the CO₂ emissions coefficient. This method is based on the apparent energy consumption. Since there is no direct carbon emission detection data in China and the monopoly of refined oil production and supply in China is very high, most of the calculation research is based on the apparent energy consumption, that is, top-down estimation method which is used in our present study.

The monthly fuel consumption of fuel vehicles is obtained by multiplying the proportion of the annual fuel consumption of transportation sector in the total annual fuel consumption of the whole country by the apparent fuel consumption of each month. China consumed 124,1627 million tons of gasoline and 169,9654 million tons of diesel fuel in 2017, of which 56,9853 million tons of gasoline and 112,5369 million tons of diesel fuel were consumed by the transportation industry, which means that about 45.89% of gasoline and 66.21% of diesel fuel were consumed by the transportation sector [12]. The COVID-19 emerged in Wuhan, China in December 2019 and its development phase in China was from January to March 2020, after which China has basically entered a recovery phase in April 2020. Therefore, the study period in this paper is taken from September 2019 to April 2020, and the period from September 2018 to August 2019 is taken for comparison.
Carbon dioxide emissions coefficients and carbon emission factors of gasoline, diesel fuel, and standard coal are listed in Table 1. Based on the data listed in Table 1, the carbon dioxide emission of fuel vehicles can be calculated by

\[ EQ = \sum_a AC_a \cdot EF_a \]  

(1)

where, \( EQ \) is carbon dioxide emission in the unit of ten thousand ton; \( AC \) is apparent consumption of fuel in the unit of ten thousand ton; \( EF \) is \( CO_2 \) emissions coefficient in the unit of kg \( CO_2 \)/kg Fuel; \( a \) stands for fuel type.

### 2.2. Energy consumption and carbon dioxide emissions of battery electric vehicles

Nowadays, human beings have once again come to the crossroads of the transformation of transportation energy power system. The coming reform will replace oil and internal combustion engine with electric power and power battery (including fuel cell), which will bring human into the era of clean energy. Therefore, the impact of COVID-19 pandemic on energy consumption and \( CO_2 \) emissions of battery electric vehicles (BEV) is also studied in this paper. The mileage data needed for calculation comes from the National Big Data Alliance of New Energy Vehicles (NDANEV) [17]. The monthly energy consumption of BEV is obtained by multiplying the mileage data of BEV by its average power consumption. To facilitate comparison with fuel vehicles, the study period is also taken from September 2019 to April 2020, and the period from September 2018 to August 2019 is taken for comparison. Variation trend of these data can also be found in Fig. 1. It can be found that during the period from September 2018 to August 2019, the impact of the Spring Festival holiday (February 2019) is not very significant. It only shows a slightly lower trend in the first quarter of 2019, but there is still a smooth curve in the whole time period, with relatively stable data and no big fluctuation. Therefore, through comparison, COVID-19 can still be found to have a very significant impact on fuel consumption and \( CO_2 \) emissions of fuel vehicles.

### Table 1

| Fuel          | \( CO_2 \) emissions coefficient | Carbon emission factor |
|---------------|----------------------------------|-----------------------|
|               | kg \( CO_2 \)/liter Fuel | kg \( CO_2 \)/kg Fuel | kg Carbon/liter Fuel | kg Carbon/kg Fuel |
| Gasoline      | 2.30                             | 3.15                  | 0.627               | 0.86              |
| Diesel fuel   | 2.63                             | 3.06                  | 0.717               | 0.834             |
| Standard Coal | N/A                              | 2.493                 | N/A                 | 0.68              |
2.2.2. Results and discussion

Table 2 Monthly apparent consumption of gasoline and diesel fuel, gasoline and diesel fuel consumed by fuel vehicles, and CO$_2$ emissions from September 2018 to April 2020.

| Month       | Apparent consumption of gasoline/ten thousand ton \[13,14\] | Apparent consumption of diesel fuel/ten thousand ton \[15,16\] | Gasoline consumed by fuel vehicles/ten thousand ton | Diesel fuel consumed by fuel vehicles/ten thousand ton | CO$_2$ emissions/ten thousand ton |
|-------------|---------------------------------------------------------|----------------------------------------------------------|--------------------------------------------------|--------------------------------------------------|---------------------------------|
| 2018.09     | 1099.10                                                 | 1386.40                                                  | 504.38                                           | 917.94                                           | 4397.69                         |
| 2018.10     | 1190.80                                                 | 1359.00                                                  | 546.46                                           | 899.79                                           | 4474.71                         |
| 2018.11     | 1144.90                                                 | 1357.07                                                  | 525.39                                           | 898.52                                           | 4404.45                         |
| 2018.12     | 1060.90                                                 | 1325.48                                                  | 486.85                                           | 877.60                                           | 4219.03                         |
| 2019.01     | 1062.13                                                 | 1249.16                                                  | 487.41                                           | 827.07                                           | 4066.18                         |
| 2019.02     | 1110.57                                                 | 1204.24                                                  | 509.64                                           | 797.33                                           | 4045.19                         |
| 2019.03     | 1045.45                                                 | 1104.50                                                  | 479.76                                           | 731.29                                           | 3748.98                         |
| 2019.04     | 1041.20                                                 | 1084.70                                                  | 477.81                                           | 718.18                                           | 3702.72                         |
| 2019.05     | 1086.80                                                 | 1195.10                                                  | 498.73                                           | 791.28                                           | 3992.31                         |
| 2019.06     | 1021.07                                                 | 1290.10                                                  | 468.57                                           | 854.18                                           | 4089.79                         |
| 2019.07     | 987.13                                                  | 1295.80                                                  | 453.00                                           | 857.95                                           | 4052.28                         |
| 2019.08     | 1044.00                                                 | 1328.50                                                  | 479.10                                           | 879.60                                           | 4200.74                         |
| 2019.09     | 1033.25                                                 | 1309.00                                                  | 474.16                                           | 866.69                                           | 4154.68                         |
| 2019.10     | 1083.73                                                 | 1357.39                                                  | 497.32                                           | 898.73                                           | 4316.67                         |
| 2019.11     | 1005.44                                                 | 1226.40                                                  | 461.40                                           | 812.00                                           | 3938.13                         |
| 2019.12     | 1052.90                                                 | 1313.40                                                  | 483.18                                           | 869.60                                           | 4183.00                         |
| 2020.01     | 1165.57                                                 | 1347.23                                                  | 534.88                                           | 892.00                                           | 4414.40                         |
| 2020.02     | 617.87                                                  | 725.89                                                   | 283.54                                           | 480.61                                           | 2363.82                         |
| 2020.03     | 766.86                                                  | 957.20                                                   | 351.91                                           | 633.76                                           | 3047.82                         |
| 2020.04     | 818.64                                                  | 1099.00                                                  | 375.67                                           | 727.65                                           | 3409.97                         |

100 million km; W is average power consumption with the value of 14 million kWh/100 million km.

2.2.2. Results and discussion

Table 3 lists monthly running mileage, month-on-month growth in running mileage, year-on-year growth in running mileage, and energy consumption (CO$_2$ emissions) of BEV from September 2018 to April 2020. Variation trend of these data can be found in Fig. 2. From Table 3 and Fig. 2, it can be seen that before the outbreak of the COVID-19 (January 2020), the month-on-month increase in the running mileage of BEV nationwide in the period from September 2019 to December 2019 was in a stable state. This shows that the domestic traffic situation was stable before the outbreak of the COVID-19. In January 2020, the running mileage of BEV was 3.379 billion kilometers, with a month-on-month growth rate of $-17.89\%$. The growth rate turned from positive to negative, and energy consumption decreased accordingly, but the decline was not very severe. Spring Festival holiday and COVID-19 were the main reasons for the decline in growth. However, because the COVID-19 was in the early phase of outbreak and had no national impact, it had little impact on BEV mileage and CO$_2$ emissions. In February 2020, when the impact of the COVID-19 was at its peak in China, China implemented strict lockdown measures and traffic control. This led to the running mileage of BEV dropped sharply to 1.199 billion kilometers in February 2020, a sharp decrease of 64.52\% compared with January 2020 and a decrease of 13.30\% compared with February 2019. It was the first time to realize the “double drop” in the month-on-month and year-on-year basis. From Fig. 2, we can see that both mileage and energy consumption has reached the bottom, and the energy consumption has reached the lowest value of 167.86 million kWh. Thus, the impact of the COVID-19 pandemic on the BEV industry is very significant. In March 2020, COVID-19 pandemic in China was effectively controlled and the transportation system began to recover. Both the month-on-month growth rate and the year-on-year growth rate of BEV mileage “turned from negative to positive”. In particular, the month-on-month growth rate increased from $-64.52\%$ in February to 146.12\% in March. The year-on-year growth rate has also increased significantly. It can be seen that after the effectiveness of national control, BEV mileage immediately rebounded, driving the energy consumption to 413.4 million kWh. In April 2020, the pandemic has been effectively controlled nationwide and the transportation system has basically fully recovered. The mileage of BEV has returned to the level before the COVID-19 outbreak. It can be seen that the BEV mileage reached 3.882 billion kilometers, an increase of 31.55\% from the previous month and an increase of 71.24\% from the same period last year. Energy consumption has risen to 543.8 million kWh, which has reached the level before the COVID-19 outbreak.

For the same reason explained in subsection 2.1.2, the running mileage and energy consumption (CO$_2$ emissions) of BEV during the period from September 2018 to August 2019 is calculated for comparison. The results are also listed in Table 3 and the variation trend of these data can also be found in Fig. 2. From Table 3 and Fig. 2, it can be found that during the period from September 2018 to February 2019, the running mileage and energy consumption of BEV was low and stable. This was because the subsidy policy for new energy vehicles was not perfect, and the popularity of charging equipment was still low. New energy vehicles were still relatively new in the hearts of the Chinese public. People did not fully accept it, and fuel vehicles were still dominant. From Table 3 and Fig. 2, it can be found that during the period from March 2019 to August 2019, the running mileage and energy consumption of BEV have been rising. This was due to the implementation of domestic subsidies for new energy vehicles, which allowed car owners to get great discounts, resulting in a high sale of new energy vehicles (BEVs). However, from September 2019 to December 2019, we can see that the BEV mileage tends to have a small fluctuation. This is because the national subsidy policy has declined, which has led to a decrease in the sales of new energy vehicles (BEVs).
Fig. 1. Variation trend of apparent consumption of fuel, fuel consumed by fuel vehicles, and CO$_2$ emissions from September 2018 to April 2020.

Table 3
Running mileage, month-on-month growth in running mileage, year-on-year growth in running mileage, and energy consumption (CO$_2$ emissions) of BEV from September 2018 to April 2020.

| Month   | Running mileage/100 million km | Month-on-month growth in running mileage/% | Year-on-year growth in running mileage/% | Energy consumption (CO$_2$ emissions)/100 million kWh (100 million kg) |
|---------|-------------------------------|------------------------------------------|-----------------------------------------|---------------------------------------------------------------------|
| 2018.09 | 9.53                          | N/A                                      | N/A                                     | 1.3342                                                              |
| 2018.10 | 12.75                         | N/A                                      | N/A                                     | 1.785                                                               |
| 2018.11 | 14.52                         | N/A                                      | N/A                                     | 2.0328                                                              |
| 2018.12 | 14.71                         | N/A                                      | N/A                                     | 2.0594                                                              |
| 2019.01 | 14.96                         | N/A                                      | N/A                                     | 2.0944                                                              |
| 2019.02 | 13.83                         | N/A                                      | N/A                                     | 1.9362                                                              |
| 2019.03 | 23.37                         | N/A                                      | N/A                                     | 3.2718                                                              |
| 2019.04 | 22.67                         | N/A                                      | N/A                                     | 3.1738                                                              |
| 2019.05 | 27.00                         | N/A                                      | N/A                                     | 3.780                                                               |
| 2019.06 | 28.20                         | N/A                                      | N/A                                     | 3.948                                                               |
| 2019.07 | 30.90                         | N/A                                      | N/A                                     | 4.326                                                               |
| 2019.08 | 33.55                         | N/A                                      | N/A                                     | 4.697                                                               |
| 2019.09 | 34.47                         | 2.74                                     | 261.70                                  | 4.8258                                                              |
| 2019.10 | 38.22                         | 10.88                                    | 199.76                                  | 5.3508                                                              |
| 2019.11 | 38.23                         | 0.026                                    | 163.29                                  | 5.3522                                                              |
| 2019.12 | 41.15                         | 7.64                                     | 179.74                                  | 5.761                                                               |
| 2020.01 | 33.79                         | −17.89                                   | 125.87                                  | 4.7306                                                              |
| 2020.02 | 11.99                         | −64.52                                   | −13.30                                  | 1.6786                                                              |
| 2020.03 | 29.51                         | 146.12                                   | 26.25                                   | 4.1314                                                              |
| 2020.04 | 38.82                         | 31.55                                    | 71.24                                   | 5.4318                                                              |
In a short period of time after the outbreak of the COVID-19, traffic energy consumption and traffic emissions were greatly reduced. Under the situation that the COVID-19 pandemic has been controlled, the mileage of BEV has immediately rebounded in April, and can return to the level before the COVID-19 outbreak. This also shows that the impact of the COVID-19 on the new energy vehicle market is relatively small.

2.3. Comparative analysis of the impact of COVID-19 pandemic on fuel vehicles and battery electric vehicles

From the previous analysis, it can be found that when the COVID-19 pandemic reached the most serious phase in China (February 2020), energy consumption and CO₂ emissions of fuel vehicles and battery electric vehicles reached the lowest level. Later, the COVID-19 pandemic was effectively controlled in China, and energy consumption and CO₂ emissions of fuel vehicles have rebounded. However, it can be seen from the data that the energy consumption of fuel vehicles in April did not reach the level before the COVID-19 outbreak, while in April both mileage and energy consumption (CO₂ emissions) of new energy vehicles, which are represented by battery electric vehicles, have reached the state before the COVID-19 outbreak.

Regarding the difference in energy consumption and CO₂ emissions between fuel vehicles and battery electric vehicles after the COVID-19 pandemic, the authors believe that the causes are as follows.

The increase in energy consumption of vehicles is closely related to production and sales of vehicles. After all, only when the production and sales increase, will more energy consumption be generated. In terms of output, the COVID-19 pandemic has brought a huge impact to the entire automotive industry, especially in the supply of auto parts. Traditional fuel vehicles have nearly 30,000 parts. As long as one cannot be supplied on time and in quantity, the entire production line will be idled. During the pandemic period, there were thousands of parts manufacturers in Hubei Province alone. The shutdown of these parts factories had a great impact on the normal production order of automobile enterprises, and ultimately directly affected nearly 10% of the national automobile production scale.

For new energy vehicles, the situation will be much better. Electric motor controller, power battery, and vehicle controller of electric vehicles replace traditional engine and transmission system, which simplifies the vehicle design. The total number of parts of new energy vehicles (BEVs) is one-third less than that of fuel vehicles (about 20,000), which greatly simplifies the management of supply-chain of BEVs. Therefore, the final production and operation efficiency will be much higher than that of manufacturing fuel vehicles.

In terms of sales, during the COVID-19 pandemic, consumers reduced frequency of travel for safety reasons and avoided indoor activities, which caused a sharp decline in the consumption of durable goods such as automobiles. Although many dealers have launched online marketing activities, vehicle is different from general consumer goods. Consumers are relatively cautious when buying vehicles. Therefore, online marketing activities are not very attractive to new customers. After the COVID-19 pandemic, although consumers’ desire to buy will be released, many consumers’ previous purchase plans have been disrupted, and they may stay on the
sidelines again.

In order to promote automobile consumption, the executive meeting of the State Council decided to extend the new energy vehicle purchase subsidy and the exemption of vehicle purchase tax, which would expire at the end of the year 2020, for two years. Moreover, the central government will adopt the way of award instead of subsidy to support Beijing-Tianjin-Hebei and other key areas in phasing out diesel trucks with emission standards of National III and below [19]. The extension of the subsidy policy solved the urgent need for the new energy vehicle (BEV) market during the COVID-19 pandemic. The country’s active implementation of the new energy vehicle (BEV) policy is also to prepare for the replacement of fuel vehicles. The sudden outbreak of COVID-19 is an opportunity for the country to promote the replacement of fuel vehicles and promote new energy vehicles (BEVs).

Generally speaking, it is the market environment and national policies that will affect the energy consumption and CO2 emissions of vehicles. The current market environment is the market environment before and after the COVID-19 pandemic, and the policies are a series of national policies for automobile enterprises and consumers. These factors affect the energy consumption and CO2 emissions of vehicles from top to bottom.

2.4. Some thoughts on the impact of COVID-19 pandemic on emission of vehicles

Carbon Brief analysis suggested coronavirus temporarily reduced China’s CO2 emissions by a quarter [20]. Automobile is an important source of CO2 emissions. From previous calculation and analysis, it can be seen that the CO2 emissions of both fuel vehicles and battery electric vehicles (new energy vehicles) have dropped significantly during the COVID-19 pandemic. However, after the COVID-19 pandemic is gradually controlled, we can see that CO2 emissions have gradually increased. There is no doubt that the COVID-19 pandemic can reduce pollutant emissions and improve our environment, but what we have to consider is the incentive measures to be taken by the Chinese government to improve the economy impacted by the COVID-19 pandemic after it completely disappears, thereby causing pollution emissions exceed those before the outbreak. Therefore, the short-term emission decline is not normal. After the COVID-19 pandemic, energy conservation and emission reduction still have a long way to go. Determining the energy consumption and emissions in transportation sector during the COVID-19 pandemic will provide the government with a reference for future energy conservation and emission reduction in transportation sector and the further promotion of battery electric vehicles. The two-year extension of the subsidy policy for new energy vehicles also contributes to emission reduction and environmental protection.

3. Analysis of energy consumption and CO2 emissions of fuel vehicles during severe acute respiratory syndrome (SARS) epidemic

In the first half of 2003, the SARS virus, which has an extremely strong infectious capacity like the COVID-19 virus, spread in China. On January 2nd, 2003, an atypical pneumonia case was reported by Heyuan City. By June 15th, 2003, the confirmed cases and suspected cases in mainland China had been cleared. On June 24th, 2003, World Health Organization (WHO) removed its last remaining SARS travel warning for Beijing. The SARS epidemic in Mainland China has basically ended.

According to the statistical yearbook of 2003, China consumed 35.9775 million tons of gasoline and 71.0841 million tons of diesel fuel in 2003, of which 14.1937 million tons of gasoline and 26.7101 million tons of diesel fuel were consumed by the transportation industry, which means that about 39.45% of gasoline and 37.58% of diesel fuel were consumed by the transportation sector [21]. Similar to the estimation and analysis on the fuel vehicles during the COVID-19 pandemic, top-down estimation method is used to estimate the energy consumption and CO2 emissions during SARS epidemic.

According to the timeline of SARS epidemic mentioned above, the estimation period is taken from January 2003 to August 2003. Carbon dioxide emissions coefficients listed in Table 1 are also used in this estimation.

Table 4 lists monthly apparent consumption of gasoline and diesel fuel, gasoline and diesel fuel consumed by fuel vehicles, and CO2 emissions during SARS epidemic. Variation trend of these data can be found in Fig. 3.

On April 16, 2003, the World Health Organization officially named SARS virus in Geneva. Then, SARS was listed as a legal infectious disease in China on April 20, 2003. Since the end of April, the number of confirmed cases has increased rapidly, and the negative impact of SARS on the transportation industry has been gradually reflected. The passenger flow of all modes of transportation

| Month | Apparent consumption of gasoline/ten thousand ton | Apparent consumption of diesel fuel/ten thousand ton | Gasoline consumed by fuel vehicles/ten thousand ton | Diesel fuel consumed by fuel vehicles/ten thousand ton | CO2 emissions/ten thousand ton |
|-------|--------------------------------|----------------|--------------------------------|----------------|----------------|
| 2003.01 | 363.92 | 650.65 | 143.57 | 244.51 | 1200.45 |
| 2003.02 | 281.16 | 626.86 | 110.92 | 235.57 | 1070.25 |
| 2003.03 | 334.28 | 692.65 | 131.87 | 260.30 | 1211.91 |
| 2003.04 | 338.43 | 698.65 | 133.51 | 262.55 | 1223.97 |
| 2003.05 | 304.90 | 649.84 | 120.28 | 244.21 | 1126.17 |
| 2003.06 | 285.86 | 674.69 | 112.77 | 253.55 | 1131.09 |
| 2003.07 | 321.94 | 717.91 | 127.01 | 269.79 | 1225.63 |
| 2003.08 | 338.94 | 734.69 | 133.71 | 276.10 | 1266.05 |
was significantly impacted in May. However, the time span from the spread of the impact of the epidemic to the control of the epidemic was very short, and the impact of the SARS epidemic was basically over in July. Therefore, we can see that the energy consumption and CO$_2$ emissions of fuel vehicles in May showed a low point. After the epidemic was under control in June and World Health Organization (WHO) removed its last remaining SARS travel warning for Beijing, it can be seen that the energy consumption of fuel vehicles has returned to the previous level. In Fig. 3, we can see that there was also a trough in February 2003. This is due to the war threat of the United States and the United Kingdom against Iraq, which led to the rise of international oil prices, so the level of national consumption decreased.

From the data, we can see that the SARS epidemic does not seem to have a great impact on the energy consumption of domestic vehicles. This is because SARS was still in the spreading period from January to March 2003. At that time, the domestic awareness of the SARS virus was limited and domestic information communication was not as good as it is now. Therefore, energy consumption has not changed much at that time. However, the number of confirmed cases rose rapidly after April. China began to take emergency measures nationwide and implemented certain traffic control measures. Therefore, there was a decrease in energy consumption in May, but the epidemic was not as severe as we thought. After the epidemic was under control, energy consumption immediately returned to the previous level, and there was no chain effect after the epidemic.

4. Comparison of the impact of COVID-19 pandemic and SARS epidemic on energy consumption and CO$_2$ emissions in transportation sector

COVID-19 pandemic has the most serious impact on traffic energy consumption in February, just after the Spring Festival. During this period, the epidemic was most serious, and severe traffic control was implemented nationwide. Correspondingly, the most serious impact of SARS on traffic energy consumption was in May 2003, because at that time, the SARS epidemic also reached a relatively serious phase. Comparing the data of the most severe period and the time period after the two epidemics, we can find in February 2020, the month-on-month increase of gasoline and diesel consumption of fuel vehicles are $-46.99\%$ and $-46.12\%$ respectively, and the month-on-month increase of CO$_2$ emission is $-46.45\%$. The values of the above three corresponding data in May 2003 were $-9.98\%$, $-7.00\%$, and $-8.02\%$. Through comparison, we found that COVID-19 has a much larger impact on transportation energy consumption and CO$_2$ emissions than SARS. If we compare the data for the month after the most severe period of the epidemic, we can find that in March 2020, the month-on-month increase of gasoline and diesel consumption of fuel vehicles are 24.11% and 31.87% respectively, and the month-on-month increase of CO$_2$ emission is 28.94%. The values of the above three corresponding data in June 2003 were $-6.42\%$, $3.82\%$, and $0.38\%$. Regarding the month-on-month increase, whether the decline caused by the epidemic or the recovery after the epidemic is controlled, the variation in COVID-19 pandemic is greater than that during the SARS period. Moreover, we can see

![Fig. 3. Variation trend of apparent consumption of fuel, fuel consumed by fuel vehicles, and CO$_2$ emissions during SARS epidemic (2003.01–2003.08).](image-url)
that during the SARS period, its impact on the data was not great, and the number of data growth and decrease was particularly small. Regarding the different impact of the COVID-19 pandemic and SARS epidemic on the energy consumption and CO₂ emissions, the authors believe that the causes are as follows.

Firstly, in 2003, China’s car ownership was 24 million, while in 2019, China’s car ownership has reached 260 million [26]. The huge gap in the base number will inevitably cause a gap in energy consumption. Secondly, in 2003, in an era when the awareness of the virus was not particularly clear and the communication information was underdeveloped, the people’s ability to obtain information was far less than today. Lockdown measures and traffic control implemented at that time were not as strict as they are now. Therefore, there was not much reduction in traffic energy consumption.

Lastly, the outbreak of the COVID-19 coincided with the arrival of the Spring Festival. Due to the impact of the Spring Festival holiday and the early phase of the COVID-19 pandemic, the domestic travel rate has decreased. Therefore, energy consumption and CO₂ emissions of transportation sector have dropped significantly. After the Spring Festival, the government implemented traffic control across the country, and people learned about the severity of the COVID-19 pandemic, so energy consumption and CO₂ emissions reached a bottom in February. However, with the improvement of epidemic prevention and control, traffic control in many areas has been lifted. The epidemic will not cause the return demand to disappear, and delays in resuming work in various places will only cause the return demand to be delayed. When the epidemic situation is gradually controlled and subsided, the rigid demand for the return journey of spring transportation will lead to a strong rebound in passenger flow. From the substantial growth of the month-on-month increase in March, we can see that the Spring Festival transportation has a great influence. In 2003, the most severe impact of the epidemic on travel was in May, which was the traditional off-season for travel during the year. The suppressed demand is mainly daily optional travel demand, so the range of subsequent retaliatory return is not very significant from the data observation.

5. Conclusion

Coronavirus Disease (COVID-19), which emerged in Wuhan, China in December 2019. It has put the whole world in a great lockdown and greatly changed our lives. The lockdown caused by the COVID-19 pandemic has greatly affected the transportation industry in China. Therefore, energy consumption and carbon dioxide emissions of fuel vehicles and battery electric vehicles in China during the COVID-19 pandemic was estimated and analyzed by top-down estimation method.

The results show that when the COVID-19 pandemic reached the most serious phase in China (February 2020), energy consumption and CO₂ emissions of fuel vehicles and battery electric vehicles reached the lowest level. Later, the COVID-19 pandemic was effectively controlled in China, and energy consumption and CO₂ emissions of fuel vehicles have rebounded. However, it can be seen from the data that the energy consumption of fuel vehicles in April did not reach the level before the COVID-19 outbreak, while in April both mileage and energy consumption (CO₂ emissions) of new energy vehicles, which are represented by battery electric vehicles, have reached the state before the COVID-19 outbreak. After the COVID-19 pandemic, energy conservation and emission reduction still have a long way to go. Determining the energy consumption and emissions in transportation sector during the COVID-19 pandemic will provide the government with a reference for future energy conservation and emission reduction in transportation sector and the further promotion of battery electric vehicles. The two-year extension of the subsidy policy for new energy vehicles also contributes to emission reduction and environmental protection.

Analysis of energy consumption and CO₂ emissions of fuel vehicles during SARS epidemic show that it does not seem to have a great impact on the energy consumption of domestic vehicles. Through comparison, we found that COVID-19 has a much larger impact on transportation energy consumption and CO₂ emissions than SARS. Future researches may focus on the energy consumption and carbon dioxide emissions in China’s transportation sector in the post-pandemic period and their relations with the related policy.

Author contributions

Xinxin Zhang: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Writing - original draft, Writing - review & editing. Zhenlei Li: Data curation, Formal analysis, Writing - original draft. Jingfu Wang: Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

This research was supported by Beijing Natural Science Foundation (3192007). The authors gratefully acknowledge them for financial support of this work.

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