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The economic impacts of traffic consumption during the COVID-19 pandemic in China: A CGE analysis

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ABSTRACT

The transportation sector has played an important role during the COVID-19 pandemic. Like many industries, it experienced a sharp decline during the pandemic. The reduced traffic consumption has been caused by objective conditions, such as traffic control measures, and subjective factors, such as the perception of the COVID-19 pandemic. This study uses the computable general equilibrium (CGE) model to examine the economic impacts of traffic consumption during the COVID-19 pandemic in China. Moreover, to evaluate the impact of the government’s economic stimulus policy related to transportation, this study examines the policy effects of transportation investment. This study suggests that, first, China’s macroeconomy has been severely affected by reduced traffic consumption. The period when the pandemic was most severe had the largest GDP decrease (0.49%). Second, transportation consumption is closely associated with the output of all industries. As the pandemic worsens, the output of all sectors declines more. Of the transport sectors, road transport has the largest output decrease (10.17%), followed by railway (1.76%) and air sectors (1.53%). The service industry is the most negatively affected among the non-transportation sectors. Finally, transportation infrastructure investment can effectively promote the economy and create jobs. In addition, railway investment plays a more positive role in the economy than road and air transports. The findings provide a detailed understanding of the economic impact of the significantly reduced traffic consumption at different stages of the pandemic.

1. Introduction

The outbreak of coronavirus disease 2019 (COVID-19) has resulted in an ongoing pandemic. As of June 18, 2021, there have been 177,439,911 confirmed cases of COVID-19 and 3,842,43 deaths (Johns Hopkins University & Medicine, 2021). Each country has taken many measures to prevent the spread of COVID-19, particularly travel-related control measures. According to a survey by the World Conference on Transport Research Society (WCTRS) COVID-19 Task Force, nearly 70% of cities/towns experienced or were still experiencing lockdown (Zhang et al., 2021). This means that people in different countries are on some form of a coronavirus lockdown. In China, since the outbreak of COVID-19, many provinces, autonomous regions, and municipalities have adopted a series of control measures dependent on the actual situation of the local pandemic.

However, the outbreak of COVID-19 coincided with the Chinese Spring Festival holiday. The large-scale population movement before the Spring Festival aggravated the spread of the virus, which brought huge challenges to the prevention and control of the pandemic. The Ministry of Transport, the National Health Commission, the National Railway Administration, and the Civil Aviation Administration of China have issued relevant documents to fight against the COVID-19 pandemic. Many regions took traffic control measures to curb the spread of COVID-19, including closing off external passageways and suspending public transport and nonessential travel (Tan et al., 2021). These control measures were implemented to reduce the spread of the virus and also brought a huge negative impact to the transportation sector.

Some studies have examined the effectiveness of travel control measures in curbing the spread of COVID-19 (Zhao et al., 2021). Lai et al. (2020) developed susceptible–exposed–infectious–removed (SEIR) model to assess the effectiveness of different interventions across China and found that non-pharmaceutical interventions had greatly reduced the transmission of virus. Kraemer et al. (2020) and Aleta et al. (2020) used human movement data to verify the effectiveness of travel control measures in Wuhan. Their findings showed that control measures have time limits—that in the early stages of the COVID-19 outbreak, the implementation of travel restrictions is very effective. The lockdown of Wuhan and strict travel restrictions in other cities substantially reduced...
Numerous studies have analyzed the impacts of COVID-19 on transport sectors. The transport sectors play a dual role during the pandemic (Rothengatter et al., 2021). Transportation sectors have a significant influence on people’s lives and economic activities. With the development of the high-speed railway (HSR) network, the accessibility between regions has changed, and connectivity between regions has become closer (Liu et al., 2018). While improved transportation infrastructure has brought convenience, it has also contributed to the spread of the virus. Zhang et al. (2020) suggested that frequencies of air transport and HSR are closely linked to the speed of COVID-19 transmission and the number of cases. Gaskin et al. (2021) found that the risk of infection is significant for persons who live near transportation hubs. The COVID-19 pandemic significantly affects the transportation sector (Cui et al., 2021) described the mechanisms of the impact of COVID-19 on the transportation sector in China. On the one hand, the pandemic has increased the costs of protection in the transport sector and reduced production efficiency. On the other hand, the pandemic has not only reduced the demand for household travel, but also the demand for transportation of the production sector has dropped significantly. Hu et al. (2021) examined the impact of the pandemic on transit ridership. The findings showed that the COVID-19 caused an average of 72% drop in transit ridership in Chicago. Moreover, during the pandemic, the cost of time is reduced for car and public transport commuters, resulting from a reduction in car and public transport commuting activities (Hensher et al., 2021).

Previous studies have more results on the macroeconomic impacts of COVID-19 and the impacts of COVID-19 on the transportation sector. Hence, we examined the impact of the pandemic on consumer expenditure and the HSR network. HSR has had a significant impact on China’s development and the spread of the virus. Zhang et al. (2020) suggested that frequencies of air transport and HSR are closely linked to the speed of COVID-19 transmission. The pandemic has increased the costs of protection in the transport sector and reduced production efficiency. The findings showed that the COVID-19 caused an average of 72% drop in transit ridership in Chicago. Moreover, during the pandemic, the cost of time is reduced for car and public transport commuters, resulting from a reduction in car and public transport commuting activities (Hensher et al., 2021).

The COVID-19 pandemic significantly affects the transportation sector (Cui et al., 2021; Rothergatter et al., 2021; Oum et al., 2020). However, they seldom studied the economic impacts of traffic demand during the COVID-19 pandemic. When they studied the impact mechanism, they mixed traffic factors with other economic factors to describe the impact of the entire pandemic situation on the economy, rather than specifically describing how transportation consumption has affected the economy during the pandemic. The purpose of this study is to assess the economic impact of traffic consumption.

The main contributions of this study are as follows:

First, this study uses a static CGE model to study the impacts of the decline in transportation consumption on the economy, including the impact of the macroeconomy and the output of all industries. Second, based on the COVID-19 pandemic situations, we set five phases to simulate the impact of traffic consumption. In addition, this study simulates the economic impact of investment in the transportation sector. Finally, we summarize the corresponding policies based on the research results.

The remainder of this study is organized as follows: Section 2.1 shows the five phases of the COVID-19 pandemic. Section 2.2 summarizes the consumption in the railway, road, and aviation sectors during the pandemic. Section 3 and Section 4 introduce the CGE model and simulation scenarios, respectively. Section 5 discusses the simulation results. Section 6 shows the conclusions and policy recommendations.

2. COVID-19 and traffic consumption in China

This section summarizes the situation of the COVID-19 pandemic and some important time points in China. We then analyze the traffic consumption during the COVID-19 pandemic. In this study, traffic consumption refers to passenger transportation consumption, including railway, road, aviation passengers, and other transportation.

2.1. The COVID-19 pandemic in China

Our study period is from January to October 2020.

Phase 1: Outbreak of COVID-19 (January).

There were 44 cases of unknown cause of pneumonia in Wuhan on January 3, 2020. The National Health Commission (NHC) evaluation team initially considered the pathogen a new coronavirus. The national Spring Festival travel began on January 10, 2020, with travel levels spiking before the festival began. Public transport in the city of Wuhan was suspended temporarily on January 23, 2020. The outbound routes from Wuhan were closed, including flights and trains. The NHC issued a Notice and asked local governments and transport agencies to pay great attention to the transmission of the virus through transport.

Phase 2: Rapid responses to COVID-19 (February).

The number of confirmed cases of COVID-19 nationwide increased rapidly during this period. The number of daily confirmed new cases peaked at 15,152 on February 12, 2020. Hubei Province was the most serious area of the pandemic. The travel-related control measures were strictly implemented in most regions. The Spring Festival holiday was extended to February 2, 2020. The confirmed cases of COVID-19 dropped for the first time on February 19, 2020.

Phase 3: Preliminary containment of the spread of COVID-19 (March).

The outbreak of COVID-19 was under control, and the number of existing cases across China gradually decreased. The new confirmed cases of COVID-19 dropped to a single level in China on March 11, 2020. The NHC stated that the peak of the pandemic had passed in China on March 12, 2020. Other areas in Hubei lifted outbound traffic restrictions on March 25, 2020, with the exception of Wuhan. The traffic restrictions were gradually lifted in most regions.

Phase 4: Positive trend in COVID-19 pandemic prevention and control (April).

The spread of the pandemic in China, with Wuhan as the main battlefield, was curbed, and major strategic results had been achieved in the prevention and control of the national pandemic. On April 5, 2020, Wuhan lifted outbound traffic restrictions after 76 days of lockdown to contain the spread of the virus.

Phase 5: Regular COVID-19 pandemic prevention and control (From May to October).

In May, the situation of the pandemic was improved. The control measures also played an effective role during the May Day holiday. As China gradually loosened control measures, life returned close to normal, and people began to travel again. All regions across China gradually promoted the resumption of work and production and restored normal economic and social order.

2.2. Traffic consumption during the COVID-19 pandemic in China

During the COVID-19 pandemic, a series of control measures have been implemented to contain the spread of the virus. The measures include early identification and isolation of confirmed COVID-19 patients and suspected cases, travel restrictions, social distancing measures, cancelation of large event gatherings, and extension of school holidays. The transport sector was significantly affected during the COVID-19 pandemic in 2020. Fig. 1 shows the changes in passenger volume for different transportation modes in different phases of the pandemic.

During the pandemic, people would reduce their consumption, particularly those spent on the transport sector. In the first three quarters of 2020, the national per capita consumption expenditure of residents was 14,923 yuan, falling by 3.5%. Per capita consumption expenditure on transportation and communication was 1955 yuan, falling by 5.9% and accounting for 13.1% of the per capita consumption expenditure.

This reduced demand for transport is caused by both objective conditions and people’s subjective psychological perceptions of the pandemic.
The individual’s understanding, concern, and anxiety about the pandemic affect the choice behavior. People believe that there is a high risk of infection while traveling, and they prefer to stay at home as much as possible. Commuters who believe that public transportation is a high-risk mode of travel for being infected are less likely to travel by public transportation during the pandemic (Tan et al., 2021). In addition, the pandemic may change the consumption habits of some people, who are more cautious about future expectations and may tend to consume rationally and increase savings to prevent risks and accidents.

In terms of objective conditions, traffic control measures play a key role in the battle against the COVID-19. This study summarizes the control measures for several major public-transport sectors. With regard to road transport, based on the “Guidelines on Region-Specific, Multi-Level Approach to Prevention and Control of COVID-19 Pandemic in Passenger Stations and Transport Vehicles” issued by the Ministry of Transport, cities across the country were classified into high-risk, medium-risk, and low-risk areas according to the pandemic seriousness. In high-risk areas, strict passenger load factor limits were imposed on the public transport systems.

Railway departments took many measures to minimize the movement of people and prevent the risk of spreading COVID-19 through railway transport. First, based on the severity of the pandemic, some routes were temporarily suspended, which had a great impact on the passenger flow of the railway. In particular, the original railway operation plan for the Spring Festival travel rush was changed: the number of trains was reduced and the operation of some trains was halted. Wuhan not only stopped the operation at all stations from January 24, 2020, but the suspension had also been extended to the entire Hubei Province on January 25, 2020. Second, when the pandemic was most serious, the railway departments greatly relaxed the refund restrictions for tickets that were previously purchased. From January 21, 2020, refunds of tickets purchased for departure or arrival in Wuhan were free of charge. Later, this policy was applicable nationwide. According to the National Railway Administration, a total of 118 million tickets were refunded free of charge in railway departments across the country from January 21, 2020 to February 18, 2020. Additionally, the railway departments actively cooperated with the implementation of pandemic prevention measures in various regions.

Demand for air transport dropped similarly to the railway sector, and some domestic and international flights had to be cancelled. In the early period of the pandemic, the airline industry had adopted a “free ticket refund” initiative nationwide to reduce the movement of people. With the resumption of work, the passenger volume on domestic flights gradually resumed. However, because of the ongoing pandemic abroad and the implementation of the “Five Ones” policy by the Civil Aviation Administration at the end of March 2020—that is, one airline, one country, one airline, and one international flight every week—the normal operation of international flights has not been completely resumed.

3. Methodology

The CGE model provides a holistic and flexible framework, and it estimates the economic effects of the disaster on nearly any economic indicators, such as GDP, consumption, investment, exports, and the regional distribution of wages and population (Okuyama, 2007). The first CGE model (Johansen, 1960) incorporated the production and demand functions of enterprises and households, and achieved equilibrium through macroeconomic accounting equations.

In recent years, some scholars have applied the CGE model to examine various transport issues to achieve a comprehensive assessment. These studies relating to CGE modeling of transport are broad and the approach covers urban, regional, and spatial CGE models (Anas et al., 1996; Kim et al., 2004, 2017; Nitzsche et al., 2013; Shahrorki Shahraki et al., 2018). With the increasing application of CGE in traffic evaluation, some scholars also use the CGE model to study the economic consequences of traffic facility system failures caused by disasters. For instance, the CGE model was used to quantify the chain effect of traffic disruption caused by severe ice storms in Hunan Province in 2008 (Xie et al., 2013). Many studies have applied the CGE model to examine the economic loss from terrorist attacks on a U.S. airport and a domestic airliner (Rose et al., 2017), the 2005 London subway, and bus bombings (Cox et al., 2011). These studies are measured from the perspective of a single mode of transportation, and they lack comparisons within the entire transportation system.

In this study, we use a standard static CGE model based on the approaches of Loftgren et al. (2002) and Horridge et al. (2011). The model includes the following sections: production, international trade, households, enterprises, government, market closures, and clearing conditions. In our CGE model, it is hypothesized that the set of all production sectors in a region is A. The set of all commodity sectors is C, and the active sector creates only one commodity. The model uses neoclassical closure conditions, assuming that the supply of capital and labor is equal to their respective demand. The production activity in this study is a two-level nested production function, which covers the CES and the Leontief production functions. Producers use first-order optimization conditions to maximize profits or minimize costs. The production
function of value-added input is the CES function, which involves two production factors: labor and capital.

\[ Q_A = \alpha QVA + (1 - \alpha) QINTA^{1/\rho} \]  

(1)

\[ QINT = \mathcal{Q}c_{a}QNTA_{a} \]  

(2)

\[ QINTA_{a} = \sum ic_{a}P_{A}Q_{A} \]  

(3)

where:

- \( Q_{A} \): Domestic production by activity \( a \);
- \( QVA_{a} \): Value-added by activity \( a \);
- \( QINTA_{a} \): Intermediate inputs by activity \( a \);
- \( a_{f} \): Total-factor productivity for CES production functions;
- \( \delta_{a} \): Share parameters for CES production functions for value-added;
- \( 1 - \delta_{a} \): Share parameters for intermediate inputs by activity \( a \);
- \( \rho_{a} \): Elasticity parameter for value-added and intermediate inputs by activity \( a \);
- \( P_{A}Q_{A} \): Price of intermediate inputs;
- \( ic_{a}P_{A} \): Input-output coefficient of intermediate inputs.

In the open-economy CGE model, commodities comprise three segments: (1) the domestic sales part of domestic production, (2) the export sales of the domestic output, and (3) the imported goods sold on the local market. The output goods of domestic production activities include both domestic sales and exports, and the CET function represents the substitution relationship. The production price of the production activity sector is a weighted average of domestic and export prices, where international market prices and exchange rates impact the prices of export commodities.

\[ Q_A = \alpha QVA_{a}^{\delta_{a}} + (1 - \delta_{a}) QINTA_{a}^{1/\rho_{a}} \]  

(4)

where:

- \( QDA_{a} \): Domestic sales of domestically made products by activity \( a \);
- \( QE_{a} \): Export of domestically made products by activity \( a \);
- \( \rho_{a} \): Elasticity of substitution for commodities sold domestically and the export of domestically made products.

The price of export commodities is affected by the price of the international market and the exchange rate.

\[ PE = pwe_{c}(1 - t_{e})EXR \]  

(5)

where:

- \( pwe_{c} \): F.O.B. price of goods in dollars;
- \( t_{e} \): Export tax rate;
- \( EXR \): Exchange rate.

The commodities are available in the domestic market, which involves domestically produced and imported products. The need for these commodities includes the final requirements of numerous main bodies, such as customers, enterprises, and governments, and the demand for intermediate inputs to production activities. The Armington function defines the substitution relationship between goods supplied by domestic production and imports (Armington, 1969).

\[ QQ = \alpha^{\delta_{c}} QDC_{c}^{\delta_{c}} + (1 - \delta_{c}) QMK_{c}^{1/\rho_{c}} \]  

(6)

where:

- \( QQ \): Supply of commodity \( c \) on the domestic market;
- \( QDC_{c} \): Domestic sales of commodity \( c \) domestically made;
- \( QMK_{c} \): Imports of commodity \( c \);
- \( \rho_{c} \): Elasticity of substitution for commodity sold domestically and imported goods;

The income of residents is derived from labor remuneration and capital income to provide production factors to enterprises, and transfer payments reached from the government. Meanwhile, the revenue and expenditure of residents involve the payment of income tax, consumption, and savings. After deducting taxable disposable income from household income and the removal of savings, it is adopted to purchase commodities and services according to residents’ preferences. The Cobb–Douglas utility function represents consumer preferences here. Accordingly, the behavior of residents seeking to maximize utility under budget constraints is expressed in a functional form. This explains the process by which residents’ total income from factor endowments and government transfers is transformed into the need for commodities by residents; the income and expenditure of residents are balanced.

\[ YH = WL - QLS + WK - shfh_{a} - QKS + transf_{gov} \]  

(7)

\[ P_{c}QH_{c} = shfh_{a} - mpc_{c} (1 - t_{c}) YH \]  

(8)

where:

- \( YH_{c} \): Household income;
- \( WL \): Price of labor;
- \( WK \): Price of capital;
- \( QLS \): Supply of labor;
- \( QKS \): Supply of capital;
- \( shfh_{a} \): Share of household capital income in total capital income;
- \( transf_{gov} \): Transfer payments of government to households;
- \( Q KS_{a} \): Household demand of commodity \( c \);
- \( mpc_{c} \): Marginal propensity to consume of households;
- \( t_{c} \): Household income tax rate;
- \( shfh_{a} \): Share of commodity consumption expenditure in household income.

The pre-tax income of an enterprise involves income from capital inputs and the transfer payments of the government to the enterprise. In addition, the enterprise demand for goods involves intermediate input demand and investment and is considered to be given by exogenous variables. The savings of enterprises is the difference between the income and income tax of the enterprises and is not decreased by the enterprise’s investments. Therefore, in most social accounting matrices, investment is not in the corporate account but is seen as the formation of fixed capital for the entire economy and the fixed investment needs of the entire society.

\[ YENT = shfh_{ent} \cdot WK \cdot QKS + transf_{ent} \]  

(9)

\[ EINV = \sum_{c} PQ_{c} \cdot QINV_{c} \]  

(10)

where:

- \( YENT \): Capital income of enterprise;
- \( shfh_{ent} \): Share of enterprise capital income in total capital income;
- \( transf_{ent} \): Transfer payments of government to the enterprise.

The government is in control of consumption, tax, transfer payments, and savings for residents. Thus, the government obtains revenue by levy income taxes, value-added factor taxes, production taxes on residents and businesses, and import duties.

\[ YG = tvat \cdot \sum \left( WL \cdot QLD_{a} + WK \cdot QKD_{a} + t_{c} \cdot YH \right) \]
\[ h_{it} = \sum_{m} (p_{wm} \cdot Q_{M} \cdot EXR) \]  

where:

\( YG \): Government revenue.

4. Data

4.1. Data sources

The social accounting matrix (SAM) table is the main database used in the CGE model. In this study, the SAM table is mainly based on the “China Input and Output Table (2017)” and the “China Statistical Yearbook (2017)”. The original input-output table is the basic flow table of 149 sectors. In the CGE model of this study, the 149 sectors are aggregated into 9 sectors, including 6 non-transportation sectors and 3 transportation sectors. Table 1 shows the specific sector classification.

In this study, the CGE model requires exogenously given elastic coefficients including the production, CET, and Armington condition functions. The elasticity of substitution in the CGE model was obtained from the relevant literature (Zhang, 2011; Zhou et al., 2018). Other parameters, such as the input-output coefficient and share parameters for these functions, need to be estimated and calibrated using the SAM table.

4.2. Simulated scenarios

At different stages of the spread of COVID-19, the impact of the pandemic on public transportation is also different (Gkiotsalitis et al., 2020). According to the five phases of the spread of COVID-19, this study sets five traffic consumption scenarios for simulation.

The shocks of traffic consumption include the changes in demand for passenger transportation and the households’ consumption of the transport sectors. The households’ demand for passenger transportation is quantified using the passenger volume of the transportation sector. The households’ consumption of the transportation sector is the consumption expenditure on the transport equipment, and it is part of the households’ total consumption expenditure. Table 2 shows the change in passenger volume and consumption of the transport sectors for five phases in 2020.

In Phase 1, the households’ demand for railway, road, and aviation passengers falls by 4.3%, 11.9%, and 5.3%, respectively, and the households’ consumption of the transport sector falls by 2.8%. In phase 2, the households’ demand for railway, road, and aviation passengers falls by 87.2%, 88.7%, and 84.5%, respectively, and the households’ consumption of the transport sector falls by 28.9%. In Phase 3, the households’ demand for railway, road, and aviation passengers falls by 73.3%, 73.1%, and 71.7%, respectively; and the households’ consumption of the transport sector falls by 17.3%. In Phase 4, the households’ demand for railway, road, and aviation passengers falls by 63.5%, 58.8%, and 68.5%, respectively; and the households’ consumption of the transport sector falls by 12.5%. In Phase 5, the households’ demand for railway, road, and aviation passengers falls by 34.5%, 41.5%, and 29.7%, respectively; and the households’ consumption of the transport sector falls by 3.76%.

5. Results

This section summarizes the CGE simulation results for five different phases and analyzes the impact of transportation consumption on the economy during the pandemic.

5.1. Impact of traffic consumption on the macroeconomy

The macroeconomic impact of transport consumption during the COVID-19 pandemic is shown in Table 3. The reduced transport consumption has a significant impact on China’s macroeconomy.

In the early period of the COVID-19 pandemic, traffic consumption had not fallen much; and in Phase 1, GDP fell by 0.18%. Among these five phases, Phase 2 was the most severe pandemic period, and it had the largest GDP decrease (0.49%). GDP fell by 0.36% in Phase 3, followed by Phase 4 (0.31%) and Phase 5 (0.22%). Of these macroeconomic variables for each phase, consumption is the most negatively affected factor. The decline in transport demand, together with the COVID-19 pandemic, caused a sharp drop in consumption. From Phase 2 to Phase 5, consumption declined by 0.75%, 0.51%, 0.46%, and 0.43%. Moreover, a decline in traffic consumption had a significant impact on imports and exports, having a greater influence on the imports.

During all phases of the pandemic, the decline in transportation consumption had a significant negative impact on the economy. The negative impact of the decline in transportation consumption on the economy was greatest during the most severe phase of the pandemic (Phase 2). As the situation of the pandemic was improved, the decline in transportation consumption was gradually reduced.

5.2. Impact of traffic consumption on the output of sectors

The transport sector is closely connected to other industries. This section summarizes the effects of traffic consumption on various industries, including agriculture; mining; manufacturing; electricity, heat, gas, and water production and supply industry; building and service industries; and railway, road, and air transportation. From the simulation results, we can see that as transportation consumption gradually decreases, the output of all sectors also decreases (see Fig. 2). Therefore, consumption in the transport sector affects the output of all industries.

The simulation results show the difference in the impact of transportation consumption on the output of different sectors. The impact of traffic consumption on the output growth rate of different sectors is compared in Fig. 2. The output of the transport sector is more negatively impacted than that of the other sectors for each phase. In Phase 2, the output of the railway sector, road, and air sectors fell by 1.76%, 10.17%, and 1.53% respectively, with the largest reduction in transportation consumption of this phase. Of the non-transport sectors, the output of the service industry is the most negatively affected, followed by manufacturing.

5.3. The economic impacts of transportation investment

Investment in infrastructure has always been a crucial means adopted by the government to regulate and promote the economy. As a material capital of society, transportation infrastructure plays a role in society’s productions. This can affect social productivity and economic development. The Chinese government has continued to implement a proactive fiscal policy and increasingly invests in transportation infrastructure, with the goal of promoting economic growth by stimulating domestic demand. In 2008, to cope with the global economic crisis, the Chinese government turned to infrastructure construction as an important strategy to stimulate the economy.

The government and transit agencies increased investment in the
Transport policy has played a key role during the COVID-19 pandemic. This study mainly examines the changes in transportation consumption and the economic impacts during the pandemic.

Transportation infrastructure investment not only affects the output of the transport sector, but also the non-transport sector. Railway investment has a greater effect on the growth of manufacturing output, compared with the other two transport sector investments. At the stage of railway infrastructure construction, the building of runnels, railway roadbeds, and tracks might trigger large demand for building materials such as reinforced concrete and clay. At the same time, the manufacturing of locomotive vehicles needs large amounts of metal processing machines, materials handling equipment, electrical machinery, and equipment. The results show that increases in railway investment would reduce the output of air transport, and when there is an investment increase in air transport, the output of the railway sector also declines. When investment in the road sector increases, the output of all transportation sectors increases.

### 6. Conclusions and policy recommendations

The transportation sector has played a key role during the COVID-19 pandemic. This study mainly examines the changes in transportation consumption and the economic impacts during the pandemic.

| Table 2 | Traffic consumption data for each phrase. |
|---------|-----------------------------------------|
| Parameter | Phase1 | Phase2 | Phase3 | Phase4 | Phase5 |
| Households' demand for the passenger transportation Railway | −4.30% | −87.20% | −73.30% | −63.50% | −34.5% |
| Road | −11.90% | −88.70% | −73.10% | −58.80% | −41.5% |
| Aviation | −5.30% | −84.50% | −71.70% | −68.50% | −29.7% |
| Households' consumption of the transport sectors | −2.80% | −28.90% | −17.30% | −12.50% | −3.76% |

Source: National Bureau of Statistics of China; WIND.

### Table 3

Simulation results of macroeconomic impact of traffic consumption for each phrase.

| Parameter | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 |
|-----------|---------|---------|---------|---------|---------|
| GDP | −0.18% | −0.49% | −0.35% | −0.31% | −0.22% |
| Investment | −0.27% | −0.61% | −0.48% | −0.37% | −0.32% |
| Consumption | −0.29% | −0.75% | −0.51% | −0.46% | −0.43% |
| Employment | −0.15% | −0.41% | −0.39% | −0.26% | −0.46% |
| Import | −0.24% | −0.34% | −0.25% | −0.31% | −0.43% |
| Export | −0.11% | −0.28% | −0.14% | −0.19% | −0.64% |

Source: CGE model.

### Table 4

Simulation results of economic impact of transportation investment.

| Parameter | S1 | S2 | S3 |
|-----------|----|----|----|
| GDP | 0.20% | 0.08% | 0.13% |
| Consumption | 0.16% | 0.10% | 0.09% |
| Labor demand | 0.18% | 0.06% | 0.09% |
| Agriculture, forestry, animal husbandry and fishery | 0.01% | 0.06% | 0.01% |
| Mining and Dressing | 0.07% | −0.07% | −0.04% |
| Manufacturing | 0.46% | 0.23% | 0.13% |
| Electricity, heat, gas and water production and supply industry | 0.26% | 0.03% | 0.15% |
| Building industry | 0.10% | 0.01% | 0.03% |
| Service industry | 0.16% | 0.07% | 0.14% |
| Railway transport | 4.65% | 0.01% | −0.21% |
| Road transport | 0.15% | 2.09% | 0.18% |
| Air transport | −0.03% | 0.01% | 0.07% |

Source: CGE model.

Fig. 2. Changes in output of the sectors affected by traffic consumption

Source: CGE model.
The decline in transportation consumption causes significant economic impacts, including GDP, investment, consumption, employment, imports, and exports. The simulation results show that COVID-19 has disrupted the Chinese economy by transport sectors, which is consistent with the results of previous studies (Cui et al., 2021; McKibbin et al., 2021). However, in their simulated scenarios, changes in the transportation sector are included in the entire pandemic shock scenario and the policy simulation such as investment in infrastructure, are not considered. To assess the economic impact of traffic consumption at different stages of the pandemic more specifically and intuitively, this study sets up five phases for simulation based on the situation of the pandemic. To evaluate the impacts of the government’s economic stimulus policy related to transportation, this study selects the investment policy that the government implements the most for analysis.

The major findings of this study list as follows: First, when the severity of the pandemic worsened, the impacts of transportation consumption on the economy deepened. Second, regarding the output of the non-transport sectors, the manufacturing and the service sectors have greater losses and are more severely affected by traffic consumption. This shows that the economic system is highly dependent on transportation demand. Finally, the simulation results of investment show that investment in the transport sector can promote the economy and create jobs. More importantly, investment in railways plays a more positive role in the economy than that of road and air transports. The government needs to build a favorable investment environment to promote steady and long-term economic growth. Based on the above research results, we summarize some corresponding policies.

First, among the three modes of transportation, road transport has the largest decline in consumption during the pandemic. It has a greater negative impact on China’s economy, compared with railway and aviation consumption. Therefore, the government should implement timely and effective measures at different stages of the pandemic to support the road transport sector. A toll-free policy on highways was implemented in the early stages of the pandemic. For example, the Jiangsu provincial government has issued relevant fuel subsidies and operating subsidies for urban public transport, rural passenger transport, and taxi passenger transport. However, some welfare policies were limited to the most severe period of the pandemic. The economic shocks caused by transportation consumption are difficult to recover in the short term. The subsidy policy time for road passenger transport enterprises should be extended; in particular, the subsidy for the pandemic prevention and security inspection work of the road passenger transport department should be increased.

Second, the government and transit agencies should improve people’s confidence in transportation and ensure the safety of people’s travel during the pandemic. In addition, people should take protective measures to prevent viral transmission and avoid infection while ensuring their daily travel. Zhang (2020a) suggests that the PASS approach (P: prepare-protect-provide; A: avoid-adjust; S: shift-share; S: substitute-stop) is crucial for successful transport measures amid pandemics (Zhang et al., 2021b). The “Avoid-Adjust” policy is highly recommended, which includes avoiding the provision of inconsistent information, avoiding crowded vehicles, and avoiding activities/trips that need close physical distances.

Finally, the intelligent construction of transportation should be accelerated. During the pandemic, technologies have been adopted to effectively screen out special populations, such as scanning health codes, enabling people to be identified quickly, efficiently, and accurately, which provides a relatively safe and healthy environment for people, while meeting their demands for health travel.

This study has some limitations, and corresponding improvements are needed in the future. First, the policy simulation section considers only traffic investment policies, without considering other fiscal policies, and future studies can further expand in terms of policy simulation. Second, this study establishes a CGE model at the national level. However, regions in China have different transportation demands and economic levels, particularly Wuhan during the pandemic. Consequently, it is important to consider the significant disparities among regions. Future studies can build a multi-regional CGE model.

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