



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.



Research paper

# Flow of goods to the shock of COVID-19 and toll-free highway policy: Evidence from logistics data in China

Da Fang, Yan Guo\*

School of Economics, Peking University, China



## ARTICLE INFO

## JEL classification:

L92

O53

## Keywords:

COVID-19 pandemic

Logistics

Lockdown policy

Toll-free highway policy

## ABSTRACT

Using high-frequency logistics data from China, this paper quantitatively examines the negative impact of the COVID-19 pandemic on logistics. Meanwhile, our research focuses on the toll-free highway policy during the COVID-19 pandemic, analyzing the promoting effect of this policy on road freight in China. Three main conclusions are drawn from the study. Firstly, the COVID-19 pandemic led to an average daily drop of 0.67% in road freight volume and an increase of 0.48% in logistic cost compared to the pre-pandemic period. Secondly, the toll-free highway policy had a significant offset effect of pandemic on freight volume and price, stimulating the resumption of work and production. However, the dynamic effect shows that the toll-free highway policy is only temporarily effective rather than the long term. Thirdly, the effectiveness of the toll-free highway policy is moderated by the severity of the epidemic and the transportation distance. This paper contributes to research on economy recovery and transportation policy under the COVID-19 pandemic shock.

## 1. Introduction

As a bridge between production and consumption, logistics is essential to guarantee the stability of the economy and society. The outbreak of COVID-19 has severely influenced economic activities worldwide. In order to prevent the spread of the virus, many countries have imposed strict traffic restrictions (so-called “lockdown” policy) and incurred significant transportation costs (Aloi et al., 2020; Gössling et al., 2020; Ketchen & Craighead, 2020; Mahajan & Tomar, 2021; Remko, 2020a). Studies find that traffic restrictions reduce people’s mobility and cause severe economic problems, such as unemployment, food crises and loss of tourists (Fang et al., 2020; Vos, 2020; Zhang, Zhang, & Wang, 2020; Hobbs, 2020). Moreover, the lockdown policy brings higher economic costs than the infection itself (Chen, Liu, Luo, & Song, 2020). The policies to prevent the spread of the virus, such as domestic lockdown, international border closures and community social distancing, interrupted in the transport of goods in some areas, which led to supply shortages between regions (Ivanov, 2020; Remko, 2020a; McMaster et al., 2020; Xu & Long, 2021). However, most of these studies are conceptual or simulations (Chesbrough, 2020; Maliszewska et al., 2020; Queiroz et al., 2020), and very little research quantitatively estimate the loss of logistics caused by the COVID-19 due to lack of data (Fang & Zhang, 2021; Ferrari et al., 2021; Jomthanachai et al., 2021).

Anecdotal evidence reported in medias suggested that transportation industry was hit hard by the pandemic, such as shortage of truck drivers, lack of containers during the pandemic. The latest research found that workers in the transportation sector were 20.6% more likely to be unemployed because of the pandemic than workers in non-transportation industries (Mack et al., 2021). Meanwhile, governments started experimenting with different policies to restore economic activities and supply chain, promoting logistics industry. Highway toll-free policy is a temporary response to stabilize the goods transportation within China. Studies have identified the effects of highway toll policy on income inequality, reducing pollution and regional economic growth (Plotnick et al., 2011; Dong et al., 2012; Fu & Gu, 2017; Audretsch et al., 2020). Some researchers discussed the relationship between the 2008 recession and motorway tolls, arguing that motorway tolls play an important role in the transport economy (Vassallo et al., 2012a; 2012b). As the first country hit by COVID-19, the Chinese government initiated waiving highway tolls from February 17, 2020, to May 5, 2020. The toll-free highway policy is a subsidy for road logistics. Like China, many countries have provided stimulus subsidies to road shipment when air and water shipments are significantly reduced during the COVID-19 pandemic, such as India and the U.S. However, there is little research on estimating the economic effects of the free highway policy during the COVID-19 pandemic. To our knowledge, this is the first paper to

\* Corresponding author. No.5 Yiheyuan Road, 100871, Beijing, China.

E-mail addresses: [pkufd95@pku.edu.cn](mailto:pkufd95@pku.edu.cn) (D. Fang), [guoyan@pku.edu.cn](mailto:guoyan@pku.edu.cn) (Y. Guo).

evaluate the economic effectiveness of the transportation supporting policy during the COVID-19 pandemic.

This empirical study examines the effects of COVID-19 and toll-free highway policy based on high-frequency logistics data in China. We raise the following questions: (1) What degree of loss has the COVID-19 lead to Chinese logistics? (2) Does China's toll-free highway policy contribute to the recovery of the logistics industry? (3) Are there spatial and temporal heterogeneities in the effects of China's toll-free highway policy? The paper has contributions in the following three aspects: First, we use novel high-frequency logistic data to identify the economic impact of COVID-19. This paper quantitatively investigates the impact of the pandemic on the logistics industry and the Chinese economy based on daily road transportation data in China. Second, most current studies on the response policies to COVID-19 have focused on policies to stop the spread of the virus. Evaluating the effects of prompt policies on economic recovery needs further improvement. When population mobility was restricted to prevent virus transmission, incentivizing commodity flow was critical to offset the loss of social life. We focus on the toll-free highway policy during Covid-19 and examine the effectiveness of this short-term policy in promoting China's economic recovery, trying to provide some implications to policy-makers to fight against COVID-19. Third, our study provides a new perspective for analyzing the economic effects of highway toll policies under the exogenous shock of COVID-19. The conclusions on the effects of waiving highway tolls may provide policy implications to countries trying to stimulate good delivery during the pandemic.

The rest of the paper is organized as follows: Section 2 introduces the policy background and data. Section 3 presents the empirical design and main results. Section 4 discusses the dynamic effect of the toll-free highway policy during the pandemic. Section 5 examines the heterogeneities of the toll-free policy effects regarding the epidemic severity and transportation distance. Section 6 concludes with policy implications.

## 2. Background and data

### 2.1. Background

A novel coronavirus was identified by the Chinese Center for Disease Control and Prevention (CDC) in January 2020, and later on, the virus was quickly transmitted worldwide. (Chen, Liu, et al., 2020). As of December 23, 2021, the World Health Organization (WHO) reported 130,109 people infected and 5,699 deaths in China.<sup>1</sup> The first quarter of 2020 is the most severe period of the pandemic in China. In February, the average daily cases of new infections exceeded 2,000, and the number of officially notified daily new deaths from COVID-19 was close to 100, shown in Fig. 1. In order to prevent the spread of the virus, the strict traffic restrictions began in China during this stage. Wuhan was the first city in China to implement a lockdown policy because of the COVID-19 pandemic on Jan 23, 2020, after which the lockdown policy was rapidly extended nationwide.

The COVID-19 pandemic led to dramatic macroeconomic fluctuations in China for the first two quarters of 2020. For instance, China's GDP, industrial value-added and total retail sales of consumer goods declined by 10.0%, 27.2% and 33.7%, respectively, in the first quarter of 2020, the worst quarter of the pandemic. However, in the second quarter of 2020, macroeconomic indicators showed a significant bounce-back as the pandemic eased and economic stimulus policies were implemented. (shown in Table 1).

Logistics is highly correlated with macroeconomic performance. The Chinese government has attempted to stimulate economic recovery by facilitating the logistics industry during the pandemic. Highway access is an essential factor that affects road transportation and the flow of

commodities in China. According to the Ministry of Transportation (MOT),<sup>2</sup> China has 161,000 km of highways, the largest domestic highway system worldwide. China's total highway tolls were approximately RMB 593.79 billion (US\$88.6 billion) in 2019. Highway toll revenue is an important source of funding for local governments in China to maintain and develop transportation infrastructure. The prompt toll-free highway policy is to offset the negative impact of Covid-19 on the economy and promote the recovery of production and consumption. The policy began on February 17, 2020, and lasted for 78 days until May 5, 2020. In the following part, we will discuss how the toll-free highway policy has counteracted the negative shock of the pandemic on goods transportation based on truck flow.

### 2.2. China's truck flow data during the COVID-19 pandemic

According to the report of The Ministry of Transportation, China's road transport accounted for 78% of total freight transport in 2019. When offline trading was shifted to online during the COVID-19 pandemic, efficient and stable logistic service was essential (Choi, 2021). Therefore, daily truck flow data is highly representative for us proxy China's transportation economy under the shock of the pandemic. The unique data comes from a leading logistic information platform company in China.<sup>3</sup> By 2020, the platform covered more than 1,800,000 trucks and 336 prefecture-level regions out of 342 regions in China. Studies based on this data source have shown that the truck flow is significantly correlated with China's macro-economic performance and supply chain conditions (Chen, Liu, et al., 2020; ; Fang & Zhang, 2021).

The truck flow experienced a sharp decline in quarter 1, 2020 and recovered to the pre-pandemic level in quarter 2. We plot the growth rate of the city-level truck flows (inflows plus outflows) in the first two quarters in 2020 relative to the corresponding quarters in 2019 on the maps in Figs. 2 and 3, respectively. We find that the truck flows are consistent with the spatial pattern of the economic activities across China from Q1 to Q2 2020. In Fig. 2, most cities' quarter-on-year growth rate of truck flows in the first quarter of 2020 experienced a decline due to the dual impacts of the epidemic and Spring festival (Chinese New Year). The center of the pandemic, Hubei province, had the most severe decline of 90%. However, many regions saw positive growth of truck flow in the second quarter compared to the same quarter in 2019 with the ease of epidemic and stimulus of toll-free highway policy. On April 8, Wuhan's lockdown was lifted, and since then, the economic activity has recovered rapidly.

Furthermore, we show the changes in truck flows during the epidemic in a time series pattern. Fig. 4 displays the weekly year-on-year changes of truck flows from February 3, 2020, to August 31, 2020. The period covers the timing of the implementation and termination of the toll-free highway policy and the second wave of the epidemic at "Xin Fa Di market" in Beijing.

Regarding the effect of the toll-free highway policy, the year-on-year increase in truck flows in the week of February 17, 2020, was 53.8% lower than that of the same period in 2019. There was a very short-term period from February 8 to February 16, during which highway tolls resumed after the spring festival. We compare the truck flows growth in the pre-policy period, one week before February 17, 2020, to that in one week after February 17, finding that the 54.1% decline in truck flow was mitigated to 36.8%. With the toll-free highway policy implementation, the recovery rate of logistics relative to last year's same period increased rapidly. By the week of April 27, 2020, the growth was higher than the same period in 2019 by 19.2%. This rapid recovery came both from the

<sup>2</sup> Ministry of Transport of People's Republic of China (MOT). <https://www.mot.gov.cn/tongjishuju/>.

<sup>3</sup> The Business Privacy and Data Use Agreement prevents us from releasing the company's name. Readers interested in the data are welcome to contact the authors.

<sup>1</sup> World Health Organization (WHO). <https://covid19.who.int/>.

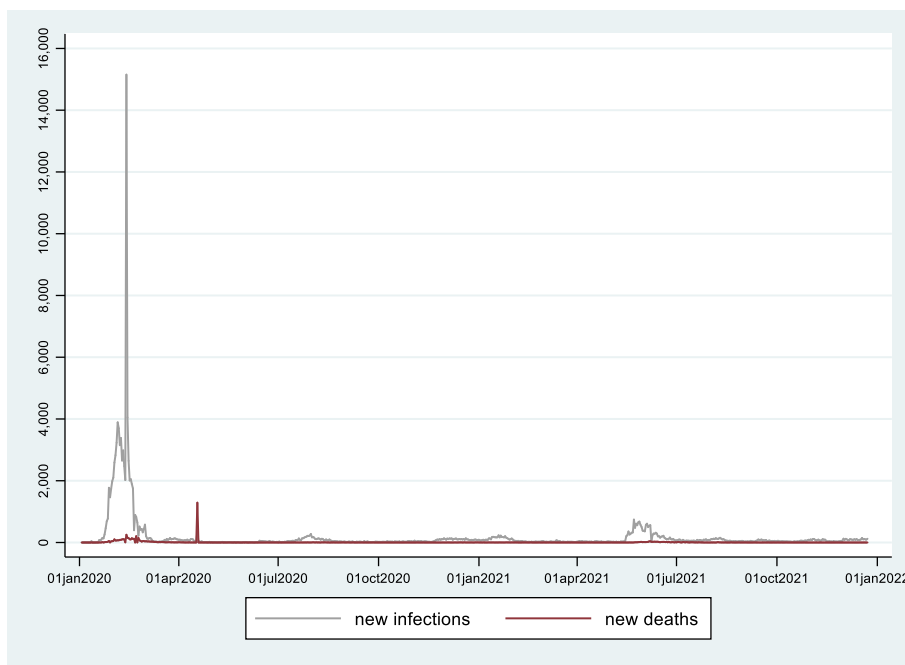


Fig. 1. Daily number of new infection cases and death cases in China.

Table 1  
Macro-economic indexes in China ( Q 4, 2019-Q 2, 2020 ).

Quarer-on-Quarter Growth (%)	Q4, 2019	Q1, 2020	Q2, 2020
GDP	1.0%	-10.0%	11.7%
Industrial value-added	10.7%	-27.2%	28.6%
Total Retail sales of consumer goods	8%	-33.7%	19.2%

easing pandemic and the effect of free highway policy. After May 6, when the policy was terminated, the growth slowed down compared to the growth during policy implementation. The post-policy decreasing growth shows that the prompt response hedged some negative shock of the COVID-19 pandemic on road freights. Fig. 4 also includes the outbreak of COVID-19 at Beijing Xinfadi Farmers Market (Xinfadi) from June 13 to August 6. The outbreak at Xinfadi is not comparable to the Wuhan outbreak in terms of scale. However, the Xinfadi outbreak led to a 1.2% year-on-year decline in road freight nationwide because Beijing

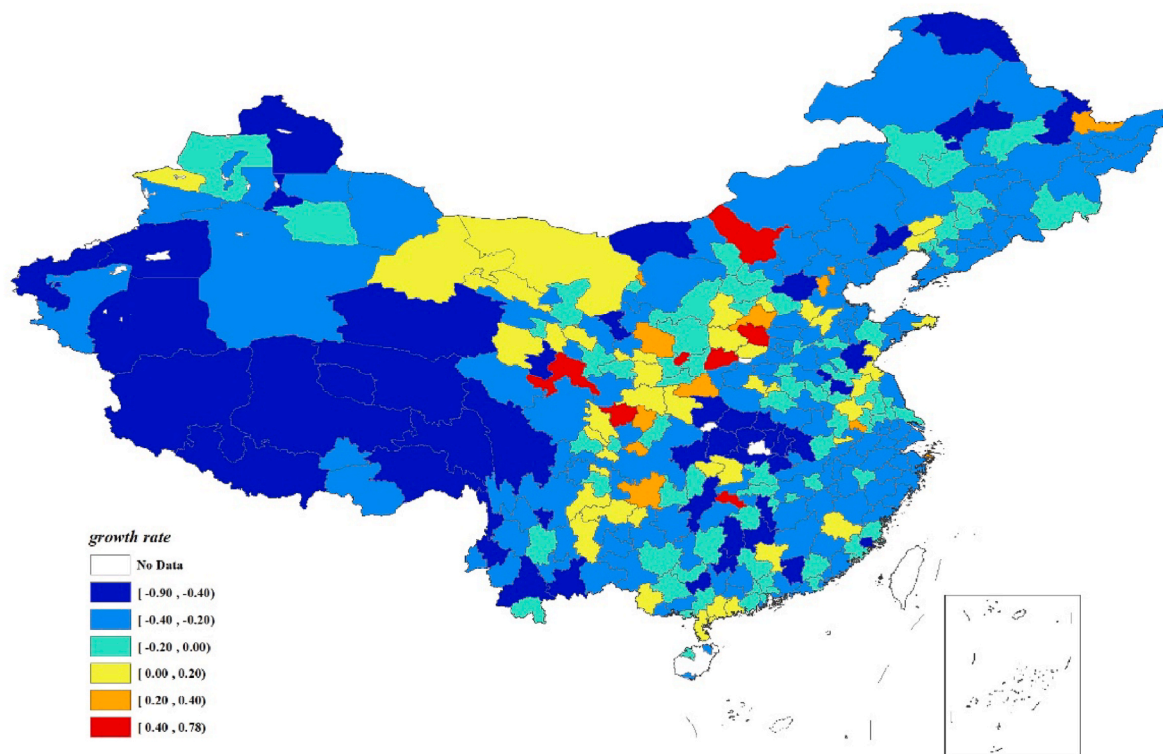


Fig. 2. Quarter-on-year growth rate of inter-regional truck flows in the 1st quarter, 2020

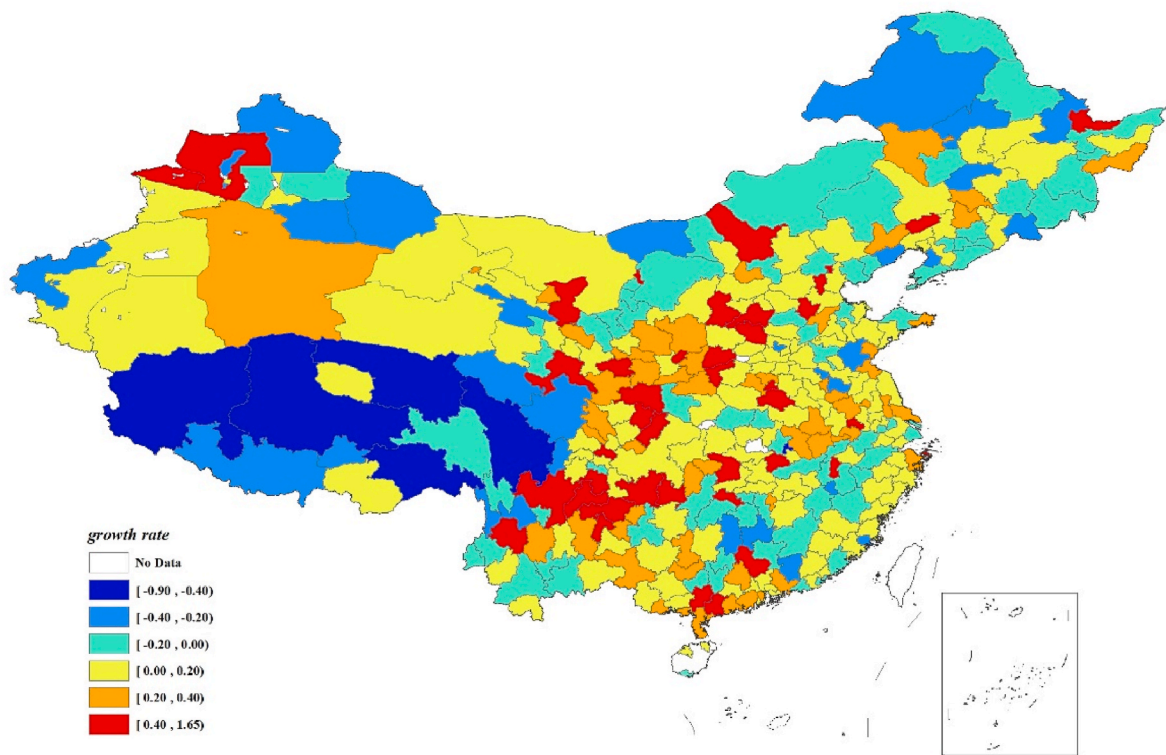


Fig. 3. Quarter-on-year growth rate of inter-regional truck flows in the 2nd quarter, 2020

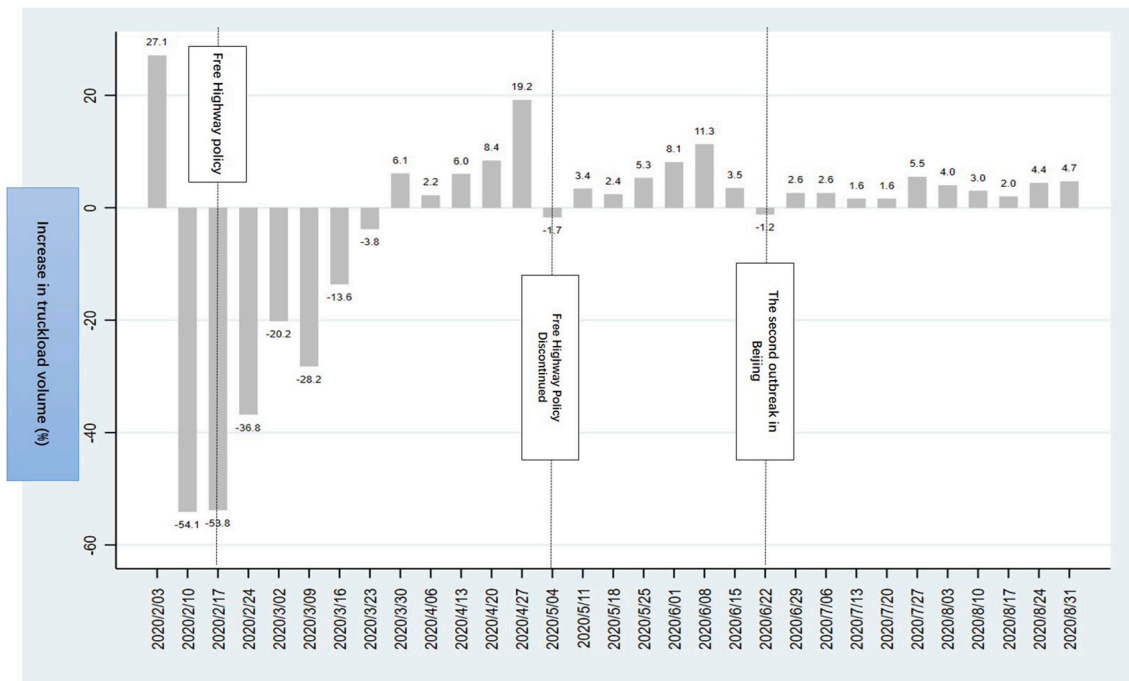


Fig. 4. Weekly year-on-year growth of truck flows.

is China’s political and economic center (Guo et al., 2021). Once again, road freight volume fell below the same period level of 2019 due to the regional lockdown. However, after August 6, when the lockdown was lifted, with the ease of the Xinfadi outbreak, the recovery of the year-on-year growth rate of truck flows was significantly slower than the growth rate during the period of the toll-free policy.

### 3. Methodology

#### 3.1. Empirical design

The ongoing COVID-19 pandemic had many negative impacts on the logistic industry. Firstly, transportation restrictions hit the inter-regional trade, which may increase the disruption risk to supply chain (Choi,

2021) Policies to prevent the spread of the virus, such as domestic lockdowns, international border closures, and community social distancing, have interrupted the transportation of products in some areas, creating supply shortages between regions (Richardson, 2020; Sharma et al., 2020; Xu & Long, 2021). Secondly, the pandemic-induced downturn in manufacture reduced logistic demand (Maria del Rio-Chanona, Mealy, Pichler, Lafond, & Doyme Farmer, 2020; Notteboom et al., 2021). Thirdly, the ongoing pandemic increased the cost of logistics due to the rising energy and fuel prices and rising wages of drivers and couriers (Akhtaruzzaman et al., 2020; Zhang, Pellegrino, et al., 2020; Le Billon et al., 2021). Fourthly, supply chain operations were also affected by financial market fluctuations (Kavussanos & Talley, 2004; Drobetz, Menzel, & Schröder, 2016). The increased financial uncertainty during COVID-19 hurt the transportation economy (Fang & Zhang, 2021; Jebabli et al., 2021). Therefore, the first question of this empirical study is to estimate how much damage the COVID-19 pandemic caused to the logistics industry regarding freight volume and rate).

In order to stabilize the supply of goods and promote economic recovery, China’s Ministry of Transportation announced to waive highway tolls from 00:00 a.m. on February 17, 2020, to 00:00 a.m. on May 6, 2020, for all the vehicles. This was the first time long-lasting nationwide toll-free policy in China. Usually, China’s highway tolls were only waived on specific holidays for non-commercial vehicles in China, the total cost of social logistics is 14.7% of GDP in 2020, much higher than the 6%–7% level of developed countries in Europe and the United States. There have been debates on whether the Chinese government should lower or eliminate highway tolls. The free highway policy is a government subsidy logistics companies to reduces to reduce transportation costs and promote economic recovery. Thus, the second question we are interested in is whether the scaled toll-free policy during the COVID-19 pandemic contributed to the recovery of logistics and economic activities. We adopt the following regression model to examine the impact of the COVID-19 shock and the toll-free highway policy on the logistics.

$$y = \alpha + \beta_1 covid + \beta_2 policy + \beta_3 covid * policy + \gamma control\ variables + \epsilon \quad (1)$$

In equation (1), the dependent variables (y) refer to road freight volume or freight price. Consistent with the data presented in section 2.2, we collect the volume of road freights (variable name: q, unit: one waybill) and freight prices (variable name: p, unit: yuan/1000 kg-km) between 336 cities in China from October 1, 2019, to June 30, 2020. All the data are aggregated to a daily time series data containing valid information of 7,966,987 cargo waybills and average freight rate for three quarters.

We focus on the impacts of two events, the COVID-19 pandemic shock and the toll-free highway policy. On January 23, Wuhan implemented a lockdown and lifted the lockdown on April 8, 2020. In equation (1), the dummy variable covid is one when the time between January 23, 2020, and April 8, 2020, and zero otherwise. Wuhan Removing lockdown represented the end of the first wave of the pandemic shock. The Ministry of Transportation announced to waive highway tolls from 00:00 a.m. on February 17, 2020, to 00:00 a.m. on May 6, 2020. Therefore, another dummy variable policy equals one between February 17, 2020, to 00:00 a.m. on May 6, 2020, and zero otherwise. Moreover, since the purpose of the toll-free highway policy is to offset the negative shock of the pandemic, we include the interaction term of covid \*policy in equation (1) to test the moderating effect of the toll-free policy to counteract the pandemic shock.

In equation (1), we control variables that may influence road transportation to avoid noises in our estimation. Road transportation is correlated with the recovery of the economic activity itself. To distinguish the effect of core independent variables (covid and policy) from the natural effect of economic recovery, we control for a one-stage lagged term of road freight volume, L. q (unit: one waybill). The Chinese Spring Festival in 2020 overlapped with the outbreak of COVID-19. According to Chinese social customs, most business activities stop

during the traditional holiday. Therefore, most logistics companies and truck drivers will not work until January 15 of the lunar calendar. We control the dummy variable festival, which is equal to one from January 17, 2020 (December 23 of the lunar calendar, indicates the start of Spring Festival) to February 8, 2020 (January 15 of the lunar calendar, indicates the end of Spring Festival) to capture the holiday effect. The descriptive statistics for each variable are shown in Table 2.

### 3.2. Baseline results

We take the log number of each dependent variable to capture the daily changes of freight volumes and freight rates during the period covered by the sample. The regression results are reported in Table 3.

Based on the baseline results, we can draw the following two conclusions.

First, the pandemic shock severely hit road transportation. Models 1 to 3 show the significant negative coefficients of the dummy variable covid. More specifically, the COVID-19 pandemic shock caused the average daily freight volume to drop by about 0.67% compared to the non-shock period when other variables were controlled. Meantime, the pandemic significantly increased the freight price, reflecting the rising logistics cost during the pandemic as mentioned earlier in this paper. In model 6, the COVID-19 shock increased the daily freight price by 0.48% compared to the non-shock period.

Second, the toll-free highway policy played a significant positive role in promoting logistics. The coefficient of the dummy variable policy in model 2 is positive at 1% significance level, indicating that the free highway policy led to an increase in daily freight volume by 0.13%. In model 3, although the coefficient of policy is insignificant, the coefficient of interaction term policy\*covid is significantly positive. The toll-free policy effectively offset the negative shock of COVID-19. Moreover, as a prompt emergency measure, waiving highway tolls achieved the policy objective to boost production recovery by lowering transportation prices shown in models 5 and 6.

### 3.3. Robustness check

To prevent the chance of impact caused by the selection of variables on the empirical results, we select two alternative variables to replace the dependent variables in the baseline regressions. The opening rate of logistics parks and the Road Index, respectively, and conduct robustness tests on the conclusions of the underlying regressions. The replacement variables are defined as follows.

The Logistics park opening rate (variable name: park, unit: percentage) is calculated as the ratio of open parks over the total number of public logistics parks. When the cargo throughput of the logistics park exceeds 10% of last year’s peak season (November 2019), the park is considered open, and vice versa, the park is closed. The opening rate of public logistics parks is also an important indicator reflecting the operating situation of freight transportation. As an essential transfer station for cargo transportation, the opening of logistics parks is influenced by various factors such as market supply and demand, smoothness of logistics supply chain and transportation policies. We use the opening rate of public logistics parks during the pandemic period provided by the platform company as a proxy for the volume of shipping orders as the dependent variable. The Road Index (variable name: road, unit:

**Table 2**  
Statistic description of variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
q	274	29076.59	9406.323	3223	40813
p	274	68.79951	45.81693	50.2164	605.39
covid	274	0.281022	0.450321	0	1
policy	274	0.284672	0.452084	0	1
festival	274	0.083942	0.277808	0	1

**Table 3**  
Baseline results.

Dependent variable	(1) lnq	(2) lnq	(3) lnq	(4) lnp	(5) Lnp	(6) lnp
covid	-0.8251*** (-9.09)	-0.1085* (-1.84)	-0.6659*** (-7.18)	-0.0014 (-0.06)	0.5070* (1.85)	0.4845*** (3.93)
policy		0.1331*** (4.05)	-0.0146 (-1.40)		-0.0785*** (-2.35)	-0.3581*** (-5.03)
policy*covid			0.6786*** (10.15)			-0.4935*** (-4.44)
Control Variable	yes	yes	yes	yes	Yes	yes
F	551.63***	645.85***	882.26***	10.31***	34.46***	42.42***
R-squared	0.9167	0.9434	0.9727	0.5466	0.5564	0.5672

Note: \*\*\*, \*\*, and \* represent the 1%, 5%, and 10% significance levels, respectively. T-value is in parentheses.

percentage) is a weekly index provided by the platform company. It is defined as the percentage of the road mainline freight volume over last year's peak season (November 2019) road mainline freight volume. Consistent with the baseline regression method, the regression results after replacing variables are shown in Table 4. The coefficients of *covid*, *policy*, and the interaction term of *policy\*covid* in Table 4 remain stable in sign and significance level.

**4. The dynamic effect of the toll-free highway policy on the logistics industry**

The baseline regression results in section 3 show that the toll-free highway policy significantly promoted the logistics recovery. However, the toll-free policy lasted for 78 days, and the effects of the policy might vary with the development of the pandemic and the recovery of economic activities. Therefore, we further test the dynamic effects of the toll-free highway policy. To look at the dynamic effects of the policy, we divide the policy period into three sub-phases according to China's resumption of work and production. The regression model is set as equation (2).

$$y = \alpha + \sum_i \beta_i \text{stage}_i + \theta \text{covid} + \gamma \text{control variables} + \varepsilon \tag{2}$$

In equation (2), we split the entire policy shock period variables into four dummy variables, *stage1*, *stage2*, *stage3* and *after* for regression. They are defined as follows. *stage1* is from February 17 to March 4. On March 4, the State Council issued the Notice of the General Office of the State Council on Further Streamlining Approval and Optimizing Services to Promote Enterprises' Resumption of Work and Production Precisely and Steadily. This stage was the critical period of preventing and controlling the spread of the virus. During the first stage of the policy, the population and goods were more restricted, and the resumption of work and production progress was relatively slow. *stage2* is from March 5 to April 10. The Notice of the General Office of the State Council put forward the requirement of "clearing and eliminating cumbersome procedures that hinder the orderly return of labor and transportation of materials." In the second stage, the State systematically encouraged the

**Table 4**  
Robustness check.

Dependent variable	(1) park	(2) road
covid	-0.4642*** (-11.70)	-0.4944*** (-11.56)
policy	0.0216** (2.08)	0.0509** (2.42)
policy*Covid-19	0.4089*** (10.63)	0.3621*** (7.89)
Control Variable	yes	yes
F	203.43	693.55
R-squared	0.9143	0.8869

resumption of work and production when the pandemic was under control and the social order was stabilized. *stage3* was the end of implementing the toll-free policy from April 11 to May 5. According to the Ministry of Industry and Information Technology, as of April 10, the small and medium enterprises (SMEs) work and production resumption rate reached 80%. The order of economic life was restored. Dummy variable *after* is from May 5 to June 30, 2020. The toll-free policy was terminated at this stage. We set these dummy variables to test the dynamic effects of policy on logistics. The other control variables and regression methods remain the same as equation (1).

Table 5 shows the dynamic effects of toll-free policy on freight volume and freight rate at different stages. The policy had significant counter effects on COVID-19 shock to freight volumes and freight rate at stage 1 and stage 2. The positive effect of the toll-free policy on the freight volumes was enhanced from stage1 to stage2 and became insignificant from stage3. The same pattern follows for the freight rate at different stages. When the economy was back to normal, the promoting effect of toll-free policy on logistics diminished. The operations of logistics companies were at a relative standstill during the early stage of the outbreak of COVID-19, just like other industries, due to the strict traffic blockade and fear of virus spread. As a result, the policy took some time to achieve its objective of promoting economic recovery. Nevertheless, the income effect of the toll-free policy on logistic companies and the substitution effect of road transport for other modes of freight transport were significantly brought into play at the first two stages. Then, as economic activities gradually returned to normal and the market returned to equilibrium, the policy stimulus slowed down and disappeared. To summarize, the results of the dynamic effect again show that the positive effects of the free highway policy are temporary rather than long-term.

**Table 5**  
Dynamic effect of toll-free highway policy.

Dependent variable	(1) lnq	(2) lnp
covid	-0.5481*** (-3.46)	0.1636** (2.02)
stage1	0.5084*** (7.07)	-0.2612*** (-2.71)
stage2	0.5629*** (4.03)	-0.2002** (-2.29)
stage3	-0.0161 (-1.38)	-0.0190 (-1.52)
after	0.0075 (0.64)	-0.0158 (-1.57)
Control Variable	yes	yes
F	642.02***	35.85***
R-squared	0.9667	0.5746

## 5. Heterogeneity analysis of the effect of free highway policy

### 5.1. Impact of the covid-19 severity on the effect of free highway policy

The toll-free highway policy was implemented simultaneously across the country, but the severity of the pandemic varied across China. Therefore, we want to understand whether the severity of the pandemic in different regions would impact the effectiveness of implementing the toll-free policy. Referring to [Chen and Pan \(2020\)](#), provinces with cumulative infections of over 10,000 were classified as epidemic regions (Epidemic), and a total of five provinces, Hubei, Hunan, Guangdong, Henan, and Zhejiang, had cumulative infections of over 10,000 during the sample period of this study. Therefore, we ran regressions based on the subsamples of epidemic regions and the other regions, respectively, to identify the heterogeneous policy effects regarding the degree of severity of the pandemic. [Table 6](#) shows the results of the sub-sample regression.

As expected, the effects of the toll-free highway policy are stronger in severe epidemic regions than that in other regions. For example, the coefficient of the interaction term *covid\*policy* in column 1 is significantly greater than in column 3, indicating that the policy improved freight volume in epidemic regions more than in other regions. Likewise, the reduction in transport costs in areas with a severe pandemic is significantly larger than in areas with a relatively mild pandemic. Regional heterogeneity is also depicted in [Fig. 3](#). In the second quarter of 2020, during which the free highway policy was most effective, inter-regional truck flows grew faster in regions like Hubei, Guangdong and Zhejiang, which were hit more severely by the pandemic. The above results again suggest that the toll-free policy was an effective short-term policy to hedge the negative shock of the pandemic on the logistics industry and boosted economic activities nationwide through lowering transportation costs.

### 5.2. Transport distances and the effect of the toll-free highway policy

Considering the differences between long-distance and short-distance transportation in terms of highway use, logistics costs and types of goods, we distinguished waybills between long-distance freight and short-distance freight. According to the Regulations on the Implementation of the Law of the People’s Republic of China on Road Traffic Safety,<sup>4</sup> and Decree No. 139 of the Ministry of Public Security of the People’s Republic of China,<sup>5</sup> 480 km is a threshold between long-distance and short-distance freight. We ran regressions based on the

**Table 6**  
Heterogeneity in the severity of the epidemic.

	(1)	(2)	(3)	(4)
Dependent variable	lnq (epidemic regions)	lnp (epidemic regions)	lnq (other regions)	lnp (other regions)
<i>Covid</i>	-0.7373*** (-7.63)	1.1424*** (5.15)	-0.3132*** (-8.86)	0.3065*** (4.78)
<i>Policy</i>	-0.0029 (-0.21)	-0.3917*** (-4.98)	-0.0152 (-0.83)	-0.0098** (-2.14)
<i>covid*policy</i>	0.7487*** (10.60)	-0.8896*** (-4.03)	0.2338*** (6.11)	-0.1652*** (-4.00)
Control variable	yes	yes	yes	Yes
F	1159.30***	56.32***	585.19***	38.25***
R-squared	0.9737	0.5042	0.9341	0.4188

Note: \*\*\*, \*\*, and \* represent the 1%, 5%, and 10% significance levels, respectively. T-value is in parentheses.

two subsamples to examine the effects of toll-free policy on the shock of COVID-19. The results are displayed in [Table 7](#).

First, compared to short-distance freight volume, long-distance freight is more significantly affected by the COVID-19 pandemic due to the transportation restriction. The absolute value of the coefficient of *covid* in column 2 is bigger than that in column 1, assuring that the pandemic shock worsened the long-distance logistics. Second, the role of toll-free highway policy in reducing the negative impact of the COVID-19 pandemic on long-distance freight is more significant. The coefficient of *policy\*covid* in column 2 is significantly higher than that in column 1. Long-distance freights use highways more often and pay more highway tolls in the transportation costs. When highway tolls were waived, long-distance freights benefited more from the subsidy than short-distance freights. The results indicate that the toll-free highway policy had a more significant positive impact on the resumption of work and inter-regional connections during COVID-19. Third, the toll-free policy reduced the long-distance freight rates more significantly than the short-distance freight rates. The impact of the toll-free policy on short-distance freight rates is insignificant, because some short-distance freights do not use highways.

## 6. Conclusions and policy implications

Using high-frequency road freights data, we quantitatively examine the negative shock of the COVID-19 pandemic on China’s logistics. Meanwhile, we focus on the toll-free highway policy during the pandemic, analyzing the policy effect on mitigating the negative shock of COVID-19. Three main conclusions are drawn from the study. Firstly, the pandemic led to an average daily drop of 0.67% in road freight volume and an increase of 0.48% in road freight rate compared to that in the non-pandemic period. [Deriu et al. \(2021\)](#) predict that the land transport and pipeline transport services would drop by 31.4% based on a three-month lockdown simulation. Our research shows a 40.42% decline in road transport in China during COVID-19 lockdown between January 23, 2020, to April 8, 2020, providing empirical evidence to theoretical simulation. Furthermore, our empirical result also consistent with the findings by [Mack et al. \(2021\)](#).

Secondly, the toll-free highway policy significantly offset the adverse effects of the pandemic on freight volumes and prices, stimulating the resumption of production and inter-regional connection. Although many countries provided stimulus to logistics, particularly truck drivers, to stabilize commodities supply, very rare studies examine the effects of these instruments on land transport. To our knowledge, this is the first empirical work to identify the effectiveness of the transportation supporting policy during the COVID-19 pandemic. However, the dynamic effects of the toll-free policy show that it is effective only temporarily rather than long-term. As economic activities gradually return to normal and the market returns to equilibrium, the counter-effects of toll-free

**Table 7**  
Distances and the effect of the toll-free highway policy.

	(1)	(2)	(3)	(4)
Dependent variable	lnq (short distance)	lnq (long distance)	lnp (short distance)	lnp (long distance)
<i>covid</i>	-0.5817*** (-5.18)	-0.7252*** (-8.14)	0.2231*** (7.45)	1.6641*** (5.21)
<i>policy</i>	-0.1913 (-1.32)	-0.0092 (-0.83)	-0.0496 (-0.42)	-0.0132 (-1.27)
<i>covid*policy</i>	0.5910*** (8.28)	0.7319*** (10.56)	-0.0873 (-1.59)	-0.1785*** (-12.90)
Control variable	yes	yes	yes	yes
F	515.31***	921.86***	65.58***	46.10***
R-squared	0.9533	0.9743	0.4494	0.5725

Note: \*\*\*, \*\*, and \* represent the 1%, 5%, and 10% significance levels, respectively. T-value is in parentheses.

<sup>4</sup> [http://www.gov.cn/banshi/2005-08/23/content\\_25579.htm](http://www.gov.cn/banshi/2005-08/23/content_25579.htm).

<sup>5</sup> [http://www.gov.cn/gongbao/content/2016/content\\_5070752.htm](http://www.gov.cn/gongbao/content/2016/content_5070752.htm).



policy to COVID-19 disappear. The results also provide implications for policymakers regarding the highway tolls policy in China.

Thirdly, there are heterogeneities in the effects of the COVID-19 pandemic and the toll-free highway policy. On one hand, the toll-free policy had more mitigating effects in regions with a severe pandemic than in less severe regions. On the other hand, long-distance freight is more significantly affected by the COVID-19 pandemic and toll-free highway policy than short-distance. Therefore, when COVID-19 lockdown occurs to prevent population mobility, it is more critical to maintain sustainable logistic services. Our paper enriches research on transportation policy, supply chain risk and economic recovery (Aloi et al., 2020; Ivanov & Dolgui, 2020; Choi, 2021) by providing empirical evidence based on big logistic data.

With the mutation of the virus, the global economy is still shrouded in uncertainty. Therefore, a review and quantitative assessment of government policies during the pandemic shock provides policy implications for policymakers to respond promptly to the sudden negative shock on economic activity in the future by formulating sound and scientific, economic promotion policies.

As the pivotal link between production and consumption, logistics ensures the timely supply of production materials and consumer goods. Moreover, there is a high correlation between road freight volume and the leading macroeconomic indicators. Therefore, the performance of the logistics industry can be referred to as one of the core indicators for monitoring economic performance when a negative shock like a pandemic hits an economy.

Ensuring the smooth flow of goods and reducing the cost of transporting goods is conducive to economic recovery when the economy faces a negative shock. A sustainable supply chain may benefit the whole economy to protect production and consumption from the lockdown during the pandemic. Many countries globally, such as Germany, Italy and Austria, charge highway tolls for trucks. Our study on the toll-free policy during the pandemic may apply to these countries and provide empirical evidence for them to refer. Waiving highway tolls can be a good instrument to lower transport cost and mitigate the effect of lockdown due to COVID-19. Unlike traditional counter-cycle macroeconomic policies, which will have a significant lag effect on economic recovery, a precise and timely policy response to sudden shock is necessary to mitigate the adverse effect and help recover the economy. During the COVID-19 pandemic, when economic activities shift from offline to online, the smooth flow of goods is particularly critical. Providing subsidies to logistics services can significantly stabilize the economy based on our results. The role of the Chinese government in sustaining economic activity and promoting the resumption of work and production in a country amid the pandemic through supportive policies for the logistics sector, particularly road transport, is worthy of emulation around the world.

Charging highway tolls has been a controversial issue in transportation economics. However, the dynamic effect of the toll-free highway policy on the restoration of logistics freight volume tends to change from strong to weak with the development of the pandemic. When the economy returns to a pre-pandemic level, the effect of toll-free policy on logistics is no longer significant. This result helps policymakers quantitatively assess highway toll exemptions costs and benefits and address the ever-controversial issue of whether highway tolls should be eliminated from a social welfare perspective.

Logistics high-frequency big data provide a new facility to increase the tracking and analysis of more detailed logistics information, such as goods categories, inter-regional transport conditions, and logistics cost structure. In future research, big data can be introduced into more quantitative analysis models about supply chain risks (such as Choi & Chiu, 2012; Zheng et al., 2017). However, it is worth pointing out that other policies, such as production stimulus policy, or monetary policy may influence logistics and confound with toll-free policy during the COVID-19 pandemic. Unfortunately, due to the data limit, we cannot distinguish the additional policy impacts in this research.

## CRedit authorship contribution statement

**Da Fang:** Data curation, Formal analysis, Methodology, Software, Writing – original draft. **Yan Guo:** Conceptualization, Project administration, Resources, Supervision, Validation, Writing – review & editing.

## Declaration of competing interest

None.

## Acknowledgements

We are grateful to the editor, the associate editor and two anonymous reviewers for their insightful comments and suggestions. The authors are responsible for any remaining errors.

## References

- Akhtaruzzaman, M., Boubaker, S., Chiah, M., & Zhong, A. (2020). COVID-19 and oil price risk exposure. *Finance Research Letters*, 42, 101882. <https://doi.org/10.1016/j.frl.2020.101882>
- Aloi, A., Alonso, B., Benavente, J., Cordera, R., Echániz, E., González, F., Ladisa, C., Lezama-Romanelli, R., López-Parra, A., Mazzei, V., Perrucci, L., Prieto-Quintana, D., Rodríguez, A., & Sañudo, R. (2020). Effects of the COVID-19 lockdown on Urban mobility: Empirical evidence from the City of Santander (Spain). *Sustainability*, 12 (9). <https://doi.org/10.3390/su12093870>. Article 3870.
- Audretsch, D. B., Dohse, D. C., & dos Santos, J. P. (2020). The effects of highway tolls on private business activity—results from a natural experiment. *Journal of Economic Geography*, 20(6), 1331–1357. <https://doi.org/10.1093/jeg/lbaa003>
- Chen, J., Liu, E., Luo, J., & Song, Z. (2020). *The economic impact of COVID-19 in China: Evidence from city-to-city truck flows. Working paper.* University of Princeton.
- Chen, Q., & Pan, S. (2020). Transport-related experiences in China in response to the coronavirus (COVID-19). *Transportation Research Interdisciplinary Perspectives*, 8, 100246. <https://doi.org/10.1016/j.trip.2020.100246>
- Chen, N., Zhou, M., Dong, X., Qu, J., Gong, F., Han, Y., Qiu, Y., Wang, J., Liu, Y., Wei, Y., Xia, J., Yu, T., Zhang, X., & Zhang, L. (2020). Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: A descriptive study. *The Lancet (British Edition)*, 395(10223), 507–513. [https://doi.org/10.1016/S0140-6736\(20\)30211-7](https://doi.org/10.1016/S0140-6736(20)30211-7)
- Chesbrough, H. (2020). To recover faster from covid-19, open up: Managerial implications from an open innovation perspective. *Industrial Marketing Management*, 88, 410–413. <https://doi.org/10.1016/j.indmarman.2020.04.010>
- Choi, T. (2021). Risk analysis in logistics systems: A research agenda during and after the COVID-19 pandemic. *Transportation Research Part E: Logistics and Transportation Review*, 145. <https://doi.org/10.1016/j.tre.2020.102190>. Article 102190.
- Choi, T., & Chiu, C. H. (2012). *Risk analysis in stochastic supply chains: A mean-risk approach.* New York, USA: Springer's International Series in Operations Research and Management Science. [http://refhub.elsevier.com/S1366-5545\(20\)30832-2/h0095](http://refhub.elsevier.com/S1366-5545(20)30832-2/h0095).
- Deriu, S., Cassar, I. P., Pretaroli, R., & Soggi, C. (2021). The economic impact of covid-19 pandemic in Sardinia. *Research in Transportation Economics*. Article 101090 <https://doi.org/10.1016/j.retrec.2021.101090> (in press).
- Dong, B., Guo, G., & Wang, Y. (2012). Highway toll pricing. *European Journal of Operational Research*, 220(3), 744–751. <https://doi.org/10.1016/j.ejor.2012.02.017>
- Drobtz, W., Menzel, C., & Schröder, H. (2016). Systematic risk behavior in cyclical industries: The case of shipping. *Transportation Research Part E: Logistics and Transportation Review*, 88, 129–145. <https://doi.org/10.1016/j.tre.2016.01.008>
- Fang, H., Wang, L., & Yang, Y. (2020). Human mobility restrictions and the spread of the Novel Coronavirus (2019-nCoV) in China. *Journal of Public Economics*, 191. <https://doi.org/10.1016/j.jpubeco.2020.104272>. Article 104272.
- Fang, D., & Zhang, X. (2021). The protective effect of digital financial inclusion on agricultural supply chain during the COVID-19 pandemic: Evidence from China. *Journal of Theoretical and Applied Electronic Commerce Research*, 16(7), 3202–3217. <https://doi.org/10.3390/jtaer16070174>
- Ferrari, C., Persico, L., & Tei, A. (2021). Covid-19 and seaborne trade: The Italian perspective. *Research in transportation economics*. Article 101162 <https://doi.org/10.1016/j.retrec.2021.101162> (in press).
- Fu, S., & Gu, Y. (2017). Highway toll and air pollution: Evidence from Chinese cities. *Journal of Environmental Economics and Management*, 83, 32–49. <https://doi.org/10.1016/j.jeem.2016.11.007>
- Gössling, S., Scott, D., & Hall, M. C. (2020). Pandemics, tourism and global change: A rapid assessment of COVID-19. *Journal of Sustainable Tourism*, 29(1), 1–20. <https://doi.org/10.1080/09669582.2020.1758708>
- Guo, Y., Zhang, X., & Fang, D. (2021). Impact of the free highway policy on the resumption of work and production under COVID-19. *Based on Big Data of Logistics. Economics Science*, 43(5), 114–129. <https://doi.org/10.12088/PKU.jjkk.2021.05.08> (In Chinese).
- Hobbs, J. E. (2020). Food supply chains during the COVID-19 pandemic. *Canadian Journal of Agricultural Economics*, 68(2), 171–176. <https://doi.org/10.1111/cjag.12237>
- Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2)

- case. *Transportation Research Part E: Logistics and Transportation Review*, 136. <https://doi.org/10.1016/j.tre.2020.101922>. Article 101922.
- Ivanov, D., & Dolgui, A. (2020). Viability of intertwined supply networks: Extending the supply chain resilience angles towards survivability. A position paper motivated by covid-19 outbreak. *International Journal of Production Research*, 58(10), 2904–2915. <https://doi.org/10.1080/00207543.2020.1750727>
- Jebabli, I., Kouaissah, N., & Arouri, M. (2021). Volatility spillovers between stock and energy markets during crises: A comparative assessment between the 2008 global financial crisis and the covid-19 pandemic crisis. *Finance Research Letters*, 102363. <https://doi.org/10.1016/j.frl.2021.102363> (in press).
- Jomthanachai, S., Wong, W., Soh, K., & Lim, C. (2021). A global trade supply chain vulnerability in COVID-19 pandemic: An assessment metric of risk and resilience-based efficiency of CoDEA method. *Research in Transportation Economics*. <https://doi.org/10.1016/j.retrec.2021.101166>. Article 101166, (in press).
- Kavussanos, M. G., & Talley, W. K. (2004). Shipping finance and port issues. *Transportation Research Part E: Logistics and Transportation Review*, 40(4), 271–272. <https://doi.org/10.1016/j.tre.2004.04.001>
- Ketchen, D. J., & Craighead, W. C. (2020). Research at the intersection of entrepreneurship, supply chain management, and strategic management: Opportunities highlighted by COVID-19. *Journal of Management*, 46(8), 1330–1341. <https://doi.org/10.1177/0149206320945028>
- Le Billon, P., Lujala, P., Singh, D., Culbert, V., & Kristoffersen, B. (2021). Fossil fuels, climate change, and the COVID-19 crisis: Pathways for a just and green post-pandemic recovery. *Climate Policy*, 21(10), 1347–1356. <https://doi.org/10.1080/14693062.2021.1965524>
- Mack, E. A., Agrawal, S., & Wang, S. (2021). The impacts of the COVID-19 pandemic on transportation employment: A comparative analysis. *Transportation Research Interdisciplinary Perspectives*, 12. <https://doi.org/10.1016/j.trip.2021.100470>. Article 100470.
- Mahajan, K., & Tomar, S. (2021). COVID-19 and supply chain disruption: Evidence from food markets in India. *American Journal of Agricultural Economics*, 103(1), 35–52. <https://doi.org/10.1111/ajae.12158>
- Maliszewska, M., Mattoo, A., & van der Mensbrugge, D. (2020). *The potential impact of COVID-19 on GDP and trade: A preliminary assessment*. (No. 9211). Washington, DC: World Bank.
- María del Río-Chanona, R., Mealy, P., Pichler, A., Lafond, F., & Doyne Farmer, J. (2020). Supply and demand shocks in the COVID-19 pandemic: An industry and occupation perspective. *Oxford Review of Economic Policy*, 36(S1), S94–S137. <https://doi.org/10.1093/oxrep/graa033>
- McMaster, M., Nettleton, C., Tom, C., Xu, B., Cao, C., & Qiao, P. (2020). Risk management: Rethinking fashion supply chain management for multinational corporations in light of the COVID-19 outbreak. *Journal of Risk and Financial Management*, 13(8). <https://doi.org/10.3390/jrfm13080173>. Article 173.
- Notteboom, T., Pallis, T., & Rodrigue, J. (2021). Disruptions and resilience in global container shipping and ports: The COVID-19 pandemic versus the 2008–2009 financial crisis. *Maritime Economics & Logistics*, 23(2), 179–210. <https://doi.org/10.1057/s41278-020-00180-5>
- Plotnick, R. D., Romich, J., Thacker, J., & Dunbar, M. (2011). A geography-specific approach to estimating the distributional impact of highway tolls: An application to the puget sound region of Washington state. *Journal of Urban Affairs*, 33(3), 345–366. <https://doi.org/10.1111/j.1467-9906.2011.00551.x>
- Queiroz, M. M., Ivanov, D., Dolgui, A., & Fosso Wamba, S. (2020). Impacts of epidemic outbreaks on supply chains: Mapping a research agenda amid the COVID-19 pandemic through a structured literature review. *Annals of Operations Research*, 1–38. <https://doi.org/10.1007/s10479-020-03685-7>
- Remko, van H. (2020a). Research opportunities for a more resilient post-COVID-19 supply chain – closing the gap between research findings and industry practice. *International Journal of Operations & Production Management*, 40(4), 341–355. <https://doi.org/10.1108/IJOPM-03-2020-0165>
- Richardson, R. (2020). Bending the arc of COVID-19 through a principled food systems approach. *Agriculture and Human Values*, 37(3), 653–654. <https://doi.org/10.1007/s10460-020-10048-2>
- Sharma, R., Shishodia, A., Kamble, S., Gunasekaran, A., & Belhadi, A. (2020). Agriculture supply chain risks and COVID-19: Mitigation strategies and implications for the practitioners. *International Journal of Logistics*, 1–27. <https://doi.org/10.1080/13675567.2020.1830049> (in press).
- Vassallo, J. M., Ortega, A., & de los Angeles Baeza, M. (2012a). Impact of the economic recession on toll highway concessions in Spain. *Journal of Management in Engineering*, 28(4), 398–406. [https://doi.org/10.1061/\(ASCE\)ME.1943-5479.0000108](https://doi.org/10.1061/(ASCE)ME.1943-5479.0000108)
- Vassallo, J. M., Ortega, A., & de los Angeles Baeza, M. (2012b). Risk allocation in toll highway concessions in Spain: Lessons from economic recession. *Transportation Research Record*, 2297(1), 80–87. <https://doi.org/10.3141/2297-10>
- Vos, J. de (2020). The effect of covid-19 and subsequent social distancing on travel behavior. *Transportation Research Interdisciplinary Perspectives*, 5. <https://doi.org/10.1016/j.trip.2020.100121>. Article 100121.
- Xu, D., & Long, Y. (2021). The role of supply chain integration in the transformation of food manufacturers: A case study from China. *International Journal of Logistics*, 24(2), 198–212. <https://doi.org/10.1080/13675567.2020.1729707>
- Zhang, X., Pellegrino, F., Shen, J., Copertaro, B., Huang, P., Kumar Saini, P., & Lovati, M. (2020). A preliminary simulation study about the impact of COVID-19 crisis on energy demand of a building mix at a district in Sweden. *Applied Energy*, 280, Article 115954. <https://doi.org/10.1016/j.apenergy.2020.115954>, 115954.
- Zhang, Y., Zhang, A., & Wang, J. (2020). Exploring the roles of high-speed train, air and coach services in the spread of covid-19 in China. *Transport Policy*, 94, 34–42. <https://doi.org/10.1016/j.tranpol.2020.05.012>
- Zheng, W., Li, B., & Song, D. (2017). Effects of risk-aversion on competing shipping lines' pricing strategies with uncertain demands. *Transportation Research Part B: Methodological*, 104, 337–356. <https://doi.org/10.1016/j.trb.2017.08.004>