Economic impact of the most drastic lockdown during COVID-19 pandemic—The experience of Hubei, China

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Summary
This paper uses a panel data approach to assess the evolution of economic consequences of the drastic lockdown policy in the epicenter of COVID-19—the Hubei Province of China during worldwide curbs on economic activity. We find that the drastic 76-day COVID-19 lockdown policy brought huge negative impacts on Hubei's economy. In 2020:q1, the lockdown quarter, the treatment effect on GDP was about 37% of the counterfactual. However, the drastic lockdown also brought the spread of COVID-19 under control in little more than two months. After the government lifted the lockdown in early April, the economy quickly recovered with the exception of passenger transportation sector which rebounded not as quickly as the rest of the general economy.

KEYWORDS
COVID-19, Hubei, LASSO, Lockdown, Panel data, Program evaluation

1 | INTRODUCTION

Pandemics, such as the Black Death and Great Influenza Pandemic of 1918–1920, have had strong adverse effects on economic prosperity. Contrary to the finding that the recovery after a war was usually quick, Jorda et al. (2020) studied the major pandemics dating back to the 14th century and found significant adverse macroeconomic impacts after outbreaks of these pandemics persisting for decades.

In December 2019, a disease of unknown causes suddenly afflicted Wuhan, a megacity in Hubei province in central China with 60 million inhabitants, and quickly spread to the whole nation. Moreover, COVID-19 also quickly spread to 216 countries around the world. As of 1 October 2020, there were 34,048,240 confirmed cases and 1,015,429 deaths worldwide. The World Health Organization (WHO) has declared the virus a serious global health emergency. The UN Secretary-General Antonio Guterres said that COVID-19 has caused the greatest economic disaster and largest unemployment since the Great Depression, and has seriously endangered human rights. These observations raise the concerns about whether the impact of pandemics can be controlled (e.g., Financial Times article on 13 March 2021 pointed out that ‘History shows pandemics rarely end neatly.’) and the consequences of different control policies.

Facing the raging COVID-19 epidemic, the Chinese government rolled out perhaps the most agile and aggressive disease containment effort in history (WHO, 2020). To cut off the chain of COVID-19 transmission, the Chinese government took the risk that the economy might fall into a temporary downturn or even stagnation by implementing

1See Chudik et al. (2020) for an analysis of economic consequence of COVID-19.
2The strategy that underpinned this containment effort was initially a national approach that promoted universal body temperature monitoring, masking, and hand-washing. However, as the outbreak evolved, and knowledge was gained, a science and risk-based approach was taken to tailor implementation. Specific containment measures were adjusted to the provincial, county and even community context, the capacity of the setting, and the nature of novel coronavirus transmission there (WHO, 2020).
an unprecedentedly strict and thorough lockdown policy in Hubei, including its capital city, Wuhan. All transport in and out of the province of Hubei was prohibited from 10:00 AM on 23 January 2020 by suspending the operation of international passenger flights, ferries, long-distance passenger transport, airports and railway stations in Hubei; road and waterway passenger transport lines entering Wuhan; and public transport within Wuhan and Hubei. In the meantime, local authorities at various levels have also enacted strict community grid measures 24 h a day. The central government also quickly dispatched national medical teams from across the nation to provide medical support to Wuhan and Hubei, using an all-out effort to save lives. As a result, in little more than a single month, the rising spread of the virus was contained; in around two months, the daily increase in domestic COVID-19 cases had fallen to single digit. When the government lifted the lockdown of Wuhan and Hubei on 8 April 2020, all counties and districts had had no confirmed cases or newly confirmed cases for 14 consecutive days. The ‘Great Isolation’ in Hubei lasted for 76 days. In terms of the population covered, it is the largest cordon sanitaire in human history (Tian et al., 2020).

By June 30, 2020, Mainland China has reported a total of 83,534 confirmed cases, with 78,479 recoveries, and 4,634 deaths (National Health Commission of China [NHC], 2020). Through painstaking efforts and tremendous sacrifice made by the Chinese people, China succeeded in turning the situation around.

What is the cost and benefit of the unprecedented ‘lockdown’? There is an ongoing debate about the macroeconomic consequences of different containment strategies (e.g., Dievert & Fox, 2020; Eichenbaum et al., 2020a, 2020b). In this paper, we focus on assessing the macroeconomic impacts of possibly the largest cordon sanitaire in human history, the ‘Great Isolation’ of Hubei Province in times of global afflictions. The approach to construct counterfactuals is not based on extrapolating the pre-COVID19 lockdown trend. Instead, we assume a factor structure for all the units under study, namely that the outcomes of all units are driven by some common factors, even though the impacts of these common factors on each unit are different (e.g., Stock & Watson, 2005). We then use the panel approach proposed by Hsiao et al. (2012) and Hsiao and Zhou (2019) to construct the counterfactuals during worldwide curbs on economic activity to tackle the pandemic so as to identify the economic impact of Hubei lockdown and its aftermath.

We find that the large-scale COVID-19 lockdown lasting for 76 days (from 23 January to 8 April 2020) brought huge losses to Hubei Province’s aggregate economy in the lockdown quarter. However, once the lockdown was lifted, the recovery was speedy. Our results show that the huge negative impact of the drastic COVID-19 lockdown on Hubei’s economy was temporary and generally controllable. The fundamentals and development trend of the province’s economy have not been changed. Our study complements existing literature in two aspects. First, to the best of our knowledge, this is the first study identifying the dynamic macroeconomic consequences of the COVID-19 lockdown policy in the epicenter of China in times of pandemic. The counterfactuals are constructed in the absence of ‘lockdown’, in times of pandemic not in the absence of pandemic. To get a whole picture, we assess the consequences on total output and its sectoral components, its private components, and the transportation sector. Second, our method does not involve modelling how COVID-19 spread and how the COVID-19 and other factors have affected the evolution of GDP, investment, or retail sales. Our results do not depend on the specific model specifications assumed in some current studies. It appears that as the world is facing the complex situation of global anti-epidemic efforts, our estimated results could shed light on how to formulate effective public policy in times of pandemic crisis.

The rest of the paper is organized as follows: Section 2 describes the methodology of Hsiao et al. (2012). Section 3 briefly introduces China’s public policies against COVID-19 in the epicenter and non-epicenter regions. Section 4 discusses the data and the settings. Section 5 provides both treatment effects estimates and robustness checks. Concluding remarks are in Section 6.

2 | ECONOMETRIC METHODOLOGY

We know what happened to Hubei economy after the lockdown. We do not know what would have happened to Hubei economy in the absence of lockdown, but in times of COVID-19 pandemic. There are many different ways to construct counterfactuals and each is based on different set of assumptions (e.g., Abadie et al., 2010; Bai et al., 2014; Hsiao et al., 2012; Hsiao & Zhou, 2019; Ouyang & Peng, 2015; Xu, 2017). In this paper, we follow Hsiao et al. (2012) (HCW) to assume that the N cross-sectional units $\tilde{y}_i = (y_{1t}, \ldots, y_{Nt})$ are generated from

$\bar{y}_t = 0$

$\ldots$

$y_{Nt}$

$\ldots$
\[ \tilde{y}_i = \tilde{\alpha} + B \tilde{f}_i + \tilde{u}_i, \]  

where \( \tilde{\alpha} = (\alpha_1, ..., \alpha_N)' \) are \( N \times 1 \) fixed unit specific effects, \( \tilde{f}_i \) are \( r \times 1 \) common factors, \( B \) is an \( N \times r \) factor loading matrix, and \( \tilde{u}_i = (u_{1i}, ..., u_{Ni})' \) are \( N \times 1 \) idiosyncratic error term with \( E(\tilde{u}_i|\tilde{f}_i) = 0 \). Then

\[ y_{it} = E(\tilde{y}_it|\tilde{y}_{-i,t}) + \eta_{it}, i = 1, ..., N \tag{2} \]

where \( \tilde{y}_{-i,t} = (y_{1t}, y_{2t-1}, ..., y_{it+1}, ..., y_{Nt})' \) is the \( (N-1) \times 1 \) vector of \( \tilde{y}_i \) excluding the \( i \)th unit. By construction,

\[ \eta_{it} \perp \tilde{y}_{-i,t}. \tag{3} \]

Let \( y_{it}^1 \) and \( y_{it}^0 \) denote the outcomes of receiving the treatment and not receiving the treatment, respectively. Let the dummy variable \( d_{it} \) denote the treatment status for unit \( i \) at time \( t \) with \( d_{it} = 1 \) indicating receiving treatment and \( d_{it} = 0 \) otherwise. We assume that between time 1 to \( T \), no unit received the treatment, \( y_{it} = y_{it}^1 \), and at time \( T+1 \), the first unit received the treatment, \( y_{it} = y_{it}^1 \), \( t = T+1, ..., T \), while other units still received no treatment, \( y_{it} = y_{it}^0 \), \( i = 2, ..., N \) and \( t = 1, ..., T \).

Then

\[ y_{it}^0 = E(\tilde{y}_{it}^0|\tilde{y}_{-i,t}) + \eta_{it}, t = T+1, ..., T. \tag{4} \]

Under the assumption that conditional on \( \tilde{f}_i \),

\[ \tilde{y}_{-i,t} \perp d_{it}, \text{ for any } s, t = 1, ..., T. \tag{5} \]

HCW suggests to approximate \( E(\tilde{y}_{it}^0|\tilde{y}_{-i,t}) \) by \( a + b \tilde{y}_{-i,t} \) and to predict \( y_{it}^0 \) by

\[ \tilde{y}_{it}^0 = a + b \tilde{y}_{-i,t}, \tag{6} \]

where \( \tilde{y}_{-i,t} \) is a subset of \( \tilde{y}_{1,t} \). To select \( \tilde{y}_{-i,t} \), HCW suggested using some model selection criterion, say AIC (Akaike, 1973, 1974) or AICC (Hurvich & Tsai, 1989). Li and Bell (2017) suggested using LASSO (Tibshirani, 1996).

Then treatment effects are estimated by

\[ \hat{\Delta}_{it} = y_{it} - \tilde{y}_{it}^0, t = T+1, ..., T. \tag{7} \]

The standard error of \( \hat{\Delta}_{it} \) is simply the standard error of \( y_{it}^0, s_{y0} \), which can be estimated by some standard prediction error variance formula.\(^4\) The confidence band is then just \( \Delta_{it} \pm cs_{y0} \), where \( c \) is the critical value of the desired significance level.

The average treatment effect (ATE) averaged over the whole policy evaluation period \( T+1 \) to \( T \) can be estimated by

\[ \hat{\Delta} = \frac{1}{T-T_1} \sum_{t=T_1+1}^{T} \hat{\Delta}_{it}. \tag{8} \]

\(^4\)Although the data we use are non-stationary, under \( E(\eta_{it}|\tilde{y}_{-i,t}) = 0 \), it was shown by Phillips and Durlauf (1986) and Masini and Medeiros (2020) that the asymptotic distribution of the least square estimator is mixed normal, hence conventional \( t \) and \( F \)-test statistics can still be applied.
3 | CHINA’S CONTAINMENT POLICIES TOWARDS THE OUTBREAK OF COVID-19

Wuhan City was the epicenter of COVID-19 in China. By 24:00 on 23 January, the confirmed cases in Wuhan and all the Hubei Province (including Wuhan) reached 495 and 549 respectively, accounting for 76.98% and 85.40% of the confirmed cases in China.

After about a month of uncertainty towards the transmission mechanism of COVID-19, China adopted the risk-based prevention and control measures (WHO, 2020) to contain its spread. To strike a balance between epidemic prevention and control, and sustainable economic and social development, different containment policies were adopted depending on the risk level. Each region at or above the county level was classified by risk level: low, medium, and high. The risk level assessment is comprehensively judged according to both the newly confirmed COVID-19 cases and cumulative confirmed cases of counties (cities, districts) (The State Council, 2020). Different prevention and control measures for ‘epicenter’ and ‘non-epicenter’ were then adopted.

3.1 | Epicenter of COVID-19

To suppress the spread of COVID-19, the central government of China imposed an unprecedented closure of Wuhan starting from 10 AM on 23 January 2020 with the rest of Hubei Province following the next day. First, all external traffic to all municipalities in Hubei was closed. The cordon sanitaire around Wuhan and neighbouring municipalities effectively prevented further exportation of infected individuals to the rest of the country (WHO, 2020).

Second, to minimize mobility among all communities and villages in urban and rural areas, Hubei Province implemented closed management and community grid measures 24 h a day. For instance, Wuhan City organized more than 30,000 cadres and workers to go into its 7148 different residential areas to monitor body temperature and human movement. Combined with nucleic acid testing, dynamic rolling screening was carried out for all residents. This medical ‘isolation’ played a key role in effectively reducing infection in communities.

Third, the central government quickly mobilized the best national medical resources including three academic teams, the top medical teams, over 40 thousand medical workers, various anti-epidemic materials, and necessities to support the health care system in Wuhan city and Hubei province. With the sudden COVID-19 outbreak overwhelmed the health-care system, specialist hospitals ‘Leishenshan’ and ‘Huoshenshan’ were built within 10 days which increased the number of beds for severe cases to more than 9100. For patients with mild symptoms, 16 temporary Fangcang shelter hospitals were built for early medical intervention. The practice managed ‘to relieve the huge pressure on the healthcare system, Fangcang shelter hospitals have also been crucial’ (The Lancet, 2020).

Fourth, to identify the ‘four types of people’ (confirmed, suspected, fever and close contacts of confirmed patients) as early as possible, timely testing, and quarantining was very important. The Chinese government traced the health status of different individuals working containment rate and even non-economic activities containment rate of susceptible, infected and recovered people, and imposed ‘social distancing’ policies to minimize the interactions among people (Eichenbaum et al., 2020a, 2020b). During the lockdown period, Wuhan City conducted two rounds of net-pulling COVID-19 testing on 4.21 million residents to ensure that no new potential infection sources occurred. After the lockdown was lifted, 9.9 million residents all over Wuhan were tested and the detection rate of asymptomatic infection was merely 0.303 per 10,000 people.

Footnotes:
5 The Third Plenary Session of the 18th Central Committee of the Communist Party of China (CPC) in 2013 first initiated the community grid management system, which aims at building a better, more efficient and modernized platform for social management and services. The system divides populous urbanized areas into “grids”/various blocks and communities, to let high-tech digital platforms, social volunteers and local police jointly and actively find and handle social issues for local residents, so to improve the management and service over the whole society.
https://www.globaltimes.cn/content/1178528.shtml
6 The teams are led by Nanshan Zhong, Lanjuan Li, and Chen Wang.
7 Infected people do not work unless they recover. As a result, all susceptible people can work without fear of becoming infected. The planner sets the consumption of infected people to a minimum. Because infected people are completely isolated, the initial infection quickly dies out without causing a recession (Eichenbaum et al., 2020a).
The combination of the above-mentioned decisive and strict containment measures and the rescue strategy allowed Hubei Province, the ‘epicenter’ with a population of around 60 million to achieve zero newly confirmed cases for 14 consecutive days in about two months of ‘Great Isolation’, and to restore the normal social-economic order.8

### Non-epicenter regions in China

The newly and cumulative confirmed cases in the non-epicenter regions were far below those of the epicenter, hence the prevention and control measures in the non-epicenter regions were small-scale, much less restrictive, and accordingly lasted for a short period. Specifically, low-risk regions were requested to remain vigilant against any potential inbound transmission while maintaining normal order in work and daily life; medium-risk regions had to prevent inbound from high risk regions and to (i) wear face masks in public places; (ii) register resident’s personal information and submit them to temperature check when leaving or entering the residential area or village; (iii) control the capacity of public transport; (iv) cancel mass gathering activities, etc. in order to restore normal work and daily life as soon as possible.

Table 1 provides a time table for the various anti-epidemic actions taken and their gradual reduction between 31 December 2019 and May 2020.

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8Dr. Tedros, the WHO Director-General, comments that Wuhan and Hubei’s “Great Isolation” is a “heroic act” which was unprecedented and unparalleled anywhere else in the world.
We focus on the 31 provinces (municipalities and autonomous regions) in mainland China that consistently reported data are available. Provincial-level macroeconomic variables are mainly drawn from the National Bureau of Statistics of China (NBSC). We convert nominal variables into real terms with appropriate and available price deflators/index (provincial-level GDP index and consumer price index [CPI]). Table 2 provides the period and frequencies of the variables under study.

Hubei is the only treatment province in our study. As for the control group, we note that COVID-19 cases have been confirmed in all provinces of China. Conditional on the common factors, \( f_t \), (5) requires \( \bar{y}_{-1:t-1} \perp d_t \). We use two criteria to select the control units: (i) the severity of the COVID-19 across regions; (ii) the economic interdependence between Hubei and the control group province.9

The risk-based prevention and control approach allowed different regions to impose different containment measures depending on the perceived risk level. Figure 1 graphically shows the severity of the COVID-19 epidemic, measured as the number of confirmed COVID-19 cases, in Hubei Province and non-epicenter regions in China. It shows that as of 30 June 2020, there were a total of 68,135 confirmed COVID-19 cases in Hubei Province, accounting for 82% of cases in the whole nation and far more than any other single province in China. For instance, Guangdong Province had the second-highest number (1641), but only accounted for 2.41% of the cases in Hubei Province. Tibet had the lowest number, indeed, only one person. The confirmed cases of COVID-19 in Guangdong, Henan, Zhejiang, Hunan, Anhui, Heilongjiang, Jiangxi, Beijing, Shandong and Shanghai, all exceeded 1% of the confirmed cases in Hubei (682 people).

Since the risk level assessment was judged according to the newly confirmed COVID-19 cases and cumulative confirmed cases of counties (cities, districts) (NHC, 2020), we use Figure 1 to determine our non-confounded units. Under this criterion, provinces having more newly confirmed COVID-19 cases or cumulative confirmed cases should have adopted stricter control measures, and their macro-economies were more likely to be

9Some might be concerned that the lockdown in Hubei may have affected the control group through supply chain disruptions condition on that there are important supply chain linkages between Hubei and control group provinces. We address this concern by setting the second control group selection criterion to formally test the economic interdependence between Hubei and the control group provinces.
significantly affected. Based on this consideration, we exclude the ten provinces whose confirmed COVID-19 cases exceeded 1% that of Hubei Province—Guangdong, Henan, Zhejiang, Hunan, Anhui, Heilongjiang, Jiangxi, Beijing, Shandong, and Shanghai (shown in Figure 1) to minimize the influence of Hubei control measures on our control group provinces.10

We are not able to find interprovincial trade data to check the interdependence of the economy between Hubei and other regions. So we resort to use the correlations between Hubei’s first, second, and tertiary industries, export, steel output, auto output (denoted as \(i = 1, 2, 3, 4, 5, 6\), respectively) with each possible control unit’s GDP, first, second, third industry, retail sales, import and export, fixed capital investment, real estate investment, road freight volume, steel and auto output (denoted by \(j = 1, 2, \ldots, 11\), respectively). However, in a multivariate framework pair-wise correlations or no correlations could be spurious due to the failure to take account the impact of omitted factors (e.g., Hsiao, 1982a, 1982b).11 Therefore, we propose to simultaneously test all pairwise correlation coefficients equal to zero to avoid possible omitted variables effects.12 Taking account that \(\rho_{ij} \neq \rho_{ji}\) and available degrees of freedom for estimating \(\rho_{ij}\) could be

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10As a referee points out, Hubei is a major labour export province, the production in other provinces may have been impacted by the absence of employees who left for the Lunar New Year but could not return due to travel restrictions. However, such impact is limited in our study, because Hubei’s outgoing population mainly flowed to Guangdong Province, Zhejiang Province, Shanghai and Beijing municipalities, which have already been excluded from our control group. These provinces/municipalities are economically well-developed, and Hubei has close economic relations and frequent personnel exchanges with them. As a result, the confirmed cases of COVID-19 in Guangdong, Zhejiang, Beijing, and Shanghai, all exceeded 1% of the confirmed cases in Hubei (Figure 1), hence have been dropped from our control group.

11The concept of causality has intrigued philosophers and scientists for millennia. Short of an econometric model to capture the causal relations among the variables under consideration, correlation measures are used. However, ‘causality does not necessarily imply nonzero correlation. There could be a third factor or nonlinearity that leads to weak or no correlation, even if the true relationship is causal’, as pointed out by a referee.

12For details about the computation of pair-wise correlation coefficients, please see supporting information Part A.

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FIGURE 1 Map of the COVID-19 distribution in China, cumulative number of confirmed cases at the province level. Notes: Data were accessed on 30 June 2020, from COVID-19 information updates from the Baidu COVID-19 live information provided and updated by the national and provincial official health commissions (https://voice.baidu.com/act/newpneumonia/newpneumonia)
different for different pairs, we generalize the Breusch and Pagan (1980) Lagrange Multiplier test to compute the statistics (LM)\(^{13}\):

\[
LM = \sum_{i=1}^{6} \sum_{j=1}^{11} T_{ij} \hat{\rho}_{ij}^2
\]  

where \(T_{ij}\) denotes the number of time series observations used to compute \(\hat{\rho}_{ij}\). \(\hat{\rho}_{ij}\) is computed by taking the first difference of the logarithm of the corresponding observed quantities. Under the null of no correlation, the LM is asymptotically Chi-Square distributed with 66 degrees of freedom.

Table 3 presents the LM statistics p-value with each possible control unit with the degrees of freedom adjusted due to the unavailability of some data. Based on a significance level of 10%, we further exclude Liaoning province from the control group.

### 5 | EMPIRICAL ANALYSIS

In this section, we use the HCW approach introduced in Section 2 to estimate the treatment effects of Hubei Province’s strict and large-scale COVID-19 lockdown policy lasting for 76 days on its macroeconomic outcomes, including GDP,

\(^{13}\)Breusch and Pagan (1980) derived the asymptotic distribution under the assumptions that \(\sqrt{T} (\hat{\rho}_{ij} - \rho_{ij})\) is \(N(0,1)\) and \(\rho_{ij} = \rho_{ji}\). Here, \(\rho_{ij} \neq \rho_{ji}\) and the time series observations, \(T_{ij}\), for estimating \(\hat{\rho}_{ij}\) could be different for different pairs.
value added in the first, second, and the tertiary industries respectively; the ‘Troika’ of the economy, that is, investment, consumption, export and import. We also evaluate the impacts on the real estate and the transportation sectors.

## 5.1 Quarterly data models

### 5.1.1 Hubei GDP and value added for the first, second, and tertiary industries

Data from 2012:q1 to 2019:q4 are used to predict the quarterly GDP before the implementation of the lockdown in Hubei, and the policy evaluation period is from 2020:q1 to 2020:q3/q4 due to different data availability.

Table 4 provides the estimated models for GDP (A) and the value added of the primary (B) secondary (C), and tertiary (D) industries in the upper panels. Table 4 provides the estimated treatment effects in the lower panels. Table 4

### TABLE 4 GDP and its sectoral components (100 million yuan)

| (A) GDP | (B) Primary industry value added |
|------------------|------------------|
| \[ y_{it}^0 = 1012.281 - 0.3609Jilin + 1.0308Shaanxi + 1.0347Guizhou \] | \[ y_{it} = -99.0103 + 1.7246Hainan + 2.5588Gansu \] |
| (212.9653) | (77.4295) |

| R^2 = 0.9838 | R^2 = 0.9777 |

### Treatment effects, 2020:q1-q4

|          | Actual | Predicted | Treatment |
|----------|--------|-----------|-----------|
| 2020:q1  | 4709.3180 | 7481.8810 | -2772.5630 |
| 2020:q2  | 8341.8320 | 8628.3170 | -286.4854 |
| 2020:q3  | 9210.3390 | 9154.1320 | 56.2070 |
| 2020:q4  | 10348.6300 | 10058.3800 | 290.2471 |
| Average  | 8152.5300 | 8830.6780 | -678.1486 |

|          | Actual | Predicted | Treatment |
|----------|--------|-----------|-----------|
| 2020:q1  | 399.1517 | 480.5468 | -81.3952 |
| 2020:q2  | 586.3435 | 567.6416 | 18.7019 |
| 2020:q3  | 1239.0140 | 1365.6230 | -126.6088 |

|          | Actual | Predicted | Treatment |
|----------|--------|-----------|-----------|
| 2020:q1  | 4709.3180 | 7481.8810 | -2772.5630 |
| 2020:q2  | 8341.8320 | 8628.3170 | -286.4854 |
| 2020:q3  | 9210.3390 | 9154.1320 | 56.2070 |
| 2020:q4  | 10348.6300 | 10058.3800 | 290.2471 |
| Average  | 8152.5300 | 8830.6780 | -678.1486 |

|          | Actual | Predicted | Treatment |
|----------|--------|-----------|-----------|
| 2020:q1  | 399.1517 | 480.5468 | -81.3952 |
| 2020:q2  | 586.3435 | 567.6416 | 18.7019 |
| 2020:q3  | 1239.0140 | 1365.6230 | -126.6088 |

| (C) Second industry value added | (D) Tertiary industry value added |
|------------------|------------------|
| \[ y_{it}^0 = 416.4963 + 0.5901Fujian + 2.8073Ningxia \] | \[ y_{it} = -683.5792 - 0.6772Gansu + 0.3857Jinangsu + 0.8263Yunnan \] |
| (186.2969) | (219.3129) |
| (0.0373) | (0.0382) |
| (0.4419) | (0.0501) |

| R^2 = 0.9019 | R^2 = 0.9390 |

### Treatment effects, 2020:q1-q3

|          | Actual | Predicted | Treatment |
|----------|--------|-----------|-----------|
| 2020:q1  | 1584.9430 | 2913.3120 | -1328.3690 |
| 2020:q2  | 3521.2780 | 3760.4240 | -239.1455 |
| 2020:q3  | 3640.6560 | 3769.3240 | -128.6680 |
| Average  | 2915.6270 | 3481.0260 | -565.3942 |

|          | Actual | Predicted | Treatment |
|----------|--------|-----------|-----------|
| 2020:q1  | 399.1517 | 480.5468 | -81.3952 |
| 2020:q2  | 586.3435 | 567.6416 | 18.7019 |
| 2020:q3  | 1239.0140 | 1365.6230 | -126.6088 |
| Average  | 399.1517 | 480.5468 | -81.3952 |

|          | Actual | Predicted | Treatment |
|----------|--------|-----------|-----------|
| 2020:q1  | 399.1517 | 480.5468 | -81.3952 |
| 2020:q2  | 586.3435 | 567.6416 | 18.7019 |
| 2020:q3  | 1239.0140 | 1365.6230 | -126.6088 |
| Average  | 399.1517 | 480.5468 | -81.3952 |

Note: 1. The table reports the baseline estimated results including (1) the predictive models using the pretreatment period sample when the COVID-19 lockdown policy was not implemented and (2) the estimated COVID-19 lockdown treatment effects for each time point, which is the difference between actual data and the predicted values approximated using the predictive models for quarterly GDP (A), value added for primary, secondary and tertiary industries (B–D), respectively. 2. Standard errors are in parentheses. 3. Data source: National Bureau of Statistics of China (NBSC).
(A) shows that using the AICC model section criterion, Jilin, Shaanxi, and Guizhou provinces are selected to construct the hypothetical growth path of Hubei GDP had there been no drastic COVID-19 lockdown. The coefficients are significant at 1% level and R-square is above 0.98.  

To predict the post-treatment counterfactuals for Hubei, we apply the estimated weights to the post-treatment data from 2020:q1 to 2020:q4 of the control group provinces. The actual GDP of Hubei and the counterfactuals constructed upon the control groups are reported in lower panels of Table 4 (A). The estimated COVID-19 lockdown impacts are simply the difference between the two. Figure 2a,b plots the actual and constructed growth paths for the period 2020:q1 to 2020:q4. The dotted lines in Figure 2b denote the 95% confidence bands of the counterfactuals. The corresponding data series are presented in Table 4 (A).

Figure 2a,b shows that starting from the treatment quarter 2020:q1 when Hubei Province was under the strict, large-scale lockdown policy, the hypothetical line diverges from the solid line: The counterfactual GDP values are above the actual GDP lines for the post-treatment period. It indicates the lockdown had immediately caused a pronounced negative impact on Hubei's aggregate GDP. And the effect is statistically significant at a 5% level as indicated in Figure 2b. Table 4 (A) suggests that in the lockdown quarter, the treatment effect was $-277.2563$ billion yuan, around 37% of the predicted counterfactual value.

The COVID-19 epidemic in Wuhan and Hubei was completely suppressed in early April and the lockdown policy was lifted. Table 4 (A) shows that in the second quarter, the magnitude of the huge negative impact on GDP quickly narrowed, from $277.2563$ billion yuan to $28.6485$ billion yuan (around 3% of the predicted counterfactual). In the first two quarters of 2020, the average treatment impact was $-152.9524$ billion yuan. And in the whole year of 2020, the average treatment impact decreased to $-67.8149$ billion yuan. Figure 2b indicates that the COVID-19 lockdown policy effect on Hubei's quarterly GDP in 2020:q2 is negative and statistically significant at 5% level but quickly becomes zero in 2020:q3. Moreover, it becomes positive in the fourth quarter, although it is barely statistically significant.

Based on the above evidence, we find that the strict COVID-19 containment policy caused Hubei's economy to bear huge costs. However, after re-opening, the magnitude of the huge loss was quickly reduced. As a matter of fact, the GDP of Hubei restored to the counterfactual level without the COVID-19 lockdown policy in the third quarter of this year.

To further investigate the potential heterogeneous responses of different sectors to the COVID-19 lockdown policy in Hubei, we estimate its impacts on the value added of the primary, secondary and tertiary industries respectively.

The upper panels of Table 4 (B–D) present the estimated predictive models based on the pretreatment data. The control provinces are Hainan and Gansu for primary industry, Fujian and Ningxia for secondary industry, and Gansu, Jiangsu, and Yunnan for tertiary industry. The R-squares are all high and t-statistics of the coefficients of all these provinces are significant.

Figure 2c–e plots the actual and hypothetical series on value added for the primary, secondary, and tertiary industries before and after the treatment. The corresponding data series are presented in Table 4 (B–D). The estimated treatment effects are summarized as follows.

For primary industry, Table 4 (B) shows that in 2020:q1, the treatment effect was $-8.1395$ billion yuan suggesting that primary industry value added in Hubei was 17% below that of the counterfactual Hubei. After the lockdown was lifted, this negative impact quickly reduced to zero in 2020:q2 (There is a positive treatment effect, however, it is not statistically significant at 5% level). The results suggest that the impact of the COVID-19 lockdown on the agriculture value added was temporary, i.e., limited to the lockdown period, and quickly recovered.

Our finding is supported by statistics provided by the Department of Agriculture in Hubei Province. In the first half of 2020, Hubei achieved a ‘Double Harvest’ of summer grain and summer oil, with output increased by 3.3% and 14.0%, respectively. Therefore, although agricultural value added declined dramatically during lockdown, the loss was temporary. Also, we notice that there is a negative impact of $12.6609$ billion yuan in 2020:q3. The impact of the COVID-19 lockdown on spring ploughing in Hubei may lead to a decline in agricultural output in autumn, thus reducing agricultural value added in the third quarter.

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14Some of the coefficients are negative because the HCW approach is not a causal analysis. It is to select control units that can help to obtain more accurate predictions, whether they are positively or negatively correlated with the outcomes.

15Since $T_1$ is much larger than $(T-T_1)$, as shown by Masini and Medeiros (2020), the conventional approach of constructing confidence bands still holds under (5) even the data are non-stationary.

16To graphically show whether the estimated COVID-19 lockdown effect is statistically significant at 5% level, we draw Figure 2b showing the estimated treatment effects' 95% confidence band for GDP as an illustrative example. All the other post-treatment figures are available from the authors upon request.

17Satellite remote sensing monitoring data of spring ploughing in Hubei Province shows that, the uncultivated land area in Hubei Province decreased by about 5% in March 2020 compared with March 2019.
Figure 2. Treatment effects on GDP, value added for the primary, second, and tertiary industries, and total retail sales estimated using quarterly data models, and treatment effects on industry value added growth rate, fixed capital investment, real estate investment, import and export, export, import, road passenger ridership, and road freight transport volume using monthly data models. Notes: 1. Panels (a)–(n) except panel (b) are for the full sample period including pre-COVID-19 lockdown and post-COVID-19 lockdown period. To graphically show whether the estimated COVID-19 lockdown effect is statistically significant at 5% level, we draw panel (b) showing the estimated treatment effects’ 95% confidence band for GDP as an illustrative example. All the other post-treatment figures are available from the authors upon request. 2. In each figure, the first vertical line denotes the initial time of the COVID-19 lockdown in Wuhan and Hubei, specifically, for panels (a)–(f), $T_1 + 1$ is 2020:q1 and for the rest of the figures, $T_1 + 1$ is 2020:m2 except panel (g). For panel (g), $T_1 + 1$ is 2020:m3, as data in 2020:m2 for industry value added growth rate on a year-by-year basis is not reported by NBSC. 2. In each figure, the second vertical line denotes the time when the unlock policy was implemented, for panels (a)–(f) it is 2020:q2 and for the rest of the figures, it is 2020:m4. 3. For fixed capital investment, the NBSC only reports the monthly cumulative value, for example, for m1-m2, m1-m3, m1-m4, and so on, so we can calculate the cumulative value of months m1-m2, and the monthly values for m3, m4, m5, ..., m12 respectively. 4. There is missing data for road passenger ridership for Hubei in 2020:m2, but data are available for the control group provinces hence counterfactual Hubei in 2020:m2 can be predicted as shown in panel (j). Data source: National Bureau of Statistics of China (NBSC).
(g) Industry value added growth rate

(h) Fixed capital investment

(i) Real estate expenditure

(j) Import & export

(k) Export

(l) Import

(m) Road passenger ridership

(n) Road freight volume

FIGURE 2  (Continued)
For secondary industry, Table 4 (C) shows that in 2020:q1 the COVID-19 lockdown caused a 132.8369 billion yuan loss of the value added, accounting for over 46% of the counterfactual values had there been no treatment. This loss was much larger in both magnitude and percentage compared with the loss in the primary industry value added. However, after the lockdown policy was lifted, the loss quickly reduced to 23.9146 billion yuan (approximately 6% of the predicted counterfactual). The average loss in the first three quarters of 2020 was 56.5394 billion yuan. Our results also show that the negative treatment effects for 2020:q1 and 2020:q2 are statistically significant at 5% while the negative impact become almost statistically insignificant in 2020:q3.

For tertiary industry, Table 4 (D) shows the magnitude of the quarterly value added loss was 124.9954 billion yuan (31% of the counterfactual Hubei) during the lockdown period which was reduced to 46.2165 billion yuan (10% of the counterfactual Hubei) on average after re-opening. The treatment effects are statistically significant at 5% level. Compared with primary and secondary industries, tertiary industry recovered more slowly. One possible explanation is that the service sector, in general, most requires face-to-face communication. For Hubei, the epicenter of COVID-19, even if there were no newly confirmed cases after re-opening, people might still prefer to cut back unnecessary travel or consumption compared with non-treated regions in the short-run. In particular for tourism, hotel and catering, and traditional offline commerce, these industries suffered the most damage due to the epidemic, and need a much longer time to recover.

Lastly, Table 4 suggests that Hubei’s GDP in the first half of 2020 (470.9318 + 834.1832 = 1305.115 billion yuan) has recovered to 81% of the counterfactual value (748.1881 + 862.8317 = 1611.0198 billion yuan) although effective working time was reduced by more than two months due to COVID-19 lockdown. In the whole year 2020, this ratio has further increased to 92%. And for primary, secondary, and tertiary industries, their value added has recovered to approximately 94%, 77%, and 82% of their counterfactuals respectively in the first half of 2020, and to 92%, 84%, and 84% in the whole year 2020.

5.1.2 | Consumption expenditure

Since modern economies are driven substantially by consumer demand, we also evaluate the total retail sales of consumer goods, a major indicator of consumption, during the lockdown and its aftermath. Table 5 shows the estimated coefficients of the predicted model based on AICC criterion selected control group provinces: Sichuan and Shaanxi. The value of $R$-square is very high for the in-sample fit of this index, suggesting that retail sales in control provinces serve as good predictors for that of Hubei.

Figure 2f shows a similar pattern for the total retail sales of consumer goods, it bottomed out in the quarter of COVID-19 lockdown and then rebounded rapidly in the quarter when Hubei was unlocked. The right panel in Tables 4 and 5 shows that the value of the negative treatment impact narrowed significantly by around 58%, i.e., from around −92.6388 billion yuan to −38.9490 billion yuan. Although the lockdown has led to significant drop in retail sales, Hubei’s consumption market has quickly recovered since the second quarter of 2020. The lockdown did not shatter consumer confidence because since April, various industries in Hubei Province have vigorously resumed work and production, and the living order of residents has quickly recovered. In addition, the central and local governments, as well as enterprises, have provided various stimulus packages. Data from Hubei Provincial Bureau of Statistics shows that, (1) the consumption of basic living goods (grain, oil and food) recovered rapidly. (2) Consumption has changed from offline to online, which has greatly promoted the development of new online retail formats. (3) The most affected industries are catering and tourism. In order to accelerate the recovery of tourism, on May 1 Hubei provincial government announced the measures to support the recovery and revitalization of cultural tourism industry. Further, in July, Hubei Provincial Department of Culture and Tourism issued the notice on promoting tourism enterprises to expand resumption of work and business.

We notice that the counterfactual path for Hubei’s retail sales after the COVID-19 lockdown treatment also has a V-shaped pattern as shown in Figure 2f. Our finding also corroborates the Mid-year Report on the Analysis and Forecast of China’s Macro-economy in 2020 (Shanghai University of Finance and Economics, 2020). Using the dynamic structural model to do counterfactual and scenario analysis, the Report finds that after matching the decline of total output, consumption dropped by 17.3%, far more than the extent that total output decreased, and 72% of the decline is due to the cutback in this category. The data suggests that during the COVID-19 lockdown period, the travel restrictions severely dampened consumption in this area. Moreover, the COVID-19 also triggered a massive spike in uncertainty could be another main cause of consumption decline.
Lastly, although effective working time was reduced by more than two months due to the COVID-19 lockdown, Table 5 suggests that total retail sales have recovered to around 82% of its counterfactual level.

### 5.2 Monthly data models

In this section we use monthly data to study the impacts of lockdown on Hubei economy.

#### 5.2.1 Industry value added growth rate

Based on AICC we selected Xinjiang, Jilin, Shaanxi, Gansu, Shanxi, Tibet, and Inner Mongolia to construct the hypothetical growth path of Hubei on a year-by-year basis. Table 6 reports the OLS weights for the period 2017:m7 to 2019:m12 and shows the standard errors of the coefficients of the selected provinces and $R^2$-square. Figure 2g plots the actual and constructed growth paths for the period 2017:m7 to 2020:m12 and shows that before treatment, the counterfactual path of industry value added growth rate traces quite well the actual path of Hubei before the start of the COVID-19 lockdown.

Table 6 shows that when the COVID-19 lockdown policy started in Hubei, the monthly industry value added growth rate on a year-by-year basis of Hubei dropped sharply by about 54% in March relative to the counterfactual. But when the ‘lockdown’ was lifted, the drop in growth rate quickly reduced to approximately −6% in April, −6% in July, and −1.2% in December. The average negative effect was −54% during the lockdown period and −4% after re-opening, indicating that approximately 93% of the drop in industry value added growth rate has been recovered. The monthly negative effects during the lockdown and its aftermath become statistically insignificant since 2020:m9.

Hubei government statistics corroborate our findings. Provincial Department of Economy and Information Technology reports that in the first quarter of 2020, the value added growth rate on a year-by-year basis maintained positive only for tobacco products, mining, and oil and gas exploitation industries among the 41 major industries in Hubei, while all the other 38 industries declined. However, by mid-April (after Wuhan was re-opened), the rate of work resumption for enterprise above the designated size in Hubei quickly reached 98.2%, approaching the national average. In the first quarter, Hubei’s comprehensive production capacity recovered by nearly 60%. And the negative impacts of industry value added growth rate in Hubei Province fully recovered in the second half of 2020.

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18Provincial-level industry value added values are not available from NBSC, but its growth rate on a year-by-year basis is available and consistently reported, so we use the growth rate instead.
5.2.2 | Private fixed capital investment

Table 7 reports the monthly predicted model for private fixed capital investment. The AICC selected control provinces are Sichuan, Gansu, Chongqing, and Guizhou. Table 7 (lower panel) reports the monthly impact of lockdown and its aftermath.

Table 7 shows that the drastic COVID-19 lockdown in Hubei caused the fixed capital investment to decrease by 168.8403 billion yuan in 2020:m2. And by 2020:m3, the value of the loss further falls to 278.6635 billion. The average loss equals −223.7519 billion yuan during the lockdown period, approximately 82% of the counterfactual. However, when Hubei Province was unlocked, the huge losses in fixed capital investment gradually recovered from April to June and to December. The average loss after re-opening (2020:m4–2020:m6) equalled −161.2526 billion yuan, 41% of the counterfactual and further reduce to 36% in December. Table 7 also suggests that fixed capital investment by the end of 2020 had recovered to more than 57% of the counterfactual.

Lastly, Figure 2h shows that it is quite remarkable that, the post-sample predictions closely matched the actual turning points at a higher level for the COVID-19 lockdown treatment period for fixed capital investment, even when no Hubei data were used.

5.2.3 | Real estate expenditure

To construct counterfactuals for the real estate expenditure in Hubei, Table 8 shows that our AICC selected control provinces are Jilin, Shanxi, Hebei, and Chongqing, and in-sample fits well. Figure 2i also shows that the dashed hypothetical lines track the solid line quite closely before the treatment.

### Table 6

| Province       | Industry value added growth rate |
|----------------|----------------------------------|
| Xinjiang       | $0.0760 – 0.1827Xinjiang – 0.0845Jilin – 0.1224Shaanxi + 0.1312Gansu + 0.2645Shanxi + 0.0654Tibet – 0.1390Inner Mongolia| |
| Jilin          | (0.0089)                        |
| Shanxi         | (0.0637)                        |
| Gansu          | (0.0482)                        |
| Tibet          | (0.0607)                        |
| Inner Mongolia | (0.0370)                        |
| Xinjiang       | (0.0882)                        |
| Jilin          | (0.0320)                        |
| Shanxi         | (0.0458)                        |
| R²             | 0.6535                          |

**Treatment effects, 2020:m3–2020:m12**

| Year          | Actual | Predicted | Treatment |
|---------------|--------|-----------|-----------|
| 2020:m3       | −0.4690| 0.0735    | −0.5425   |
| 2020:m4       | −0.0240| 0.0656    | −0.0896   |
| 2020:m5       | 0.0200 | 0.0752    | −0.0552   |
| 2020:m6       | 0.0200 | 0.0651    | −0.0451   |
| 2020:m7       | 0.0220 | 0.0886    | −0.0666   |
| 2020:m8       | 0.0490 | 0.1048    | −0.0558   |
| 2020:m9       | 0.0620 | 0.0927    | −0.0307   |
| 2020:m10      | 0.0930 | 0.0850    | 0.0080    |
| 2020:m11      | 0.0610 | 0.0954    | −0.0344   |
| 2020:m12      | 0.0790 | 0.0909    | −0.0119   |
| Average       | −0.0087| 0.0837    | −0.0924   |
| 2020:m3       | −0.4690| 0.0735    | −0.5425   |
| Average       | −0.4690| 0.0735    | −0.5425   |
| 2020:m4–2020:m12 |       |           |           |
| Average       | 0.0424 | 0.0848    | −0.0424   |

**Note:** 1. The table reports the baseline estimated results for industry value added growth rate. 2. As NBSC does not report industry value added growth rate for January or February, our post-treatment period of this index starts from 2020:m3 and the average treatment effect in the lockdown period is just the monthly estimates for 2020:m3. 3. Other notes are the same as notes 2 and 3 in Table 4.
Table 8 suggests that in February 2020, the COVID-19 lockdown policy in Hubei province sharply decreased the real estate purchases around 14.95 billion yuan and the loss further increased to 40.68 billion yuan in March. When Hubei was unlocked, the negative impacts bottomed out in April, rebounded to about 5.22 billion yuan in May and turned positive since July. In sum, in the first half of 2020, real estate expenditure recovered to around 63% of its counterfactual value and the ratio was even higher at 94% for the whole year 2000.

5.2.4 | Import and export

For the pretreatment period, Table 9 (A) presents the estimated weights based on the pretreatment data and the AICC selected control provinces. Table 9 (A) also presented the post-treatment outcomes. It shows that the COVID-19 lockdown caused the values of Hubei to drop by about −7.6497 billion yuan in 2020:m2, and the loss expanded to over −14.0589 billion yuan in 2020:m3. When Wuhan and Hubei were unlocked in April, the negative impacts narrowed rapidly and further reduced to around −2.4302 billion yuan in 2020:m6. Since 2020:m9, the impacts have become positive but statistically insignificant at 5% level. The average loss was −10.8543 billion yuan (about 28% of the counterfactual value) in the lockdown quarter (2020:m2–2020:m3) and −1.6660 billion (around 4% of the counterfactual value) after re-opening (2020:m4–2020:m12).

For export, Table 9 (B) shows that the average loss was 7.9367 billion yuan (approximately 36% of the counterfactual) during the lockdown period and decreased to 2.1565 billion yuan (around 8% of the counterfactual) after the unlock policy. For import, results show that the average loss was 4.5330 billion yuan (about 25% of the counterfactual) during the lockdown period and decreased to 0.5114 billion yuan (around 4% of the counterfactual) in the re-opening period 2020:m4–2020:m12.
In sum, the treatment effects for export (Table 9B) and import (Table 9C) show that (1) there are decreasing trends for the magnitude of the losses for both export and import; (2) the magnitude of the average treatment effects for the losses of export is 2.5 times that of the import losses.

In addition, results in Table 9 show that in the first half of 2020, Hubei’s total import and export value has recovered to over 82% of the counterfactual level, among which export recovered to 77% and import reached 81%. Especially after re-opening (2020:m4 – 2020:m12), the values of total import and export, export, import recovered as high as 96%, 92% and 96%.

5.2.5 | Transportation sector

We evaluate the impacts on road passenger ridership and road freight volume.\textsuperscript{19} Table 10 shows that the COVID-19 lockdown in Hubei Province resulted in a huge reduction in road passenger ridership of more than 22 million people in 2020:m3 (92% of the counterfactual). After the lift, the losses of passenger ridership were basically kept at this level, but the proportion of the loss relative to their counterfactuals for each month kept decreasing. It was 53% of the counterfactual in 2020:m12. This is owing to the downward trend for road passenger ridership because when income increases, more and more people shifted to using private cars and high-speed rail (the solid line in Figure 2m).

For the impacts on road freight volume, the maximum loss appeared in 2020:m4 (−130.1666 million tons) and then turned to positive in 2020:m6 (31.7554 million tons) and 2020:m12 (15.2892 million tons), due to the quick recovery of

\textsuperscript{19}Consistently reported provincial panel data are available for road transport but not for rail or air aviation.
|                | Predictive model 1 | Predictive model 2 | Predictive model 3 |
|----------------|--------------------|--------------------|--------------------|
|                | R^2                | R^2                | R^2                |
| Actual         | Predicted          | Treatment          | Actual             | Predicted          | Treatment          | Actual             | Predicted          | Treatment          |
|                 |                    |                    |                    |                    |                    |                    |                    |                    |
| 2020:m2        | 386.5230           | 463.4690           | 51.5644            | 179.4426           | 235.5398           | 56.0782            |                    |                    |
| 2020:m3        | 140.0179           | 181.2307           | -101.3668          | 99.2969            | 133.8517           | -34.5878           |                    |                    |
| 2020:m4        | 235.9702           | -61.3905           | -18.9227           | 139.1529           | 133.4536           | -20.9977           |                    |                    |
| 2020:m5        | 253.9669           | -54.3986           | -32.3823           | 111.1253           | 133.8517           | -21.3263           |                    |                    |
| 2020:m6        | 234.3656           | -16.1982           | -12.5591           | 131.0628           | 133.4536           | -14.3714           |                    |                    |
| 2020:m7        | 239.8773           | -57.4616           | -31.1317           | 132.0792           | 132.0792           | -25.8622           |                    |                    |
| 2020:m8        | 348.9504           | -24.9015           | -20.9977           | 139.1529           | 139.1529           | -14.3714           |                    |                    |
| 2020:m9        | 283.9714           | -36.4666           | -21.3263           | 111.1253           | 111.1253           | -14.3714           |                    |                    |
| 2020:m10       | 235.9702           | -61.3905           | -18.9227           | 139.1529           | 139.1529           | -20.9977           |                    |                    |
| 2020:m11       | 253.9669           | -54.3986           | -32.3823           | 111.1253           | 111.1253           | -21.3263           |                    |                    |
| 2020:m12       | 234.3656           | -16.1982           | -12.5591           | 131.0628           | 133.4536           | -14.3714           |                    |                    |
| Average        | 367.1490           | 401.5156           | 32.0743            | 135.7669           | 148.1935           | 12.4266            |                    |                    |

Note: 1. The table reports the baseline estimated results for import and export, export and import, respectively. 2. Other notes are the same as notes 2 and 3 in Table 4.
the second industries. Overall, the recovery process of road freight transportation is consistent with the recovery of GDP in the first half of 2020 as shown in Section 5.1.1.

5.3 Robustness checks

We conduct two robustness checks to evaluate if our constructed counterfactual paths are sensitive to the choice of the control group and predictive models.

5.3.1 LASSO

Our baseline analysis used a model selection criterion, AICC, to select the predictors for constructing counterfactuals. To test the robustness of treatment effects estimates concerning different methods of choosing the best prediction models, we follow Hsiao and Zhou (2019) suggestion to use the LASSO method.

5.3.2 Control group

We also test the sensitivity of the baseline estimation results to changes in our control group. First, some have argued that all the neighbouring provinces which border the epicenter of COVID-19 could be affected by the drastic lockdown
policy due to geographical proximity. We therefore further exclude Chongqing and Shaanxi provinces from the control group and re-conduct the estimation of treatment effects for the macroeconomic variables that have selected Chongqing or/and Shaanxi with non-zero weights in the baseline results (The variables are GDP, industry value added growth rate, fixed capital investment, retail sales and real estate investment).

Second, we drop Eastern coastal provinces that are more export-oriented and have a closer relationship with international markets than inland regions. It is to test whether certain control group provinces could be significantly affected by COVID-19 spread and/or control measures worldwide. Specially, we exclude provinces/municipality with export and import volume ranking Top 5 in China in the pretreatment years 2017–2019 (Guangdong, Jiangsu, Shanghai, Zhejiang, and Beijing). Although in our baseline control group, Guangdong, Shanghai, Zhejiang and Beijing have already been excluded due to the confirmed COVID-19 cases exceeding 1% of those in Hubei, it is helpful to see whether the inclusion of Jiangsu Province changes our conclusions. As the only one variable selecting Jiangsu Province with non-zero weight is tertiary industry value added, we use the same procedure to estimate the impact of the COVID-19 lockdown on it.

Both the findings due to using LASSO method to select the predictors and changes in control units are summarized in Table 11.20 The results are not much different from those reported in Table 12.

### Table 11 Summary of the loss/completion due to LASSO method of selecting the predictor or changes in control units

|                      | Proportion of loss to counterfactual | Proportion of completion to counterfactual |
|----------------------|-------------------------------------|-------------------------------------------|
|                      | LASSO | Control group | LASSO | Control group | LASSO | Control group |
| GDP                  | 35%   | 36%           | 81%   | 82%           | 92%   | 91%           |
| Primary industry value added | 21%   | —             | 94%   | —             | 92%   | —             |
| Second industry value added | 47%   | —             | 77%   | —             | 90%   | —             |
| Tertiary industry value added | 31%   | 32%           | 83%   | 83%           | 86%   | 89%           |
| Industry value added cumulative growth rate | 54%   | 54%           | 82%   | 82%           | 92%   | 91%           |
| Fixed capital investment | 80%   | 80%           | 44%   | 47%           | 56%   | 56%           |
| Retail sales         | 29%   | 31%           | 78%   | 76%           | 77%   | 81%           |
| Export and import    | 28%   | —             | 84%   | —             | 94%   | —             |
| Export               | 34%   | —             | 79%   | —             | 88%   | —             |
| Import               | 16%   | —             | 91%   | —             | 97%   | —             |
| Real estate expenditure | 73%   | 73%           | 62%   | 59%           | 92%   | 86%           |
| Road passenger ridership | 92%   | —             | 38%   | —             | 45%   | —             |
| Road freight volume  | 99%   | —             | 63%   | —             | 88%   | —             |

**Note:** 1. Notes are the same as those in Table 12. 2. As for the robustness checks with respective to changes in control group, we re-estimate the impact of COVID-19 lockdown on variables which select Hubei’s neighbouring provinces or Eastern coastal provinces with none-zero weights in our baseline analysis. See text for details.

### 6 DISCUSSION AND CONCLUSION

We used the HCW and Hsiao and Zhou (2019) panel data programme evaluation approach to assess the economic impacts of Hubei Province’s lockdown policy in times of COVID-19 pandemic. Both aggregate and disaggregate approach demonstrate a common pattern: the impact of lockdown on Hubei’s macroeconomy was huge, but it was temporary and generally controllable. The fundamentals and development trend of the economy have not been changed. Table 12 summarizes the proportion of losses (treatment effects) on Hubei Province’s macroeconomy in 2020:q1 (the COVID-19 lockdown quarter), the proportion of accomplished actual values relative to the counterfactuals in 2020:q2

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20The details of the robust analysis are in the online supplement of this paper.
TABLE 12  Summary of the loss/completion relative to counterfactual Hubei

|                                | Proportion of loss to counterfactual | Proportion of completion to counterfactual |
|--------------------------------|-------------------------------------|------------------------------------------|
|                                | Lockdown quarter                    | Re-opening quarters                      | First half of 2020 | Whole year 2020 |
| GDP                            | 37%                                 | 100%                                     | 81%              | 92%             |
| Primary industry value added   | 17%                                 | 94%                                      | 94%              | 92%             |
| Second industry value added    | 46%                                 | 95%                                      | 77%              | 84%             |
| Tertiary industry value added  | 31%                                 | 90%                                      | 82%              | 84%             |
| Industry value added cumulative| 54%                                 | 96%                                      | 82%              | 91%             |
| growth rate                    |                                     |                                          |                  |                 |
| Fixed capital investment       | 82%                                 | 64%                                      | 46%              | 57%             |
| Retail sales                   | 30%                                 | 87%                                      | 77%              | 82%             |
| Export and import              | 28%                                 | 96%                                      | 82%              | 92%             |
| Export                         | 36%                                 | 92%                                      | 77%              | 88%             |
| Import                         | 25%                                 | 96%                                      | 81%              | 92%             |
| Real estate expenditure        | 71%                                 | 106%                                     | 63%              | 94%             |
| Road passenger ridership       | 92%                                 | 44%                                      | 38%              | 45%             |
| Road freight volume            | 99%                                 | 95%                                      | 63%              | 88%             |

Note: 1. In the table, we have two types of data: quarterly and monthly. For quarterly data, the lockdown quarter is 2020:q1, re-opening quarters are 2020:q2–2020:q4 for GDP and 2020:q2–2020:q3 for value added of the primary, secondary, tertiary industries, and retail sales respectively. For monthly data (fixed capital investment, export, import, real estate expenditure, road passenger ridership and road freight volume), the lockdown quarter is 2020:m2–2020:m3; and for industry value added cumulative growth rate, the lockdown quarter is 2020:m3. The re-opening quarters are 2020:m4–2020:m12 for all the variables. The first half of the year refers to policy evaluation period from the lockdown quarter to 2020:m6 or 2020:q2. And the whole year 2000 refers to the whole policy evaluation period from the lockdown quarter to the end of the re-opening quarters for each macroeconomic indicator respectively.

The first quarter after the unlock policy), the first half of the year 2020, and the whole year 2000 to the Hubei economy without ‘lockdown’ during COVID-19.

Specifically, compared with the counterfactual value had there been no lockdown, the total GDP decreased 37% in 2020:q1. Among them, secondary industry value added had the biggest loss accounting for 46%, and the losses of the service industry and agriculture are 31% and 17% respectively. For the private components of GDP, investment, consumption, export, and import lost 82%, 30%, 36% and 25% of their respective counterfactual values. In addition, real estate investment decreased by 71%. Road passenger ridership and freight volumes suffered huge losses of 92% and 99% to their counterfactuals, respectively. The big loss in the COVID-19 lockdown quarter in Hubei Province lowered China’s GDP growth rate (year-by-year) by 6.8% in the first quarter of 2020. This is the first negative quarterly GDP growth rate since 1992. The severity of this huge loss is rare in the history of the People’s Republic of China.

We also find that since the re-opening quarter after lifting the lockdown, Hubei’s GDP and the value added of its sectoral components all have quickly recovered to over 90% of their counterfactual values. Consumption, export and import, real estate investment, and road freight volume recovered to at least 87% of their counterfactuals. However, the recovery of fixed capital investment and road passenger ridership was relatively slow accounting for 64% and 44% of their counterfactuals, respectively.

How did China achieve such a quick turn around? First, the ‘lockdown’ is temporary. It has not affected the fundamental structure of the economy. Second, the Chinese experience showed that government has a critical role to play in times of pandemic crisis. The ‘lockdown’ brought the spread of COVID-19 to a halt in three months. The central and local governments have coordinated to implement comprehensive plans to resume the production of key enterprises, industrial chain supporting enterprises and small business, as well as to increase the intensity of technological transformation and upgrading of traditional industries. Supports for enterprises with new formats and technologies such as big data, Internet of Things (IoT), 5G and artificial intelligence to integrate, innovate and develop in the fields of social governance, epidemic prevention and control, unmanned logistics and telecommuting were strengthened. All localities were required to set specific targets for major projects of stabilizing, supplementing and strengthening the industrial chain, quantitative assess, and to give priority to the provincial and local key project promotion plans. Enterprises with
annual business income of RMB 20 million and above whose industrial chain and supply chain have been disrupted were requested to submit the situation of enterprises and import demand for the government and China Council for the Promotion of International Trade (CCPIT) to help to resume production as soon as possible through finding alternative domestic or foreign suppliers (https://www.sogou.com/link?url=hedJjaC291Ok-E9WTygIKrVvNc_sKic_gTsDwvrW-3wMpq7G7hr9Q..http://www.hubei.gov.cn/zfwj/ezf/202003/t20200312_2180269.shtml) (Portal website of Hubei Provincial Government). As a result, when the lockdown was lifted, the return-to-work rate has quickly reached 98.8% for large enterprises and 86.9% for small and medium-sized enterprises by the end of June, both have caught up with the national average. Moreover, 1598 new projects were started. Compared with the pre-COVID period, by May, 2020 there was a net increase of 826 new projects.

Third, resilience of people in Hubei also played a pivotal role. They quickly seized the new impetus to stimulate the economy provided by the government and opportunities of reshuffling the supply chain due to the trade tension between China and the US as well as taking advantage of the new opportunities due to COVID-19, such as the new demand for laptops and tablets to support working from home and the new stimulus packages to create new industries and expand existing activities. In June, the value added to Hubei's high-tech manufacturing industry increased by about 9%, which was 7% higher than the growth rate of all the above-scale industries. The output of high-tech products, such as microcomputers, optical fibers, and lithium-ion batteries have increased by around 18%, 11% and 49% respectively. From January to May, the growth rate of the revenue of internet and related services, software, and information technology services were approximately 23% higher than the average growth rate of all service enterprises with annual income of 20 million RMB and above.

In short, conditional on the same assumptions made in HCW, our analysis of the Hubei experience during COVID-19 pandemic showed that a strict lockdown could result in huge economic loss in times of pandemic but it also showed that as long as the epidemic could be quickly contained, the economic loss was temporary and controllable. The economy could quickly return to its pre-pandemic path. However, it should be noted that our analysis was confined to the impacts on the economy of the drastic lockdown policy and did not take into account impacts on quality of life. A smart public policy during pandemic should take account both economic and social factors.

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OPEN RESEARCH BADGES
This article has been awarded Open Data Badge for making publicly available the digitally-shareable data necessary to reproduce the reported results. Data is available at http://qed.econ.queensu.ca/jae/datasets/ke001/.

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