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The Impact of the COVID-19 on Online Food Delivery Service: Evidence from China

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Completed Research Paper

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Abstract

The COVID-19 has had a profound effect on society as a whole. To examine the effect of the COVID-19 on online food delivery services, we collected sales data from a large online food delivery platform in 195 Chinese cities from November 2019 to July 2020. Interrupted time series analysis and time-varying difference-in-difference methods were used to estimate the impact of the COVID-19 and city lockdown policies on online food delivery services. The COVID-19 had a considerable negative effect on the online food delivery services. Lockdown policies caused further disruptions. As the pandemic and lockdown policies ended, the negative impacts dissipated. This finding reflected digital channels' resilience to the catering industry during the pandemic and helped it withstand its impact. There were significant differences among urban characteristics. The government can formulate relevant policies to deal with potential public health risks in the future based on these findings.

Keywords: COVID-19, lockdown policy, OFD services, digital resilience

Introduction

The 2019 coronavirus disease (COVID-19) has spread rapidly, dramatically altering daily life at an unprecedented rate and magnitude (Huang et al. 2020). To control the rapid extension of COVID-19 and ensure social distancing, lockdown policies have been implemented by governments across the world. These lockdown policies include to maintain social distancing and reduce the use of public transportation and public gatherings, school closures, and working from home where possible (Chinazzi et al. 2020). China was one of the first regions to be impacted by COVID-19, and they implemented some of the most rigorous measures, including a restaurant dining ban (Pan et al. 2020). The COVID-19 has caused a tremendous shock to the restaurant industry, leading to decline substantially in sales and employment (Kim et al. 2020).

In the face of this extraordinary situation, restaurants are changing their operations as consumers change their dining behavior. The emergence of large online food delivery (OFD) service platforms such as Meituan and Ele.me has become critical for the survival of the catering industry (Kumar and Shah 2021). OFD is an internet-based service that connects customers with cooperative restaurants by website or mobile applications. As a result, OFD service platforms have become a critical mediator between consumers and restaurants (Ray et al. 2019). Contactless delivery of food prevents direct human contact. Due to the restrictions on dine-in restaurants caused by COVID-19, numerous restaurants have made changes and become heavily dependent on contactless and OFD services to survive. Simultaneously, the OFD service platform has positively impacted consumers. It enables individuals to purchase and obtain food without departing from their residences, providing OFD services with a significant edge (Ahmed et al. 2020).

The following research questions are being attempted to be addressed: (1) What effects did the COVID-19 and its associated lockdowns have on OFD services? (2) How has the impact of COVID-19 on OFD services varied across different urban characteristics?

To explore the effects and resistance capabilities related to the pandemic and associated lockdowns on OFD services, this paper empirically investigates how the COVID-19 affected OFD services platforms. We collected sales data for 195 cities from November 2019 to July 2020 from a major domestic OFD services platform. First, a combination of interrupted time series and meta-analysis was applied to estimate the overall change in OFD services following the COVID-19 outbreak. Second, we combined time-varying difference-in-difference methods with lockdown policy information to determine the effects of implementing and lifting lockdown policies on OFD services. Furthermore, we analyzed the heterogeneity across cities based on the cities' characteristics to further identify which factors affected OFD services during the lockdowns. Finally, a sequence of robustness tests was performed to ascertain the stability of the empirical findings.

Literature Review

OFD services

OFD services are internet-based platforms that enable the ordering and have meals delivered to home. Unlike traditional food ordering systems, OFD is a form of O2O commerce that uses an intermediary platform to process online orders and delivery from an extensive range of registered food restaurants (Ray et al. 2019). As the OFD service industry flourishes (Cheng et al. 2021), OFD services and their impact have attracted scholarly attention. Much literature has discussed social value, economic benefits and development challenges of OFD services.

Studies focused on various geographical locations, including Indonesia (Safira and Chikaraishi 2022), China (Zhang and Wen 2022), Malaysia (Eu and Sameeha 2021), Colombia (Correa et al. 2019), and South Korea (Roh and Park 2019). These studies investigated adoption and consumption intentions of OFD services across regions, focusing on service quality, platform technology and consumer behavior. Navigation design (Kapoor and Vij 2018), information quality (Kang and Namkung 2019), real-time tracking systems (Alalwan 2020), visual design (Cho et al. 2019) and other OFD services platform technologies can make a substantial difference on the readiness to utilize OFD services platforms. In addition, service quality in the management processes such as order delivery (Correa et al. 2019), delivery cost (Safira and Chikaraishi 2022), operational capability (Zhao and Stank 2003), delivery speed (He et al. 2019), and risk management (Govindan et al. 2019) can significantly impact consumer willingness to engage OFD services. Furthermore, convenience (Roh and Park 2019), consumer experience (Morosan and DeFranco 2016), online reviews (Alalwan 2020), subjective norms (Gunden et al. 2020), hedonic motivation (Yeo et al. 2017), and other consumer-intrinsic factors exert a direct influence on the consumption intention of OFD services

Although OFD services have brought convenience to society and benefited the economy, there are some problems related to the development of OFD services (Akkaş and Gaur 2022). In the long term, OFD services could affect lifestyles and family structures (Melián-González 2022). In most cases, OFD services may reduce an individual's physical activity level, leaving people at work or home, skipping shopping, commuting to restaurants, and skipping the labor of preparing meals and cleaning up afterwards. The shift in behavior is expected to heighten the likelihood of negative health consequences, including obesity and diabetes (Healy et al. 2008). Simultaneously, the rapid expansion of OFD services is causing an increase in non-biodegradable waste, which considerably impacts the environment (Molina-Besch 2020). Furthermore, OFD services can exacerbate food waste behaviors (Filipová et al. 2017). Research methods on OFD services are primarily questionnaires, interviews, and experiments; quantitative studies based on large volumes of data are lacking.

OFD services during the COVID-19

During the pandemic, the food service industry experienced substantial operational transformations and new trends surfaced to accommodate the demand for physical distancing while consuming food (Kim et al. 2021b). OFD services have adopted a no-contact delivery method to ensure minimal exposure (Brewer and Sebby 2021). This change has increased the popularity of OFD services (Kim et al. 2021a; Sharma et al. 2021) leading to increased study of the phenomenon. Research on OFD services during the pandemic covers the following areas (Meena and Kumar 2022).

Firstly, it changed consumer thinking and behavior (Cheong and Law 2022; Polizzi et al. 2020). During the pandemic, it is important to determine the elements that affect the sustained utilization of OFD services by consumers. Consumers who order food through OFD service platforms perceive fewer risks and exhibit increased purchasing patterns, perceived advantages, and engagement with the product (Uzir et al. 2021). Social influence (Jun et al. 2021), food quality, enjoyment motivation (Sharma et al. 2021), safety and mobile software information layout (Kaur et al. 2021) considerably impact customer contentment and allegiance. Hedonic motivation plays a considerable role in determining pricing strategies, ensuring the quality of information, and designing effective promotional campaigns (Ray and Bala 2021). The quality and safety measures implemented by OFD services can have a significant influence on the content and devotion of customers (Wang et al. 2021). Loyalty is heavily influenced by satisfaction. OFD service platform information design significantly impacts contentment and allegiance.

Secondly, the use of OFD service platforms has received continuous attention the pandemic in China (Zhao and Bacao 2020), Brazil (Zanetta et al. 2021), the United States (Hong et al. 2021), India (Mehrolia et al. 2021) and Mexico (Ramos 2022). Cost-saving orientation (Ramos 2022), habits (Zanetta et al. 2021), performance expectations (Zanetta et al. 2021), effort expectancy (Kumar and Shah 2021), perceived usefulness and employee confidence (Chakraborty et al. 2022) influenced consumer willingness to use OFD services during the COVID-19. Similarly, health, action control and social isolation, perception, subjective norms (Yeo et al. 2021) significantly influenced consumer willingness to continue using OFD services. The study found that usability, convenience, cost savings, and food variety among OFD services (Dirsehan and Cankat 2021) affect the willingness to continue using these services.

Furthermore, the instability of the delivery workforce worsened during the COVID-19. It impacted unemployment, health risks, and occupational concerns of delivery workers (Meena and Kumar 2022). Among Chinese delivery workers, job insecurity, financial hardship, health risks, and livelihood crises were observed to intensify racism (Huang 2022). During the pandemic, OFD personnel faced challenges in last-mile delivery (Puram et al. 2021). Research on OFD services during the pandemic focused on consumers and platforms, utilizing surveys, interviews, and experimental methods. Due to measurement errors in surveys and interviews, the researchers' subjective judgments, and sample limitations, it is vital to conduct objective data analysis.

Data and methods

Data sources

OFD service sales

Data from a large OFD service platform in China from 4 November 2019 to 12 July 2020 was collected and aggregated into weekly data. Weekly data is used to mitigate the impact of significant daily variations in OFD service sales. It is relatively easy to present a stable data trend using weekly data. The dataset for our final research was a 36-week balanced panel data from 195 cities on OFD service sales, with no missing values in each city.

COVID-19 confirmation data

To ascertain the COVID-19 outbreak status of each city, we compiled the number of confirmed cases published in real time on the city government websites during the pandemic. The city is facing a COVID-19 crisis, as indicated by the appearance of new confirmed cases. There were no new confirmed cases for 14 consecutive days, indicating that the COVID-19 in the city has temporarily ended. Finally, the onset and end time points of the pandemic were determined according to the confirmed COVID-19 outbreak data in a city.

Lockdown policy data

We collected lockdown policy data from significant media and government announcements. Due to the varying severity of COVID-19 across regions, some city governments differed in the prevention and control measures. We established that a city was in lockdown when it enforced the following three preventive measures: (a) Restricting non-essential commercial operations; (b) Forbidding gatherings; (c) Limiting the

use of private and public transport (He et al. 2020). 67 cities implemented the city lockdown policies, of the 195 cities categorized according to whether the city lockdown policies were implemented (Figure 1).

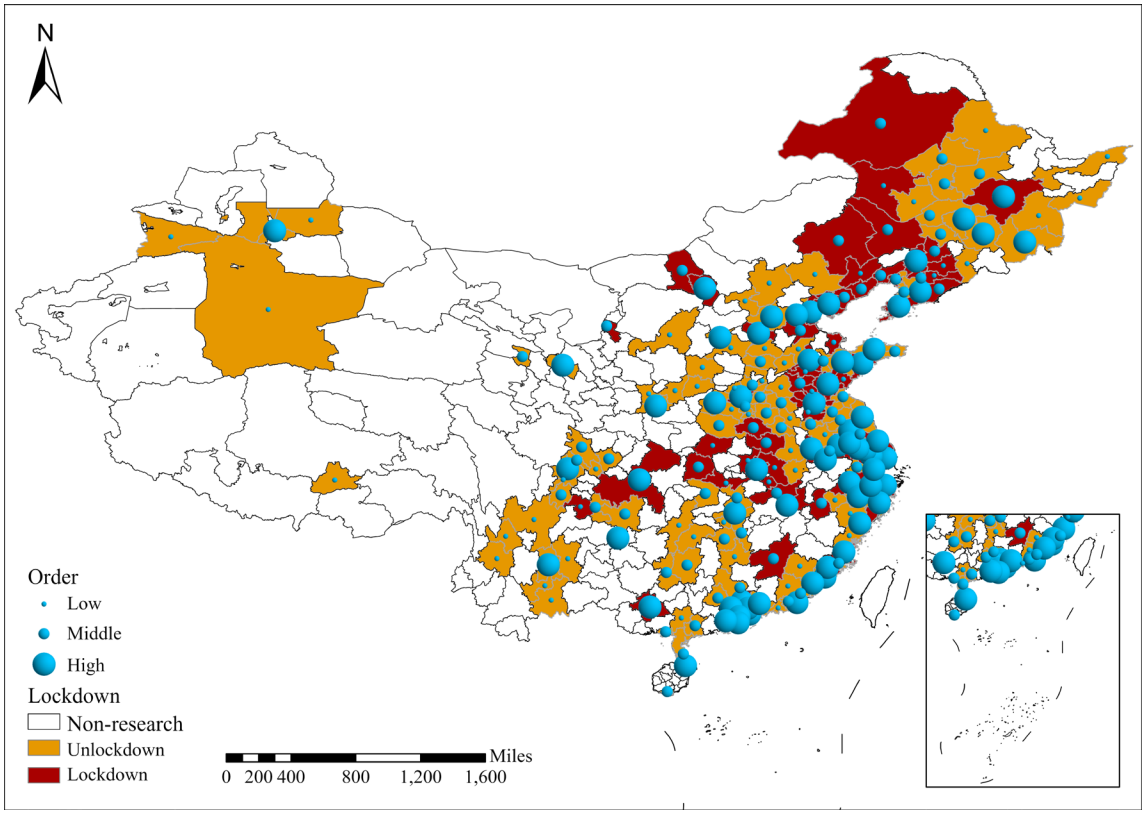

Figure 1. Distribution of study areas

Air quality and weather data

We controlled for air quality and meteorological conditions, as they can affect OFD services. Daily data on 195 urban air quality indicators from 4 November 2019 to 12 July 2020 were collected through the Air Quality Data Platform. The median values of AQI, $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, and O_3 from the monitoring stations in each city are used to determine the air quality data. Daily data on meteorological conditions, including temperature, sensible temperature, humidity, precipitation, and wind level, were collected for 195 cities through the National Weather Science Data Center from 4 November 2019 to 12 July 2020. The weekly data for OFD service sales is made consistent with the weekly average values of air quality and meteorological data by calculation. Summary statistics of the dataset are shown in Table 1.

Variables	N	Mean	SD	Min	Max
Order ($\times 10^4$)	7,020	15.112	24.552	0.003	263.540
Lockdown	7,020	0.069	0.254	0.000	1.000
Lift lockdown	7,020	0.160	0.366	0.000	1.000
AQI	7,020	74.236	31.433	16.000	357.143
$PM_{2.5}$ (μg/m3)	7,020	40.028	27.809	4.429	285.571
PM_{10} (μg/m3)	7,020	65.637	38.044	8.429	783.286
SO_2 (μg/m3)	7,020	10.557	6.835	2.000	76.143
NO_2 (μg/m3)	7,020	28.005	14.055	3.429	102.429

CO (mg/m3)	7,020	0.780	0.339	0.200	4.200
O_3 (μg/m3)	7,020	88.814	35.513	14.286	229.286
Temperature (℃)	7,020	18.072	11.216	-25.000	40.143
Sensible temperature (℃)	7,020	15.518	13.339	-33.286	42.000
Humidity (%)	7,020	0.575	0.180	0.083	0.968
Precipitation (mm)	7,020	5.609	10.579	0.000	119.343
Wind (m/s)	7,020	5.812	1.486	2.143	11.143

Table 1. Summary Statistics

Modelling methods

Interrupted time series analysis

The most effective quasi-experimental design for assessing the longitudinal impact of interventions that occur at specific times is the Interrupted Time Series Analysis (ITSA) (Jiang et al. 2022). ITSA can be utilized to determine the impact of introducing an intervention, as well as to estimate the impact of fully or partially withdrawing an intervention. As OFD services are a fast-growing industry, it is unreasonable to use previous contemporaneous data for a controlled study in light of the full impact of COVID-19. We employed ITSA to compare OFD service consumption before and after the COVID-19 to address this issue. ITSA was utilized to estimate changes in consumer behavior for OFD services after the "interruption" of the COVID-19. In this analysis, potential confounding factors such as long-term trends, autocorrelation, and other confounders that change over time were taken into consideration (Bernal et al. 2017). We included the periodic outbreak and ending of the COVID-19. A multi-stage ITSA was performed according to the model specified below.

$$Order_t = \beta_0 + \beta_1 time + \beta_2 outbreak + \beta_3 time_1 + \beta_4 finish + \beta_5 time_2 \quad (1)$$

Where $Order_t$ is OFD service sales at t. $time$ is the time variable from the start of the study to the end of the study. $outbreak$ is a dummy variable indicating whether COVID-19 has occurred, taking the value 1 if COVID-19 occurs in the city and 0 otherwise. $time_1$ is the time variable from the outbreak to the end of the COVID-19. $finish$ is a dummy variable representing whether the COVID-19 has ended. $time_2$ is the time variable after the end of the COVID-19. β_0 is the intercept term, representing the initial level of the OFD service sales. β_1 is the slope before the COVID-19, indicating a pre-existing trend. β_2 is the difference between the OFD service sales at the time of the COVID-19 and assuming the intervention did not occur, reflecting the immediate effect of the COVID-19 (immediate effect). β_3 represents the difference in slope before and after of the COVID-19 outbreak, reflecting the sustained impact of the COVID-19 (sustained effect). β_4 is the difference between the sales of OFD services at the end and during of the COVID-19. β_5 represents the change in slope before and after the conclusion of the COVID-19, reflecting the persistent effect of ending the COVID-19. We used the Cumby-Huizinga test to test the autocorrelation of the interrupted time series. The order of autocorrelation was processed using the Newey-West method.

Meta-analysis

To evaluate the overall effect of the outbreak and end of COVID-19 on OFD services in all cities, the effect values for each city affected by COVID-19 were combined using meta-analysis. Due to local variations in COVID-19 and policies, a random effects model was utilized to calculate pooled effects (Borenstein et al. 2010). The proportion of variation that is due to heterogeneity is indicated by the I^2 statistic, with values exceeding 75% suggesting a high level of heterogeneity between outcomes. To explore the heterogeneity between cities, meta-regression analysis was conducted to explore the influence of each factor on the merger effect, which can also provide a basis for subsequent subgroup analysis.

Time-varying difference-in-difference model

This paper employs the DID method to investigate the effect of city lockdown policies on urban OFD services. It asks whether there is some resilience in urban OFD services to help withstand the impact of the lockdown policies and recover at the end of the lockdown policies. As the timing of the policy varies across cities, we used a time-varying DID regression approach. The article employs two types of time-varying DID models (Cui et al. 2020; Parker et al. 2016). First, we combined three stages in the first time-varying DID regression: before the lockdown, during the lockdown, and after the lockdown. The advantage of this method is that the more extended panel structure can help reduce the standard errors of the estimates. To evaluate the influence of the lockdown policies, we used the following model to calculate the relative change in OFD service sales between the cities that received treatment and those that served as controls.

$$Lnorder_{it} = \alpha + \beta_1 lockdown_{it} + \beta_2 [lift\ lockdown]_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

where $Lnorder_{it}$ denotes the logarithm of OFD service sales in city i in week t. β_1 is the policy effect of implementing lockdown policies on OFD services. β_2 represents the policy effect of ending the lockdown on OFD services. $lockdown_{it}$ is a dummy variable that takes on the value of 1 if city i implemented lockdown policies and 0 otherwise. $[lift\ lockdown]_{it}$ is also a dummy variable that takes on the value of 1 if the city i that implemented the lockdown policies ended the lockdown and 0 otherwise. γ is the coefficient of the control variable. X_{it} is a control variable that varies with time and city. μ_i is urban fixed effect. λ_t is time fixed effect and ε_{it} is error term.

We performed a separate time-varying DID regression analysis in the second time-varying DID regression. The advantage of this method is that we obtain two sets of estimates. We performed time-varying DID regressions between the pre- and in-lockdown period and the pre- and post-lockdown stage:

$$Lnorder_{it} = \alpha + \beta lockdown_{it}([lift\ lockdown]_{it}) + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

Where β indicates the policy effect of implementing city lockdown policies on OFD services (indicates the policy effect of ending city lockdown on OFD services).

Impact of the COVID-19 on OFD services

Main results

In this paper, the effect of COVID-19 on OFD services was estimated. The effect of COVID-19 was felt across China. Since the outbreak, with the OFD service industry serious shocks. However, as OFD services are in a rapid stage of development, comparing with last year's data is not a viable option. To evaluate the effect of the COVID-19 on OFD services, ITSA was adopted. Furthermore, cities without lockdowns were included to mitigate the effect of lockdown policies on OFD services.

Next, we used ITSA to estimate the effect of the COVID-19 on OFD service sales. By analyzing trends of OFD service sales in 126 cities without lockdown policies, 126 effect values were obtained. To summarize these findings, the overall mean effect of the COVID-19 on OFD services was calculated using a meta-analysis method。

The overall average effect value represents the rate of change in OFD services compared to the non-COVID-19 situation (Table 2). OFD service sales fell by 96.9% overall after the COVID-19 outbreak. Overall sales of OFD services increased by 77.7% after the end of the COVID-19 stage. The overall average effect value suggests that changes in OFD service sales are associated with the COVID-19 outbreak. I^2 value exceeding 75% signifies considerable inconsistency in the effect values of OFD services among different cities.

	Overall ES	Heterogeneity statistic	P-value	95% CI lower	95% CI upper	I^2	N
Shock	-0.969	1535.65	<0.001	-0.997	-0.942	91.9%	126
Recovery	0.777	1137.25	<0.001	0.545	1.009	89.0%	126

Table 2. Overall average effect of the COVID-19 on OFD services

Subgroup analysis

We determined why there is substantial heterogeneity in the impact of the COVID-19 on OFD services across cities and whether these heterogeneities stem from varying urban characteristics. We estimated the variation in the effect size of the pandemic on OFD services across urban cultural differences, levels of economic development, city levels, and COVID-19 severity using subgroup analysis.

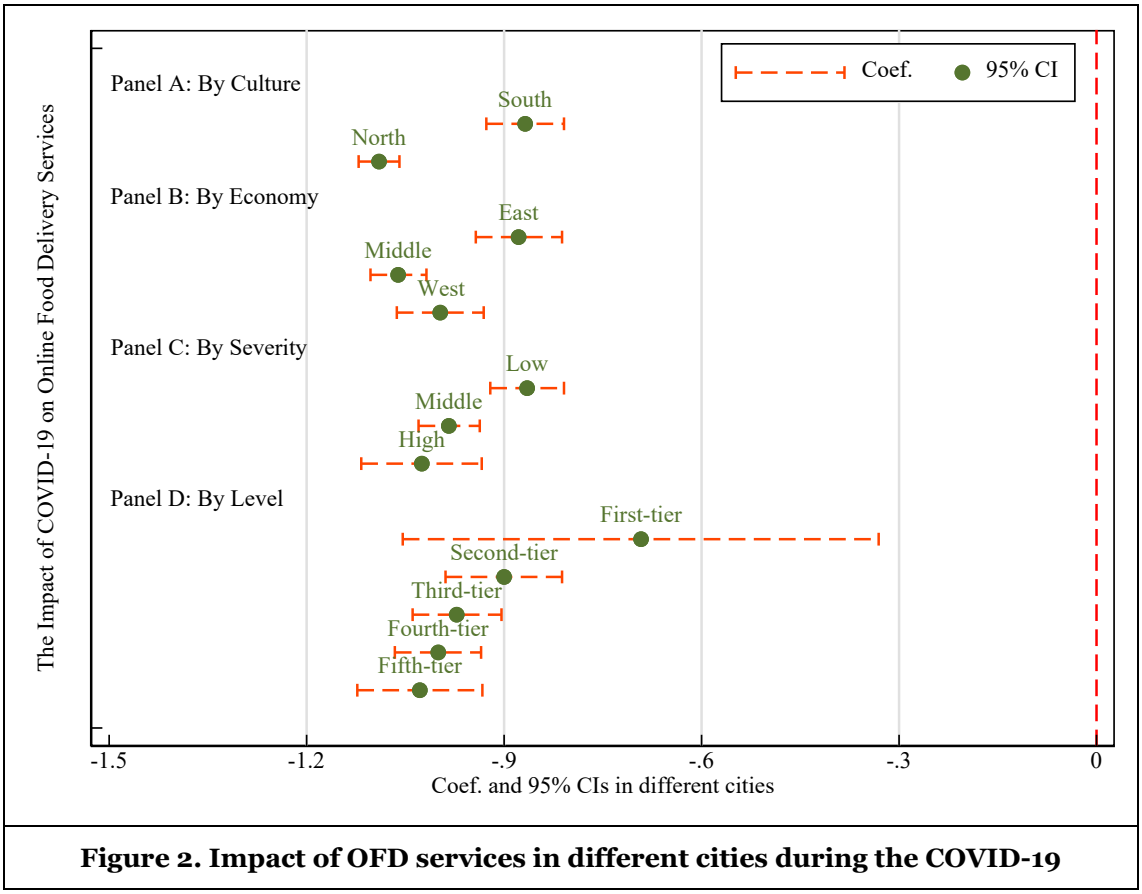

Figure 2. Impact of OFD services in different cities during the COVID-19

As shown in Figure 2, the subgroup analysis identified significant differences in the impact of the COVID-19 on OFD services across city characteristics. The more severe the outbreak, the worse the impact on OFD services in the city. The northern region has been more severely impacted than the southern region. Economically underdeveloped areas have been more severely impacted than economically developed areas. At the same time, larger cities are better able to resist the impact of COVID-19 on OFD services.

As shown in Figure 3, significant variances in the effects of COVID-19 were observed in the subgroup analysis on the recovery of OFD services across urban characteristics. The lower outbreak severity correlated with faster recovery and OFD services growth after the pandemic. Cities in the northern regions experienced faster recovery than those in the southern regions. There were no significant gaps in OFD services in cities after the end of COVID-19 in regions with different levels of economic development. However, there were faster growth rates in the less economically developed western regions. Lower levels of economic development correlated with weaker OFD services. As the impact of COVID-19 subsided, cities with lower levels experienced faster growth in their OFD services.

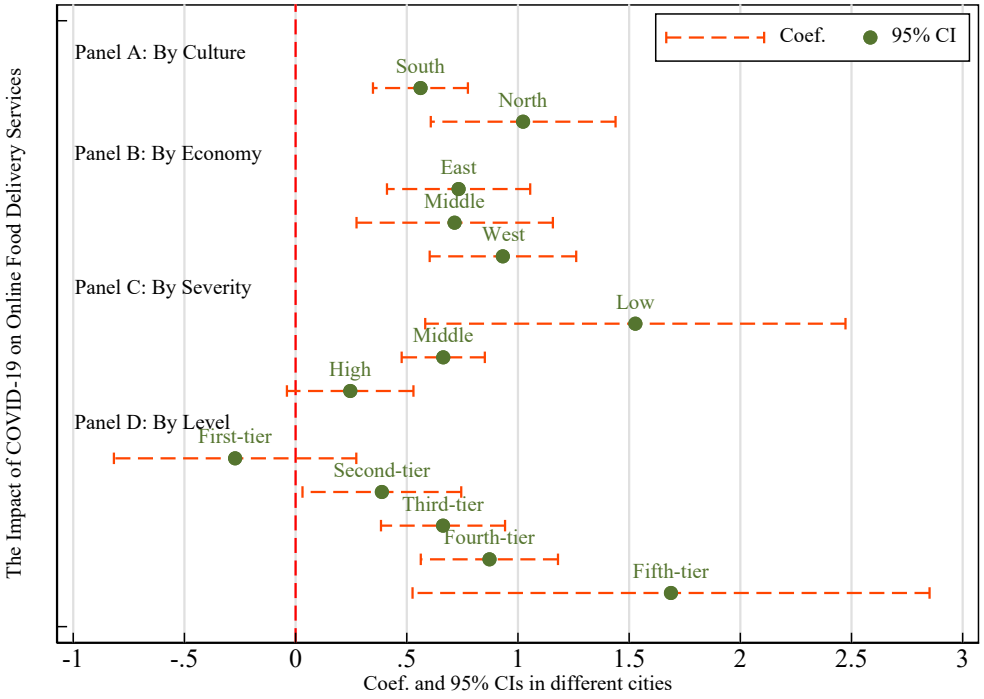

Figure 3. Impact of OFD services in different cities after the COVID-19

The impact of lockdown policies on OFD services

Main results

After the COVID-19 outbreak, many cities implemented measures to control its spread. Among the most stringent policies were the lockdowns. We employed a time-varying DID analysis to investigate the effect of lockdown policies on OFD services. The result of regression analysis is presented in Table 3. The regression outcomes of the initial time-varying DID approach are presented in columns (1) and (2). Columns (3) to (6) report the regression results of the second time-varying DID method. Control variables were added in columns (1), (3), and (5) but not in columns (2), (4), and (6). Urban fixed effects and time fixed effects were controlled for in all regressions. The model's robustness was established through the consistency of the results in columns (1) to (6). The agreement between the two regression techniques employed was established, regardless of whether control variables were added or not. As shown in Table 3, we observed a significant decline in OFD service sales during the implementation of the lockdown policies, followed by a significant recovery after the policies were lifted. As shown in column (1), the average number of OFD service sales decreased by 20.8% during the implementation of the lockdown policies (calculated by 1 – exp (−0.233)). After lifting the lockdown policies, the negative impact on OFD services decreased to approximately 3.8%. The results indicate that the enforcement of lockdown policies during the COVID-19 had a considerable negative effect on OFD services, which subsided as the lockdowns were lifted.

	(1)	(2)	(3)	(4)	(5)	(6)
lockdown	-0.238** (-2.40)	-0.233** (-2.35)	-0.251** (-2.07)	-0.229* (-1.83)		
lift lockdown	-0.040* (-1.95)	-0.039* (-1.92)			-0.036* (-1.90)	-0.045** (-2.07)
Constant	1.987*** (39.2)	2.129*** (183.32)	2.474*** (15.54)	2.129*** (120.40)	2.113*** (82.74)	2.129*** (302.09)

R-squared	0.740	0.739	0.742	0.732	0.704	0.668
Control	Yes	No	Yes	No	Yes	No
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,020	7,020	3,315	3,315	4,875	4,875
Number of cities	195	195	195	195	195	195
Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1						

Table 3. Time-varying DID model regression

Robustness tests

Parallel trend test

Event study is used to model the trend of parallel test method, with the specific regression model being as follows.

$$Lnorder_{it} = \alpha + \sum_{j=-M}^{N} \delta_j policy_{i,i-j} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

where $Lnorder_{it}$ is the logarithm of OFD service sales in city i in week t. $policy_{i,t-j}$ is a dummy variable. If the city i implements the lockdown policies during the period $t-j$, the value of this variable is 1; otherwise, it is 0. M and N represents the number of periods before and after the policy time point, respectively. Further analysis is performed in an intuitive graphical way according to the regression results (Figure 4). The estimated coefficient was insignificant before the lockdown policies (the 95% confidence interval included a value of 0) but was significantly negative during the lockdown and became insignificant again after the lockdown policies ended. These results suggest that there was no clear difference between treatment and control groups before the lockdown policy was implemented. Thus, they can be compared, assuming that parallel trends are satisfied.

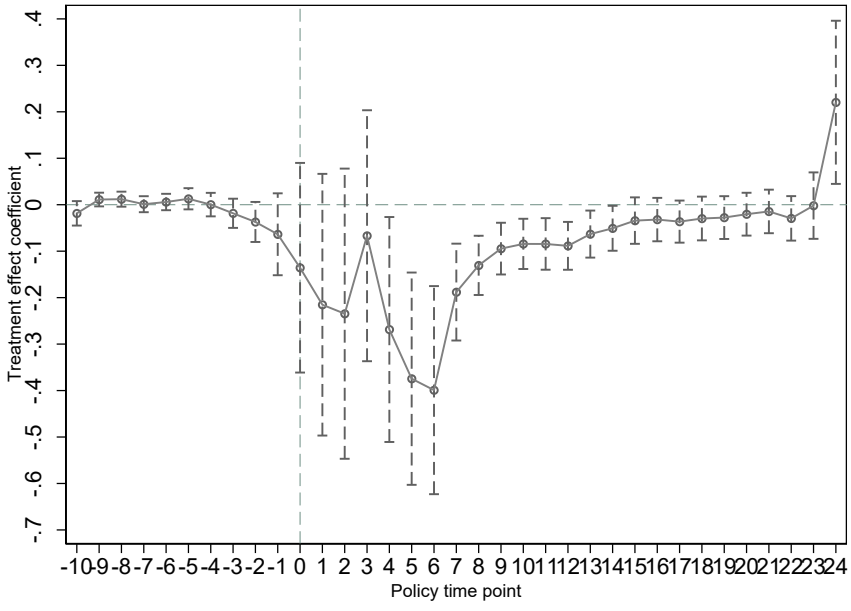

Figure 4. Parallel trend hypothesis test

Placebo test

In this study, 67 of 195 cities implemented lockdown policies. Therefore, it is necessary to randomly select 67 cities from the 195 cities as the "pseudo-treatment group." The assumption is that the lockdown policies are being enforced in these 67 cities, with the remaining cities acting as control groups. The "pseudo-policy dummy variable" was generated for regression. Stata16 software repeats this method 500 times to obtain 500 regressions randomly. The plotted distributions of p-values and the estimated coefficients of the 500 "pseudo-policy dummy variables" were finally obtained. Figure 5 presented the outcomes of the placebo test. The coefficients that were estimated were found to be centered around 0. The majority of the estimates had p-values larger than 0.1, which is considered insignificant at the 10% level. There was a significant gap between the estimated results of this study and the estimated results of the random sham treatment group, suggesting that the estimation results are improbable to be obtained randomly. Thus, it is improbable that the results are affected by other policies or random factors.

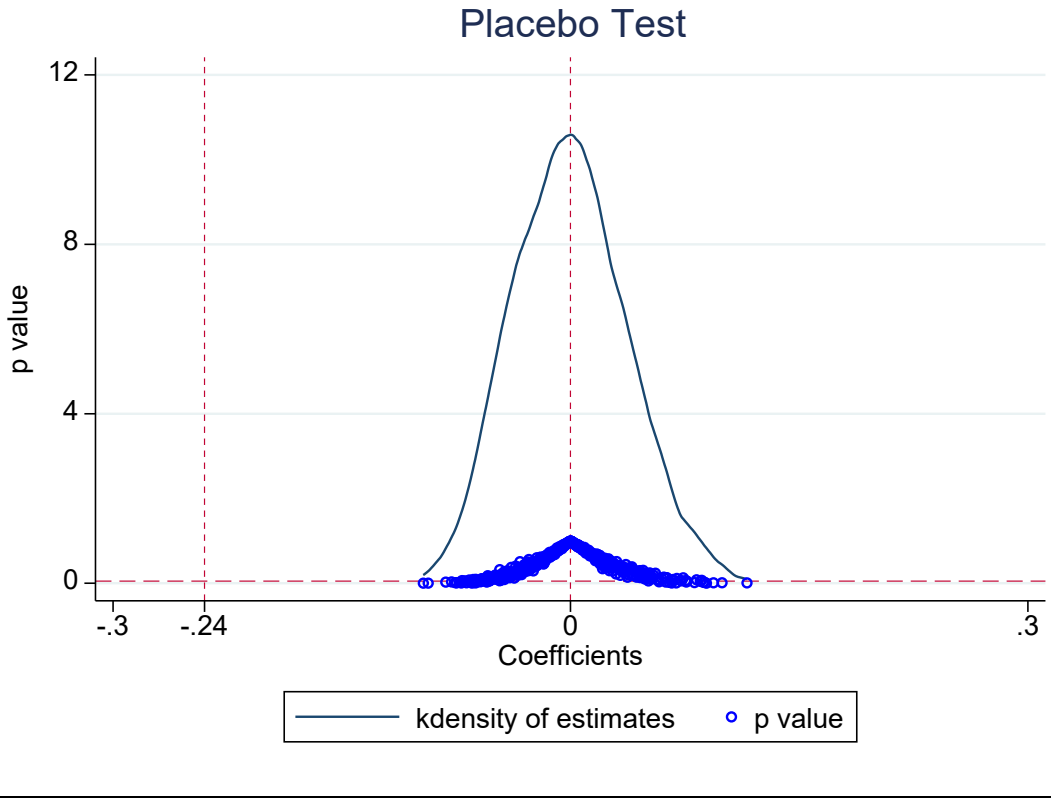

Figure 5. Placebo test

Heterogeneity analysis

We estimated the average impact of lockdown policies on OFD services in cities. However, research suggests disparities in developing OFD services across regions (Kathuria et al. 2020). Therefore, we examined the heterogeneous effects of lockdown policies across cities. Understanding this heterogeneity enables an understanding of how lockdown policies affected the resilience of OFD services during the pandemic and guide urban governance and OFD service platforms.

We determined whether the impact of lockdown policies on OFD services in cities differed significantly across urban areas. Note that the heterogeneity analysis does not have a causal explanation but helps understand the channels through which city lockdown policies affect OFD services in cities. We focused on the following four different urban characteristics: (a) Differences between cultures across cities; (b)

differences between the severity of the COVID-19 across cities; (c) differences between economic conditions across cities; (d) differences between levels of cities.

The heterogeneity of implementing lockdown policies across cities

First, we compared cities with cultural differences. China is an expansive nation with a diverse natural landscape and a significant population. Because there are 56 ethnic groups, regional cultural differences are significant. China is divided into north and south regions along the Qinling Mountains and the Huai River. According to Buckle, human life and destiny are primarily determined by four natural factors: climate, food, soil, and topography. Furthermore, the long-term inheritance and accumulation of cultural genes have significantly influenced the differences between the cultures of northern and southern China. Panel A of Figure 6 demonstrates a significant negative impact of implementing the lockdown policies on OFD services in the southern region, consistent with the main effect results. In northern China, implementing lockdown policies significantly positively impacted urban OFD services. This finding diverges from the main effect result. Through data analysis in the northern region, we found unreasonable behaviors in implementing the lockdown policies. Some cities severely impacted by COVID-19 did not implement lockdown policies. In contrast, some cities with less severe COVID-19 impacts implemented strict lockdown policies. As a result, we identified significant differences in implementing the lockdown policies between cultures.

Second, we compared cities with varying COVID-19 severity levels. From this analysis, it was discovered that the policy effects of implementing the lockdown were significantly impacted by the severity of COVID-19. To observe differences in the effects of the lockdown policies across the severity of the pandemic, cities were categorized into three groups based on the cumulative number of confirmed cases in the city: low-risk cities (< ten cases), medium-risk cities (between ten and 100 cases) and high-risk cities (≥100 cases) (Zhang et al. 2020). Panel B of Figure 6 shows a significant negative impact of lockdown policies on OFD services in high-risk areas. In contrast, implementing the city lockdown policies did not significantly impact these services in medium- and low-risk areas. These results suggest that COVID-19 severity correlated with the impact of the lockdown policies on urban OFD services. This finding is due to the fear generated among people during the pandemic, which decreased OFD services. The severity of COVID-19 correlated with fear and impact.

Next, we compared cities across economic levels. The Chinese economy has maintained steady development in recent decades. The overall national strength was strengthened, and living standards improved. However, due to history, geographical location, unbalanced distribution of resources, and other reasons, there have been increasing differences in economic levels between regions. To determine whether different economic levels altered the effect of the lockdown policies, cities were separated into eastern, central, and western regions according to the division of the three economic belts. Panel C of Figure 6 shows that implementing lockdown policies significantly negatively impacted urban OFD services in eastern and central regions. The inter-group coefficient analysis revealed that OFD services were more severely affected in the central cities. In contrast, implementing lockdown policies in western regions did not significantly impact OFD services in urban areas. These findings suggest that lockdown policies severely impact urban OFD services in cities with moderate economic levels. This finding might be explained by the higher level of OFD services S in cities with higher economic levels and superior ability to withstand the impact of lockdown policies. By contrast, in cities with low economic levels, OFD services are smaller and less impacted by lockdown policies.

Finally, we compared cities of varying levels. In addition to the economic level, factors such as the administrative level, city size, and population size may also influence the impact of lockdown policies on urban OFD services. Cities were categorized into first-tier, second-tier, third-tier, fourth-tier, and fifth-tier according to future plasticity, urban hub, the concentration of commercial resources, lifestyle diversity, urban human activity (Li et al. 2021). Panel D in Figure 6 shows results similar to the economic level. The enforcement of lockdown policies only had a considerable negative effect on OFD services in cities of the third–tier. However, these services are not significantly affected in cities of the first and second tiers with higher grades, or in cities of the fourth and fifth tiers with lower grades. The results are similar to the economic level. OFD services are higher in cities with higher grades. The ability to withstand the impact of lockdown policies was also more robust. However, the scale of OFD in low-level cities was small, and the impact of the lockdown policies was also small.

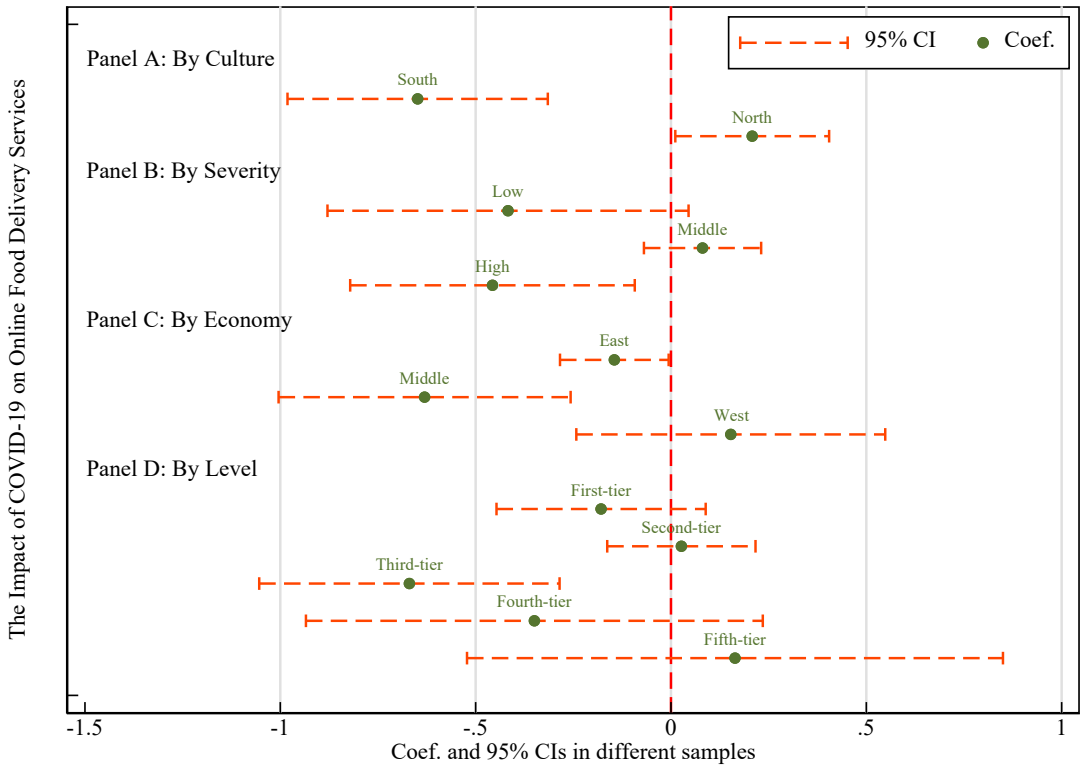

Figure 6. The heterogeneous effects of lockdowns on the OFD services

The heterogeneity of ending lockdown policies across cities

We found significant differences in lockdown's impact on OFD services across cities. As the COVID-19 was controlled, OFD services quickly returned to pre-pandemic standards in most cities and grew faster than before the pandemic. As cities began to end lockdown policies, there were concerns about whether the impact on OFD services would last and whether the development of OFD services across cities would differ significantly because of the lockdown policies. To ascertain if there were any notable disparities in the development of OFD services across cities after the end of lockdown policies, we compared cultures, pandemic severity, and economic and level differences across cities. The outcomes are displayed in Figure 7.

After the lockdown policies ended, there were significant differences in whether lockdown policies had been implemented in OFD services. This finding suggests that lockdown policies' impact during the pandemic was short-lived and recoverable. OFD services were resilient in the face of lockdowns. The heterogeneity analysis after the lockdown policies ended showed no significant differences in OFD services across cities with different cultures and lockdown levels. In other words, the heterogeneous effects of implementing lockdown policies across cultures and levels will likely disappear with the end of the lockdown policies. However, after comparing the COVID-19 severity and the economic level of different cities, we found heterogeneity of OFD services across cities after the end of lockdown policies.

When studying the heterogeneity of lockdown policies in cities with the severity of the COVID-19, It's found that lockdown policies in areas with more severe epidemics had more severe impacts on urban OFD services. However, when analyzing the heterogeneity after the lockdown policies ended, the recovery of OFD services was slower in medium- and low-risk areas where lockdowns had been implemented. This finding suggests that lockdown policies in low-risk and medium-risk areas affect people's judgment of the actual severity of the COVID-19. After ending the lockdown policies, the change of the policies could not be perceived quickly, affecting the recovery of OFD services.

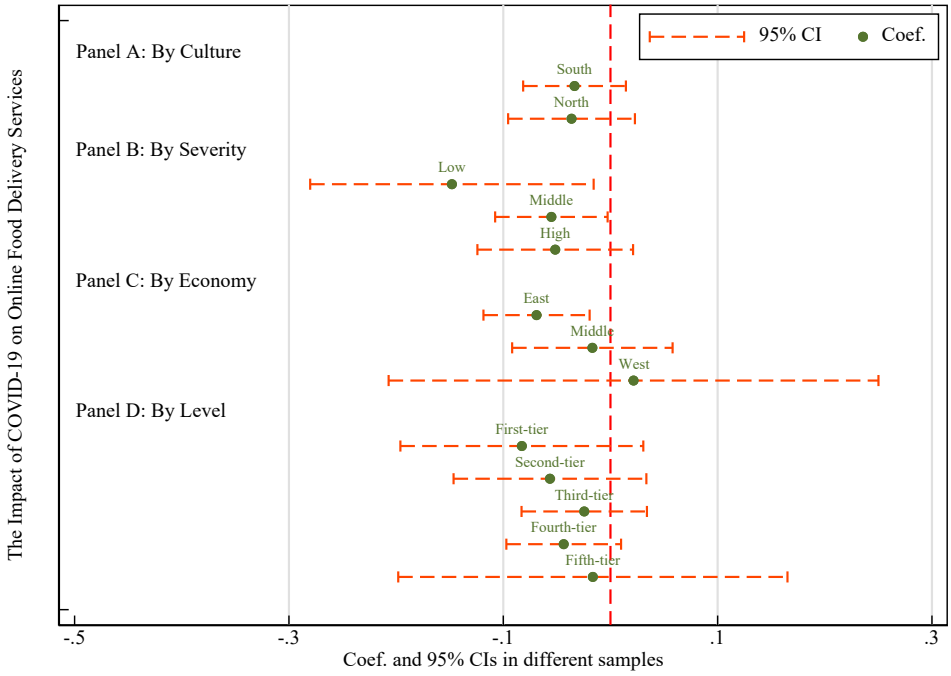

Figure 7. The heterogeneous effects of lockdowns ending on OFD services

Conclusion and discussion

Discussion

To investigate the changes in urban OFD service consumption was the objective of this research during the COVID-19. By analyzing sales data from a large OFD platform in 195 cities in China from November 2019 to July 2020, we have reached the following conclusions and discussions:

Firstly, during the outbreak of the COVID-19, the research results indicate a significant decline in urban OFD services. With the improvement of the situation, not only did the service recover to pre-pandemic levels, but it even surpassed the overall pre-pandemic consumption levels. During the COVID-19, it demonstrates the strong digital resilience of OFD services and important role in helping the catering industry overcome the impact of the crisis. Therefore, the catering industry should further enhance its digital capabilities, strengthen cooperation with OFD platforms and improve service flexibility to meet consumer demands and adapt to similar public health shocks that may arise in the future (Lam and Law, 2019).

Furthermore, the study also identified discrepancies in the influence of the COVID-19 severity on OFD services. The more rigorous the COVID-19 situation in a region, the greater the impact on OFD services and the slower the recovery. Additionally, The lower the level of OFD services in a region, the more severe the influence of the COVID-19. Therefore, in the situation of a comparable public health crisis in the future, it is essential to prioritize the improvement of logistics and delivery efficiency in these regions to meet consumer demands (Kuo and Chen, 2010).

Further analysis indicates that the enforcement of lockdown policies has adversely affected the OFD services. Cities that implemented lockdown policies have experienced slower recovery of the OFD services compared to that did not implement lockdown policies. The implementation of lockdown measures has been instrumental in curbing the transmission of COVID-19, they have also had far-reaching effects on urban life. Therefore, when implementing lockdown policies, it is essential to take into account both the COVID-19 severity and the importance of OFD services to ensure the scientific and flexible of the policies (Laranja, Uyarra and Flanagan, 2008). Governments can support and encourage the expansion of the

online service industry, strengthening the capacity and resilience of online service to address the effects of potential public health risks on urban life in the future (Amankwah-Amoah et al., 2021).

Finally, the paper analyzed the impact of heterogeneity factors between different cities on OFD service. It founds that culture, economy, urban level and the COVID-19 severity affect the policies effect of lockdown policies on OFD services. Therefore, when formulating and implementing relevant policies in the future, it is essential to consider the variations among various cities to ensure the pertinence and effectiveness of the policies (Sicard et al., 2020).

Theoretical contributions

In the following ways, this paper provides theoretical insights. First, there were limitations in consumer behavior characteristics and research data in previous studies. Most studies on the consumption of OFD services focused on the micro level of the consumer. Few studies analyze cities at a macro level. This study reveals the changes in OFD services from a macro perspective in the background of the COVID-19. It enriches the literature on the COVID-19 and OFD services. Secondly, we found that OFD services recovered quickly as the pandemic abated during the pandemic when examining the changes in OFD services. The industry was quick to respond and adapt to changes in the market. The digitization of OFD services, as a channel for the catering industry, assisted in the timely tackle to the effect of the COVID-19. Therefore, the paper provides a theoretical basis for investigating the digital resilience of the catering industry. It can also be used as a reference for future research on the changes in the catering industry due to unexpected events. Finally, studying the impact of lockdown policies on OFD services against the background of the pandemic can provide a new perspective on socio-economic theory. It can also promote understanding and response to policy changes. As an emerging field in social development, OFD services played a critical role during the pandemic. Our findings can help governments and OFD services platforms to cope with the new socio-economic environment. These findings can also help anticipate and respond to the challenges posed by future socio-economic complexities.

Practical implications

Significant practical implications for the government, enterprises, and consumers are present in this study. Firstly, this research can help the government to deeply understand the development trend and changing rules of the OFD service during the pandemic. It has important reference significance for the government to formulate relevant policies, promote the development of the OFD service industry and improve service levels, in order to cope with the risks of potential public crises and other emergencies in the future. Secondly, this study can provide a reference for other online-to-offline service industries. It can help them understand how to more effectively use digital platforms to improve service levels during public crises. At the same time, it can promote business development and provide more comprehensive services to consumers. Furthermore, it can help businesses improve their digital resilience to face potential risks in the future. Finally, this study provides consumers with valuable insights into the dependability of OFD services during times of public health crises. This information can instill confidence in consumers, enabling them to make informed decisions and better assess risks when faced with similar situations in the future.

Limitations and future research

This study has the following limitations. First, while the platform selected for this study is one of China's largest OFD service platforms, selecting a single platform may lead to biased results. Therefore, we suggest that future studies consider platform-wide aggregation studies. Second, we examined data on OFD services in Chinese cities; therefore, our findings might not be generalizable to other countries. Therefore, we recommend that future studies focus on different regions and countries, and we encourage cross-cultural comparisons. Finally, this study only studied OFD services during the COVID-19 and its corresponding policy implementations. Whether the findings are generalizable to other emergencies and their corresponding response policies is uncertain. Therefore, we suggest that future studies study the impacts of different emergencies to identify effective response measures.

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