Front. Econ. China 2021, 16(4): 744–777
https://doi.org/10.54605/fec20210407

RESEARCH ARTICLE

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The Impact of the COVID-19 Pandemic on Consumption: Evidence from Weekly UnionPay Card Transaction Data in Shanghai

Abstract The new coronavirus outbreak provides a genuinely exogenous unanticipated shock that enables this study to identify its impact on offline consumption, using unique weekly UnionPay card transaction data in 16 districts of 206 business circles in Shanghai, after China's outbreak in late January 2020. Based on the difference-in-differences estimation strategy, this study finds that weekly offline consumption fell by 1.843 million RMB, and offline consumption frequency fell 447 times per business circle during the 20 subsequent weeks. It also finds a significant heterogeneity effect on different districts and categories, different times in a day of offline consumption spending in the post-COVID-19 pandemic window period, in which the government implemented different level policy responses for major public health emergencies. These findings suggest that offline consumption fell drastically after the unanticipated pandemic shock, which also means that policymakers need to be cautious in achieving a balance between economic recovery and epidemic prevention and control.

Keywords COVID-19, pandemic, consumption, transaction data, Shanghai, policy response
JEL Classification E21, E61, E62

Received May 28, 2021

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1 Introduction

In late December 2019, a new coronavirus outbreak occurred in Wuhan. On March 12, 2020, the World Health Organization (WHO) announced it as a pandemic. This pandemic has been seen as the world's worst public health crisis since the Spanish flu in 1918. By January 19, 2021, the coronavirus had infected more than 93,800,000 people worldwide with over 2,026,000 deaths, and there was no end in sight. Governments around the world have implemented stringent public health emergency response measures, such as the complete lockdown of cities, traffic control, mandatory wearing of masks in public places, community isolation, and business shutdowns to maintain social distance and avoid close contact with the spread of the epidemic.

The strict implementation of public health emergency response measures has effectively curbed the spread of the epidemic, but has also had a severe negative impact on economic activities. The International Monetary Fund predicts that the global economy will decline by 4.4% by 2020. According to the data released by the National Bureau of Statistics of China, China's economy declined by 6.8% in the first quarter of 2020, but still achieved a positive annual growth rate of 2.3%. Stimulating consumption has become the top priority in stabilizing countries' economy worldwide. The unprecedented nature of the event has led researchers to think about how public health policies can achieve a balance between curbing the spread of the new coronavirus and reducing its negative impact on the economy. Several studies have evaluated the impact of the outbreak on outcomes, such as GDP, per capita income, stock prices, economic growth, poverty, the housing market, employment, and firm performance (Barro et al., 2020; Atkeson, 2020; Gormsen and Koijen, 2020; Fezzi and Fanghella, 2020; Jeehoon Han, et al., 2020; Kim, et al., 2020; Shen, 2020; Liu and Su, 2020), but the impact on consumption has not been taken seriously (Baker et al., 2020).

Previous studies have pointed out that the negative impact of natural disasters and other unexpected events on consumption mainly comes from the loss of income and the unpredictability of risk (Hill, 1997; Carter, 2006; Kun, 2013). The new coronavirus epidemic has similar effects as a serious public health event. Household segregation, enterprise shutdown, and unemployment resulted in many residents' income being significantly reduced or even lost. Even in the absence of negative income shocks, great uncertainty makes residents feel unsafe,

anxious, and panic, which psychologically reduces residents' willingness to consume. All of these factors lead to a reduction in consumption.

In this study, we examine the impact of the COVID-19 pandemic on consumption in Shanghai, which is the economic and financial center of China. The outbreak of COVID-19 desolated the golden week of the Shanghai Spring Festival, and the negative impact was expected to continue for a period of time. On January 24, 2020, Shanghai launched a first-level response mechanism for major public health emergencies.

We use unique weekly UnionPay card transaction data from 16 districts of 206 business circles in Shanghai to study how consumption spending responds to this pandemic. Our analysis is based on a difference-in-differences regression approach to examine the impact of COVID-19 on consumption. Our findings are summarized as follows. First, we find that the average spending of all consumption types and categories decreased by 1.843 million RMB, and the consumption frequency fell to 447 times on average for each business circle relative to the counterfactual path without the COVID-19 outbreak event during the 20 weeks after the government launched the first-level response policy for major public health emergencies. Second, the post-COVID-19 pandemic window period is decomposed into the first-level, second-level, and third-level period. We find a significant decline in the total spending of all consumption types and categories in all three windows: 1.729 million RMB decline in the first-level period, 1.521 million RMB in the second-level period, and 2.444 million RMB in the third-level period. For consumption frequency, spending declines to 441.3 times in the first-level period, 377.8 times in the second-level period, and 543.4 times after the third-level period. These results show that the negative impact on consumption first gradually decreases with the downgrading of the prevention and control response policy, and then rebounds to a certain extent.

We also conducted a series of heterogeneity tests. First, we investigated heterogeneity across districts. The results show that, except for Huangpu District, all 15 other districts of 206 business circles experienced significant weekly consumption decreases with magnitudes ranging from 0.226 million RMB to 9.274 million RMB, or weekly consumption frequencies decrease from 46.90 to 1565.1 times. Within all the districts, Jing’an fell the most, followed by Hongkou and Xuhui, which are all in the central urban areas. Noncentral urban areas, such as Chongming, Songjiang, and Jinshan, are relatively less affected. Second, we

investigated the heterogeneity across different categories. We find that within all the categories except the others category, including government enterprise consumption expenditures, spending on the remaining nine categories of goods or services is significantly affected, with a declining range from 0.513 million RMB to 7.190 million RMB or weekly consumption frequencies ranging from 47.88 to 1353.5 times. For spending amounts, real estate services fell the most, followed by wholesale and restaurants. For spending frequency, restaurants fell the most, followed by life services and retail relative to the counterfactual path without the COVID-19 outbreak event relative to the previous year. The basic consumption of housing and food has been seriously impacted. In addition, we also examined the impact of COVID-19 at different times of the day, and found that within all three policy response window periods, the average consumption amount and frequency both fell the most from 6:00 to 18:00, followed by 18:00 to 24:00.

The contributions of our study to the literature can be summarized as follows. First, according to the permanent income hypothesis, consumption should respond to unexpected shocks rather than expected shocks, and the consumption response to shocks depends on the persistence of the shocks (Frideman, 1957). Sometimes, consumption does not follow theoretical predictions, showing excessive sensitivity or smoothness (Paxson, 1993; Shapiro, Matthew and Slemrod, 1995; Carroll, 1997; Gruber, 1997; Stephens, 2003; Jappelli and Pistaferri, 2010; Parker, et al., 2013; Freyaldenhoven, et al., 2019). The existing literature mostly studies the impact of expected shocks on consumption but less on unexpected shocks, mainly because it is difficult to define which shocks are genuinely exogenous and unanticipated (Agarwal and Qian, 2014). The new coronavirus outbreak provides a genuinely exogenous unanticipated shock that enables this study to identify its impact on consumption.

Second, compared to early evidence on the US household consumption behavior and China's city consumption changes at the start of the pandemic (Baker et al., 2020; Chen, et al., 2020), this study focuses on the impact of changes in the intensity of the public health emergency response and relates it to the epidemic severity over time on consumption. We also investigated the impact on consumption across different districts and categories.

Third, this study helps us understand how to achieve a balance between the strength of public health emergency response policies and economic recovery.

Several studies have shown that limiting interpersonal contact or restricting traffic effectively hinders the spread of the virus (Greenstone and Nigam, 2020; Fang, et al., 2020). However, these social distancing measures also brought some negative effects (Correia, Luck and Verner, 2020; Duan, Wang and Yang, 2020; Eichenbaum, Rebelo and Trabandt, 2020). Our findings suggest that consumption fell after the unanticipated pandemic shock, which means that policymakers need to be cautious in achieving a balance between economic recovery and epidemic prevention and control.

The remainder of this paper is organized as follows. Section 2 introduces the data and empirical methodology. Section 3 presents an empirical analysis. Finally, Section 4 concludes the paper.

2 Data and Empirical Methodology

2.1 Consumption and COVID-19

On January 24 (the fourth week), 2020, Shanghai launched the first-level response mechanism for major public health emergencies. A novel coronavirus infection prevention and control conference was held by the Shanghai municipal government. The report was heard by the leading group office on the new type of coronavirus-infected pneumonia prevention and control. The meeting decided that novel coronavirus response mechanisms for major public health emergencies should be launched in Shanghai, the requirements of the state concerning pneumonia and infectious diseases in this new type of coronavirus infection should be strictly implemented, and the strictest scientific prevention and control measures should be undertaken. The city would further implement 14 days of isolation and observation at home or in a centralized way for people arriving in Shanghai from key areas, comprehensively implement health quarantines for all kinds of traffic crossings in the city, cancel all large-scale public activities, refine and implement various joint prevention and control measures, strengthen the publicity and popularization of health and health knowledge, enhance the citizens' self-awareness of health, and ensure the health and urban public safety of Shanghai residents.

On March 24 (the 13th week), 2020, the emergency response level of major public health emergencies in Shanghai was adjusted from the first-level response to the second-level response. Since March 3, there had been no new local

confirmed cases in Shanghai. According to the relevant national laws and regulations and the "special emergency plan for public health emergencies in Shanghai," the municipal government decided to adjust the emergency response level of major public health emergencies in Shanghai from level 1 to level 2 from 0:00 on March 24.

On May 9 (the 19th week), 2020, the emergency response level of major public health emergencies in Shanghai was adjusted from level 2 to level 3. Since March 3, there had been no new locally confirmed cases. According to the relevant national laws and regulations and the "special emergency plan for public health emergencies in Shanghai," the municipal government decided to adjust the emergency response level of major public health emergencies in the city from level 2 to level 3 from 0:00 on May 9.

At the end of April and the beginning of May, Shanghai held a series of activities of the May 5 Shopping Festival, the whole city discount season, by organizing marketing activities in key business districts, characteristic commercial streets, commercial enterprises, and brand enterprises to drive physical consumption through online drainage and promote consumption compensation and potential release.

The consumption data were collected from the China UnionPay transaction data. *UnionPay is China's largest payment service provider for offline spending.* It is a joint organization of bank cards of China through UnionPay's clearing system for interbank transactions, which enables the interconnection and sharing of resources among commercial banking systems and ensures the cross-bank, cross-regional, and cross-border use of bank cards. UnionPay's data contain all the interbank transaction flows of UnionPay cards. *Relative to traditional surveyed consumption datasets, our sample provides high-frequency, up-to-week, transaction-based information about consumers' offline spending before and after the outbreak of COVID-19 in 16 districts of 206 business circles in Shanghai.*

2.2 Summary Statistics

The summary statistics for each business circle's weekly consumptions are listed in Table 1. Based on the event date of each year, we divided the 2019 and 2020 samples into two periods: the pre-period and post-period. Panel A reports the

summary statistics for the 2019 sample (control group). The average business circle-level weekly consumption for the entire sample period, the pre-period, and the post-period are 4.2054, 4.1963, and 4.2078 (units: million RMB), respectively. Relative to the pre-period, the post-period increases slightly by 0.0115 million RMB or 0.27%. The median weekly consumption for the three sample periods was 0.3107, 0.3670, and 0.2975, respectively. Compared to the pre-period, the median for the post-period decreased by 0.0695 million RMB or 18.94%. The average business circle-level weekly consumption frequencies for

Table 1 Summary Statistics of Business Circle Weekly Consumption in Shanghai

Panel A: 2019 Samples							
Spending amount (in million RMB)							
	Obs	Mean	p10	p25	p50	p75	p90
All	150,246	4.2054	0.0087	0.0561	0.3107	1.3561	5.9723
Pre: [–5, 1]	30,335	4.1963	0.0096	0.0649	0.3670	1.6101	6.6452
Post: [0, 20]	119,911	4.2078	0.0085	0.0541	0.2975	1.2994	5.8118
Consumption frequency							
	Obs	Mean	p10	p25	p50	p75	p90
All	150,246	996	5	22	116	484	1,777
Pre: [–5, 1]	30,335	1,066	5	24	129	547	1,992
Post: [0,20]	119,911	978	5	22	112	469	1,725
Panel B: 2020 Samples							
Spending amount (in million RMB)							
	Obs	Mean	p10	p25	p50	p75	p90
All	119,288	2.9152	0.0035	0.0226	0.1320	0.6667	3.4627
Pre: [–3, 1]	16,917	4.3917	0.0066	0.0456	0.2656	1.2772	5.9354
Post: [0, 20]	102,371	2.6712	0.0032	0.0203	0.1183	0.5870	3.1202
Consumption frequency							
	Obs	Mean	p10	p25	p50	p75	p90
All	119,288	657	3	11	56	247	1,002
Pre: [–3, 1]	16,917	958	4	19	98	426	1,614
Post: [0, 20]	102,371	607	3	10	51	226	900

Note: Post is defined as 1 for post periods after Jan. 23, 2020 (the fourth week and after), for 2020 samples, and for post periods after Feb. 3, 2019 (the sixth week and after), for 2019 samples.

the entire sample period, the pre-period, and the post-period are 996, 1066, 978, respectively. Relative to the pre-period, the post-period decreased by 87.84, or 8.23%. The median weekly consumption for the three sample periods was 116, 129, and 112, respectively. Compared to the pre-period, the median for the post-period decreased by 17, or 13.18%.

Panel B reports summary statistics for the 2020 sample (treated group). The average business circle-level weekly consumption for the entire sample period, pre-period, and post-period is 2.9152, 4.3917, and 2.6712 (units: million RMB), respectively. Relative to the pre-period, the post-period decreases by 1.72 million RMB, or 39.18%. The median weekly consumptions for the full-period, pre-period, and post-period samples are 0.1320, 0.2656, and 0.1183, respectively. Compared to the pre-period, the median for the post-period decreased by 0.1473 million RMB or 55.45%. The average business circle-level weekly consumption frequencies for the entire sample period, the pre-period, and the post-period are 657, 958, and 607, respectively. Relative to the pre-period, the post-period decreases by 351% or 36.66%. The median weekly consumptions for the three sample periods were 56, 98, and 51, respectively. Compared to the pre-period, the median for the post-period decreased by 47, or 47.96%. Compared with the percentage change before and after the event date in 2019, there is an additional sharp decrease in 2020 based on the mean and median for consumption amount and frequency.

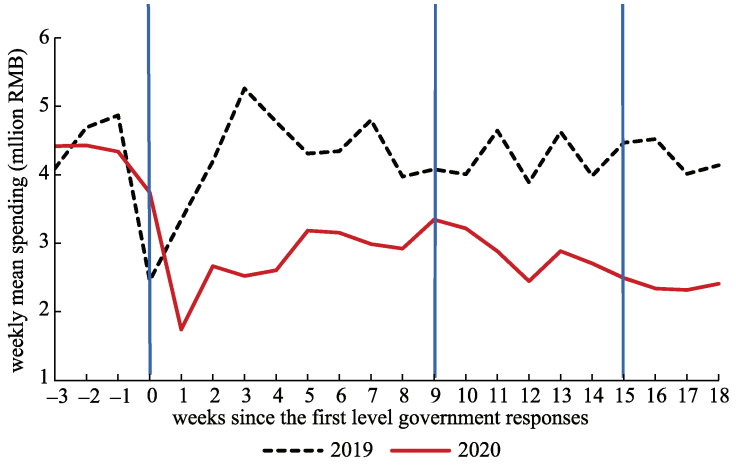

Figure 1 Time Series Pattern of the Weekly Mean Offline Consumption of All the Business Circles in Shanghai

To view the time series pattern of the weekly offline consumption, Figure 1[1] presents the time series pattern of the weekly mean offline consumption and Figure 2 presents the time series pattern of the weekly mean spending frequency of all the business circles in Shanghai. The figure suggests that the weekly mean offline consumption amount and frequency series in 2020 before the data of the outbreak of the new coronavirus pandemic (red line) shows no significant difference with the counterpart data in 2019(black dash line), but is almost always below that of 2019 (black dash line) and the gap widened in the post period. In addition, the consumption amount and frequency fell by a significant amount in the post-period for 2020 and the trend continued for a long time, while the time series of 2019 (black line) recovered very fast since the Chinese New Year's Eve week, and was almost back to the average level of the pre-period. Therefore, the data satisfies the parallel trend hypothesis. There is reason to think that the incremental part of the gap in the post period should have contributed to the shock of COVID outbreak event. The difference-in-differences strategy can be employed to estimate the change in consumption relative to the counterfactual change in spending based on data in 2019.

Table 2 further reports the mean difference in weekly consumption between the pre-period and the post-period by consumption category. In 2019, the weekly consumption of most types and categories fell slightly. In 2020, the decrease in most types and categories of consumption expanded. For more detailed consumption categories, we focus on describing the percentage changes in 2020. Within all the categories, transportation and logistics services fell the most by 50.99%, followed by life services with a decrease of 42.17%, and retail with a decrease of 41.85%. Based on the relative percentage changes from 2019, the top three categories are transportation and logistics services (73.39%), retail

[1] Note: The weekly total offline consumption is calculated as the sum of all spending through Union-pay Merchant Service (UMS) POS machines and QR scanners for each circle-week. Our sample covers 16 districts with more than two hundred business circles. The sample period is from the first week to the twenty-third week of 2020, with the fourth week of 2020 (when the government launched the first-level response mechanism for major public health emergencies) defined as the start of the outbreak. To capture the counterfactual consumption pattern, we use the same week from the first week to twenty-fifth week of 2019 as the benchmark group, and evaluate the impact on consumption through a DID regression approach. Note that we match the sample in 2019 and 2020 by the lunar calendar instead of the calendar date to capture the seasonality variation in consumption related to the Chinese New Year. Accordingly, we use sixth week of 2019 (the week the Chinese New Year's Eve similar to the fourth week of 2020) as the cut-off date to define the pre and post period for 2019.

(49.90%), and accommodations (49.10%). It is not surprising that the others category, including public service and social organization consumption, increased by 16.71%, as consumers need more public services during outbreak periods. Within consumption frequencies, life services fell the most by 40.88%, followed by transportation and logistics services with a decrease of 37.97%, and restaurants with a decrease of 37.55%. Based on the relative percentage changes from 2019, the top three categories are accommodations (40.78%), recreation & entertainment (37.66%), and insurance financial services (34.76%).

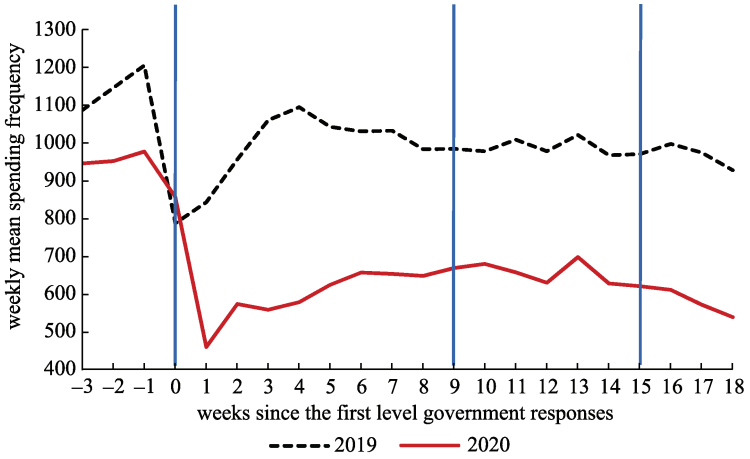

Figure 2 Time Series Pattern of the Weekly Mean Spending Frequency of All the Business Circles in Shanghai

Table 2 Summary of Different Categories

Panel A: Spending amount (in million RMB)

	2019			2020		
	Pre	Post	Post-Pre	Pre	Post	Post-Pre
All	4.1963	4.2078	0.0115	4.3917	2.6712	–1.7205
Category:						
Transportation and logistics services	0.7740	0.9474	0.1734	0.9229	0.4523	**–0.4706**
Recreation & entertainment	3.0352	3.5457	0.5105	3.4031	2.5002	**–0.9029**
Accommodations	2.6175	2.9801	0.3626	2.7159	1.7611	**–0.9548**
Insurance financial services	3.9571	3.9232	–0.0339	2.4468	2.8349	**0.3880**
Others	1.0735	0.7923	–0.2812	1.9908	1.3513	**–0.6395**

(*To be continued*)

(*Continued*)

Panel A: Spending amount (in million RMB)						
	2019			2020		
	Pre	Post	Post-Pre	Pre	Post	Post-Pre
Real estate services	11.9037	13.2810	1.3773	9.1739	6.7348	**–2.4391**
Wholesale	6.1927	4.9849	–1.2078	3.7715	2.5880	**–1.1835**
Life services	3.6960	3.1750	–0.5210	3.7383	2.1620	**–1.5764**
Retail	4.5603	4.9273	0.3670	5.5225	3.2113	**–2.3112**
Restaurant	4.4382	3.9559	–0.4823	3.3072	2.0227	**–1.2845**
Panel B: Consumption frequency						
	2019			2020		
	Pre	Post	Post-Pre	Pre	Post	Post-Pre
All	1,066	978	–88	958	607	**–351**
Category:						
Transportation and logistics services	440	418	–22	375	233	**–143**
Recreation & entertainment	765	823	58	708	494	**–213**
Accommodations	1,087	1,146	59	1,059	685	**–374**
Insurance financial services	162	225	63	50	52	**2**
Others	291	257	–34	512	398	**–115**
Real estate services	89	76	–13	31	20	**–11**
Wholesale	351	275	–76	130	102	**–28**
Life services	1,166	991	–175	1,006	595	**–411**
Retail	1,164	1,088	–76	1,114	708	**–406**
Restaurant	2,555	2,413	–142	1,827	1,141	**–686**

Note: Post is defined as 1 for post periods after Jan. 23, 2020 (the fourth week and after), for 2020 samples, and for post periods after Feb. 3, 2019 (the sixth week and after), for 2019 samples.

2.3 Empirical Methodology

We use a difference-in-differences regression approach to examine the impact of COVID-19 on consumption. The treatment group corresponds to business circles in 2020 after the COVID-19 pandemic outbreak, and the control group corresponds to business circles in 2019. The pretreatment period was 2020:01-2020:03 (three weeks), and the post-treatment period was 2020:04-2020:23 (20

weeks)[2]. First, we estimated the average weekly response to the outbreak of the pandemic using the following regression:

$$Consumption_{cdt} = \alpha_0 + \beta_0 \text{treat} * \text{post} + \sigma_d + \delta_c + \pi_{cdt} \quad (1)$$

where the dependent variable, $\text{Consumption}_{\text{cdt}}$, is the weekly spending amount (in millions of RMB) or weekly spending frequency for business circle c. The dummy variable treat is defined as 1 for 2020 sample observations and 0 otherwise. The post is defined as 1 for post periods after Jan. 23, 2020 (the fourth week and after)[3], for 2020 samples, and for post periods after Feb. 3, 2019 (the sixth week and after), for 2019 samples. σ_d is the district fixed effect, and δ_c is the business circle fixed effect. The coefficient β_1 captures the average weekly post-pandemic spending amount or frequency response for the treated business circle (compared to the benchmark period, i.e., from 2019:06 to 2019:25) relative to the post-Spring festival of the control group. Standard errors in all regression analyses were clustered at the business circle level.

Following Agarwal et al. (2007) and Agarwal et al. (2014), we also divide the post-pandemic window into the first-level response mechanism, the second-level response mechanism, and the third-level response mechanism for the major public health emergency period to compare the effects in these three windows separately.

$$\begin{aligned} Consumption_{cdt} = \alpha_0 &+ \beta_1 \text{treat} * \text{post}_1 + \beta_2 \text{treat} * \text{post}_2 \\ &+ \beta_3 \text{treat} * \text{post}_3 + \sigma_d + \delta_c + \pi_{cdt} \end{aligned} \quad (2)$$

Specifically, post1 is a binary variable equal to 1 for the nine weeks during the first-level response policy for the major public health emergency period window(2020:04-2020:12), post2 is a binary variable equal to 1 for the six weeks

[2] we use the first level government responses date (the fourth week of 2020) as the start of the outbreak and compare the consumption before and after. To capture the counterfactual consumption pattern, we use the same period data in 2019 as the benchmark group. Instead of using the same calendar date to divide the 2019 sample, we use the lunar calendar to define the event date to account for the seasonal variation in consumption related to the Chinese New Year (CNY) period. The fourth week of 2020 is the CNY eve week and thus we use the corresponding lunar calendar week in 2019 as the cut off to define the pre and post period (the sixth week of 2019). In the difference-in-differences regressions, we include district- and circle- fixed effects to absorb unobserved district and circle heterogeneity.

[3] That is, for 2020, the first three weeks are defined as 0, and the fourth week and after are defined as 1. For 2019, the first five weeks are defined as 0, and the sixth week and after are defined as 1.

during the second-level response policy for the major public health emergency period window (2020:13-2020:18), and post3 is a binary variable equal to 1 for the five weeks during the third-level response policy for major public health emergency period window (2020:19-2020:23).

3 Results Analysis

3.1 Basic Regression

We begin by estimating the average effect of COVID-19 on weekly offline consumption, and the results are presented in Table 3. Table 3 presents the estimated results of equation (1) with the weekly spending amount (in millions of RMB) and consumption frequency as the dependent variable. Column 1 shows the estimated results for the total spending of all consumption types and categories. The coefficient of the interactive term treat*post is −1.843, statistically significant at the 1% level, implying a decrease of 1.843 million RMB in weekly spending on average for each business circle relative to the counterfactual path without the COVID-19 outbreak event. Column 2 shows the estimated results for the total spending frequency for all consumption types and categories. The coefficient of the interactive term treat*post is –447, statistically significant at the 1% level, implying a decrease of 447 times in weekly consumption on average for each business circle relative to the counterfactual path without the COVID-19 outbreak event. Columns 3 and 4 report the estimated results after controlling for the district fixed effect, and the results are similar to those in Columns 1 and 2.

On January 23, the COVID-19 outbreak was announced as a pandemic in China. On January 24th, Shanghai launched a novel coronavirus first-level response policy for major public health emergencies (the fourth week in 2020). On March 24 (the 13th week), the response level of major public health emergencies in Shanghai was adjusted from the first to the second-level. On May 9 (the 19th week), the response level of major public health emergencies in Shanghai was adjusted from the second-level to the third-level. This enables us to investigate different levels of major public health emergency effects separately. Following the previous setting (Agarwal et al., 2014), we estimate equation (2) by decomposing the post-COVID-19 pandemic window into the first, second, and third-level periods. Table 4 presents the estimated results of equation (2) with

the weekly spending amount (in million RMB) and consumption frequency as the dependent variable. We find a significant decline in the total spending of all consumption types and categories in all three windows: the spending amount declines by 1.729 million RMB in the first-level period, 1.521 million RMB in the second-level period, and 2.444 million RMB after the third-level period.

Table 3 Basic Results

	(1) Spending amount (in million RMB)	(2) Consumption frequency	(3) Spending amount (in million RMB)	(4) Consumption frequency
*treat*post*	−1.843***	−447.0***	−1.848***	−448.6***
	(0.169)	(23.17)	(0.169)	(23.11)
Constant	9.358***	1294.5***	9.000***	1494.1***
	(1.102)	(55.44)	(1.116)	(68.29)
Observations	269,534	269,534	269,534	269,534
R^2	0.051	0.090	0.054	0.095
Circle fixed effect	Yes	Yes	Yes	Yes
District fixed effect	No	No	Yes	Yes

Note: The stars denote significance levels: * p < .10, ** p < .05, and *** p < .01. Standard errors are clustered at the business circle level and are reported in parentheses. The post is defined as 1 for post periods after Jan. 23, 2020 (the fourth week and after), for 2020 samples, and for post periods after Feb. 3, 2019 (the sixth week and after), for 2019 samples.

For offline consumption frequency, spending declines 441.3 times in the first-level period, 377.8 times in the second-level period, and 543.4 times after the third-level period. From the above results, we can observe that after the prevention and control policy downgraded from the first-level response to the second-level response, consumption showed signs of slow recovery, and the estimated coefficient of the DID variable, that is, the interactive term treat*post decreased from −1.729 to −1.521. However, when the prevention and control policy was downgraded from second-level response to third-level response, the negative impact on consumption rebounded again, and the estimated coefficient of the DID variable, that is, the interactive term treat*post, was even lower than that of the first-level response, which means that the government's prevention and control measures have a certain effect on the recovery of consumption, but it

is not as obvious as expected. The negative impact on consumption is characterized by a degree of persistence, likely due to the recurrence of the epidemic itself, the persistence of people's psychological impact, and the shift of many consumer activities from offline to online.

Table 4 Three Levels of the Major Public Health Emergency

	(1)	(2)	(3)	(4)
	Spending amount (in million RMB)	Consumption frequency	Spending amount (in million RMB)	Consumption frequency
*treat*post_1*	–1.729***	–441.3***	–1.738***	–444.0***
	(0.257)	(33.79)	(0.257)	(33.76)
*treat*post_2*	–1.521***	–377.8***	–1.517***	–377.7***
	(0.233)	(34.04)	(0.233)	(33.94)
*treat*post_3*	–2.444***	–543.4***	–2.452***	–545.3***
	(0.153)	(23.51)	(0.153)	(23.51)
Constant	9.360***	1294.8***	9.000***	1494.5***
	(1.102)	(55.44)	(1.116)	(68.31)
Observations	269,534	269,534	269,534	269,534
R^2	0.051	0.090	0.054	0.095
Circle fixed effect	Yes	Yes	Yes	Yes
District fixed effect	No	No	Yes	Yes

Note: The stars denote significance levels: * p < .10, ** p < .05, and *** p < .01. Standard errors are clustered at the business circle level and are reported in parentheses. Post_1 is defined as 1 between the first-and second-level periods (from the 4th week to the 12th week), for 2020 samples; post_ 2 is defined as 1 between the second-and third-level periods (from the 13th week to the 18th week) for 2020 samples. Post_3 is defined as 1 for post periods after May 9, 2020 (from the 19th week to the 23rd week) for 2020 samples. Post_1, post_2, and post_3 are defined as 1 for post periods the 6th week to 14th week, 15th week to 20th week, and 21st week to 25th week, respectively.

3.2 Heterogeneity

In this section, we conduct a series of heterogeneity tests to investigate the heterogeneity across different districts and categories. Table 5 reports the estimated results for the 16 districts. The results show that, except for Huangpu District, all 15 other districts of 206 business circles experienced significant

Table 5 District Heterogeneity

	Jiading	Fengxian	Baoshan	Chongming	Xuhui	Putuo	Yangpu	Songjiang	Pudong	Hongkou	Jinshan	Changning	Minhang	Qingpu	Jing'an	Huangpu
								Panel A: Spending amount (in million RMB)								
*treat*post*	−1.607***	−0.762***	−1.146***	−0.226***	−1.945***	−1.200***	−1.483***	−0.638***	−1.569***	−3.919***	−0.333***	−1.178***	−1.442***	−1.013***	−9.274***	1.584
	(0.136)	(0.0759)	(0.0893)	(0.0270)	(0.180)	(0.113)	(0.115)	(0.0603)	(0.0981)	(0.518)	(0.0289)	(0.130)	(0.111)	(0.158)	(1.270)	(2.183)
Constant	1.688***	2.481***	1.231***	0.178***	5.170***	4.278***	4.690***	0.568***	2.421***	5.834***	0.458***	2.816***	9.194***	0.0659**	2.853*	0.000300***
	(0.0871)	(0.155)	(0.0722)	(0.0171)	(0.826)	(0.302)	(0.339)	(0.0345)	(0.118)	(0.715)	(0.0335)	(0.210)	(1.134)	(0.0287)	(1.595)	(0.0000559)
Observations	15690	12447	17577	10190	16229	14724	10709	20151	37813	11598	13743	13173	27576	9310	23955	14649
R^2	0.036	0.037	0.031	0.060	0.035	0.032	0.057	0.028	0.046	0.050	0.027	0.025	0.035	0.049	0.064	0.043
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
								Panel B: Consumption frequency								
*treat*post*	−308.3***	−191.3***	−295.8***	−46.90***	−408.3***	−300.9***	−674.2***	−209.3***	−501.8***	−716.1***	−113.0***	−501.7***	−334.2***	−331.7***	−1565.1***	−219.4
	(19.09)	(19.51)	(18.84)	(9.229)	(32.70)	(21.39)	(47.64)	(13.91)	(20.39)	(58.14)	(9.102)	(31.31)	(12.99)	(32.33)	(168.7)	(299.4)
Constant	567.5***	889.6***	507.6***	74.44***	503.9***	1323.2***	1564.4***	280.7***	884.0***	1027.3***	214.2***	779.4***	1248.4***	24.26***	263.2	1.684***
	(31.94)	(54.11)	(28.11)	(6.481)	(21.23)	(87.04)	(85.21)	(14.48)	(48.18)	(78.67)	(17.29)	(34.70)	(56.25)	(9.047)	(170.6)	(0.167)
Observations	15690	12447	17577	10190	16229	14724	10709	20151	37813	11598	13743	13173	27576	9310	23955	14649
R^2	0.058	0.055	0.048	0.085	0.082	0.060	0.063	0.045	0.061	0.093	0.062	0.059	0.080	0.055	0.099	0.090
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The stars denote significance levels: * p < .10, ** p < .05, and *** p < .01. Standard errors are clustered at the circle level and are reported in parentheses. Post is defined as 1 for post periods after Jan. 23, 2020 (the fourth week and after), for 2020 samples, and for post periods after Feb. 3, 2019 (the sixth week and after), for 2019 samples.

weekly consumption decreases with magnitudes ranging from 0.226 million to 9.274 million RMB, or weekly consumption frequencies ranging from 46.90 to 1565.1. Within all the districts, Jing'an District fell the most, followed by Hongkou District and Xuhui District. The coefficients of the interactive term treat*post are –9.274, –3.919, and –1.945, respectively, and all are statistically significant at the 1% level, implying a decrease of 9.274 million, 3.919 million, and 1.945 million RMB respectively, in weekly consumption on average for Jing'an business circle, Hongkou business circle, and Xuhui District relative to the counterfactual path without the COVID-19 outbreak event. For Huangpu District, the coefficient of the interactive term treat*post is not significant.

Regarding spending frequency, Jing'an District fell the most, followed by Hongkou District and Xuhui District. The coefficients of the interactive term treat*post are –1565.1, –716.1, and –408.3, respectively, and all are statistically significant at the 1% level, implying a decrease of 1565.1, 716.1, and 408.3, respectively, on average for each Jing'an business circle, Hongkou business circle, and Xuhui District relative to the counterfactual path without the COVID-19 outbreak event. Figure 3 presents the point-fold line chart for the 16 districts to view the impacts on consumption across different districts. We observe that the central urban areas, such as Jing'an District, Hongkou District, and Xuhui District, are most severely affected. Non-central urban areas such as Chongming District, Songjiang District, and Jinshan District are relatively less affected.

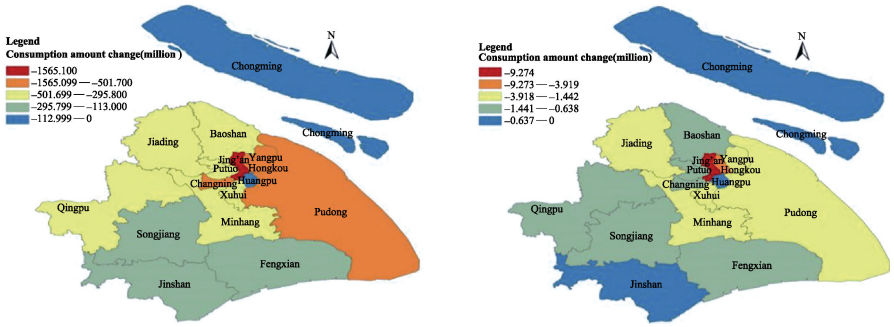

Figure 3 Point-fold Line Chart: Impacts on Consumption across Different Districts of Shanghai

In Table 6, we further estimate the differences of consumption shocks in different districts after the three-level response policy for major public health emergencies. The results show that, similar to Table 4, with the downgrade in the

Table 6 Three Levels of Emergency Response of District Heterogeneity

	Jiading	Fengxian	Baoshan	Chongming	Xuhui	Putuo	Yangpu	Songjiang	Pudong	Hongkou	Jinshan	Changning	Minhang	Qingpu	Jing'an	Huangpu
								Panel A: Spending amount (in million RMB)								
*treat*post_1*	−1.816***	−0.882***	−1.318***	−0.222***	−2.294**	−1.437***	−1.747***	−0.740***	−1.915***	−3.661***	−0.352***	−1.439***	−1.640***	−1.374***	−9.593***	7.102*
	(0.141)	(0.0831)	(0.0954)	(0.0318)	(0.185)	(0.129)	(0.126)	(0.0673)	(0.102)	(0.673)	(0.0342)	(0.129)	(0.118)	(0.127)	(1.313)	(3.990)
*treat*post_2*	−1.280***	−0.635***	−0.966***	−0.210***	−1.584**	−0.866***	−1.200***	−0.541***	−1.166***	−4.076***	−0.293***	−0.906***	−1.250***	−0.815***	−7.563***	1.340
	(0.183)	(0.0899)	(0.111)	(0.0324)	(0.233)	(0.205)	(0.164)	(0.0804)	(0.170)	(0.509)	(0.0358)	(0.177)	(0.126)	(0.183)	(1.548)	(3.341)
*treat*post_3*	−1.649***	−0.723***	−1.074***	−0.254***	−1.796**	−1.211***	−1.384***	−0.583***	−1.464***	−4.184***	−0.353***	−1.059***	−1.342***	−0.645	−10.83***	−7.988***
	(0.153)	(0.0972)	(0.117)	(0.0335)	(0.257)	(0.145)	(0.181)	(0.0859)	(0.140)	(0.573)	(0.0372)	(0.199)	(0.136)	(0.468)	(1.374)	(1.489)
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15690	12447	17577	10190	16229	14724	10709	20151	37813	11598	13743	13173	27576	9310	23955	14649
								Panel B: Consumption frequency								
*treat*post_1*	−331.0***	−210.2***	−309.8***	−37.74***	−458.0**	−317.3***	−713.8***	−225.9***	-535.2***	-683.7***	−114.6***	−532.0***	−356.2***	−372.5***	−1587.6***	230.9
	(22.77)	(23.82)	(23.38)	(12.40)	(39.72)	(27.08)	(53.75)	(16.78)	(24.75)	(74.18)	(11.45)	(34.51)	(15.95)	(37.54)	(179.4)	(509.9)
*treat*post_2*	−274.4***	−165.9***	−267.4***	−47.85***	−352.5**	−271.1***	−626.0***	−183.8***	−462.6***	−720.2***	−103.0***	−472.9***	−304.6***	−286.6***	−1342.9***	255.2
	(25.04)	(26.08)	(24.97)	(12.22)	(48.64)	(29.18)	(56.02)	(18.44)	(26.27)	(58.64)	(12.78)	(35.41)	(16.70)	(43.63)	(199.7)	(511.6)
*treat*post_3*	−311.1***	−191.6***	−307.0***	−61.88***	−392.6**	−310.0***	−666.8***	−212.2***	−492.2***	−769.2***	−122.8***	−484.5***	−333.5***	−319.2***	−1801.0***	−1614.8**
	(25.84)	(26.46)	(26.13)	(12.48)	(53.49)	(30.09)	(58.98)	(18.70)	(27.41)	(61.33)	(13.05)	(38.76)	(17.35)	(47.37)	(187.1)	(267.8)
Observations	15690	12447	17577	10190	16229	14724	10709	20151	37813	11598	13743	13173	27576	9310	23955	14649
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The stars denote significance levels: * p < .10, ** p < .05, and *** p < .01. Standard errors are clustered at the circle level and are reported in parentheses. Post_1 is defined as 1 between the first-and second-level periods (from the 4th week to the 12th week), for 2020 samples; post_ 2 is defined as 1 between the second-and third-level periods (from the 13th week to the 18th week) for 2020 samples. Post_3 is defined as 1 for post periods after May 9, 2020 (from the 19th week to the 23rd week) for 2020 samples. Post_1, post_2, and post_3 are defined as 1 for post periods the 6th week to 14th week, 15th week to 20th week, and 21st week to 25th week, respectively.

level of prevention and control response policy, the negative impact on consumption first gradually decreased, and then rebounded to a certain extent (as shown in appendix Figure 5 to Figure 10).

Table 7 reports the estimated results for ten consumption categories. The results show that except for the others category, including government enterprise consumption expenditures, spending on the other nine categories of goods or services is significantly affected, with declines ranging from 0.513 million to 7.190 million RMB. Within all the categories, real estate services fell the most, followed by wholesale and restaurants. The coefficients of the interactive term treat*post are –7.190, –2.969, and –2.161, respectively, and all are statistically significant at the 1% level, implying a decrease of 7.190 million, 2.969 million, and –2.161 million RMB in weekly consumption on average for real estate services, wholesale, and restaurants relative to the counterfactual path without the COVID-19 outbreak event. For spending frequency, restaurants fell the most, followed by life services and retail. The coefficients of the interactive term treat*post are –1353.5, –478.6, and –468.1, respectively, and all are statistically significant at the 1% level, implying a decrease of 1353.5, 478.6, and 468.1 in weekly consumption frequencies on average for these categories relative to the counterfactual path without the COVID-19 outbreak event.

To view the impacts on consumption across different categories, Figure 4 presents a point-fold line chart for 10 categories. We observe that housing, restaurants, and other industries have been seriously impacted.

We also estimate the differences of consumption shocks in different categories after the three-level response policy for major public health emergencies and report the results in Table 8. From the estimation results we can observe that with the downgrade in the level of the epidemic response policy, the negative impact on the consumption scale of most industries first decreased, and then rebounded, such as wholesale, life service, retail, restaurant, recreation & entertainment accommodation and insurance financial services. However, for transportation and logistics services and real estate services, with the relaxation in the prevention and control policy, the negative impact on these industries gradually weakened (As show in appendix Figure 11 and Figure 12).

Table 7 10 Category Heterogeneity

	Transportation and logistics services	Recreation & Entertainment	Accommodation	Insurance financial services	Others	Real estate services	Wholesale	Life service	Retail	Restaurant
	Panel A: Spending amount (in million RMB)									
*treat*post*	−0.513***	−1.301***	−1.365***	−1.683***	0.295***	−7.190***	−2.969***	−1.338***	−2.077***	−2.161***
	(0.0715)	(0.156)	(0.100)	(0.325)	(0.0825)	(0.567)	(0.203)	(0.0627)	(0.372)	(0.149)
Constant	0.735***	1.615***	2.187***	4.590***	0.775***	17.28***	9.913***	5.442***	15.55***	3.089***
	(0.0424)	(0.0832)	(0.115)	(0.672)	(0.0891)	(2.093)	(0.606)	(0.490)	(2.688)	(0.133)
Observations	10324	10992	10967	6677	7673	7384	9943	75680	117818	12076
R^2	0.376	0.744	0.759	0.161	0.577	0.360	0.525	0.099	0.078	0.699
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Panel B: Consumption frequency									
*treat*post*	−206.2***	−386.7***	−528.4***	−179.7***	78.81***	−47.88***	−201.0***	−478.6***	−468.1***	−1353.5***
	(34.33)	(31.55)	(34.09)	(31.02)	(20.92)	(2.379)	(19.52)	(16.73)	(48.85)	(64.17)
Constant	489.2***	655.9***	1388.6***	210.5***	242.6***	62.02***	358.8***	1419.4***	1555.2***	2759.9***
	(25.73)	(29.95)	(98.80)	(19.00)	(24.71)	(5.922)	(16.69)	(118.8)	(93.92)	(127.3)
Observations	10324	10992	10967	6677	7673	7384	9943	75680	117818	12076
R^2	0.227	0.765	0.743	0.121	0.497	0.618	0.442	0.088	0.110	0.704
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The stars denote significance levels: * p < .10, ** p < .05, and *** p < .01. Standard errors are clustered at the circle level and are reported in parentheses. Post is defined as 1 for post periods after Jan. 23, 2020 (the fourth week and after), for 2020 samples, and for post periods after Feb. 3, 2019 (the sixth week and after), for 2019 samples.

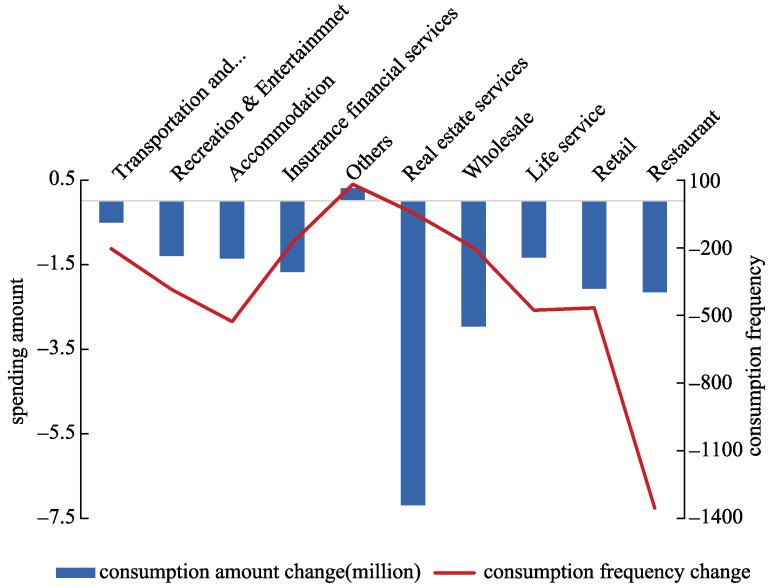

Figure 4 Point-fold Line Chart: Impacts on Consumption across Different Categories

Tables 9 and 10 report the estimated results for 13 consumption types. The results show that except for the other categories, including government enterprise consumption expenditures, cultural retail, sporting goods and equipment, and travel services, spending on the other 27 categories of goods or services is significantly affected, with declines ranging from 0.154 million RMB to 8.965 million RMB. Within all categories, warehouse supermarkets fell the most, followed by real estate services, government services, and public utilities, and the sales and service of vehicle parts. The coefficients of the interactive term treat*post are −8.965, −7.190, −5.222, and −4.235 and all are statistically significant at the 1% level, implying a decrease of 8.965, 7.190, 5.222, and 4.235 million RMB respectively, in weekly consumption on average for warehouse supermarkets, real estate services, government services and public utilities, and service of vehicle parts relative to the counterfactual path without the COVID-19 outbreak event. Warehouse supermarkets fell the most, followed by catering, textile, and retail clothing stores. The coefficients of the interactive term treat*post are −2403.5, −1353.5, and −690.5 and all are statistically significant at the 1% level, implying a decrease of 2403.5, 1353.5, and 690.5 respectively, on average for these categories relative to the counterfactual path without the COVID-19 outbreak event.

Table 8 Three Levels of Emergency Response of 10 Category Heterogeneity

	Transportation and logistics services	Recreation & Entertainment	Accommodation	Insurance financial services	Others	Real estate services	Wholesale	Life service	Retail	Restaurant
				Panel A: Spending amount (in million RMB)						
*treat*post_1*	−0.544***	−1.313***	−1.538***	−2.251***	−0.142*	−11.19***	−3.598***	−1.535***	−1.430**	−2.477***
	(0.0730)	(0.184)	(0.119)	(0.384)	(0.0848)	(0.630)	(0.244)	(0.0761)	(0.559)	(0.179)
*treat*post_2*	−0.477***	−1.013***	−1.215***	−1.356***	0.730***	−5.968***	−2.434***	−0.991***	−1.843***	−2.020***
	(0.0857)	(0.182)	(0.121)	(0.451)	(0.152)	(0.861)	(0.250)	(0.0953)	(0.509)	(0.180)
*treat*post_3*	−0.426***	−1.432***	−1.563***	−1.829***	0.568***	−5.804***	−2.547***	−1.419***	−3.600***	−2.396***
	(0.125)	(0.256)	(0.165)	(0.559)	(0.173)	(0.963)	(0.390)	(0.104)	(0.342)	(0.245)
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
				Panel B: Consumption frequency						
*treat*post_1*	−286.7***	−403.0***	−600.8***	−207.5***	−35.05*	−61.55***	−243.8***	−527.8***	−395.6***	−1563.6***
	(15.80)	(36.38)	(38.94)	(39.98)	(19.49)	(3.446)	(24.01)	(20.27)	(71.16)	(76.38)
*treat*post_2*	−97.36	−317.8***	−482.7***	−174.1***	192.4***	−42.85***	−164.9***	−415.6***	−393.5***	−1235.9***
	(105.5)	(36.00)	(42.42)	(36.60)	(39.15)	(3.379)	(20.59)	(22.28)	(70.92)	(77.28)
*treat*post_3*	−187.9***	−405.9***	−553.8***	−204.2***	138.8***	−51.64***	−145.6***	−474.9***	−707.0***	−1362.4***
	(26.08)	(52.98)	(56.19)	(42.53)	(45.62)	(3.618)	(33.49)	(23.98)	(48.04)	(107.1)
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The stars denote significance levels: * p < .10, ** p < .05, and *** p < .01. Standard errors are clustered at the circle level and are reported in parentheses. Post_1 is defined as 1 between the first-and second-level periods (from the 4th week to the 12th week), for 2020 samples; post_ 2 is defined as 1 between the second-and third-level periods (from the 13th week to the 18th week) for 2020 samples. Post_3 is defined as 1 for post periods after May 9, 2020 (from the 19th week to the 23rd week) for 2020 samples.

Table 9 30 Category Heterogeneity

	Hardware, furniture and interior decoration materials retail	*Transportation and logistics services*	*Warehouse supermarket*	*Leisure and entertainment industry*	*Accommodation industry*	*Insurance financial services*	*Information and computer services*	*Savings related transactions*	*Others*	*Other retail stores*	*Rental and rental services*	*Gas station*	*Specialized retail of medicine and medical equipment*	*Hygiene*	*Business services*
	Panel A: Spending amount (in million RMB)														
*treat*post*	−0.553**	−0.513***	−8.965***	−1.301***	−1.365***	−1.683***	−0.391***	−3.840***	0.295***	−0.788***	0.0206**	−0.337***	−0.154***	−2.466***	−1.042***
	(0.225)	(0.0715)	(2.723)	(0.156)	(0.100)	(0.325)	(0.0271)	(0.113)	(0.0825)	(0.0641)	(0.00947)	(0.0705)	(0.0128)	(0.120)	(0.153)
Constant	0.871***	0.735***	5.787***	1.615***	2.187***	4.590***	0.558***	18.98***	0.775***	3.810***	-0.00605	1.561***	0.263***	2.342***	2.421***
	(0.133)	(0.0424)	(1.253)	(0.0832)	(0.115)	(0.672)	(0.0307)	(0.951)	(0.0891)	(0.512)	(0.00471)	(0.0946)	(0.0147)	(0.195)	(0.185)
Observations	9761	10324	12440	10992	10967	6677	9941	12233	7673	11651	987	8338	10735	9682	11561
R^2	0.606	0.376	0.429	0.744	0.759	0.161	0.429	0.488	0.577	0.594	0.570	0.162	0.711	0.789	0.567
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Panel B:Spending frequency														
treat post*	−90.15***	−206.2***	−2403.5***	−386.7***	−528.4***	−179.7***	−411.6***	−1971.7***	78.81***	−233.2***	−5.988**	−351.5***	−96.18***	−628.5***	−379.0***
	(25.33)	(34.33)	(346.7)	(31.55)	(34.09)	(31.02)	(24.42)	(51.03)	(20.92)	(13.07)	(2.488)	(16.55)	(3.858)	(21.12)	(25.82)
Constant	90.52***	489.2***	6893.3***	655.9***	1388.6***	210.5***	468.4***	8053.4***	242.6***	497.6***	9.465***	1658.7***	324.2***	664.1***	617.4***
	(11.20)	(25.73)	(276.3)	(29.95)	(98.80)	(19.00)	(20.65)	(363.7)	(24.71)	(14.62)	(1.622)	(94.84)	(10.31)	(40.56)	(35.68)
Observations	9761	10324	12440	10992	10967	6677	9941	12233	7673	11651	987	8338	10735	9682	11561
R^2	0.672	0.227	0.442	0.765	0.743	0.121	0.487	0.501	0.497	0.742	0.511	0.377	0.669	0.816	0.718
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The stars denote significance levels: * p < .10, ** p < .05, and *** p < .01. Standard errors are clustered at the circle level and are reported in parentheses. Post is defined as 1 for post periods after Jan. 23, 2020 (the fourth week and after), for 2020 samples, and for post periods after Feb. 3, 2019 (the sixth week and after), for 2019 samples.

Table 10 30 Category Heterogeneity (continue)

	Luxury goods and crafts	*Retail of household appliances and electronic products*	*Real estate services*	*Wholesale*	*Government service and public utilities*	*Education*	*Retail of culture, sports goods and equipment*	*Travel services*	*Department store*	*Direct merchants*	*Textile and clothing retail store*	*Maintenance service*	*Sales and service of vehicle parts*	*Retail of food, beverage and tobacco products*	*Catering*
	Panel A:Spending amount (in million RMB)														
*treat*post*	−2.293***	−1.004***	−7.190***	−2.969***	−5.222***	−0.722***	0.0182	−0.205	−2.877***	−0.0518***	−1.476***	−0.0775***	−4.235***	−0.571***	−2.161***
	(0.249)	(0.141)	(0.567)	(0.203)	(0.282)	(0.0313)	(0.0721)	(0.143)	(0.268)	(0.00635)	(0.173)	(0.0274)	(0.268)	(0.0367)	(0.149)
Constant	2.524***	3.891***	17.28***	9.913***	24.29***	0.935***	0.211***	0.187***	3.035***	0.00492***	2.507***	0.0588***	150.9***	0.824***	3.089***
	(0.169)	(0.179)	(2.093)	(0.606)	(2.754)	(0.0647)	(0.0356)	(0.0562)	(0.171)	(0.00175)	(0.113)	(0.0166)	(22.22)	(0.0651)	(0.133)
Observations	9522	10263	7384	9943	6348	7763	9155	4616	10074	1992	11073	4211	9570	11582	12076
R^2	0.598	0.529	0.360	0.525	0.628	0.394	0.267	0.702	0.508	0.676	0.654	0.411	0.501	0.701	0.699
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Panel B:Spending frequency														
*treat*post*	−312.1***	−205.7***	−47.88***	−201.0***	−243.6***	−377.1***	416.2***	−81.70***	−861.2***	−11.67***	−690.5***	2.028	−246.5***	−245.1***	−1353.5***
	(30.42)	(17.72)	(2.379)	(19.52)	(13.01)	(53.75)	(112.4)	(19.02)	(51.87)	(4.352)	(44.13)	(6.464)	(11.67)	(11.74)	(64.17)
Constant	476.4***	781.0***	62.02***	358.8***	1032.9***	221.1***	6.355	44.31***	1815.7***	1.364***	2648.5***	1.701	3259.5***	595.0***	2759.9***
	(26.12)	(31.06)	(5.922)	(16.69)	(94.50)	(28.43)	(64.12)	(8.714)	(83.44)	(0.148)	(166.4)	(3.158)	(481.1)	(24.39)	(127.3)
Observations	9522	10263	7384	9943	6348	7763	9155	4616	10074	1992	11073	4211	9570	11582	12076
R^2	0.618	0.625	0.618	0.442	0.428	0.418	0.287	0.718	0.624	0.276	0.689	0.554	0.620	0.757	0.704
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The stars denote significance levels: * p < .10, ** p < .05, and *** p < .01. Standard errors are clustered at the circle level and are reported in parentheses. Post is defined as 1 for post periods after Jan. 23, 2020 (the fourth week and after), for 2020 samples, and for post periods after Feb. 3, 2019 (the sixth week and after), for 2019 samples.

In addition, we examined the impact of COVID-19 at different times in a day. Table 11 reports the average effect of COVID-19 on weekly consumption, and the results show that within the three periods, the average consumption amount and frequency both fell the most from 6:00 to 18:00, followed by 18:00 to 24:00. Table 12 reports the estimated results for 16 districts at different times of the day. We can observe that for the spending amount within all the districts, consumption decreases the most from 06:00 to 18:00, but for the consumption frequency, all the districts fell the most from 0:00 to 6:00. Tables 13, 14, and 15 report the estimated results for ten consumption types at different times in a day. Within all categories, restaurant consumption decreased the most from 18:00 to 24:00. For the other nine categories, the average consumption amount and frequency fell the most from 6:00 to 18:00, followed by 18:00 to 24:00.

Table 11 Time Variation Effect

Panel A	Period 1 00:00-06:00		Period 2 0006:00-18:00		Period 3 18:00-24:00	
	Spending amount (in million RMB)	Consumption frequency	Spending amount (in million RMB)	Consumption frequency	Spending amount (in million RMB)	Consumption frequency
*reat*post*	–0.0138***	–4.006***	–1.511***	–324.8***	–0.323***	–119.8***
	(0.000901)	(1.357)	(0.123)	(16.31)	(0.0479)	(7.155)
Constant	0.0286***	18.61***	8.303***	1161.2***	0.668***	314.4***
	(0.00241)	(1.438)	(1.062)	(52.73)	(0.0738)	(16.63)
I	269,534	269,534	269,534	269,534	269,534	269,534
*R*2	0.050	0.005	0.052	0.087	0.055	0.101
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Panel B	Period 1 00:00-06:00		Period 2 0006:00-18:00		Period 3 18:00-24:00	
	Spending amount (in million RMB)	Consumption frequency	Spending amount (in million RMB)	Consumption frequency	Spending amount (in million RMB)	Consumption frequency
*reat*post_1*	–0.0141***	–6.721***	–1.441***	–311.8***	–0.283***	–125.4***
	(0.00131)	(0.306)	(0.187)	(23.78)	(0.0718)	(10.29)
*reat*post_2*	–0.0132***	–0.438	–1.271***	–281.9***	–0.233***	–95.32***
	(0.00112)	(4.280)	(0.157)	(22.37)	(0.0799)	(12.03)

(*To be continued*)

(*Continued*)

Panel B	Period 1 00:00-06:00		Period 2 0006:00-18:00		Period 3 18:00-24:00	
	Spending amount (in million RMB)	Consumption frequency	Spending amount (in million RMB)	Consumption frequency	Spending amount (in million RMB)	Consumption frequency
*reat*post_3*	–0.0142***	–3.746***	–1.933***	–401.1***	–0.505***	–140.5***
	(0.00101)	(1.219)	(0.115)	(16.71)	(0.0411)	(7.540)
Constant	0.0286***	18.69***	8.303***	1161.2***	0.668***	314.7***
	(0.00241)	(1.419)	(1.062)	(52.75)	(0.0739)	(16.64)
I	269,534	269,534	269,534	269,534	269,534	269,534
r^2	0.050	0.005	0.052	0.087	0.055	0.101
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effect	Yes	Yes	Yes	Yes	Yes	Yes

Note: The stars denote significance levels: * p < .10, ** p < .05, and *** p < .01. Standard errors are clustered at the circle level and are reported in parentheses. Post_1 is defined as 1 between the first-and second-level periods (from the 4th week to the 12th week), for 2020 samples; post_ 2 is defined as 1 between the second-and third-level periods (from the 13th week to the 18th week) for 2020 samples. Post_3 is defined as 1 for post periods after May 9, 2020 (from the 19th week to the 23rd week) for 2020 samples. Post_1, post_2, and post_3 are defined as 1 for post periods the 6th week to 14th week, 15th week to 20th week, and 21st week to 25th week, respectively.

4 Conclusion

The COVID-19 outbreak provides a genuinely exogenous unanticipated shock that enables this study to identify its impact on consumption. Using unique weekly UnionPay card transaction data, this study examines the impact of COVID-19 on the twenty-week post-outbreak period in Shanghai. It estimates how 206 business circles in 16 districts in Shanghai respond to an unanticipated pandemic outbreak in late January 2020, using the difference-in-differences methodology. The results show that the average offline spending of all consumption types and categories decreased by 1.843 million RMB, and the offline consumption frequency fell 447 times on average for each business circle relative to the counterfactual path without the COVID-19 outbreak event. By decomposing the post-COVID-19 pandemic window into the first-level, second-

Table 12 District Heterogeneity Time Variation Effect

	Jiading	Fengxian	Baoshan	Chongming	Xuhui	Putuo	Yangpu	Songjiang	Pudong	Hongkou	Jinshan	Changning	Minhang	Qingpu	Jing'an	Huangpu
Panel A: Spending amount (in million RMB)																
Period 1 00:00-06:00																
*treat*post*	−0.00736***	−0.00442***	−0.00878***	−0.00111***	−0.0102***	−0.0123***	−0.0113***	−0.00612***	−0.0139***	−0.0308***	−0.00113***	−0.0289***	−0.0103***	−0.00847***	−0.0429***	−0.0144
Period 2 0006:00-18:00																
*treat*post*	−1.410***	−0.673***	−1.011***	−0.206***	−1.759***	−1.072***	−1.278***	−0.522***	−1.320***	−2.977***	−0.288***	−0.867***	−1.269***	−0.827***	−6.809***	0.639
Period 3 18:00-24:00																
*treat*post*	−0.189***	−0.0854***	−0.126***	−0.0185***	−0.176***	−0.117***	−0.194***	−0.110***	−0.234***	−0.911***	−0.0438***	−0.282***	−0.162***	−0.177***	−2.422***	0.960
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Panel B: Consumption frequency																
Period 1 00:00-06:00																
*treat*post*	−5.031***	−2.758***	−5.285***	−1.431***	−5.611***	−5.147***	−10.41***	−3.780***	−7.029***	−8.130***	−1.191***	−14.67***	−7.353***	−4.574***	−10.75***	36.17
Period 2 0006:00-18:00																
*treat*post*	−0.00022***	−0.00014***	−0.00021***	−0.000033**	−0.00033***	−0.00022***	−0.00051***	−0.00015***	−0.00036***	−0.00051***	−0.000083**	−0.00035***	−0.00024***	−0.00024***	−0.00110***	−0.000211
Period 3 18:00-24:00																
*treat*post*	−0.000082**	−0.000051**	−0.000080**	−0.000012**	−0.000074**	−0.000081**	−0.00015***	−0.000060**	−0.00013***	−0.00020***	−0.000029**	−0.000140***	−0.000091**	−0.000089**	−0.00045*	−0.000045
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The stars denote significance levels: * p < .10, ** p < .05, and *** p < .01. Standard errors are clustered at the circle level and are reported in parentheses. Post is defined as 1 for post periods after Jan. 23, 2020 (the fourth week and after), for 2020 samples, and for post periods after Feb. 3, 2019 (the sixth week and after), for 2019 samples.

Table 13 10 Category Heterogeneity Time Variation Effect

Period 1: 00:00-06:00	Transportation and logistics services	Recreation & Entertainment	Accommodation	Insurance financial services	Others	Real estate services	Wholesale	Life service	Retail	Restaurant
	Panel A: Spending amount (in million RMB)									
*treat*post*	0.00584***	−0.0339***	−0.00202	−0.00265***	−0.000155	−0.00116***	−0.0115***	−0.0144***	−0.0132***	−0.0491***
	(0.00196)	(0.00352)	(0.00291)	(0.000851)	(0.000148)	(0.000299)	(0.00169)	(0.000574)	(0.00180)	(0.00351)
Constant	0.00948**	0.0608***	0.0488***	0.00107***	0.0000645	0.00332**	0.00478***	0.0403***	0.00758***	0.116***
	(0.00416)	(0.00909)	(0.00616)	(0.000394)	(0.0000627)	(0.00165)	(0.00108)	(0.00458)	(0.000872)	(0.0110)
Observations	10324	10992	10967	6677	7673	7384	9943	75680	117818	12076
R^2	0.154	0.640	0.591	0.068	0.155	0.028	0.814	0.054	0.044	0.476
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Panel B: Consumption frequency									
*treat*post*	57.42*	−14.25***	−18.07***	−0.465***	−0.131***	-0.0965***	−1.756***	−9.204***	−3.336***	−17.88***
	(32.47)	(0.685)	(0.821)	(0.140)	(0.0191)	(0.00904)	(0.247)	(0.292)	(0.326)	(0.752)
Constant	−17.53	26.73***	73.26***	0.188***	0.0547***	0.190***	0.732***	29.13***	3.595***	48.58***
	(14.33)	(2.736)	(6.412)	(0.0660)	(0.0123)	(0.0688)	(0.163)	(2.606)	(0.287)	(3.347)
Observations	10324	10992	10967	6677	7673	7384	9943	75680	117818	12076
R^2	0.080	0.627	0.627	0.065	0.368	0.276	0.393	0.057	0.060	0.672
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The stars denote significance levels: * p < .10, ** p < .05, and *** p < .01. Standard errors are clustered at the circle level and are reported in parentheses. Post is defined as 1 for post periods after Jan. 23, 2020 (the fourth week and after), for 2020 samples, and for post periods after Feb. 3, 2019 (the sixth week and after), for 2019 samples.

Table 14 10 Category Heterogeneity Time Variation Effect

Period 2: 06:00-18:00	Transportation and logistics services	Recreation & Entertainment	Accommodation	Insurance financial services	Others	Real estate services	Wholesale	Life service	Retail	Restaurant
	Panel A: Spending amount (in million RMB)									
*treat*post*	−0.383***	−0.826***	−1.061***	−1.442***	0.270***	−6.764***	−2.787***	−1.146***	−1.663***	−0.953***
	(0.0569)	(0.0862)	(0.0605)	(0.284)	(0.0767)	(0.524)	(0.191)	(0.0563)	(0.270)	(0.0799)
Constant	0.590***	0.936***	1.668***	4.481***	0.784***	16.59***	9.788***	4.817***	14.50***	1.115***
	(0.0324)	(0.0462)	(0.0830)	(0.662)	(0.0872)	(2.062)	(0.604)	(0.458)	(2.567)	(0.0482)
Observations	10324	10992	10967	6677	7673	7384	9943	75680	117818	12076
R^2	0.373	0.697	0.738	0.183	0.558	0.367	0.533	0.095	0.079	0.670
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Panel B: Consumption frequency									
*treat*post*	−198.9***	−217.2***	−411.3***	−142.8***	74.70***	−39.95***	−171.1***	−370.5***	−343.0***	−712.4***
	(9.220)	(15.82)	(18.17)	(20.53)	(19.97)	(2.174)	(17.13)	(13.41)	(34.78)	(33.40)
Constant	410.1***	366.2***	966.7***	194.7***	244.2***	52.76***	322.6***	1114.3***	1226.5***	1383.3***
	(14.98)	(15.51)	(60.60)	(16.19)	(24.39)	(5.683)	(15.41)	(88.85)	(78.28)	(57.17)
Observations	10324	10992	10967	6677	7673	7384	9943	75680	117818	12076
R^2	0.533	0.712	0.747	0.149	0.479	0.625	0.447	0.089	0.111	0.703
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The stars denote significance levels: * p < .10, ** p < .05, and *** p < .01. Standard errors are clustered at the circle level and are reported in parentheses. Post is defined as 1 for post periods after Jan. 23, 2020 (the fourth week and after), for 2020 samples, and for post periods after Feb. 3, 2019 (the sixth week and after), for 2019 samples.

Table 15 10 Category Heterogeneity Time Variation Effect

Period 3: 18:00-24:00	Transportation and logistics services	Recreation & Entertainment	Accommodation	Insurance financial services	Others	Real estate services	Wholesale	Life service	Retail	Restaurant
	Panel A: Spending amount (in million RMB)									
*treat*post*	−0.135***	−0.441***	−0.301***	−0.238***	0.0252***	−0.425***	−0.170***	−0.178***	−0.401***	−1.159***
	(0.0158)	(0.0733)	(0.0420)	(0.0696)	(0.00756)	(0.0766)	(0.0229)	(0.00944)	(0.106)	(0.0711)
Constant	0.136***	0.618***	0.470***	0.107***	-0.00945**	0.683***	0.120***	0.585***	1.046***	1.857***
	(0.0128)	(0.0400)	(0.0344)	(0.0338)	(0.00367)	(0.156)	(0.0132)	(0.0679)	(0.142)	(0.0939)
Observations	10324	10992	10967	6677	7673	7384	9943	75680	117818	12076
R^2	0.345	0.771	0.760	0.089	0.637	0.114	0.289	0.099	0.069	0.711
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Panel B: Consumption frequency									
*treat*post*	−64.70***	−155.2***	−99.05***	−36.44***	4.236***	−7.833***	−28.10***	−98.86***	−121.7***	−623.2***
	(3.020)	(16.52)	(16.66)	(10.70)	(1.230)	(0.332)	(2.844)	(3.400)	(14.45)	(32.06)
Constant	96.54***	263.0***	348.6***	15.54***	−1.661***	9.065***	35.50***	276.0***	325.1***	1327.9***
	(4.945)	(13.95)	(32.74)	(5.021)	(0.602)	(0.792)	(1.988)	(28.44)	(19.20)	(70.78)
Observations	10324	10992	10967	6677	7673	7384	9943	75680	117818	12076
R^2	0.449	0.790	0.716	0.080	0.642	0.401	0.347	0.084	0.099	0.695
Circle fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The stars denote significance levels: * p < .10, ** p < .05, and *** p < .01. Standard errors are clustered at the circle level and are reported in parentheses. Post is defined as 1 for post periods after Jan. 23, 2020 (the fourth week and after), for 2020 samples, and for post periods after Feb. 3, 2019 (the sixth week and after), for 2019 sample

level, and third-level policy response periods, we find that after the prevention and control policy downgraded from first-level response to second-level response, offline consumption showed signs of slow recovery; however, when the prevention and control policy was downgraded from second-level response to third-level response, the negative impact on offline consumption rebounded again.

We also find a significant heterogeneity effect on different districts and categories, at different times of a day of offline consumption spending relative to the counterfactual path without the COVID-19 outbreak event. The results show that, for the average offline consumption spending amount and frequency, central urban districts decreased more severely, while the non-central urban districts were relatively less affected; for all categories, offline spending amounts of real estate services fell the most, followed by wholesale and restaurants; offline spending frequency of restaurants fell the most, followed by life services and retail; for different times of a day of consumption spending, the average consumption amount and frequency both fell the most from 6:00 to 18:00, followed by 18:00 to 24:00. Furthermore, we also find a significant heterogeneity effect on different districts and categories, different times of consumption spending in the post-COVID-19 pandemic window period, in which the government implemented different level response policies for major public health emergencies.

These findings suggest that offline consumption fell drastically after the unanticipated pandemic shock, and with the downgrade in the prevention and control response policy, the negative impact on consumption first gradually decreases, and then rebounds to a certain extent, which means that the government's prevention and control measures have a certain effect on the recovery of consumption, but it is not as obvious as expected. The negative impact of COVID-19 on consumption shows sustainability, likely due to the recurrence of the epidemic itself, the persistence of people's psychological impact, and the shift of many consumer activities from offline to online.

China is the first country in the world to experience a large-scale outbreak and has successfully controlled the spread of the new coronavirus epidemic disease. The sample city of Shanghai is the economic and financial center of China, which ensures we obtain credible findings and some helpful policy implications for governments around the world. Our findings provide suggestions for policymakers to use prompt and adequate interventions to alleviate the negative impact, especially in severely affected sectors, such as real estate services and

wholesale and retail industries. Compared to the early evidence on US household consumption behavior and China's city consumption changes at the start of the pandemic (Baker et al., 2020; Chen, et al., 2020), this study focuses on the impact of changes in the intensity of the public health emergency response policy and relates it to the epidemic severity on consumption over time. Our findings help us understand how to achieve a balance between the strength of public health emergency response policies and economic recovery.

Acknowledgments We gratefully acknowledge financial support from the National Social Science Foundation of China (Project Number: 17ZDA049, 17BJY046), the Natural Science Foundation of China (Project Number: 71773071), 2019 Shanghai Philosophy and Social Science Planning Education Youth Project (Project Number: B1903), Shanghai Pujiang Program (Project Number: 16PJC034), and Special Program for Plateau Discipline Construction of College of business and Economics (Project Number: SWJJ-GYZX-2021-01). The authors accept responsibility for remaining errors. Also, we thank China UMS for their generous help in providing the transaction data, and appreciate Doctor Shi Wentian for his generous help in drawing Figure 3 and Figures 5-10.

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