

COVID-19, Product Selection, and The Performance of Pharmaceutical Enterprises: Evidence from China

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Abstract: Since the worldwide outbreak of COVID-19, enterprises all the world have suffered from a crisis, which both threatens human health and impacts production activities. Due to the particularity of listed companies in the pharmaceutical industry up against COVID-19, this study evaluates how COVID-19 affects the financial performance of pharmaceutical companies and the influential factors of the performance differentiation. Our research shows that COVID-19 leads to a decline in the performance of listed companies in the pharmaceutical industry. However, the impacts vary because of different domains of main products, among which the impact on listed companies producing commodities related to epidemic prevention and control such as vaccines and masks shows the least significant. In addition to the factors of listed companies themselves, we also find that companies located in less economically advantaged and less densely populated areas are slightly less impacted. According to the research results, policymakers should consider strengthening the financial supervision of enterprises and paying attention to the implementation of public health work. Moreover, business managers should choose suitable domains of main products and key development areas to reduce the negative impact of potential economic recession.

Keywords: COVID-19; Pharmaceutical Industry; Firm Performance; Product Selection; Business domain; CSR.

1. Introduction

In December 2019, COVID-19 was discovered in Wuhan, China. On March 11, 2020, the coronavirus pneumonia outbreak was defined as a global pandemic by the WHO. As of June 23, 2022, there were 4,483,878 confirmed cases in China[1]. With the unprecedented scale of the COVID-19 pandemic, its economic consequences may lead to a long-term decline in global economic output [2], affecting the world economy including the pharmaceutical industry. As of May 22, 2022, nearly 1 billion people in low-income countries were not vaccinated. The expert group from WHO insisted that it is necessary to keep supporting all countries to achieve 70% vaccination coverage as soon as possible, including 100% of people over 60 years old, 100% of medical staff, and 100% of people with underlying diseases [3]. This suggests that there will be a big market for COVID-19 vaccines and other related products, which is a great opportunity for listed companies in the pharmaceutical industry.

The global economic slowdown caused by COVID-19 also undermined the economic growth rate of the pharmaceutical industry. At the same time, due to the repeated resurgence of the epidemic, the trade and logistics between countries were blocked, which made the import and export of raw materials and medicines a challenge, leading to difficulties in medicine production and a shortage of medicines in the market [4]. With the decreasing vigilance in western countries on epidemic prevention and control, China, as a country with the strictest epidemic prevention measures, undertook a prevention and control strategy as rigid as the initial stage of the epidemic in 2020. However, it strove to preserve economic development while fighting against the epidemic, which is special with representative importance in the world. As one of the largest economies in the world, China experienced economic stagnation in early 2020, with its GDP decreasing by 5.8% in 2020 compared with 2019 [5]. Nonetheless, with the continued recovery of the national economy, its GDP exceeded 110 trillion yuan for the first time in 2021, an increase of 8.1% compared with 2020. In the efforts to effectively control the epidemic and recover the economy, China became the first country to avoid economic recession. Taking China as an example, it is of great significance to analyze the

causal relationship between COVID-19, economic destruction, and post-pandemic recovery in the same year of 2020.

Under the weaving of various factors, is the impact of COVID-19 on the performance of listed companies in China's pharmaceutical industry negative or positive? Is this influence related to the company's product selection? This paper will study the above problems from the perspective of the economy and analyze them from the aspect of public health.

The financial performance of a firm refers to the effectiveness and efficiency with which they use assets and capital to generate income and profits [6]. It is measured by several profitability indicators (ROA, ROE, ROCE, etc.) and turnover rate (asset turnover rate, fixed asset turnover rate, etc.). On the other hand, firm performance is also assessed by the market performance of the firm's stocks represented by Tobin's q [7]. However, the firm's market performance may also be affected by investors' subjective sentiments or other irrational behavior [8]. Therefore, in order to test the firm performance, accounting-based measures should be preferred, because they reflect the firm internal performance and are not affected by external factors. Due to the daunting negative effects of the COVID-19 spread in the stock market, accounting measures were used instead of market-based indicators in this study.

In addition to the impact on the environment, the outbreak of COVID-19, a dangerous infectious disease, has caused great changes in the pharmaceutical industry, forcing the industry to break its own processes, models, and activities. Besides, such changes may last for a long time. COVID-2019 has damaged the financial and non-financial performance of enterprises [9]. Although epidemics have sparked fear among investors, triggering their negative sentiments, they have also improved their sentiments towards investment in the pharmaceutical industry. Investors in this domain expect that vaccine development will maximize returns for pharmaceutical stocks in the future [10]. In the short term, the pandemic may transform medicine demand, regulatory amendments, research and development processes, telecommunication, and telemedicine in the pharmaceutical industry [4].

Meanwhile, the whole industry of medical technology has responded to the changing needs and obstacles brought about by the pandemic, which is likely to be a constant driving force in the long term [11]. The pandemic has led to a slowdown in economic growth in many countries, which may give rise to a slowdown in the pharmaceutical industry sensitive to national economic growth. However, it should be noted that some cases related to the healthcare industry were less sensitive to the economic slowdown in previous recessions [12]. Sun et al. (2021) studied the impact of investor sentiments on mainland China, Hong Kong, South Korea, Japan, and the United States during the epidemic. The results indicate that the COVID-19 outbreak had a significant positive impact on the pharmaceutical portfolio in this market [13]. According to the research method of the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model, Wang et.al (2021) found that COVID-19 has a significant impact on the stock prices of listed companies in China.

However, the degree of this impact on different industries varies. The epidemic has had a positive impact on the medicine manufacturing listed companies, while its impact on health care firms is negative but not significant, which is far lower than the negative impact of the pandemic on restaurants and other service industries [14]. Zheng et.al (2021) revealed the impact of COVID-19 on firm financial performance utilizing quarterly data from 126 Chinese-listed companies in 16 industries. It shows the results of the industry heterogeneity test on the epidemic's impact on the financial performance of Chinese enterprises. The coefficient of the medical industry is significant and positive in all models. Thus, fighting against this epidemic, Chinese medical enterprises have achieved higher financial performance. Generally speaking, COVID-19 gave a blow to the financial performance of Chinese listed companies, such as revenue growth rate, return on total assets, return on net assets, and asset turnover rate, but its impact on the pharmaceutical industry was positive [15].

Due to the overall impact of the COVID-19 pandemic on the economic environment, it can be predicted that the annual growth rate of listed companies' performance indicators in the pharmaceutical industry may slow down. However, thanks to the particularity of the pharmaceutical industry, its resistance to such economic impact may be stronger than that of other industries. This

manifests that the economic impact of the COVID-19 pandemic is special to the pharmaceutical industry. For a long time, most literature on the epidemic impact focuses on examining how it affects the performance of the stock market, while few studies research firm financial performances. Furthermore, literature about the comparison of firm financial performance in the pharmaceutical industry and specific reasons for its relatively less influence is even fewer [16, 17]. In addition, most of the documents mentioned above were published when the epidemic broke out in 2020. But with the variation of the virus, how do the preciser Chinese epidemic prevention and changing control methods affect the performance of listed pharmaceutical enterprises in a new manner?

Due to the heterogeneity of pandemic effects on the stock market [8], considering the characteristics of the COVID-19 spreading in China and Chinese strict measures, this paper, through the annual data of listed companies in China's pharmaceutical industry, aims to clarify how the epidemic affects their financial performance represented by operating income value, operating income growth rate, net profit value, and net profit growth rate.

Apart from paying attention to the epidemic's impact on enterprise financial indicators, another purpose of this study is to explore whether this impact on enterprise performance is related to its product selection. In the long term, scholars with various backgrounds have focused on explaining enterprise performance and identifying the sources of different performance among enterprises¹⁸. With the development of the times, the idea that corporate attributes, assets, and actions are the driving forces behind performance has harvested a wide recognition strategically [19]. In this paper, two aspects of the business domain and corporate social responsibility are used to explain the reasons why product selection may have an impact on firm performance.

In most cases, the term "business domain" refers to the intersection between the supply side (the industry, a product-oriented classification) and the demand side (the "served market" in business language) [20]. Therefore, a business area can be defined as a competitive arena where companies with similar products target customers with similar needs. As for pharmaceutical companies, products are the link between the supply side and demand side. Thus, choosing the firm's main products is equivalent to choosing business domains in essence. It is found that it is strategic for enterprises to choose the right business domains because of their lasting performance impacts and consequences. The variations in business domains account for about 8% of the performance differences between companies in the industry analyzed by the Institute²⁰. By explicitly considering their business domains, companies can improve their analysis of competitors and competition as well as simplify their competitors' intelligence. In addition, significant threats and opportunities will be identified timely, providing a better basis for the development of appropriate short-term tactics and long-term strategy [21].

The concept of corporate social responsibility (CSR) emerged in the 1950s [22], and has been dissected from various theoretical perspectives. However, a common definition is shared, that is, CSR means social and environmental activities to ensure that enterprises comply with the legal and ethical framework, together with a viewpoint of "self-enlightenment" [23]. The COVID-19 pandemic is a sudden and dangerous infectious disease. Since its outbreak, the demand for protective equipment, nucleic acid detection reagents, vaccines, specific medicines, and other epidemic-related products has surged. Enterprises produce related products, supplement the material gap, and help prevent and control the epidemic, which is the concrete embodiment of CSR in the COVID-19 pandemic. With regard to the connection between CSR and firm performance, it has not been generally recognized. Although neoclassical economics holds that CSR reduces firm performance for extra costs adding to the business [24], the comprehensive theory believes that CSR brings returns to the business, because it meets the needs of different stakeholders [25], prevents its reputation risks [26], and increases employee engagement and long-term stock returns [27].

Although much research has been done on why business domains and CSR affect firm performance, most of them are theoretical with complex data processing. Few opportunities can directly and objectively prove it, but an epidemic outbreak provides such an opportunity. Since the outbreak, most countries have implemented restrictions to varying degrees to stop the virus spread,

including a series of non-pharmaceutical interventions (NPIs) (such as wearing masks, keeping physical distance, restricting movement and social gatherings), which are combined with testing, contact tracing, quarantine interventions, and repeated lockdown of different intensities [28, 29]. NPIs are beneficial for pandemic control, but they also have direct and indirect harmfulness, including interruption or delay in access to health care services, which will affect disease prevention and treatment. These effects on disease incidence will also affect the selection of main products corresponding to pharmaceutical companies, thus influencing the firm performance. Therefore, in addition to studying the impact of COVID-19 on the annual performance of listed companies in China's pharmaceutical industry, this paper will also study the changing annual performance of enterprises producing related products (such as representative pharmaceuticals for treating respiratory system, cardiovascular systems, and mental diseases, as well as COVID-19 protective equipment, nucleic acid detection reagents, and vaccines) before and after the epidemic, so as to explain a reason for the epidemic impact on the annual performance of pharmaceutical companies.

Based on the annual report data of 319 listed pharmaceutical firms (excluding those with null values of net income and operating income published since 2016), this study evaluates whether there are any appreciable differences in financial performance indicators such as operating income value, operating income growth rate, and net income value and net income growth rate around 2020. Furthermore we evaluate whether the financial performance of businesses for various commodity categories by the classification of their primary product performs differently on the face of COVID-19. Additionally, we investigate how the company's location affects changes in its financial performance.

This study will be composed of four parts. The introduction consists of the research background, existing findings of how the COVID-19 pandemic impacts firm performance, and the explanation of reasons why enterprises' product selections may affect firm performance from two aspects including business domain and CSR. Subsequently, the methodology provides a detailed data collection process and research design. In the third part, detailed data analysis and discovery are put forward. Finally, the results and limitations of this study are summarized, with some suggestions put forward for relevant stakeholders.

2. Hypotheses

Since the epidemic outbreak appeared in Wuhan in 2019, COVID-19 has swept the world. The strict blockade and isolation in some areas have caused the enterprises' supply chain to be interrupted. With the unprecedented scale of the COVID-19 pandemic, its economic effects may lead to a long-term decline in global economic output, changing the worldwide economic situation including the pharmaceutical industry. Aifuwa et.al (2020) believes that the pandemic in 2019 has damaged the financial and non-financial performance of enterprises, and Hassan et.al (2020) holds that the epidemic has led to demand collapse, supply chain disruption, declining employee well-being, and the increasing uncertainty [30]. According to Donadelli et al. (2017), a dangerous infection may harm the firm performance [10]. However, although the firm performance is negatively affected by the epidemic, with the epidemic stabilization in China, enterprises in most areas have resumed work and production to the level before the epidemic. In 2021, China's GDP exceeded 110 trillion yuan for the first time, an increase of 8.1% over 2020 [5], with more resistance to the impact of the epidemic for listed companies in the pharmaceutical industry. Nicola et.al (2020) notes that demand for commodities and manufactured goods has plummeted amid the spread of COVID-19, while that for medical supplies and food has soared [31]. Zheng et.al (2021) pointed out the heterogeneity of enterprises' financial performance in Chinese various industries against COVID-19. The coefficient of the medical industry is significant and positive in all models. Therefore, under this epidemic background, Chinese medical enterprises have achieved higher financial performance [15].

Premised on the above facts, this study proposes hypothesis 1:

H1: The COVID-19 pandemic has impacted the financial performance of listed companies in the pharmaceutical industry.

Although the overall impact of COVID-19 on the economy is negative, it is undeniable that it also endows pharmaceutical companies with opportunities. In order to control the epidemic, China has implemented strict non-pharmaceutical interventions (NPIs) since 2020, including but not limited to increasing disinfection times in public places, normalizing nucleic acids, wearing masks, restricting movements and social gatherings, etc., which greatly affect people's lives. According to the COVID-19 Nucleic Acid Sampling Training Program provided by the National Health Commission of the People's Republic of China, standardized nucleic acid sampling sites should be equipped with medical protective masks, latex gloves, protective screens or goggles, isolation gowns or protective clothing, working caps, disinfectant alcohol, chlorine-containing disinfectants, nose/throat swabs, collection tubes, etc [32]. With the comprehensive development of nucleic acid census, these materials have huge daily consumption and provide abundant demands for their manufacturers. At the same time, the COVID-19 pandemic and the implementation of NPIs in this environment also affect the incidence of some diseases by influencing people's daily lifestyles and enterprises' production and operation modes.

Although there is no unified conclusion on the pharmaceutical treatment for COVID-19, with the evolutionary COVID-19 virus strain, there is no doubt that the pandemic outbreak will lead to a series of changes in the pharmaceutical market. In terms of respiratory diseases, the above-mentioned patients suffering from COVID-19 may have related sequelae, which incur an increasing incidence of respiratory diseases, but more people have reduced the concentration of PM2.5 due to strict sealing control [33]. Besides, there is a strong positive correlation between short-term PM2.5 exposure and hospitalization due to respiratory diseases [34]. Concerning cardiovascular diseases, out-of-hospital cardiac arrests have increased by 120% since the pandemic because of the longer time from cardiac arrest to ambulance arrival [35]. Meanwhile, due to the epidemic closure and control, frequencies of physical activities have reduced sharply, which may give rise to the rapid deterioration of cardiovascular health and premature death of people with increased cardiovascular risks [36]. Even short-term (1-4 weeks) inactivity is associated with adverse effects on cardiovascular function and structure as well as increased cardiovascular risk factors. In terms of mental health, Hubei Province in China was subjected to the strictest lockdown management in the early days of the pandemic, which has caused a high price on the mental health of many residents. Significant negative effects on depression, anxiety, and fear have been observed in isolated individuals. The lockdown of Hubei Province has left long-term psychological side effects on 59 million people staying there [37].

Based on the challenges brought by the COVID-19 pandemic, the product sales volume and the proportion of product sales to operating income in pharmaceutical companies will change, especially for companies whose business domains meet relevant product needs with CSR.

Premised on the above facts, this study proposes hypothesis 2:

H2: Under the COVID-19 pandemic, the financial performance of listed companies in the pharmaceutical industry which produce different pharmaceutical products differs.

The WHO experts insist that it is necessary to keep supporting all countries to achieve 70% vaccination coverage as soon as possible. However, as of May 22, 2022, nearly 1 billion people in low-income countries are not vaccinated. A few developed countries, such as the United States, failed to achieve this goal³.

In China, although the vaccination rate has exceeded 70%³, it was put forward in the government report of the State Council in 2022 that it is vital to do a good job in the prevention and control of the normalized epidemic. Besides, we should speed up the research and development of vaccines and specific medicines and forge ahead in vaccination. As of June 11, 2022, the number of people who have completed vaccination in China was 1,266,938,522¹, with still hundreds of millions of people in China not completing the whole vaccination.

According to the Statistical Report on the Development of National Health in 2021 published by the National Health Commission of the People's Republic of China, there were 11,937 medical and

health institutions providing Chinese nucleic acid detection services in 2021, with a total detection capacity of 41.68 million copies/day. There were more than 800 designated hospitals for COVID-19 treatment. These suggest a broad market for COVID-19 nucleic acid detection and products related to the COVID-19 vaccine, which is a great opportunity for listed companies in the pharmaceutical industry.

Premised on the above facts, this study proposes hypothesis 3:

H3: The financial performance of listed companies in the pharmaceutical industry that select to produce epidemic-related products (epidemic prevention materials and COVID-19 vaccine) is less negatively affected by COVID-19 than other companies producing other products.

Information transparency of listed companies ensures that all market participants have access to the same information, so as to obtain the financial position, performance, and risks of the company before making effective investment decisions. In areas with a relatively advantaged economy, the local government has a more sound market supervision system and practical experience, which can better perform the governmental supervision function. Thus, the financial information transparency of locally listed companies may be higher than that of listed companies in areas with a relatively disadvantaged economy. So when attacked by the dangerous COVID-19 epidemic, listed companies are prone to be negatively affected. The financial data displayed by listed companies in cities with higher GDP can reflect the impact of companies in a more timely manner. On the contrary, the financial data displayed by listed companies in cities with lower GDP levels may be more gentle.

Premised on the above facts, this study proposes hypothesis 4:

H4: The better the economic situation in the region where the company is located, the more significant the negative impact of COVID-19 on the financial performance of listed companies in the pharmaceutical industry.

In addition to the economy of the city where the company is located, the financial performance of listed companies in the pharmaceutical industry may be affected by COVID-19. The author speculates that the population density of the city where the company is located may also be impacted. Due to the “urban variability” of COVID-19 transmission, that is, the transmission rate of SARS-CoV-2 is higher in cities with higher population density, which may be related to the increased contact rate in areas with higher population density, R_0 will increase by 0.16 for every added logarithmic population density unit [40]. Therefore, as for cities with higher population density, when the epidemic spreads, the faster the number of cases increases, the stricter the NPIs imposed by the government, which may have a greater negative impact on the financial performance of listed companies in the pharmaceutical industry.

Premised on the above facts, this study proposes hypothesis 5:

H5: The greater the population density in the area where the company is located, the greater the negative impact of COVID-19 on the financial performance of listed companies in the pharmaceutical industry.

3. Methodology

Data

The data used in this study include the basic information of listed pharmaceutical companies in the Chinese mainland and their performance measurement indicators, which comes from Wind Financial Terminal (version: 22.7.0); the number of new cases of COVID-19 in various provinces, municipalities, and autonomous regions in Chinese mainland from 2020 to 2021, which originates from the National Health Commission of the People’s Republic of China. The data reflect the basic information of economy, population, science and technology, education, and health of provinces, municipalities, and autonomous regions in the Chinese mainland, which is obtained from the National Bureau of Statistics.

Variables

The variables in this study mainly focus on listed companies in the pharmaceutical industry in the Chinese mainland. According to the Classification Guidelines of Listed Companies in China (CSRC Classification) formulated by China Securities Regulatory Commission, this study screened 319 pharmaceutical-related companies belonging to the CSRC pharmaceutical manufacturing industry and CSRC health industry (as of August 10, 2022). The basic information of all companies is collected, including securities code, securities abbreviation, the English name of the company, enterprise scale, establishment date, business scope, main product name, main product type, and administrative division. In these variables, based on the business scope, main product names, and main product types, the author read them one by one, extract keywords, and comprehensively evaluate their main products in combination with relevant network reports. Then they are divided into the following categories: companies pertinent to the respiratory system, COVID-19 vaccine or epidemic-related consumables, cardiovascular system, mental system, and other categories. Table 1 is shown for details.

Table 1 Main Product Categories of Listed Companies in the Pharmaceutical Industry in Chinese Mainland

Category Code	Category Name	Classification Standard
1	Respiratory system	Contain keywords such as “breathing”, “lung”, and the main product whose name is related to the efficacy of treating respiratory diseases, in combination with relevant network reports
2	COVID-19 Vaccine or Epidemic-related Consumables	COVID-19 vaccines: defined as COVID-19 vaccines that meet the necessary standards for safety and effectiveness after being evaluated by WHO (4 in total) Epidemic-related consumables: contain keywords such as “nucleic acid”, “sampling box”, “diagnostic reagent”, “consumables”, and “swab”, in combination with relevant network reports
3	Cardiovascular System	Contain keywords such as “heart”, “circulation”, and the main product whose name is related to the efficacy of treating cardiovascular system diseases and circulatory system diseases, in combination with relevant network reports
4	Mental System	Contain keywords such as “spirit” and the main product whose name is related to the efficacy of treating mental system diseases, in combination with relevant network reports
9	Others	-

Note: In addition to other categories coded as 9, a company can specialize in multiple types of products.

The main dependent variable of this study is the related evaluation index of the operating performance of listed companies in the pharmaceutical industry in the Chinese mainland. Considering the fear that the negative impact of the COVID-19 pandemic will spread in the stock market and the stock market indicators are vulnerable to external factors, accounting measures are used instead of the indicators based on the stock market when selecting the variables related to the firm operating performance. It includes gross revenue, retained profits, return on assets (ROA), debt asset ratio, total assets turnover, gross revenue ration (year-on-year growth rate), retained profit ratio (year-on-year growth rate), the ratio of profits to cost, and total assets in eight quarters from 2020 to 2021.

The main independent variable in this study is the number of new COVID-19 cases in 31 provinces, municipalities, and autonomous regions in the Chinese mainland from 2020 to 2021. The original data comes from the daily number of newly confirmed cases published by the National Health Commission of the People’s Republic of China. The number of new cases of COVID-19 in each quarter is the sum of the daily number of new cases in that quarter.

In addition to the number of new COVID-19 cases, there are other independent variables in this study, including GDP and population density. The quarterly GDP data comes from the official website of the National Bureau of Statistics. Population density comes from two original data, that is, regional resident population and land survey area, both of which come from the official website of the National Bureau of Statistics. Due to the lack of accurate data, given that the resident population and land survey area will not change drastically in a short time, the quarterly data of the resident

population is replaced by the resident population of that year, and the land survey area of each quarter is replaced by the data of 2008 in this area. The quarterly population density of this area is calculated by quarterly resident population and quarterly land survey area respectively.

In order to eliminate the inherent differences between provinces and cities on the experimental results, this study uses a large number of control variables between provinces and cities. Because the governance ability and objective conditions of provinces and cities may affect their ability and treatment measures to deal with a sudden crisis, this study controls the influence of inherent differences between regions on the experimental results from the aspects of comprehensive strength and the respective strength of science and technology, education, culture, and health. In terms of comprehensive strength, this study uses public finance expenditure.

The original data comes from the National Bureau of Statistics, with the quarterly public finance expenditure calculated by the sum of the monthly data of the quarter. As for the strength of science and technology, this study uses R&D expenditure and R&D expenditure input intensity (R&D expenditure/GDP). The original data comes from the National Bureau of Statistics, and the annual data in 2020 replaces the quarterly data of the region, with the R&D expenditure input intensity calculated by the quarterly R&D expenditure and quarterly GDP of the region. As for the strength of education, this study uses education funds and the investment intensity of education funds (education funds/GDP). The original data comes from the National Bureau of Statistics, and the annual data in 2020 replaces the quarterly data, with investment intensity of education funds calculated by quarterly education funds and quarterly GDP in this region.

As for the strength of culture, this study uses Per Capita Consumption Expenditure of All Residents: Education, Culture, and Entertainment, whose original data comes from the National Bureau of Statistics and replaces the quarterly data with the annual data of 2020. As for the strength of health, this study uses the number of health institutions and health personnel. The original data comes from the National Bureau of Statistics, with the number of health institutions in each quarter calculated by the number of health institutions in each month, and the number of health personnel in each quarter of that year replaced by the number of health personnel in each quarter of that year.

Table 2 The List of All Variables and Their Data Source

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Contents		Name	Raw Data	Original Data Type	Original data source	Data processing process
Dependent Variable		Evaluation index of the operating performance of listed companies in the pharmaceutical industry	Gross revenue, retained profits, return on assets (ROA), debt asset ratio, total assets turnover, gross revenue ratio (year-on-year growth rate), retained profits ration (year-on-year growth rate), the ratio of profits to cost	Quarterly data	Wind Financial Terminal	-
Independent Variable	Main independent variable	Number of quarterly new COVID-19 cases	Number of new COVID-19 cases	Diurnal data	National Health Commission of the People’s Republic of China	Quarterly data = sum of daily data in the quarter
	Secondary independent variable	GDP	GDP	Quarterly data	National Bureau of Statistics	-
Control Variable	Local level	Population density	Resident population, land survey area(2008)	Annual data	International Bureau of Statistics	Population density = resident population/land survey area

	Local public finance expenditure	Local public finance expenditure	Monthly data	International Bureau of Statistics	Quarterly data = sum of monthly data in the quarter
	R&D funds and input intensity of R&D funds	R&D funds (2020)	Annual data	National Bureau of Statistics	Input intensity of R&D funds = R&D funds/GDP
	Education funds and investment intensity of education funds	Education funds (2020)	Annual data	National Bureau of Statistics	Input intensity of education funds = education funds/GDP
	Per Capita Consumption Expenditure of All Residents: Education, Culture, and Entertainment	Per Capita Consumption Expenditure of All Residents: Education, Culture, and Entertainment (2020)	Annual data	National Bureau of Statistics	-
	Number of health institutions	Number of health institutions	Monthly data	National Bureau of Statistics	Quarterly data = sum of monthly data in the quarter
	Health population	Health population	Annual data	National Bureau of Statistics	-
Company level	Control variables at the company level	Total assets, company attributes, company scale, number of employees, years of establishment	Quarterly data	Wind Financial Terminal	-

In order to gain a more convenient and short expression during the experiment, we gave abbreviations to some variables, which are not universal, so we show the common names and abbreviations of these variables together in Table 3.

Table 3 Generic Names of Some Variables and Their Abbreviations

	Generic Names	Abbreviations
Company Variables	Gross Revenue	Gross_revenue
	Retained Profits	retainedprofits
	Return On Assets	JROA
	Debt Asset Ratio	DAR
	Total Assets Turnover	TAT
	Gross Revenue Ratio	Grossrevenue_R
	Retained Profits Ratio	Retainedprofits_R
	Ratio Of Profits To Cost	RPC
	Total Assets	TA
Control Variables	Public Finance Expenditure	PFE
	Resident Population	RP
	Land Survey Area	LSA
	Density Of Population	DP
	Health Personnel	HP
	Health Care Institutes	HCIs
	Educational Fund	EF
	Educational Fund Intensity	EFI
	R&D Fund	RDF
	R&D Fund Intensity	RDI
	Per Capita Consumption Expenditure Of All Residents: Education, Culture, And Entertainment	ECEC

Model

After collecting the relevant information on COVID-19 new cases in eight quarters from 2020 to 2021, the basic information of listed companies in the pharmaceutical industry, and the panel data of financial performance, we run the Fixed Effect model and the Random Effect model. However,

considering that the model of fixed panel effect controls the special effects of individuals, we mainly apply the model of fixed panel effect, with the basic equations as follows:

$$Y_{it} = \alpha_0 + \alpha(COVID - 19)_{it} + \beta X_{control} + v_{it} + \varepsilon_{it}$$

i and t represent the region and time respectively, the dependent variable Y refers to the financial performance index of listed companies. α_0 is the constant item and α is the coefficient of the number of new cases of $COVID - 19$ as independent variables. $X_{control}$ is the control variable, v_{it} is the individual effect, and ε_{it} is the residual.

In addition to simply analyzing the impact of COVID-19 on the performance of listed companies, we also try to evaluate the mixed impact of the number of new COVID-19 cases and the local population density on the financial performance of listed companies. The model of fixed panel effect is also applied, with the equation as follows:

$$Y_{it} = \alpha_0 + \alpha(DP \times COVID - 19)_{it} + \beta X_{control} + v_{it} + \varepsilon_{it}$$

i and t represent the region and time respectively, the dependent variable Y refers to the financial performance index of listed companies. $DP \times COVID - 19$ (hereafter abbreviated DPcovid) is the product of the regional population density and the number of COVID-19 new cases. α_0 is the constant term, α is the coefficient of DPcovid. $X_{control}$ is the control variable, v_{it} is the individual effect, and ε_{it} is the residual.

4. Empirical Analysis

In Table 4, Model (1) and Model (2) represent Random Effect and Fixed Effect respectively. The results show that the new cases of COVID-19 in the model (1) and model (2) are significant at the level of 1% for gross revenue, with an absolute value of 2.9×10^4 , which indicates that the gross revenue of enterprises decrease by 2.9×10^4 yuan for each COVID-19 new case. After controlling the heterogeneity of different companies, the absolute value of coefficients in the Fixed Effect model is smaller than that in the Random Effect model, indicating that they have a greater impact on the gross revenue of companies (retained profit decreased by 6.9%). The new cases of COVID-19 in the model (1) and model (2) are significant at the level of 1% for the total assets turnover, with an absolute value of 0.001, which indicates that the total assets turnover of enterprises will decrease by 0.001% for every new case of COVID-19. The profit margin of COVID-19 new cases in model (1) and model (2) is significant at the level of 5% for the ratio of profits to cost, with an absolute value of 0.001, which indicates that the enterprises' profit margin for the ratio of profits to cost will decrease by 0.001% for each new case of COVID-19. This proves Hypothesis 1, that is, the COVID-19 pandemic has affected the financial performance of listed companies in the pharmaceutical industry (Table 4).

Table 4 The Regression Result of Basic Models

	(1) Random Effect			(2) Fixed Effect		
	(1) Gross revenue	(2) TAT	(3) RPC	(1) Gross revenue	(2) TAT	(3) RPC
COVID 19_new	-3.1e+04*** (-2.991)	-0.001*** (-3.346)	-0.001** (-1.980)	-2.9e+04*** (-2.791)	-0.001*** (-3.111)	-0.001** (-1.998)
Control Variable	Yes	Yes	Yes	Yes	Yes	Yes
Time	Yes	Yes	Yes	Yes	Yes	Yes
Individual	No	No	No	Yes	Yes	Yes
N	4488	4486	4445	4488	4486	4445

T value in parentheses

*, **, and *** represent signals at 10%, 5%, and 1% levels respectively

Table 5 to Table 8 shows how COVID-19 impacts the performance of pharmaceutical enterprises when they mainly produce and operate different kinds of medicines, among which they are classified as respiratory system, COVID-19 vaccines or epidemic-related consumables, cardiovascular system, and mental system in turn. Compared with Table 5-Table 8, it is not difficult to find that the performance indicators of COVID-19 vaccine or epidemic-related consumables in Table 6 have no significant changes, while other tables have significant financial indicators. This shows that when

listed pharmaceutical companies producing COVID-19 vaccines or epidemic-related consumables are impacted by the COVID-19 pandemic, they are less obvious than companies producing other categories. This proves hypothesis 2 and hypothesis 3, that is, up against the COVID-19 pandemic, the financial performance of listed companies in the pharmaceutical industry that select to produce respiratory medicines, cardiovascular medicines, psychiatric medicines, and COVID-19 related products (epidemic prevention materials and COVID-19 vaccine) changes because of COVID-19. Moreover, the financial performance of listed companies in the pharmaceutical industry that select to produce epidemic-related products (epidemic prevention materials, COVID-19 vaccine) is less negatively affected by COVID-19 than other companies producing other products.

Table 5 The Regression Result of Respiratory System

Respiratory	(1) Gross revenue	(2) JROA	(3) DAR	(4) TAT	(5) Grossrevenue R	(6) Retainedprofits R
COVID19_new	0.021 -0.721	-0.002** (-2.030)	0.001 -0.186	-0.001*** (-3.005)	-0.013** (-2.578)	-0.070** (-2.491)
Control Variable	Yes	Yes	Yes	Yes	Yes	Yes
Time	Yes	Yes	Yes	Yes	Yes	Yes
Individual	Yes	Yes	Yes	Yes	Yes	Yes
N	400	400	400	400	398	398

Table 6 The Regression Result of Covid-19-related Industries

Related to COVID-19	(1) Gross revenue	(2) JROA	(3) DAR	(4) TAT	(5) Grossrevenue R	(6) Retainedprofits R
COVID19_new	-1.40E +03 (-0.069)	-0.001 (-1.546)	0.001 -0.096	-0.001 (-1.520)	-0.005 (-1.457)	-0.108 (-0.208)
Control Variable	Yes	Yes	Yes	Yes	Yes	Yes
Time	Yes	Yes	Yes	Yes	Yes	Yes
Individual	Yes	Yes	Yes	Yes	Yes	Yes
N	483	483	483	483	462	462

Table 7 The Regression Result of Cardiovascular System

Cardiovascular	(1) Gross revenue	(2) JROA	(3) DAR	(4) TAT	(5) Grossrevenue R	(6) Retainedprofits R
COVID19_new	-1.4e+05*** (-3.703)	-0.001 (-0.516)	0.001 -1.019	-0.001 (-1.637)	-0.001 (-0.942)	-0.001 (-0.011)
Control Variable	Yes	Yes	Yes	Yes	Yes	Yes
Time	Yes	Yes	Yes	Yes	Yes	Yes
Individual	Yes	Yes	Yes	Yes	Yes	Yes
N	893	893	893	893	891	891

Table 8 The Regression Result of Psychiatry System

Psychiatry	(1) Gross revenue	(2) JROA	(3) DAR	(4) TAT	(5) Grossrevenue R	(6) Retainedprofits R
COVID19_new	-1.5e+05*** (-2.962)	-0.001 (-0.306)	0.001 -1.179	-0.001 (-1.354)	-0.001 (-1.064)	-0.003 (-0.329)
Control Variable	Yes	Yes	Yes	Yes	Yes	Yes
Time	Yes	Yes	Yes	Yes	Yes	Yes
Individual	Yes	Yes	Yes	Yes	Yes	Yes
N	185	185	185	185	185	185

T value in parentheses

*, **, and *** represent signals at 10%, 5%, and 1% levels respectively

Table shows the impact on the financial performance of listed companies in the pharmaceutical industry in the High GDP region and the Low GDP region when facing the COVID-19 pandemic. After comparing the results of the two regions, it is not difficult to find that the financial performance indicators of listed companies located in the High GDP region are significantly affected by COVID-19, while the financial performance indicators of listed companies in the Low GDP region are not. Thus, relatively speaking, the financial performance of listed companies located in the High GDP region is more significantly impacted, which successfully verifies hypothesis 4.

Table 9 The Regression Result of Different Regions as to GDP

	Low GDP			High GDP		
	(1) Gross revenue	(2) TAT	(3) RPC	(1) Gross revenue	(2) TAT	(3) RPC
COVID 19_new	-2.20E+05 (-0.733)	-0.001 (-1.426)	-0.001 (-0.239)	-2.9e+04*** (-2.651)	-0.001*** (-2.779)	-0.001* (-1.889)
Control Variable	Yes	Yes	Yes	Yes	Yes	Yes
Time	Yes	Yes	Yes	Yes	Yes	Yes
Individual	Yes	Yes	Yes	Yes	Yes	Yes
N	1313	1312	1304	3175	3174	3141

T value in parentheses

*, **, and *** represent signals at 10%, 5%, and 1% levels respectively

Finally, Table 10 shows the impact of the population density in the company's area and the intersection of COVID-19 new cases on the financial performance indicators of listed companies. Besides, the intersection of population density in the area where the company is located and new cases of COVID-19 is significant for retained profits and total asset turnover at the level of 1%. However, the population density in the area where the company is located and the multiplication item of COVID-19 new cases are significant at the level of 5%, which indicates that the retained profits of the enterprise will decrease by 9.9×10^3 yuan, with the total assets turnover and the ratio of profits to cost decreasing by 0.001%. This validates hypothesis 5, that is, the greater the population density in the region where the company is located, the greater the negative impact of COVID-19 on the financial performance of listed companies in the pharmaceutical industry.

Table 10 The Regression Result of Different Regions as to Population Density

	(1) Gross revenue	(2) TAT	(3) RPC
DPcovid	-9.9e+03*** (-3.012)	-0.001*** (-3.036)	-0.001** (-2.153)
Control Variable	Yes	Yes	Yes
Time	Yes	Yes	Yes
Individual	Yes	Yes	Yes
N	4488	4486	4445

T value in parentheses

*, **, and *** represent signals at 10%, 5%, and 1% levels respectively

5. Conclusion and Discussion

This paper presents new evidence for the impact of the COVID-19 pandemic on the financial performance of listed companies in the pharmaceutical industry. In previous studies, this has not been determined and it is generally believed that the COVID-19 pandemic has damaged the financial and non-financial firm performance⁹. However, for listed companies in the pharmaceutical industry, COVID-19 also brought new development opportunities, which made many investors optimistic about the development trend of listed companies in the pharmaceutical industry. By analyzing the panel data of listed companies in the pharmaceutical industry, this paper finds the following empirical facts.

First of all, COVID-19 still has a negative impact on the financial performance of listed companies in the pharmaceutical industry, which is similar to most previous research results. This shows that although the pharmaceutical industry has a certain particularity during the COVID-19 epidemic, its resistance to adverse effects facing infectious diseases is better than that of other industries⁴¹. However, it still cannot reverse the overall trend of negative effects of COVID-19 on all industries of the economy [42, 43].

Secondly, we prove that pharmaceutical companies producing different types of medicines do have various performances when facing the threat of COVID-19, which is manifested by the fact that the

financial performance of listed companies producing epidemic prevention products was not significantly impacted. This result suggests that the selection of business domains and the development of listed companies' CSR can make them more resistant to large-scale crises, which is also similar to the previous research results[44]. We hope that this result could remind listed companies to actively fulfill their CSR and apply it to the selection of business domains to achieve higher economic performance.

Finally, we discuss whether pharmaceutical companies in different regions are exposed to the threat posed by COVID-19 variously. Surprisingly, listed companies in regions with higher GDP have been more significantly affected by the COVID-19 pandemic. On the contrary, previous studies have reported that countries with more advanced financial systems and better governance mechanisms are less affected by the negative impact of COVID-19[42]. We speculate that the difference in results may come from the particularity of China. Chinese epidemic control is highly valued and strict in all provinces and cities. Therefore, in terms of disease prevention and control, the provincial and municipal governments have limited space to choose independently.

Therefore, the governmental financial supervision ability and enterprises' consciousness have aroused the results presented in our research. In addition, we also explored the relationship between the local population density and the severity of the negative impact on the company. We found that for cities with relatively small population density, the negative impact on the financial performance of local pharmaceutical companies is relatively small, which coincides with the previous research results of Krenz et al. (2021)[45]. Whether from the perspective of medical health or urban planning, cities with less population density have less population mobility, which reduces the adverse impact of the COVID-19 pandemic on the financial performance of locally listed companies.

In the end, a limitation of this study is that although the stricter epidemic control measures in China have stopped since the December of 2022, the COVID-19 continues to spread scatterly and new epidemics may spread from time to time. In addition, the SARS-CoV-2 virus is constantly mutating, while specific medicines and preventive vaccines for treating COVID-19 are still under research and development. With the advancement of time and related research, the financial performance analysis of listed companies in the pharmaceutical industry may affect these conclusions in the future. Despite these limitations, this study contributes to the existing literature by adding new evidence on the global COVID-19 outbreak. It may help regulators, policymakers, and the pharmaceutical industry to formulate public and corporate governance strategies for the preparedness and response of future emergency accidents.

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