Check for updates

Received: 29 June 2023 | Revised: 30 June 2024 | Accepted: 19 October 2024

DOI: 10.1111/twec.13656

ORIGINAL ARTICLE

The World Economy WILEY

Covid-19 pandemic and its impact on capital and output distortions: Evidence from China

Chuanglian Chen[1] | **Yixin Li**[2] | **Jingqun Shan**[3] | **Shujie Yao**[4,5]

[1]Institute of Finance and School of Economics, Jinan University, Guangzhou, China

[2]School of Economics, Jinan University, Guangzhou, China

[3]School of Finance, Zhejiang University of Finance and Economics, Hangzhou, China

[4]Li Anmin Institute of Economics Research, Liaoning University, Shenyang, China

[5]School of Economics and Business Administration, Chongqing University, Shenyang, China

Correspondence
Jingqun Shan, Zhejiang University of Finance and Economics, Hangzhou, China.
Email: shanjingqun@zufe.edu.cn

Shujie Yao, School of Economics and Business Administration, Chongqing University, Shenyang, China.
Email: yaoshujie@cqu.edu.cn

Funding information
National Natural Science Foundation of China, Grant/Award Number: 72071094; Chinese Ministry of Education, Grant/Award Number: 24YJA790081; Natural Science Foundation of Guangdong, Grant/Award Number: 2024A1515012673; Technology Elite Navigation Project of Guangzhou, Grant/Award Number: 2024A04J6373; Research achievement of Zhejiang Federation of Social Sciences, Grant/Award Number: 2024N033

Abstract

Based on Harrold's neutral technological progress production function, this paper studies the impact of Covid-19 on output distortion and capital mismatch of China's A-share listed firms in 2006–2022. It also identifies the 'positive transmission' and 'backward forcing' mechanisms of this impact effect. The empirical results suggest that there existed positive output distortion and negative capital allocation distortion and the pandemic is found to have exacerbated such distortions, especially in the manufacturing and services industries, the central and eastern regions, high-tech industries and private firms. In the 'positive transmission' mechanism, reducing capital cost and improving technological progress are found to have restrained the distortions induced by the pandemic. In the 'backward forcing' mechanism, reducing product price is found to have reduced the distortions, but promoting market share competition is only found to have mitigated output distortion. There is heterogeneity in the efficiency of the transmission mechanisms between industries, regions, technological industry and ownership types. This study provides a solid theoretical basis and empirical evidence guiding central and regional authorities on how to alleviate

 © 2024 John Wiley & Sons Ltd.

resource allocation distortions and improve firm performance in response to an unexpected external shock such as the Covid-19 pandemic.

KEYWORDS
backward forcing, Covid-19, positive transmission, resource allocation distortion

1 | INTRODUCTION

The outbreak of Covid-19 pandemic (Covid-19 hereafter) in 2020 has had a profound impact on the global economy. As of 21 November 2022, the cumulative number of confirmed cases worldwide exceeded 630 million, and the cumulative number of deaths exceeded 6.6 million. Figure 1 shows the cumulative confirmed cases, new confirmed cases, cumulative cure cases and deaths by quarter from 2020 to 2022. According to publicly available data from the National Health Commission of China, the country had a cure rate of 83.49% and a mortality rate of 1.21% as of December 2022. After experiencing a surge in Covid-19 infection from December 2022 to January 2023, the pandemic in China was officially said to have ended despite the contagion still continuing in May 2023. Covid-19 has caused enterprises' production and operation activities to be restricted, especially those enterprises with weak ability to resist risks are faced with difficulties such as market demand contraction, rising costs, falling income and so on. Their production and sales volume have been greatly reduced. To stabilise the negative impact of the pandemic on the economy, the Market Supervision Bureau strictly forbade price-gouging and hoarding during the prevention and control period, and encouraged financial institutions to lower interest rates on loans to enterprises. Due to output constraints and changes in capital cost, the impact of the pandemic may have distorted the pattern of resource allocation of enterprises. The purpose of this paper was to answer three relevant questions: (1) under the new model framework and data, what is the status of China's enterprise resource mismatch? (2) will the breaking out of Covid-19

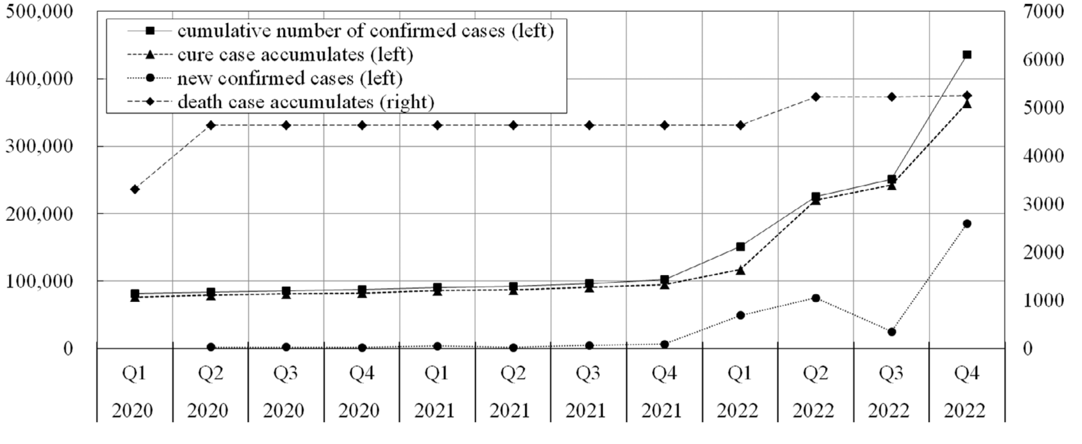

FIGURE 1 Cumulative confirmed cases, new confirmed cases, cumulative cure cases and deaths by quarter from 2020 to 2022. *Data source:* National Health Commission of China.

further exacerbate the distortion in resource allocation? (3) does the transmission mechanism come from the demand side or supply side?

Few scholars have estimated and observed the impact of Covid-19 on resource misallocation based on a large number of corporate data. However, more literatures have explored the severe blow that Covid-19 has caused to world trade and economy. In fact, early scholars such as Brainerd and Siegler (2002) studied the spread of 1918 Spanish influenza from the production demand to supply side, and found that public health emergencies disrupted the development of macroeconomic production in a short period of time, not only caused consumer panic and anxiety, but also reduced consumer demand, and leading to production and supply chain disruptions and market shortages. Subsequent studies have confirmed that public health emergencies have a significant inhibitory effect on both production and investment (Keogh-Brown & Smith, 2008). The food and health sector faces increased demand pressure due to panic buying and shortages of medical supplies during the pandemic (Nicola et al., 2020). According to Luo and Tsang (2020), Covid-19 initially affected China and disrupted supply chains because China is at the centre of many global value chains. Fernandes (2020) noted that global oil prices are already showing the impact of Covid-19 on the supply and demand side, as global demand continues to decline, embargoes persist and consumer spending declines. In the case of Turkey and China, Kazancoglu et al. (2023) assessed the sectoral impact of Covid-19 on global supply chains and found that it had a negative impact on inter-country supply chain operations, leading to reduced capacity utilisation and industrial production in many countries, as well as imbalances in inter-country maritime trade. In addition, other scholars have focused on exploring the trade and economic implications of the Covid-19 pandemic (Espitia et al., 2022; Fang et al., 2021; Kejžar et al., 2022; Mou, 2020).

Of course, far less literature has explored in more depth the transmission mechanism of the resource mismatch caused by the Covid-19 epidemic. As far as we know, scholars have actively explored effective ways to mitigate the negative impact of public health emergencies on the macro economy and enterprise production. Taking the 1918–1919 influenza pandemic in the United States as an example, Prager et al. (2017) believed that government measures to prevent and control the spread of the disease and assistance policies can reduce economic losses. They encourage governments to promptly adopt assistance policies to help businesses and individuals going through difficult times and avoiding an economic recession. Especially for developing countries, due to their dense population and relatively high risk of disease transmission, Yu et al. (2020) argue that governments should adopt effective control measures such as strengthening health monitoring and implementing social isolation to timely restore economic development and alleviate the impact of the epidemic on people's livelihood. Combined with the literature review and research ideas of the above two paragraphs, this paper finds that although the impact of major public health emergencies such as Covid-19 on the macro level, such as the negative impact of national consumption and production supply, is undeniable, at the micro level of enterprises, The impact of the epidemic on the allocation of enterprise resources lacks a large amount of empirical evidence from enterprises in China, a typical country affected by the Covid-19 epidemic, and further in-depth analysis is needed to propose effective measures to control the negative impact of the epidemic by studying how the epidemic affects the transmission mechanism of enterprise resource misallocation.

In the field of resource mismatch research, the most typical papers are the studies of Hsieh and Klenow (2009). Although they created capital distortion index and output distortion index to reflect the resource mismatch of micro-enterprises, their focus is not on this. It is 'physical productivity' (TFPQ) and 'revenue productivity' (TFPR). Moreover, they assume that the production function of each differentiated product is determined by the Cobb–Douglas function of firm TFP, capital and labour. In addition, Restuccia and Rogerson (2013) proposed two other methods to measure the degree of market distortion: the direct method and the indirect method. The direct method uses the method proposed by Atkinson and Halvorsen (1984) to calculate the subsidy or tax on the input factors. The indirect method analyses the efficiency gap between the optimal allocation and the actual allocation under the condition of profit maximisation without considering the cause of distortion (Brandt et al., 2013). The production function setting of the resource distortion measure we know is mostly based on the technological progress of 'output growth' in the form of Hicks-neutral Cobb–Douglas, and has not been deeply discussed on the technological progress of 'labour growth' in the context of Harrod-neutral technological progress.

Furthermore, Hsieh and Klenow (2009) used industrial data from the United States, China and India to conclude that economic efficiency could be improved by 30%–50% and 40%–60%, respectively, if resource allocation distortions were eliminated. Since then, there has been a lot of other literature to support this conclusion. For example, Baqaee and Emmanuel (2020) show that TFP rose by 15% if the country were to eliminate the improper distribution caused by large and dispersed data estimates. Taking Chile, Ukraine and China as examples, Chen and Irarrazabal (2015), Ryzhenkov (2016) and Li et al. (2017) all used the measurement framework of Hsieh and Klenow (2009) to analyse the resource misallocation in manufacturing. The results showed that resource misallocation reduction accounted for 40% of TFP in Chile during 1983–1996. The reduction in output subsidies for the least productive factories was the main reason for resource misallocation. Ukraine's manufacturing sector suffered from serious resource misallocation, and if all market distortions were eliminated, manufacturing productivity could be doubled. China's innovation efficiency significantly improved during 1999–2012, and the degree of distortion among regions tended to converge. Furthermore, advanced financial markets were favourable for innovation efficiency. Therefore, the misallocation of resources will seriously inhibit the total factor productivity of enterprises. Therefore, this can further explain why this paper is committed to eliminating the distortion of resource allocation, which is also the research goal of this paper.

As for the reasons to improve the efficiency of enterprise resource allocation or reduce resource mismatch, some scholars have also carried out thinking and exploration. Unlike the Hsieh and Klenow (2009) study, Dias et al. (2016) extend their capital and labour resource factor model to include intermediate inputs and consider all economic sectors (agriculture, manufacturing and services). They found that resource misallocation within industries in Portugal nearly doubled in 1996–2011. Regarding the reasons for low TFP in state-owned enterprises, Hsieh and Klenow (2009) argued that improper resource allocation is the main reason for China's industrial TFP being 49% lower than that of the United States. Furthermore, countries with more sophisticated financial systems and stricter environmental regulations tend to have less resource misallocation and higher capital allocation efficiency (Huang et al., 2014; Li et al., 2023). In comparison with countries with low levels of ownership, countries with higher levels of ownership tend to have higher capital allocation efficiency, and financial markets improve capital allocation (Wurgler, 2000). In addition, the risk aversion of managers and the cost of adjusting optimal investment portfolios also have important impacts on capital allocation efficiency (Agyei-Boapeah et al., 2019; Tao et al., 2017; Zhou et al., 2016). It can be seen that the perfection of the financial system, environmental supervision and state ownership are factors that affect resource misallocation, our research systematises the transmission mechanism.

The paper for the first time uses the labour-augmenting Harrod's neutral technological progress production function to derive and measure two resource distortion indicators of Harrodian technical progress, output distortion and capital misallocation, using quarterly data of China's A-share listed firms in 2006–2022. It also combines the cumulative confirmed Covid-19-infected cases of various cities in China, and uses a panel data double fixed-effect model to empirically test the impact of Covid-19 on enterprise resource misallocation.

In addition, the full sample is divided into different industries, regions, sectors and ownership types for heterogeneity analysis. The Generalised Moment Estimation of Instrumental Variables (IV-GMM) model with Covid-19 indicators lagged by one and two periods is used for endogeneity test, as well as the robustness test used the virtual variables representing the pandemic, shortened sample length and supplemented the fixed effect model of region and industry. Furthermore, this paper proposes for the first time two mechanisms, 'positive transmission' and 'backward forcing'. The 'positive transmission' mechanism is to analyse the impact from the perspective of enterprise supply through capital cost and technological progress. The 'backward forcing' mechanism is to analyse the impact of changes in consumer demand on the supply of enterprises from the perspective of market demand through product price and market share. By using the interaction term between each mechanism factor and Covid-19, this paper examines the transmission channels of the pandemic impact on capital misallocation, output distortion, aiming for identifying the effective ways to improve resource allocation efficiency and TFP under the pandemic shock. The research results provide relevant policy references and guidance for the government to actively respond to the pandemic's impact and help relieve corporate difficulties. It not only helps to reveal the dual-layer structured impact mechanisms of the pandemic on enterprise resource allocation but also promotes the sustainable and high-quality development of the Chinese economy.

The main conclusion of this paper is that China's listed A-share enterprises have positive output distortion and negative capital allocation distortion, indicating that the increase in the number of infected people caused by the Covid-19 significantly exacerbated the degree of output distortion and capital distortion. In addition, the pandemic is found to have had a more significant impact on resource and output distortions in the manufacturing and services industries, the central and eastern regions, high-tech industries and private enterprises. Further study of the two transmission mechanisms of this impact found that reducing capital cost, improving technological progress and lowering production prices are found to have curbed the extent of enterprise resource distortion under the pandemic, but promoting market share competition is only found to have effectively reduced the degree of output distortion. Similarly, there is heterogeneity in the efficiency of transmission mechanisms among industries, regions, technological industries and types of ownership.

This paper will make three new contributions to the literature. First, there is limited empirical literature on resource allocation distortion based on Harold's neutral enterprise production function. The typical representative literature Hsieh and Klenow (2009) assume that the production function of each differentiated product is determined by the Cobb–Douglas function of the total factor productivity, capital and labour of the enterprise. The Chinese economy is transitioning from high-speed growth driven by traditional factors and investment to high-quality growth driven by innovation and talent, which is more in line with Harold's neutral technological progress and long-term dynamic growth of human capital. It is transitioning from an output growth model to a labour growth model of technological progress. The output distortion and capital mismatch derived in this article are still consistent with Hsieh and Klenow (2009), but with relatively higher technological progress, which is more consistent with the reality of China.

Second, the existing literature focuses more on the impact of technological progress, R&D investment, open market and financial system development on the efficiency of resource allocation. Few studies have explored the impact of the Covid-19 on the efficiency of resource allocation. However, for the first time, based on the Covid-19 outbreak in China in 2020, a major public health emergency, our study carried out a sample study of all A-share listed enterprises in China, as well as heterogeneity in different regions, industries and ownership types. This study provides a new perspective and solution for improving the efficiency of enterprise resource allocation and total factor productivity, and conducts in-depth microeconomic analysis of the multidimensional impact of the pandemic on the production and economic development of the sample firms, which can provide policy recommendations for them to optimise resource allocation in the face of sudden external shocks such as Covid-19 in the future.

Third, existing research has rarely systematically analysed why the impact of the pandemic on resource allocation distortion in enterprises. However, our research further explores the transmission mechanism of this result. Two innovative transmission mechanisms, 'forward communication' and 'reverse coercion' are proposed from the perspectives of enterprise supply and market demand. This study will help to find effective ways to alleviate resource mismatches caused by the pandemic. At the same time, in response to other similar public health events that China and the world may encounter in the future, it also provides basic ideas and prevention suggestions for timely and effective relief of improper resource allocation, ensuring stable economic growth.

2 | NEUTRAL TECHNOLOGICAL PROGRESS, CAPITAL MISALLOCATION AND OUTPUT DISTORTION INDEXES

2.1 | Harrold neutral technical progress

In contrast to Hsieh and Klenow (2009) assumption of Hicks's technology-neutral technological progress, we set the firm production function as Harrold's neutral technological progress, which is more consistent with the long-term dynamic growth of human capital.[1] It can be explained that the marginal output of capital is constant with the progress of technology, and the progress of technology is neutral under the given capital output ratio. Further, we have rigorously and scientifically derived Harrold's neutral technological progress, output distortion and capital misallocation. This study provides an index for exploring the impact of Covid-19 on resource allocation distortion.

We assume that the production function for each differentiated downstream intermediate product is given by the firm Cobb–Douglas function for Harrold's neutral technological progress

[1]We also consider the classical formulation of Hsieh and Klenow's (2009) Cobb–douglas function and found that the output distortion index and the capital Misallocation index are the same, but the difference is technological progress, our results are relatively high. In the follow-up study of the 'Positive transmission' mechanism, technological progress under the framework of Hsieh and Klenow's (2009) was not significant in resource misallocation to Chinese Enterprises, and the interaction terms between epidemic and technological progress were not significant either; this suggests that the framework may not be suitable for China's changing economic growth pattern, while the long-term dynamic growth of Harrold neutral technological progress is more suitable for China in transition.

A_{it}, capital K_{it}, labour L_{it}, industry s, capital intensity α, then the output Y_{it} of A-share listed firm i can be expressed as follows:

$$Y_{it} = K_{it}^{\alpha}\left(A_{it}L_{it}\right)^{1-\alpha}, \tag{1}$$

The model allows different shares of capital and labour among different industries, but the same share among different firms in the same industry.

According to the marginal output of capital and labour, the relationship between our access to labour and capital is as follows:

$$\frac{r_{it}}{w_{it}} = \frac{\partial Y/\partial K}{\partial Y/\partial L} = \frac{\alpha}{1-\alpha}\frac{L_{it}}{K_{it}}. \tag{2}$$

Harrold's neutral technological progress is attained in combination with the production function:

$$A_{it} = \left(\frac{Y_{it}}{K_{it}}\right)^{\frac{1}{1-\alpha}}\left(\frac{\alpha}{1-\alpha}\frac{w_{it}}{r_{it}}\right). \tag{3}$$

The formula above shows that Harrold's neutral technological progress is influenced by the ratio of output to capital, the ratio of return on labour to capital and capital intensity.

2.2 | Resource misallocation

Since there are two factors of production, capital and labour, we can change the distortion of marginal output of one factor relative to the other to identify the distortion affecting capital and labour. Output distortion $\tau_{Y_{it}}$ that causes a change in marginal output can produce the same proportion of capital and labour. For example, due to a government cap on the size of a firm, and a higher cost of transporting means of production or products and other reasons, if the higher the government's restrictions on the size of the business, the higher $\tau_{Y_{it}}$. Conversely, if generous subsidy more, the lower $\tau_{Y_{it}}$. Capital misallocation $\tau_{K_{it}}$ causes the distortion of capital marginal output relative to labour marginal output. For example, the higher financing cost, the higher $\tau_{K_{it}}$, otherwise when the financing cost is lower, $\tau_{K_{it}}$ is also lower.

Assuming that the market conditions for downstream intermediate products are perfectly competitive, the firm profit function with output distortion and capital distortion is defined as:

$$\pi_{it} = \left(1-\tau_{Y_{it}}\right)P_{it}Y_{it} - w_{it}L_{it} - \left(1+\tau_{K_{it}}\right)r_{it}K_{it}. \tag{4}$$

According to $P_{it} = P_t Y_t^{\frac{1}{\sigma}} Y_{it}^{-\frac{1}{\sigma}}$, the first-order conditions of capital and labour in (4) are:

$$\left(1-\tau_{Y_{it}}\right)\frac{\partial P_{it}Y_{it}}{\partial L_{it}} = \left(1-\tau_{Y_{it}}\right)\left(1-\frac{1}{\sigma}\right)(1-\alpha)\frac{P_{it}Y_{it}}{L_{it}} = w_{it}, \tag{5}$$

$$\left(1-\tau_{Y_{it}}\right)\frac{\partial P_{it}Y_{it}}{\partial K_{it}} = \left(1-\tau_{Y_{it}}\right)\left(1-\frac{1}{\sigma}\right)\alpha\frac{P_{it}Y_{it}}{K_{it}} = \left(1+\tau_{K_{it}}\right)r_{it}. \tag{6}$$

The capital-to-labour ratios combines (5) and (6), so we can derive,

$$\frac{K_{it}}{L_{it}} = \frac{\alpha w_{it}}{(1-\alpha)\left(1+\tau_{K_{it}}\right)r_{it}}. \tag{7}$$

We can derive the product price of firm i in industry s by combining equations (1), (5) and (7):

$$P_{it} = \frac{\sigma}{\sigma-1}\left(\frac{w_{it}}{A_{it}(1-\alpha)}\right)^{1-\alpha}\frac{\left(1+\tau_{K_{it}}\right)^{\alpha}}{\left(1-\tau_{Y_{it}}\right)}\left(\frac{r_{it}}{\alpha}\right)^{\alpha} \tag{8}$$

and we can also derive the capital, labour and output as follows:

$$K_{it} = \left(\frac{\sigma-1}{\sigma}\right)^{\sigma}\left(1-\tau_{Y_{it}}\right)^{\sigma}P_t^{\sigma}Y_t\left(A_{it}\right)^{(\alpha-1)(1-\sigma)}\left(\frac{\alpha}{\left(1+\tau_{K_{it}}\right)r_{it}}\right)^{\alpha(\sigma-1)+1}\left(\frac{1-\alpha}{w_{it}}\right)^{(\sigma-1)(1-\alpha)}, \tag{9}$$

$$L_{it} = \left(\frac{\sigma-1}{\sigma}\right)^{\sigma}\left(1-\tau_{Y_{it}}\right)^{\sigma}P_t^{\sigma}Y_t\left(A_{it}\right)^{(\alpha-1)(1-\sigma)}\left(\frac{\alpha}{\left(1+\tau_{K_{it}}\right)r_{it}}\right)^{\alpha(\sigma-1)}\left(\frac{1-\alpha}{w_{it}}\right)^{\sigma(1-\alpha)+\alpha}, \tag{10}$$

$$Y_{it} = \left(\frac{\sigma-1}{\sigma}\right)^{\sigma}\left(1-\tau_{Y_{it}}\right)^{\sigma}P_t^{\sigma}Y_t\left(A_{it}\right)^{\sigma(1-\alpha)}\left(\frac{\alpha}{\left(1+\tau_{K_{it}}\right)r_{it}}\right)^{\sigma\alpha}\left(\frac{1-\alpha}{w_{it}}\right)^{\sigma(1-\alpha)}. \tag{11}$$

We assume that all firms pay the same salary. Profit maximisation creates the standard condition that output price is a fixed addition to firms' marginal cost.

The relationship between total investment and total labour of all firms in industry s is as follows:

$$\frac{K_{it}}{L_{it}} = \frac{\alpha}{(1-\alpha)}\frac{w_{it}}{r_{it}}\frac{1}{\left(1+\tau_{K_{it}}\right)}, L_{it} \propto = \frac{\left(A_{it}\right)^{(\alpha-1)(1-\sigma)}\left(1-\tau_{Y_{it}}\right)^{\sigma}}{\left(1+\tau_{K_{it}}\right)^{\alpha(\sigma-1)}}, Y_{it} \propto \frac{\left(A_{it}\right)^{\sigma(1-\alpha)}\left(1-\tau_{Y_{it}}\right)^{\sigma}}{\left(1+\tau_{K_{it}}\right)^{\sigma\alpha}}.$$

Resource allocation across firms depends not only on the TFP of each firm, but also on output and capital misallocation. To some extent, resource allocation is caused by distortions rather than fixed TFP, leading to a difference between the marginal products of capital $MRPK_{it}$ and labour $MRPL_{it}$.

According to $P_{it}Y_{it} = P_t Y_{it}^{\frac{1}{\sigma}} Y_{it}^{1-\frac{1}{\sigma}}$, and the marginal product functions of labour and capital, we can further derive the output distortion and capital misallocation as follows[2]:

[2]This paper uses Hsieh and Klenow (2009) method to estimate output and capital distortion indexes, and then empirically tests the impact of the pandemic shocks on both distortion indexes. The estimated results are consistent with the method proposed in this paper.

$$\tau_{Y_{it}} = 1 - \frac{\sigma}{(\sigma - 1)} \frac{1}{(1-\alpha)} \frac{w_{it} L_{it}}{P_{it} Y_{it}}, \tag{12}$$

$$\tau_{K_{it}} = -1 + \frac{\alpha}{(1-\alpha)} \frac{w_{it} L_{it}}{r_{it} K_{it}}. \tag{13}$$

Intuitively, the post-tax marginal income and output of capital and labour are the same between firms. The negative distortion firms without incentives have higher pre-tax marginal output than other firms, while the positive distortion firms with subsidies have lower pre-tax marginal output than other firms. Simply, firms with insufficient incentives need to pay more to increase their output, while firms with subsidies can increase their output at lower costs.

2.3 | Datasets for China

The financial data of the sample firms have been relatively complete since 2006. The data covers the 2008 global financial crisis period. The latest official data provides the basic statistics of Covid-19 cases in China up to 8 January 2023 as shown in Figure 1 in the previous section. Considering the integrity of financial data of listed companies and Covid-19 data, we select all A-share listed firms in China in 2006–2022, excluding ST and ST* listed firms with financial or other abnormal conditions, the missing and non-positive data of the original values of fixed assets in any 1 year in the sample period, a total of 1094 A-share listed companies were selected. The reason for not choosing B-shares is that B-shares have different settlement currencies compared to A-shares, and their market value and corporate size are small. This will bring many differences to the research, including the difference in the size of financing, the difference in market value and the difference in the regulatory model. The resource allocation situation and the impact of epidemic impact on enterprises studied in this paper are closely related to the market value of companies, while the valuation in different settlement currencies is huge. Therefore, this article does not include B-share companies in the sample. The data comes from the Wind database.

The selected indicators required in this paper are as follows:

2.3.1 | Capital (K_{it}) and capital income ($r_{it}K_{it}$)

We use the perpetual inventory method to estimate the capital stock: $K_{it} = I_{it} + (1-\delta)K_{it-1}$, where I_{it} is a fixed capital investment measured using the original value of fixed assets per year, δ is a depreciation rate calibrated at 0.015. The initial capital stock for the first quarter of 2006 is calculated by $K_{2006,q_1} = I_{2006,q_1} / \left[\ln\left(I_{2022,q_4} / I_{2006,q_1}\right) / 68 + \delta\right]$. We deflate the fixed asset investment price index (FAPI) for the base period of 2006. Since the downloaded data is a chain-specific fixed asset investment price index, it is also necessary to use $FAPI_T = \prod_{2006}^{T} FAPI_t / 100^{T-2006}$ to measure the actual capital investment.

We obtain the rate of return on capital of a firm by dividing capital income by capital investment, where capital income is the return on capital, measured by the sum of operating profits and depreciation of fixed assets of the manufacturing sector in the current year. The data of fixed

TABLE 1 Descriptive statistics of valuables.

Variables	Mean	Standard deviation	Minimum	Maximum	Sample size
$\ln Y$	20.4849	1.5835	12.2742	28.4868	41,496
$\ln L$	7.9885	1.3272	0.0000	13.0206	41,493
$\ln K$	23.8418	1.6168	15.2455	30.8295	41,496
$\ln wL$	16.0839	2.0538	−4.9354	23.4997	41,496
$\ln rK$	18.9015	1.7370	10.2103	26.7856	41,496
$\ln r$	−4.9403	1.3632	−13.2956	3.5498	41,496
$\ln w$	8.0956	1.6954	−9.3542	16.2762	41,493

assets depreciation is calculated by the difference between accumulated depreciation of fixed assets of the current year and the previous year. Second, we deflate the capital income data in line with the Producer Price Index (PPI). Similar to the fixed asset investment price index, we use $PPI_T = \prod_{2006}^{T} PPI_t / 100^{T-2006}$ to download the month-on-month data into the 2006-based consumer price index. Finally, we remove the non-positive capital income value to get the actual effective capital income data.

2.3.2 | Labour (L_{it}) and labour income ($w_{it}L_{it}$)

We choose the number of employees to represent labour input. The wage rate (w_{it}) is equal to the salary payable to the staff and workers $w_{it}L_{it}$ divided by labour L_{it}. The actual labour income includes the salary received by the employee and the expenses paid by the firm for unemployment insurance, endowment insurance, medical insurance, housing provident fund and housing subsidy, as well as the welfare expenses payable. However, since most data, including unemployment insurance, old-age insurance, health insurance, housing provident fund and housing subsidies and welfare costs, only began to be recorded after 2010, the lack of relevant data is a serious issue before the year. For consistency purpose, this paper uses the salary payable in the consolidated statement as a proxy variable of labour income, and adjusts labour income using the consumer price index (CPI) to the actual purchasing power in 2006. It would eliminate the effects of inflation and more accurately reflect the real income level of workers in 2006. Similar to the fixed asset investment price index and producer price index, we use $CPI_T = \prod_{2006}^{T} CPI_t / 100^{T-2006}$ to convert the downloaded ring-to-ring data into a 2006-based consumer price index.

2.3.3 | Output (Y_{it})

We choose revenues as a measure of nominal output. We then use the 2006-based producer price index (PPI) to deflate the nominal gross operating income of firms to obtain real output after discounting inflation. We also use $PPI_T = \prod_{2006}^{T} PPI_t / 100^{T-2006}$ to convert the quarter-on-quarter data into a 2006-based PPI.

The descriptive statistics of the above variables are presented in Table 1. First, average operating income of listed companies is below average capital, which means that capital intensity will be less than 1, which is consistent with the estimates in Table 2. In addition, the standard

TABLE 2 Estimation results.

Variables	Model (1)	Model (2)
Intercept	9.0409***	9.9118***
	(0.0614)	(0.0617)
$\ln K_{it}$	0.1864***	0.1630***
	(0.0038)	(0.0039)
$\ln L_{it}$	0.8136***	0.8370***
	(0.0038)	(0.0039)
t	0.0250***	
	(0.0004)	
Implied elasticity of capital substitution and capital intensity		
$\hat{\gamma}$	0.0308	
α	0.1864	0.1630
Observations	41,493	41,493

Notes: The values in parentheses are clustering robust standard error, the same is true in parentheses in all the tables below; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

deviation of operating income is smaller than that of capital income, and the difference between minimum and maximum values is also smaller than that of capital. Considering that the standard deviation of labour force is small, this indicates that one of the possible reasons for the greater heterogeneity of the operating income of enterprises is the greater heterogeneity of capital input. Second, because the return on capital is low, the return on labour, or higher wages, leads to a higher average return on labour than on capital.

2.4 | Elasticity of substitution between capital and labour

Consistent with existing research, we assume that factor efficiency increases exponentially, $A_{it} = A_0 e^{\gamma_K t}$, where γ_K represents the growth parameter of capital efficiency. Taking logarithm of both sides of $Y_{it} = K_{it}^{\alpha}\left(A_{it}L_{it}\right)^{1-\alpha}$ to get $\ln Y_{it} = (1-\alpha)\ln A_{it} + \alpha \ln K_{it} + (1-\alpha)\ln L_{it}$, and substitute$A_{it} = A_0 e^{\gamma_K t}$, we get:

$$\ln Y_{it} = (1-\alpha)\ln A_0 + (1-\alpha)\gamma t + \alpha \ln K_{it} + (1-\alpha)\ln L_{it}. \tag{14}$$

We estimate the equation to obtain the coefficients of b_1, b_2, b_3, b_4 and the corresponding parameters $(1-\alpha)\gamma = b_1$, $\alpha_s = b_2$, $1-\alpha_s = b_3$, the constant term is $(1-\alpha)\ln A_0$. We derive capital intensityα, γ and A_0 from the regression coefficients. The results are shown in Table 2. The capital logarithm $\ln K_{it}$ has a significant effect on output, indicating that for every 1% increase in capital, output per capital unit rises by 0.1864%. The elasticity of capital is also similar, at 0.1630 when time trends are not taken into account. The coefficient of time variable t is significantly positive, showing that the output has an upward trend with time. According to the coefficient of time dummy variable and the coefficient of intercept term, we can get the corresponding elasticity of capital substitution and capital intensity. Specifically, the capital efficiency growth parameters are significantly greater than zero (0.0308), indicating that capital efficiency of the sample firms shows an overall growth trend.

3 | COVID-19 AND ITS IMPACT ON RESOURCE ALLOCATION

3.1 | Research methodology design and variable selection

Based on the estimated results of the Harold's neutral technological progress index, capital misallocation and output distortion index mentioned above, this study further empirically examines the impact of Covid-19 on resource misallocation. The baseline model is set as follows.

$$X_{it} = \alpha + \beta_1 Epid_{it} + \beta_2 M_{it} + \mu_i + \lambda_t + \varepsilon_{it}. \tag{15}$$

$X_{it} = \left[\tau_{Y_{it}}, \tau_{K_{it}}\right]$ represents output distortion, capital misallocation. As an indicator of COVID-19, we choose the cumulative confirmed cases of urban epidemic/urban population/urban administrative area to reflect the confirmed cases of COVID-19 per 10,000 people per square kilometre. When the value is high, indicating that the effect of the pandemic on the urban population is serious. The permanent population data comes from the national and local statistical bureaus, and the land area of administrative regions comes from the national and local statistical bureaus, as well as the compilation of statistical data. Matrix M_{it} is the set of control variables. This study selects five factors to measure: profitability (*ROA*), asset-liability ratio (*Lev*), company asset size (*Size*), proportion of fixed assets (*Fix*) and years since the establishment of the company (*Age*). Profitability is calculated as the ratio of earnings before interest and taxes (*TTM*) to total assets (*MRQ*). Asset-liability ratio represents the proportion of total debt to total assets of the company, reflecting the proportion of assets the company uses for borrowing and financing. It can also be used to evaluate the degree of protection for creditors in liquidation. Asset-liability ratio is measured by the ratio of total liabilities to total assets. Asset size is represented by the logarithm of total assets. The proportion of fixed assets is the ratio of fixed assets to total assets. Total assets refer to the sum of all assets. The survival years since the establishment of the company are calculated as (observation year-year of company establishment) +1. Matrix β_2 characterises the impact of these five control variables on the explained variable. μ_i controls for each individual company's fixed effects, and λ_t controls for time effects by quarter. The subscript i represents the company, and t represents the quarter. In the sample regression analysis, to effectively eliminate the influence of individual and time fixed characteristics on variables, this study uses a two-way fixed effects model for individuals and time.

After reviewing relevant literature, the reason for selecting these variables is as follows. First, a high return on total assets indicates that the company has generated relatively more profit from utilising its assets, which also indicates that the company has strong asset profitability and has effectively utilised its assets. This typically reflects the company's competitiveness and good financial condition, and is an important indicator for valuation. Companies with outstanding performance are more likely to experience over-investment (Hayward & Hambrick, 1997), which may affect the allocation of resources and lead to varying degrees of distortion in output and capital. Second, the larger the company is more willingness to innovation. Such companies usually have higher technological innovation levels, and their Harrod-neutral technological progress index is also higher. Different-sized companies have different management systems, factor allocations and innovation systems due to the existence of economies of scale, resulting in different levels of efficiency. Although Covid-19 may have an impact on companies, they can maintain a certain level of profit by using their previously accumulated technology and market share. They will not blindly cut R&D and related expenses to maintain their technological innovation level and alleviate the negative impact of Covid-19 on capital mismatch and output distortion. Third, companies generally need to consider the corresponding costs and inputs when carrying out innovation activities, as each new R&D project requires a large amount of time, manpower and resources. When facing Covid-19, companies with more cash and lower costs will experience less negative impact on their resource distortions. In addition, the sudden outbreak of Covid-19 has increased the normal production and operating costs of companies, and may affect technological innovation. Therefore, reducing R&D costs will have a positive impact on resource distortions. Furthermore, companies that have been established for a longer period of time are often able to form certain technological barriers, and there are differences in investment strategies, management methods and development plans. These companies can better mitigate the potential impact of Covid-19 and make corresponding response strategies.

The sample selected in this article consists of quarterly data from A-share listed companies in China during 2006–2022. The data are sourced from the Wind database. The Covid-19 data for each region comes from public data released by the national and local health commissions. Companies listed after 1 January 2006, and those with severe missing data were excluded. Table 3 reports the descriptive statistics of the variables for the entire sample.

Table 3 shows that the average values of the capital mismatch and output distortion indexes of the sample firms are −0.9427 and 0.9421, respectively. The results indicate that there is resource mismatch in the sample firms, namely, positive output distortion and negative capital allocation distortion. The average confirmed cases of Covid-19 per million people per square kilometre during the entire sample period under population density per unit city were more than 3. However, during the outbreak period from 2020 to 2022, the average was more than 17, indicating that the confirmed cases of Covid-19 per 10,000 people per square kilometre reached 0.1781. The Harold Technology Progress Index is relatively large, and we use logarithmic form to represent it, with a mean of 9.1266 and a large variance, indicating significant differences in technological progress among enterprises.

3.2 | Empirical results using the full sample

The regression results on resource allocation distortion for the full sample are presented in Table 5. First, the coefficient of Covid-19 (*Epid*) on the distortion index of output (τ_Y) is 0.0028 at the 1% significance level, indicating that for every 1% increase in the cumulative number of

TABLE 3 Descriptive statistics of variables for the full sample.

Variables	Mean	Standard deviation	Minimum	Maximum	Sample size
$\ln Y$	20.4849	1.5835	12.2742	28.4868	41,496
$\ln L$	7.9885	1.3272	0.0000	13.0206	41,493
$\ln K$	23.8418	1.6168	15.2455	30.8295	41,496
$\ln wL$	16.0839	2.0538	−4.9354	23.4997	41,496
$\ln rK$	18.9015	1.7370	10.2103	26.7856	41,496
$\ln r$	−4.9403	1.3632	−13.2956	3.5498	41,496
$\ln w$	8.0956	1.6954	−9.3542	16.2762	41,493

Note: Since the fixed asset ratio is large, we divide the fixed asset ratio by 100 for processing.

confirmed cases per urban unit density, the degree of output distortion increased by 0.0028%. Covid-19 has led to an increase in the distortion index of output due to three main reasons. (1) The pandemic triggered global lockdowns and restrictions, resulting in production disruptions and supply chain issues. Many countries implemented lockdown measures, shutting down businesses and factories and restricting people's movement and transportation. As a result, numerous enterprises were unable to operate normally, severely constraining production activities and increasing the distortion index of output. (2) The labour market has been significantly affected by the pandemic, leading to disruptions. Employee infections, quarantines and absenteeism have caused labour shortages and decreased productivity. Many companies have had to reduce working hours, adjust schedules or seek alternative personnel to cope with labour issues. Simultaneously, the lockdowns and restrictions have resulted in job losses or forced work stoppages, leading to unstable labour supply. This has made it difficult for companies to recruit and retain employees, further exacerbating the distortion of output. (3) The pandemic has had a significant impact on consumer demand. People's demands for non-essential goods and services such as travel, dining and retail plummeted during the pandemic. Due to the uncertainty and safety concerns surrounding the pandemic, many consumers reduced their purchasing power or changed their consumption habits, causing a sharp decline in sales for certain industries, presenting challenges of demand uncertainty and market contraction for businesses. To adapt to the market conditions, companies had to reduce production scales, further intensifying the output distortion.

Second, the impact of Covid-19 (*Epid*) on the capital misallocation index (τ_Y) is significant at the 1% level. In statistical terms, this means that for every 1% increase in the cumulative number of confirmed cases per urban unit of population density, the index rises by 0.0043%. The capital distortion level of Chinese listed companies increased due to the impact of the Covid-19 pandemic for several reasons. First, the pandemic led to global economic uncertainty and volatility. The outbreak of the virus caused worldwide economic shutdowns and a decline in demand, impacting the profitability and capital market of the sample firms. The uncertainty surrounding the pandemic raised concerns among investors about the future performance and prospects of companies, leading to fluctuations in investment sentiment and an increase in capital distortion. Furthermore, the pandemic severely affected supply chains and production activities. China is a vital manufacturing hub globally, and many Chinese-listed companies rely on global supply chains for sourcing raw materials and components. The pandemic resulted in lockdowns and restrictions worldwide, causing disruptions in supply chains and logistics issues, thereby exposing companies to risks of production interruptions and delivery delays. These negative impacts on operations and profitability heightened concerns and distortion in the capital market. Finally, the pandemic significantly influenced consumer behaviour and market demand. Due to lockdowns and restrictions, many consumers changed their purchasing habits and preferences, focusing more on essential goods and health-related products. This led to a sharp decline in demand in certain industries such as tourism, retail and entertainment. Chinese-listed companies had a higher concentration in these affected industries, thereby experiencing greater impacts. This distortion in market demand further affected the profitability and firm performance in the capital market. Additionally, the increased financial uncertainty and risks during the pandemic also contributed to the capital distortion level. Firms faced numerous pandemic-related challenges, including declining revenues, cash flow pressures and risks of debt defaults. These risks lowered investor confidence, resulting in higher capital costs for companies and a reduced willingness of the capital market to invest. This further exacerbated the level of capital distortion.

In the control variables, firms with lower asset-liability ratio, larger asset scale, stronger profitability, lower fixed asset share and shorter time of establishment, were more likely to be affected by the pandemic with more apparent output distortion. The impact of the pandemic on capital misallocation of younger firms with a high proportion of fixed assets is also more potent. This indicates that the newly listed large high-quality light assets enterprises are more suggest to the Covid-19 impact regarding output mismatch. Those with heavy assets are more suggest to the Covid-19 impact regarding capital mismatch. In short, it is necessary to optimise the asset structure and extend the lifespan of enterprises to respond flexibly to the misallocation of enterprise resources caused by major public health and safety events such as Covid-19.

3.3 | Analysis of empirical results with heterogeneous samples

First, the full sample is divided into the primary industry (mainly agriculture), secondary industry (mainly manufacturing) and tertiary (services) industry. The empirical results are shown in Table 4, which indicate that except the primary industry, resource allocations in the other two industries are found to have seriously affected by the pandemic. However, the pandemic is found to have the greatest impact on output distortion in the primary industry as well as a greater impact on capital mismatch in the tertiary industry. The reasons for this can be attributed to several factors.

Traditional supply channels and product export channels in the primary industry, such as food, vegetables and poultry eggs, have been severely affected during the transportation lockdown period of the pandemic. Local supply of consumer goods and vegetables, eggs and poultry was tight, which to some extent pushed up the overall prices of agricultural products. Therefore, the impact of the pandemic on output distortion of the primary industry was more significant. The capital distortion in the tertiary industries such as tourism, transportation, accommodation and catering, wholesale and retail and rental commercial services was most severely affected by the pandemic, and output distortion was relatively more severe compared to the secondary industry. Large tourism destinations, catering and shopping malls in many areas were closed during the pandemic. The numbers of foreign residents visiting China for tourism, business trips and studying abroad were substantially reduced. The country launched a series of loan preferential policies to support the development of enterprises. Therefore, the pandemic had a greater impact on resource allocation in the tertiary industry, especially due to serious capital distortions.

The entire sample is divided into the eastern, central and western regions of the country. The empirical results are shown in Table 5. In terms of the output distortion index, the regression coefficients of Covid-19 in the eastern and central regions are positive and significant at the level of 1%. If the confirmed cases in the eastern and central regions rose by 1%, the output distortion index would increase 0.0048% and 0.0137%, respectively. The corresponding coefficient in the western region is insignificant. The results showed that Covid-19 had the greatest impact on output distortion in the eastern region, followed by the central region, and the western region was almost unaffected. For the capital mismatch index, the regression coefficients in the empirical results of the eastern and western regions were both positive and significant at the 1% level. If the confirmed cases in the eastern and western regions rose by 1%, capital mismatch would increase by 0.0137% and 0.0249%, respectively. This comparative result indicates that capital mismatch had the greatest impact in the western region, followed by the eastern and central regions.

The whole sample is also divided into the high-tech industry and medium to low tech industry sub-samples. The estimated results are shown in Table 6, which indicate that the pandemic

TABLE 4 Impact of Covid-19 on resource allocation and firm productivity by industry.

	Full sample		Primary industry		Secondary industry		Tertiary industry	
Explanatory variables	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
Epid	0.0028***	0.0043***	0.0274**	0.1065	0.0024***	0.0023**	0.0029***	0.0084*
	(0.0007)	(0.0015)	(0.0118)	(0.0915)	(0.0008)	(0.0010)	(0.0009)	(0.0047)
Lev	−0.0074***	−0.0022	0.1152	0.0855	−0.0062**	−0.0007	−0.0206**	−0.0216*
	(0.0028)	(0.0023)	(0.0900)	(0.0981)	(0.0027)	(0.0013)	(0.0096)	(0.0128)
Size	0.0059***	0.0016	−0.0251	0.0331	0.0088***	0.0037*	0.0043	0.0021
	(0.0022)	(0.0020)	(0.0454)	(0.0615)	(0.0020)	(0.0021)	(0.0048)	(0.0040)
ROA	0.0012**	0.0003	0.0097	0.1050	0.0015**	−0.0005	0.0006	0.0009
	(0.0006)	(0.0008)	(0.0124)	(0.1047)	(0.0007)	(0.0008)	(0.0007)	(0.0017)
Fix	−0.0027***	0.0036***	−6.7574	11.8745	−0.0020***	0.0037***	0.3723	0.6758**
	(0.0006)	(0.0006)	(7.5049)	(12.0523)	(0.0005)	(0.0006)	(0.2299)	(0.2743)
Age	−0.0043***	−0.1251***	0.0044	−0.0578	0.0357***	0.0230***	−0.0061***	−0.1277***
	(0.0010)	(0.0035)	(0.0055)	(0.0658)	(0.0045)	(0.0026)	(0.0006)	(0.0016)
Cons_	0.8277***	2.3427***	1.3220	0.6705	0.2986***	0.5601***	0.8978***	2.4364***
	(0.0482)	(0.0626)	(0.8864)	(1.1424)	(0.0790)	(0.0608)	(0.1048)	(0.0941)
id	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	41,440	41,432	596	596	28,870	28,865	11,974	11,971

Notes: For readers' convenience, the capital mismatch index τ_Y and the output distortion index τ_K in this table are the results of absolute values, which reflect the degree of distortion, and the following empirical results are the same. Cluster robust standard error in parentheses, as well as the standard deviation in subsequent tables. The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

TABLE 5 Impact of Covid-19 on resource misallocation and productivity by region.

Variables	Eastern region		Central region		Western region	
	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
Epid	0.0048***	0.0137***	0.0015*	−0.0000	0.0196	0.0249**
	(0.0011)	(0.0034)	(0.0009)	(0.0006)	(0.0222)	(0.0119)
Lev	−0.0011	−0.0099	−0.0070***	0.0008	−0.0686***	−0.0220
	(0.0078)	(0.0073)	(0.0013)	(0.0007)	(0.0239)	(0.0134)
Size	0.0066**	0.0012	0.0019	0.0067*	0.0124**	0.0029
	(0.0029)	(0.0026)	(0.0039)	(0.0034)	(0.0055)	(0.0040)
ROA	0.0012	0.0004	0.0021	−0.0011	0.0005	−0.0007*
	(0.0007)	(0.0014)	(0.0015)	(0.0008)	(0.0008)	(0.0004)
Fix	−0.0029***	0.0033***	0.0681***	0.0993	1.0513**	0.7631***
	(0.0007)	(0.0006)	(0.0205)	(0.0649)	(0.5093)	(0.2812)
Age	−0.0043***	−0.1260***	0.0019**	0.0029**	0.0245***	0.0152***
	(0.0006)	(0.0011)	(0.0010)	(0.0013)	(0.0027)	(0.0020)
Cons	0.8182***	2.4193***	0.8440***	0.7388***	0.3511***	0.6708***
	(0.0648)	(0.0612)	(0.0828)	(0.0693)	(0.1275)	(0.0998)
id	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes
N	28,617	28,609	6754	6754	6069	6069

Notes: The Eastern, Central and western regions are divided according to the provinces where the cities are located. The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

significantly worsened capital and output distortions in both high-tech and low-tech industries. The high-tech industries were more susceptible to the impact of the pandemic, such as the high-end medical equipment industry and new industries with high degrees of digitalisation that rapidly emerged during the pandemic.

The entire sample is further divided into state-owned enterprises and non-state-owned enterprises sub-samples. Chinese state-owned enterprises include both central and local state-owned enterprises. The purpose is to explore whether different factors such as business environment, innovative resources and cultural atmosphere faced by enterprises with different ownership systems may have had different impacts on resource mismatch during the pandemic period. The results indicate that the impact of the pandemic on capital and output distortions exhibited ownership heterogeneity. The coefficients of Covid-19 on output and capital distortions of state-owned enterprises are 0.0043 and 0.0064, respectively, indicating that the impact of the pandemic on the resource mismatch of state-owned enterprises was greater than that of the non-state-owned enterprises. This may be due to the country's high emphasis on state-owned enterprises and the provision of more preferential capital loans, resulting in more severe capital misallocation.

TABLE 6 Impact of Covid-19 on resource misallocation/productivity by industry and ownership.

Variables	High-tech industry		Medium-low-tech industry		State-owned Enterprise		Non-state-owned Enterprise	
	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
Epid	0.0044***	0.0049**	0.0016*	0.0038*	0.0043***	0.0064***	0.0011	0.0021
	(0.0010)	(0.0020)	(0.0009)	(0.0020)	(0.0009)	(0.0023)	(0.0009)	(0.0016)
Lev	−0.0045***	−0.0038***	−0.0125	−0.0074	−0.0209*	−0.0214**	−0.0064***	−0.0008
	(0.0010)	(0.0015)	(0.0105)	(0.0056)	(0.0119)	(0.0091)	(0.0024)	(0.0015)
Size	0.0017	−0.0054	0.0068**	0.0056***	0.0036	0.0051	0.0095***	−0.0000
	(0.0035)	(0.0048)	(0.0028)	(0.0022)	(0.0036)	(0.0032)	(0.0025)	(0.0023)
ROA	0.0017	−0.0006	0.0010**	0.0008	0.0023***	0.0001	−0.0005	0.0004
	(0.0015)	(0.0018)	(0.0005)	(0.0010)	(0.0007)	(0.0009)	(0.0010)	(0.0017)
Fix	−2.3157**	4.7899***	−0.0024***	0.0044***	0.1428**	0.2196*	−0.0021***	0.0035***
	(1.0902)	(1.0347)	(0.0007)	(0.0006)	(0.0652)	(0.1297)	(0.0006)	(0.0006)
Age	0.0027***	0.0062***	−0.0047***	−0.1240***	0.0025***	0.0017	−0.0041***	−0.1256***
	(0.0008)	(0.0014)	(0.0010)	(0.0036)	(0.0006)	(0.0013)	(0.0009)	(0.0037)
Cons	0.8421***	0.9047***	0.8152***	2.2633***	0.8039***	0.7841***	0.7497***	2.4388***
	(0.0703)	(0.1019)	(0.0592)	(0.0687)	(0.0720)	(0.0669)	(0.0535)	(0.0731)
id	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	13,854	13,851	27,586	27,581	25,412	25,408	16,028	16,024

Notes: According to the national economic classification (GB/T 4754–2017), high-tech industries include pharmaceutical manufacturing, information services, transportation equipment manufacturing, e-commerce services, electrical machinery and equipment manufacturing, general-purpose and specialised instrument manufacturing; medium and low-tech industries include agricultural and sideline food processing industry, food manufacturing, wine, beverage and refined tea manufacturing, textile industry, textile, clothing and footwear industry, papermaking and paper products industry, petroleum processing, coking and nuclear fuel processing industry, chemical raw materials and chemical products manufacturing, chemical fibre manufacturing, metal products industry, non-metallic mineral products industry, black metal smelting and rolling processing industry, non-ferrous metal smelting and rolling processing industry. The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

3.4 | Endogeneity and robustness test

3.4.1 | Endogenous processing

To study the problem more in-depth, this paper adopts the generalised moment estimation method of instrumental variables to deal with the endogeneity problem. Thus, the first- and second-order lag terms, which represent the severity of Covid-19, are selected as instrumental variables in this paper, which is a commonly used treatment method in most extant studies. These two lag terms are associated with the explained variable, but not with the explained variable, so they are good instrumental variables. After the regression analysis of the whole sample using the generalised moment estimation method, it is found that the result after changing the measurement method is close to the previous one and stable. In addition, the Wald statistics are all greater than the critical value, indicating that the instrumental variables are not weakly identified. The significance of Hansen statistic does not reach 10%, indicating that the null hypothesis cannot be rejected, which indicates that the selected instrumental variables are exogenous. It is further explained that the instrumental variables used in this paper are reasonable, and the measurement model is robust (Table 7).

3.4.2 | Robustness test

We test robustness from three perspectives, one of which is to replace the virtual variables. A dummy variable is added, taking the value of 1 is used for the pandemic 2020–2022 period and 0 for other years. The other is shortening the sampling time, focusing on the Covid-19 period. The last perspective is strengthening the control of the fixed benefits of the regions and industries where the enterprises are located. Although generally speaking, for few companies, the region and industry where they operate do not change significantly for some time, there is no denying that this may miss out on variables that do not vary by region and industry, leading to larger or smaller measurements. Therefore, on the basis of controlling the fixed effect of individual and time, we can better test the influence of the pandemic on individual and time, and further control the fixed effect of industry and province. The above three results are estimated based on the whole sample show that the impact of the pandemic would still significantly exacerbate the degree of resource distortions (Table 8).

4 | MECHANISMS OF COVID-19 IMPACT ON RESOURCE ALLOCATION

We further consider two internal influencing factors: capital cost (r), Harold's neutral technological progress (A), as well as two external influencing factors: product price (p) and market share (*market*). The purpose is to study whether the pandemic affected capital and output distortions through the so-called 'positive transmission' and 'backward forcing' mechanisms.

The principle of the positive transmission mechanism is as follows: Under the impact of the pandemic, the price increase of production factors such as upstream capital and labour costs may be transmitted positively to downstream consumer goods prices through the 'production chain', resulting in capital mismatch or output distortion. Alternatively, after being impacted by the pandemic, changes in the technological progress index may affect the supply of enterprises, which in turn may

TABLE 7 Results of Generalised Moment Estimation of Instrumental Variables (IV-GMM).

Explanatory variables	τ_Y		τ_K	
	Lag 1-period	Lag 2-period	Lag 1-period	Lag 2-period
Epid	0.0016*	0.0014***	0.0057***	0.0035***
	(0.0009)	(0.0005)	(0.0018)	(0.0010)
_Cons	0.8308***	0.8950***	0.8815***	0.8399***
	(0.0212)	(0.0174)	(0.0204)	(0.0230)
Controls	Yes	Yes	Yes	Yes
id	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes
N	22,649	15,896	22,642	15,889

Note: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

TABLE 8 Estimates of fixed effects by participating provinces and industries.

Explanatory variables	*Epid* is dummy variable		2019–2022		2006–2022	
	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
Epid	0.0441***	0.0617***	0.0021***	0.0030***	0.0028***	0.0044***
	(0.0074)	(0.0183)	(0.0009)	(0.0018)	(0.0007)	(0.0015)
_Cons	0.7640***	0.8364***	0.8657***	3.7155***	0.7250***	0.7924***
	(0.0333)	(0.0267)	(0.3007)	(0.3808)	(0.0388)	(0.0295)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
id	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes
Region	No	No	No	No	Yes	Yes
Industry	No	No	No	No	Yes	Yes
N	41,487	41,479	7695	7687	41,440	41,432

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

have an impact on the demand side, ultimately leading to capital mismatch or output distortion. When the supply side of the economy is impacted, affecting labour supply, capital stock and factor productivity, it will have an impact on the level of economic output in the short and long term.

The principle of the reverse force mechanism is as follows: When market demand decreases, the price of products purchased by consumers may decrease, which will lead to production enterprises taking a series of measures to cope with market shrinkage, such as reducing production or updating products to seek new profit growth points. Therefore, changes in consumer demand will be transmitted to production enterprises, prompting them to make corresponding adjustments to adapt to changes in the market environment. As a result, shrinking market demand may force enterprises to transform and develop, ultimately leading to capital mismatch or output distortion.

4.1 | Model design

Based on equation (15), let Ω_{it} denote the conduction mechanism factor matrix. Examining the 'positive transmission' mechanism, this paper selects two moderating variables: capital cost, and Harold's neutral technological progress. While, in the 'backward forcing' mechanism, we select two moderating variables: product price and market share. Testing the coefficient (β_1) of interaction between the regulatory variable and Covid-19, we can infer the effectiveness of the regulatory variable and the transmission channel. This paper also uses the individual and time bidirectional fixed effects for regression. The model design for mechanism research is as follows:

$$X_{it} = \alpha + \beta_1 Epid_{it} \cdot \Omega_{it} + \beta_2 Epid_{it} + \beta_3 \Omega_{it} + \beta_4 M_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \tag{16}$$

where, product price (p) is measured by PPI, and market share refers to product output provided by a certain enterprise to the output of the entire industry at a specific time. It reflects the ratio of a firm's sales in a specific market to the overall market sales to measure the firm's competitive position in that industry. For example, we first calculate the total output of an industry s in the first quarter of 2006, and then calculate the proportion of output contributed by firm i in the industry in the same time. μ_i and λ_t are respectively used to control firm and time effects, subscript i represents firm and t the time (quarter). The use of robust standard error methods reduces the impact of heteroscedasticity, ensuring that the estimated results are robust.

4.2 | Results of 'positive transmission' mechanism

On the basis of the model (15), the capital cost construction model (16) is introduced to test the moderating effect of capital cost and technological progress. The results are shown in Table 9. The coefficients of the impact of capital cost on output distortion and capital mismatch are 0.0023 and 0.0284, respectively, indicating that an increase in enterprise capital cost will increase the degree of resource mismatch. The interaction coefficients between the pandemic and capital cost are significantly negative, with values of −0.0006 and −0.0008, respectively, indicating that capital cost has a reverse moderating effect on the impact of pandemic on resource mismatch. It can alleviate the negative impact of the pandemic on enterprise resource allocation by reducing capital cost. The impact coefficients of Harold's technological progress on output distortion and capital mismatch are −0.0065 and −0.0201, respectively, indicating that an increase in technological progress will reduce the degree of resource mismatch. At the same time, the interaction

TABLE 9 Positive transmission of Covid-19 on resource allocation.

	Capital cost		Technological progress	
Variables	τ_Y	τ_K	τ_Y	τ_K
$Epid \cdot \Omega$	−0.0006***	−0.0008**	0.0003***	0.0006***
	(0.0002)	(0.0003)	(0.0001)	(0.0001)
Ω	0.0023***	0.0284***	−0.0065***	−0.0201***
	(0.0008)	(0.0019)	(0.0004)	(0.0008)
Lev	−0.0072**	0.0006	−0.0071**	−0.0013
	(0.0028)	(0.0016)	(0.0029)	(0.0018)
Size	0.0056***	−0.0017	0.0090***	0.0113***
	(0.0022)	(0.0022)	(0.0023)	(0.0018)
ROA	0.0012**	−0.0001	0.0014**	0.0007
	(0.0006)	(0.0009)	(0.0006)	(0.0009)
Fix	−0.0028***	0.0026***	−0.0031***	0.0025***
	(0.0005)	(0.0006)	(0.0006)	(0.0005)
Age	−0.0046***	−0.1282***	0.0032*	−0.0049***
	(0.0010)	(0.0039)	(0.0017)	(0.0015)
_Cons	0.8501***	2.6157***	0.7308***	0.8927***
	(0.0471)	(0.0732)	(0.0511)	(0.0471)
id	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes
N	41,440	41,432	41,437	41,429

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

coefficients between output distortion, capital mismatch and Harold's technological progress are 0.0003 and 0.0006, respectively. This indicates that the regulatory mechanism of technological progress is also effective. It can alleviate the resource mismatch exacerbated by the impact of the pandemic on enterprises by improving technological progress. In short, reducing capital costs and improving technological progress can help reduce resource mismatch. The 'positive transmission' channel of the impact of the pandemic on capital mismatch is unobstructed.

The heterogeneous results of the 'positive transmission' mechanism are further analysed (see Appendices A–F). Through the regression analysis of industry, ownership and region, we can find the following results. First, the interaction term between capital cost and the pandemic is found to have a significantly negative impact on the degree of output distortion in all industries, the eastern and central regions, high-tech industries and state-owned enterprises, but a significantly negative impact on the degree of capital mismatch in the secondary industry, the eastern region, high-tech industries and state-owned enterprises, indicating the heterogeneity of the impact of the pandemic on industries, regions and types of ownership. For the secondary industry, the eastern region, high-tech industries and state-owned enterprises, capital costs could be further reduced to cope with the deepening of resource mismatch caused by the impact of the pandemic. However, for the western region, medium and low-tech industries, and non-state-owned enterprises, this channel mechanism is ineffective.

The interaction between technological progress and the epidemic has a significant positive impact on the degree of output distortion in all industries, the eastern region, all industries and all enterprises with property rights. It also has a significantly positive impact on the degree of capital mismatch in the second and third industries, the eastern region, all industries and all enterprises with property rights. This indicates that the 'positive transmission' channels of output distortion caused by the pandemic are heterogeneous in different regions, and the 'positive transmission' channels of capital mismatch are heterogeneous in different industries and regions. Furthermore, for any industry and nature in the eastern region, as well as in the secondary and tertiary industries, improving technological progress could alleviate the exacerbation of resource mismatch caused by the impact of the pandemic. However, for enterprises in the central and western regions, the positive communication channel of technological progress is ineffective.

4.3 | Results of 'backward forcing' mechanism

Further, this paper examines the moderating effect of the 'backward forcing' variable of product price and market size. The results are shown in Table 10. The coefficients of the impact of product prices on output distortion and capital mismatch are 0.0595 and 0.2304, respectively, while the coefficients of the interaction between product prices and the pandemic on output distortion and capital mismatch are 0.0019 and 0.0022, respectively. The results indicated that an increase in product prices raised the degree of resource mismatch, and in urban areas with more severe contagion, resource distortion intensified. In other words, firms could respond to the worsening mismatch of resources caused by the pandemic through reducing production prices. The coefficient of influence of market size on output distortion is significantly positive (0.0796), and the interaction coefficient between the pandemic and market size on output distortion is significantly positive (0.0188). However, the impact of market size on capital distortion is insignificant, indicating that increasing market size could increase the degree of output distortion and worsen the impact of the pandemic on output distortion.

TABLE 10 Reverse transmission of Covid-19 on resource allocation.

Variables	Product price		Market share	
	τ_Y	τ_K	τ_Y	τ_K
Epid · Ω	0.0019***	0.0022**	0.0188**	0.0337
	(0.0005)	(0.0010)	(0.0092)	(0.0250)
Ω	0.0595***	0.2304***	0.0796**	−0.1634
	(0.0142)	(0.0403)	(0.0320)	(0.1173)
Lev	−0.0074***	−0.0024	−0.0076***	−0.0018
	(0.0028)	(0.0022)	(0.0029)	(0.0022)
Size	0.0059***	0.0015	0.0051**	0.0032
	(0.0022)	(0.0019)	(0.0022)	(0.0021)
ROA	0.0011**	−0.0003	0.0012**	0.0003
	(0.0006)	(0.0009)	(0.0006)	(0.0008)
Fix	−0.0027***	0.0035***	−0.0029***	0.0040***
	(0.0006)	(0.0006)	(0.0005)	(0.0006)
Age	−0.0034***	−0.1216***	−0.0040***	−0.1258***
	(0.0010)	(0.0034)	(0.0010)	(0.0035)
_Cons	0.7584***	2.0735***	0.8411***	2.3190***
	(0.0527)	(0.0806)	(0.0478)	(0.0633)
id	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes
N	41,440	41,432	41,440	41,432

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

This paper further analyses the heterogeneous results of the 'backward forcing' mechanism (see Appendices G–N). Through the regression analysis of industry, ownership and region, the following results are found. First, the interaction between production prices and the pandemic has a significant positive impact on output distortion in any industry, the eastern and central regions, high-tech industries and state-owned enterprises, while it has a significantly positive impact on capital mismatch in the eastern and western regions, high-tech industries and state-owned enterprises. It can be seen that the distorted production price channels of resources exhibit heterogeneity among different regions, industries and properties. For the eastern region, high-tech industries and state-owned enterprises, reducing production prices could be adopted to alleviate the deterioration of resource distortion caused by the impact of the pandemic. However, for medium and low-tech industries and non-state-owned enterprises, this measure is ineffective. Second, the interaction between market share and the pandemic has a significantly positive impact on output distortion in the primary and secondary industries, western regions, medium and low-tech industries and all types of enterprises, while it has a significantly positive impact on capital mismatch in the tertiary industry, eastern and western regions and high-tech industries. It can be seen that the distorted production price channels of resources exhibit heterogeneity among different regions, industries and ownership types. For the western region, reducing market share and guiding healthy market competition could be used to alleviate the deterioration of resource distortion caused by the impact of the pandemic. However, for the central region, this measure is ineffective.

5 | CONCLUSIONS AND POLICY RECOMMENDATIONS

Based on the Harrod's neutral technological progress model, the output distortion index, the capital misallocation index, this article uses data of China's A-share listed firms during 2006–2021 to investigate the impact of Covid-19 on resource misallocation from a holistic perspective, and tests the heterogeneity of industries, regions, sectors with different technology levels and ownership types. To further explore the transmission channels, four adjustment variables are selected, including capital costs, Harrod's neutral technological progress, product prices and market share. The 'positive transmission' and 'backward forcing' mechanisms are analysed in turn.

The main conclusions are as follows: (1) there are basically positive output distortion index and negative capital mismatch index in our listed enterprises. Moreover, the impact of the Covid-19 epidemic has led to the deterioration of China's corporate resource allocation distortion. (2) The impact of the epidemic situation on the distortion of resource allocation varies with different industries, regions, industries and types of ownership. Specifically, Covid-19 has a relatively large impact on the output distortion of the primary industry, the eastern region, high-tech and state-owned enterprises. It has also had a relatively significant impact on the capital mismatch in the tertiary industry, western regions, high-tech and state-owned enterprises. (3) Further research on the transmission mechanism indicates that under the 'positive transmission' mechanism, reducing capital costs and improving technological progress could help mitigating the distortion of enterprise resources under the influence of the pandemic. In the 'backward coercion' mechanism, reducing production prices could also help to reduce resource distortions, but promoting market share competition could only alleviate output distortions. (4) The transmission mechanism of the impact of the pandemic on resource mismatch also exhibits significant heterogeneity across different industries, regions and ownership types.

Based on the above research, in the face of public health emergencies such as the Covid-19, policymakers can take the following measures (similar to warning signals) to mitigate their negative impact on the resource mismatch of Chinese enterprises: First, reasonably increase the ratio of enterprise labour remuneration to capital remuneration and its ratio to operating income, optimise the employment environment of workers, improve the level of workers' income and rights protection and then essentially alleviate the degree of capital distortion and output distortion. Second, from the perspective of heterogeneity, local governments should propose differentiated management measures based on the technological characteristics and ownership nature of enterprises in different regions and industries. Due to the greater impact of the pandemic on the distortion of resource allocation in the primary industry, eastern regions, high-end technology industries and state-owned enterprises, special attention should be paid to state-owned enterprises in the eastern region that belong to high-end technology industries to cope with the further deterioration of resource allocation distortion caused by sudden public health emergencies. Third, the government should choose effective and smooth transmission mechanisms to regulate when formulating policies for enterprise relief and assistance, such as the 'positive transmission' mechanism for improving enterprise technological progress, and the 'reverse pressure' mechanism for reducing sales product prices and market share. Not only do enterprises need to focus on technological innovation to improve their supply capacity, but they also need to have the driving force even in times of market downturn caused by unexpected events. At the same time, the government needs to maintain stable market product prices and market share, encourage enterprises to cooperate in competition to resist risks and avoid the price gouging caused by enterprise monopolies or collusion. The above policy recommendations also have certain reference significance for other countries or regions to respond to global or regional public health emergencies.

Although our empirical research has reached the above conclusions, we are aware that some of the conclusions cannot be explained at the theoretical level. Therefore, it is recommended that future research develop a theoretical model to describe these empirical and mechanistic findings. In addition to the Covid-19 pandemic shock, future studies could look at more major public health events or other shocks to see if they have similar effects on corporate resource allocation distortions. It is suggested that these shocks should be related to the government's fiscal and regulatory policies in order to evaluate the policy of effectively solving the distortion of resource allocation caused by the pandemic. In addition, in the 'Reverse forcing' mechanism, this paper explores the price of products sold and market share of the two regulatory variables, suggesting that future study could further explore more regulatory factors. Finally, in the study of heterogeneity, more interesting categories can be found in the future, such as inter-regional competition, financial friction, market structure, institutional arrangements and the like.

ACKNOWLEDGEMENTS

We appreciate the research funding support provided by the National Natural Science Foundation of China (72071094) and Chinese Ministry of Education (24YJA790081) et. al.

FUNDING INFORMATION

This study was supported by the National Natural Science Foundation of China (72071094), Chinese Ministry of Education (24YJA790081), Natural Science Foundation of Guangdong (2024A1515012673), Research achievement of Zhejiang Federation of Social Sciences (Project No.: 2024N033), and the Technology Elite Navigation Project of Guangzhou (2024A04J6373).

DATA AVAILABILITY STATEMENT

I confirm that my article contains a Data Availability Statement even if no data is available (list of sample statements) unless my article type does not require one.

REFERENCES

Agyei-Boapeah, H., Osei, D., & Franco, M. (2019). Leverage deviations and acquisition probability in the UK: The moderating effect of firms' internal capabilities and deal diversification potential. *European Management Review*, *16*, 1059–1077.

Atkinson, S. E., & Halvorsen, R. (1984). Parametric efficiency tests, economies ofscale, and input demand in U.S. electric power generation. *International Economic Review*, *25*(3), 647–662.

Baqaee, D. R., & Emmanuel, F. (2020). Productivity and misallocation in general equilibrium. *Quarterly Journal of Economics*, *135*(1), 105–163.

Brainerd, E., & Siegler, M. V. (2002). The economic effects of the 1918 influenza epidemic. *CEPR Discussion Papers*, *3*, 1–14.

Brandt, L., Tombe, T., & Zhu, X. (2013). Factor market distortions across time, space and sectors in China. *Review of Economic Dynamics*, *16*(1), 39–58.

Chen, K., & Irarrazabal, A. (2015). The role of allocative efficiency in a decade of recovery. *Review of Economic Dynamics*, *18*(3), 523–550.

Dias, D. A., Marques, C. R., & Richmond, C. (2016). Misallocation and productivity in the lead up to the Eurozone crisis. *Journal of Macroeconomics*, *49*, 46–70.

Espitia, A., Mattoo, A., Rocha, N., Ruta, M., & Winkler, D. (2022). Pandemic trade: COVID-19, remote work and global value chains. *The World Economy*, *45*(2), 561–589.

Fang, J., Collins, A., & Yao, S. (2021). On the global COVID-19 pandemic and China's FDI. *Journal of Asian Economics*, *74*, 101300.

Fernandes, N. (2020). Economic effects of coronavirus outbreak (COVID-19) on the world economy. *IESE Business School Working Paper, No. WP-1240-E*, 1–33. https://doi.org/10.2139/ssrn.3557504

Hayward, M. L., & Hambrick, D. C. (1997). Explaining the premiums paid for large acquisitions: Evidence of CEO hubris. *Administrative Science Quarterly*, *42*, 103–127.

Hsieh, C. T., & Klenow, P. J. (2009). Misallocation and manufacturing TFP in China and India. *The Quarterly Journal of Economics*, *124*(4), 1403–1448.

Huang, H. C., Fang, W., & Miller, S. M. (2014). Does financial development volatility affect industrial growth volatility? *International Review of Economics and Finance*, *29*, 307–320.

Kazancoglu, Y., Ekinci, E., Mangla, S. K., Sezer, M. D., & Ozbiltekin-Pala, M. (2023). Impact of epidemic outbreaks (COVID-19) on global supply chains: A case of trade between Turkey and China. *Socio-Economic Planning Sciences*, *85*, 101494.

Kejžar, K. Z., Velić, A., & Damijan, J. P. (2022). COVID-19, trade collapse and GVC linkages: European experience. *The World Economy*, *45*(11), 3475–3506.

Keogh-Brown, M. R., & Smith, R. D. (2008). The economic impact of SARS: How does the reality match the predictions? *Health Policy*, *88*(1), 110–120.

Li, H. C., Lee, W. C., & Ko, B. T. (2017). What determines misallocation in innovation? A study of regional innovation in China. *Journal of Macroeconomics*, *52*, 221–237.

Li, X., Wang, L., & Du, K. (2023). How do environmental regulations influence resource misallocation in China? The role of investment flows. *Business Strategy and the Environment*, *32*(1), 538–550.

Luo, S., & Tsang, K. P. (2020). China and world output impact of the Hubei lockdown during the coronavirus outbreak. *Contemporary Economic Policy*, *38*(4), 583–592.

Mou, J. (2020). Research on the impact of COVID19 on global economy. *In IOP Conference Series: Earth and Environmental Science*, *546*(3), 032043.

Newey, W. K., & West, K. D. (1986). A simple, positive semi-definite, heteroskedasticity and autocorrelationconsistent covariance matrix. *Econometrica*, *55*, 703–708.

Nicola, M., Alsafi, Z., Sohrabi, C., Kerwan, A., Al-Jabir, A., Iosifidis, C., Agha, M., & Agha, R. (2020). The socio-economic implications of the coronavirus pandemic (COVID-19): A review. *International Journal of Surgery*, *78*, 185–193.

Prager, F., Wei, D., & Rose, A. (2017). Total economic consequences of an influenza outbreak in the United States. *Risk Analysis*, *37*(1), 4–19.

Restuccia, D., & Rogerson, R. (2013). Misallocation and productivity. *Review of Economic Dynamics*, *16*(1), 1–10.

Ryzhenkov, M. (2016). Resource misallocation and manufacturing productivity: The case of Ukraine. *Journal of Comparative Economics*, *44*(1), 41–55.

Tao, Q., Sun, W., Zhu, Y., & Zhang, T. (2017). Do firms have leverage targets? New evidence from mergers and acquisitions in China. *The North American Journal of Economics and Finance*, *40*, 41–54.

White, H. (1980). A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica: Journal of the Econometric Society*, 817–838.

Wurgler, J. (2000). Financial markets and the allocation of capital. *Journal of Financial Economics*, *58*(1–2), 187–214.

Yu, K. D. S., Aviso, K. B., Santos, J. R., & Tan, R. R. (2020). The economic impact of lockdowns: A persistent inoperability input-output approach. *Economies*, *8*(4), 109.

Zhou, Q., Tan, K. J. K., Faff, R., & Zhu, Y. (2016). Deviation from target capital structure, cost of equity and speed of adjustment. *Journal of Corporate Finance*, *39*, 99–120.

How to cite this article: Chen, C., Li, Y., Shan, J., & Yao, S. (2024). Covid-19 pandemic and its impact on capital and output distortions: Evidence from China. *The World Economy*, *00*, 1–42. https://doi.org/10.1111/twec.13656

APPENDIX 1

CAPITAL COST TRANSMISSION MECHANISM OF COVID-19 IMPACT ON RESOURCE ALLOCATION BY INDUSTRIES

	Primary industry		**Secondary industry**		**Tertiary industry**	
Variables	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
$Epid \cdot r$	−0.0047***	−0.0162	−0.0004**	−0.0005**	−0.0007**	−0.0017
	(0.0012)	(0.0114)	(0.0002)	(0.0002)	(0.0003)	(0.0014)
r	0.0062	0.0012	0.0032***	0.0271***	0.0013	0.0317***
	(0.0077)	(0.0568)	(0.0010)	(0.0025)	(0.0015)	(0.0030)
Lev	0.1121	0.0865	−0.0059**	0.0021*	−0.0204**	−0.0171
	(0.0882)	(0.0913)	(0.0027)	(0.0011)	(0.0096)	(0.0111)
$Size$	−0.0231	0.0341	0.0087***	0.0027	0.0040	−0.0052
	(0.0450)	(0.0567)	(0.0020)	(0.0022)	(0.0048)	(0.0044)
ROA	0.0089	0.1055	0.0014**	−0.0009	0.0005	0.0002
	(0.0124)	(0.1141)	(0.0007)	(0.0009)	(0.0007)	(0.0018)
Fix	−5.9386	12.2033	−0.0021***	0.0034***	0.3743*	0.7000**
	(7.6620)	(9.6345)	(0.0005)	(0.0005)	(0.2263)	(0.3486)
Age	0.0033	−0.0584	0.0370***	0.0340***	−0.0063***	−0.1312***
	(0.0051)	(0.0594)	(0.0048)	(0.0028)	(0.0006)	(0.0018)
Cons_	1.3283	0.6622	0.3043***	0.6067***	0.9149***	2.8294***
	(0.8896)	(1.1380)	(0.0781)	(0.0636)	(0.1040)	(0.1161)
id	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes
N	596	596	28,870	28,865	11,974	11,971

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

APPENDIX 2

CAPITAL COST TRANSMISSION MECHANISM OF COVID-19 IMPACT ON RESOURCE ALLOCATION BY REGIONS

	East region		**Central region**		**Western region**	
Variables	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
$Epid \cdot r$	−0.0015***	−0.0046***	−0.0003*	0.0000	−0.0040	−0.0027
	(0.0005)	(0.0008)	(0.0002)	(0.0001)	(0.0047)	(0.0030)
r	0.0020*	0.0286***	0.0034**	0.0308***	0.0032	0.0310***
	(0.0011)	(0.0024)	(0.0016)	(0.0032)	(0.0020)	(0.0028)
Lev	−0.0006	−0.0028	−0.0068***	0.0030***	−0.0680***	−0.0164
	(0.0077)	(0.0062)	(0.0013)	(0.0009)	(0.0240)	(0.0128)

Variables	East region τ_Y	East region τ_K	Central region τ_Y	Central region τ_K	Western region τ_Y	Western region τ_K
Size	0.0063**	−0.0030	0.0017	0.0052	0.0121**	−0.0000
	(0.0029)	(0.0029)	(0.0039)	(0.0040)	(0.0055)	(0.0046)
ROA	0.0011	−0.0002	0.0021	−0.0014	0.0005	−0.0005
	(0.0007)	(0.0015)	(0.0014)	(0.0009)	(0.0008)	(0.0007)
Fix	−0.0030***	0.0023***	0.0601***	0.0265	1.0383**	0.6427**
	(0.0006)	(0.0007)	(0.0200)	(0.0586)	(0.5067)	(0.2932)
Age	−0.0045***	−0.1292***	0.0014	−0.0016	0.0258***	0.0281***
	(0.0006)	(0.0012)	(0.0010)	(0.0016)	(0.0027)	(0.0025)
Cons_	0.8390***	2.7136***	0.8715***	0.9920***	0.3602***	0.7660***
	(0.0624)	(0.0738)	(0.0846)	(0.0810)	(0.1276)	(0.1167)
id	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes
N	28,617	28,609	6754	6754	6069	6069

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

APPENDIX 3

CAPITAL COST TRANSMISSION MECHANISM OF COVID-19 IMPACT ON RESOURCE ALLOCATION BY OWNERSHIP

Variables	High-tech industry τ_Y	High-tech industry τ_K	Medium-low-tech industry τ_Y	Medium-low-tech industry τ_K	State-owned Enterprise τ_Y	State-owned Enterprise τ_K	Non-state-owned Enterprise τ_Y	Non-state-owned Enterprise τ_K
$Epid \cdot r$	−0.0009***	−0.0006*	−0.0004	−0.0010*	−0.0009***	−0.0014**	−0.0002	−0.0001
	(0.0003)	(0.0003)	(0.0002)	(0.0005)	(0.0003)	(0.0006)	(0.0002)	(0.0002)
r	0.0026	0.0318***	0.0020**	0.0271***	0.0024**	0.0297***	0.0022**	0.0268***
	(0.0016)	(0.0026)	(0.0010)	(0.0025)	(0.0012)	(0.0028)	(0.0011)	(0.0022)
Lev	−0.0044***	−0.0019	−0.0122	−0.0031	−0.0202*	−0.0116	−0.0063***	0.0012
	(0.0010)	(0.0013)	(0.0104)	(0.0052)	(0.0120)	(0.0093)	(0.0024)	(0.0012)
Size	0.0018	−0.0051	0.0065**	0.0017	0.0033	0.0012	0.0092***	−0.0034
	(0.0035)	(0.0049)	(0.0027)	(0.0024)	(0.0036)	(0.0035)	(0.0025)	(0.0026)
ROA	0.0016	−0.0013	0.0010**	0.0006	0.0022***	−0.0002	−0.0005	−0.0001
	(0.0015)	(0.0020)	(0.0005)	(0.0010)	(0.0007)	(0.0009)	(0.0010)	(0.0019)
Fix	−2.1894**	6.3915***	−0.0025***	0.0033***	0.1339**	0.1043	−0.0021***	0.0026***
	(1.1130)	(1.2396)	(0.0007)	(0.0006)	(0.0638)	(0.1142)	(0.0006)	(0.0006)
Age	0.0024***	0.0008	−0.0049***	−0.1270***	0.0022***	−0.0029**	−0.0043***	−0.1288***
	(0.0009)	(0.0013)	(0.0010)	(0.0040)	(0.0007)	(0.0012)	(0.0010)	(0.0040)
Cons_	0.8591***	1.1361***	0.8356***	2.5406***	0.8272***	1.0878***	0.7715***	2.7087***
	(0.0670)	(0.1064)	(0.0585)	(0.0825)	(0.0697)	(0.0772)	(0.0549)	(0.0870)

Variables	High-tech industry		Medium-low-tech industry		State-owned Enterprise		Non-state-owned Enterprise	
	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
id	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	13,854	13,851	27,586	27,581	25,412	25,408	16,028	16,024

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

APPENDIX 4

TECHNOLOGICAL PROGRESS TRANSMISSION MECHANISM OF COVID-19 IMPACT ON RESOURCE ALLOCATION BY INDUSTRIES

Variables	Primary industry		Secondary industry		Tertiary industry	
	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
$Epid \cdot A$	0.0022***	0.0078	0.0003***	0.0004***	0.0003***	0.0009***
	(0.0006)	(0.0067)	(0.0001)	(0.0001)	(0.0001)	(0.0003)
A	−0.0032	−0.0507**	−0.0073***	−0.0191***	−0.0050***	−0.0218***
	(0.0032)	(0.0213)	(0.0005)	(0.0010)	(0.0008)	(0.0015)
Lev	0.1133	0.0429	−0.0060**	−0.0001	−0.0197**	−0.0165
	(0.0883)	(0.0950)	(0.0029)	(0.0017)	(0.0099)	(0.0105)
Size	−0.0251	0.0293	0.0120***	0.0120***	0.0070	0.0134***
	(0.0452)	(0.0503)	(0.0020)	(0.0019)	(0.0052)	(0.0039)
ROA	0.0103	0.1089	0.0017**	0.0000	0.0003	−0.0002
	(0.0128)	(0.0979)	(0.0007)	(0.0009)	(0.0007)	(0.0018)
Fix	−7.1110	5.2153	−0.0025***	0.0026***	−0.0025***	0.5520***
	(7.4974)	(9.0737)	(0.0005)	(0.0005)	(0.0005)	(0.1608)
Age	0.0047	−0.0491	0.0305***	0.0094***	0.0016**	−0.0066***
	(0.0057)	(0.0607)	(0.0047)	(0.0027)	(0.0007)	(0.0023)
_Cons	1.3492	1.1787	0.3556***	0.7075***	0.7919***	0.8783***
	(0.8860)	(0.8684)	(0.0801)	(0.0577)	(0.1102)	(0.0984)
id	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes
N	596	596	28,870	28,865	11,971	11,968

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

APPENDIX 5

TECHNOLOGICAL PROGRESS TRANSMISSION MECHANISM OF COVID-19 IMPACT ON RESOURCE ALLOCATION BY REGIONS

Variables	East region		Central region		Western region	
	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
$Epid \cdot A$	0.0003***	0.0011***	0.0002	0.0001	0.0032	0.0046***
	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0027)	(0.0016)
A	−0.0064***	−0.0215***	−0.0064***	−0.0171***	−0.0080***	−0.0178***
	(0.0005)	(0.0011)	(0.0010)	(0.0012)	(0.0012)	(0.0012)
Lev	0.0011	−0.0021	−0.0075***	−0.0005	−0.0666***	−0.0175
	(0.0082)	(0.0082)	(0.0013)	(0.0008)	(0.0236)	(0.0120)
$Size$	0.0099***	0.0120***	0.0038	0.0120***	0.0164***	0.0118***
	(0.0031)	(0.0025)	(0.0040)	(0.0030)	(0.0055)	(0.0036)
ROA	0.0011	0.0002	0.0022	−0.0007	0.0010	0.0004
	(0.0008)	(0.0014)	(0.0015)	(0.0009)	(0.0008)	(0.0009)
Fix	−0.0033***	0.0022***	0.0577**	0.0715	1.0368**	0.7305***
	(0.0007)	(0.0006)	(0.0234)	(0.0533)	(0.5216)	(0.2222)
Age	0.0025***	−0.0045**	0.0039***	0.0080***	0.0203***	0.0059**
	(0.0005)	(0.0019)	(0.0010)	(0.0015)	(0.0030)	(0.0027)
_Cons	0.7243***	0.8876***	0.8374***	0.7186***	0.3833***	0.7424***
	(0.0672)	(0.0636)	(0.0864)	(0.0605)	(0.1320)	(0.0914)
id	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes
N	28,614	28,606	6754	6754	6069	6069

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

APPENDIX 6

TECHNOLOGICAL PROGRESS TRANSMISSION MECHANISM OF COVID-19 IMPACT ON RESOURCE ALLOCATION BY INDUSTRIES AND OWNERSHIP

	High-tech industry		Medium-low-tech industry		State-owned enterprise		Non-state-owned enterprise	
Variables	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
$Epid \cdot A$	0.0004***	0.0005***	0.0002***	0.0007***	0.0004***	0.0008***	0.0002*	0.0004**
	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)
A	−0.0088***	−0.0254***	−0.0058***	−0.0179***	−0.0067***	−0.0202***	−0.0062***	−0.0199***
	(0.0007)	(0.0014)	(0.0005)	(0.0010)	(0.0005)	(0.0012)	(0.0006)	(0.0011)
Lev	−0.0039***	−0.0021**	−0.0107	−0.0015	−0.0166	−0.0087	−0.0065**	−0.0009
	(0.0010)	(0.0011)	(0.0109)	(0.0062)	(0.0122)	(0.0086)	(0.0026)	(0.0018)
$Size$	0.0054	0.0051	0.0092***	0.0131***	0.0065*	0.0139***	0.0125***	0.0093***
	(0.0033)	(0.0041)	(0.0029)	(0.0021)	(0.0039)	(0.0030)	(0.0026)	(0.0022)
ROA	0.0018	−0.0003	0.0011**	0.0013	0.0025***	0.0009	−0.0004	0.0007
	(0.0015)	(0.0019)	(0.0005)	(0.0010)	(0.0007)	(0.0009)	(0.0010)	(0.0018)
Fix	−4.3911***	−1.1726	−0.0028***	0.0032***	0.1030*	0.0997	−0.0024***	0.0024***
	(1.1471)	(0.9779)	(0.0007)	(0.0006)	(0.0594)	(0.0673)	(0.0006)	(0.0005)
Age	0.0046***	0.0118***	0.0031*	−0.0029	0.0043***	0.0072***	0.0035**	−0.0044*
	(0.0008)	(0.0014)	(0.0016)	(0.0020)	(0.0006)	(0.0013)	(0.0016)	(0.0024)
_Cons	0.8316***	0.8735***	0.7220***	0.8154***	0.7801***	0.7099***	0.6504***	0.9136***
	(0.0687)	(0.0886)	(0.0619)	(0.0555)	(0.0764)	(0.0624)	(0.0546)	(0.0615)
id	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	13,854	13,851	27,583	27,578	25,412	25,408	16,025	16,021

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

APPENDIX 7

PRICING TRANSMISSION MECHANISM OF COVID-19 IMPACT ON RESOURCE ALLOCATION BY INDUSTRIES

Variables	Primary industry τ_Y	Primary industry τ_K	Secondary industry τ_Y	Secondary industry τ_K	Tertiary industry τ_Y	Tertiary industry τ_K
$Epid \cdot p$	0.0175**	0.0815	0.0017***	0.0009	0.0015**	0.0039
	(0.0073)	(0.0730)	(0.0006)	(0.0007)	(0.0007)	(0.0028)
p	0.2839**	−0.4147	0.0511***	0.2126***	0.0732***	0.2685***
	(0.1151)	(0.6638)	(0.0189)	(0.0442)	(0.0195)	(0.0837)
Lev	0.1098	0.0947	−0.0063**	−0.0009	−0.0206**	−0.0213*
	(0.0875)	(0.0940)	(0.0027)	(0.0013)	(0.0096)	(0.0125)
Size	−0.0193	0.0249	0.0088***	0.0036*	0.0041	0.0016
	(0.0432)	(0.0551)	(0.0020)	(0.0021)	(0.0048)	(0.0039)
ROA	0.0014	0.1174	0.0014**	−0.0009	0.0003	0.0001
	(0.0109)	(0.1195)	(0.0007)	(0.0008)	(0.0007)	(0.0020)
Fix	−6.0589	11.0252	−0.0021***	0.0037***	0.3752	0.6869**
	(7.3279)	(10.9325)	(0.0005)	(0.0006)	(0.2293)	(0.2806)
Age	0.0001	−0.0517	0.0345***	0.0176***	−0.0050***	−0.1238***
	(0.0057)	(0.0576)	(0.0043)	(0.0024)	(0.0006)	(0.0026)
_Cons	0.9614	1.1920	0.2627***	0.4114***	0.8142***	2.1289***
	(0.8290)	(1.2667)	(0.0864)	(0.0734)	(0.1078)	(0.1477)
id	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes
N	596	596	28,870	28,865	11,974	11,971

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

APPENDIX 8

PRICING TRANSMISSION MECHANISM OF COVID-19 IMPACT ON RESOURCE ALLOCATION BY REGIONS

	East region		Central region		Western region	
Variables	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
$Epid \cdot p$	0.0024***	0.0053**	0.0013*	−0.0000	0.0152	0.0205**
	(0.0008)	(0.0025)	(0.0008)	(0.0005)	(0.0181)	(0.0094)
p	0.0640***	0.2747***	0.0060	−0.0478*	0.0450	−0.0061
	(0.0164)	(0.0483)	(0.0347)	(0.0283)	(0.0351)	(0.0199)
Lev	−0.0014	−0.0113	−0.0070***	0.0009	−0.0687***	−0.0220
	(0.0078)	(0.0074)	(0.0013)	(0.0007)	(0.0239)	(0.0134)
Size	0.0065**	0.0007	0.0019	0.0067*	0.0126**	0.0029
	(0.0029)	(0.0026)	(0.0039)	(0.0034)	(0.0055)	(0.0039)
ROA	0.0011	−0.0001	0.0020	−0.0008	0.0005	−0.0007*
	(0.0007)	(0.0014)	(0.0015)	(0.0008)	(0.0008)	(0.0004)
Fix	−0.0030***	0.0032***	0.0684***	0.0975	1.0573**	0.7622***
	(0.0007)	(0.0007)	(0.0207)	(0.0647)	(0.5072)	(0.2809)
Age	−0.0035***	−0.1226***	0.0018*	0.0037**	0.0250***	0.0151***
	(0.0007)	(0.0015)	(0.0011)	(0.0015)	(0.0025)	(0.0020)
_Cons	0.7474***	2.1142***	0.8392***	0.7773***	0.2959**	0.6783***
	(0.0695)	(0.0868)	(0.0861)	(0.0748)	(0.1232)	(0.0986)
id	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes
N	28,617	28,609	6754	6754	6069	6069

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

APPENDIX 9

PRICING TRANSMISSION MECHANISM OF COVID-19 IMPACT ON RESOURCE ALLOCATION BY INDUSTRIES AND OWNERSHIP

	High-tech industry		Medium-low-tech industry		State-owned enterprise		Non-state-owned enterprise	
Variables	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
$Epid \cdot p$	0.0031***	0.0029**	0.0010	0.0016	0.0027***	0.0029**	0.0008	0.0014
	(0.0007)	(0.0012)	(0.0007)	(0.0013)	(0.0007)	(0.0014)	(0.0007)	(0.0012)
p	0.0729**	0.2066***	0.0525***	0.2472***	0.0657***	0.2531***	0.0431***	0.1956***
	(0.0336)	(0.0525)	(0.0131)	(0.0542)	(0.0204)	(0.0558)	(0.0164)	(0.0568)
Lev	−0.0046***	−0.0042***	−0.0125	−0.0076	−0.0212*	−0.0224**	−0.0064***	−0.0007
	(0.0010)	(0.0015)	(0.0104)	(0.0054)	(0.0119)	(0.0091)	(0.0024)	(0.0014)
$Size$	0.0017	−0.0055	0.0068**	0.0056***	0.0036	0.0050	0.0095***	−0.0001
	(0.0035)	(0.0048)	(0.0028)	(0.0021)	(0.0036)	(0.0032)	(0.0025)	(0.0023)
ROA	0.0014	−0.0013	0.0009*	0.0004	0.0020***	−0.0009	−0.0004	0.0005
	(0.0014)	(0.0017)	(0.0005)	(0.0010)	(0.0006)	(0.0010)	(0.0010)	(0.0018)
Fix	−2.2288**	5.0444***	−0.0024***	0.0044***	0.1474**	0.2376*	−0.0021***	0.0035***
	(1.1027)	(1.0116)	(0.0007)	(0.0006)	(0.0662)	(0.1364)	(0.0006)	(0.0006)
Age	0.0014	0.0027*	−0.0038***	−0.1202***	0.0014**	−0.0025	−0.0034***	−0.1227***
	(0.0011)	(0.0016)	(0.0010)	(0.0037)	(0.0007)	(0.0018)	(0.0010)	(0.0037)
_Cons	0.7843***	0.7385***	0.7534***	1.9717***	0.7516***	0.5810***	0.6988***	2.2075***
	(0.0846)	(0.0929)	(0.0608)	(0.1015)	(0.0746)	(0.0774)	(0.0591)	(0.1058)
id	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	13,854	13,851	27,586	27,581	25,412	25,408	16,028	16,024

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

APPENDIX 10

MARKET SHARE TRANSMISSION MECHANISM OF COVID-19 IMPACT ON RESOURCE ALLOCATION BY INDUSTRIES

	Primary industry		Secondary industry		Tertiary industry	
Variables	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
Epid · market	0.4722***	1.6058	0.0106*	0.0135	0.0275	0.0894**
	(0.1069)	(1.3655)	(0.0063)	(0.0085)	(0.0171)	(0.0421)
market	0.4983	−0.6108	0.0713	0.0561	0.0731**	−0.2198
	(0.2941)	(0.6229)	(0.0437)	(0.1607)	(0.0369)	(0.1524)
Lev	0.1027	0.1076	−0.0063**	−0.0008	−0.0213**	−0.0202
	(0.0846)	(0.0958)	(0.0027)	(0.0013)	(0.0096)	(0.0128)
Size	−0.0486	0.0637	0.0084***	0.0033	0.0030	0.0062
	(0.0449)	(0.0802)	(0.0019)	(0.0024)	(0.0049)	(0.0041)
ROA	0.0116	0.1033	0.0014**	−0.0006	0.0005	0.0008
	(0.0131)	(0.1012)	(0.0007)	(0.0008)	(0.0007)	(0.0017)
Fix	−8.0601	14.0141	−0.0021***	0.0037***	0.3510	0.7541***
	(7.3477)	(14.0342)	(0.0005)	(0.0006)	(0.2345)	(0.2726)
Age	0.0050	−0.0594	0.0360***	0.0232***	−0.0059***	−0.1285***
	(0.0055)	(0.0662)	(0.0046)	(0.0026)	(0.0006)	(0.0014)
_Cons	1.7883*	0.0638	0.3045***	0.5650***	0.9218***	2.3651***
	(0.8578)	(1.3262)	(0.0778)	(0.0629)	(0.1060)	(0.0959)
id	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes
N	596	596	28,870	28,865	11,974	11,971

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

APPENDIX 11

MARKET SHARE TRANSMISSION MECHANISM OF COVID-19 IMPACT ON RESOURCE ALLOCATION BY REGIONS

	East region		Central region		Western region	
Variables	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
Epid · market	0.0175*	0.0441	−0.0749	−0.4357***	2.1335***	1.1781***
	(0.0093)	(0.0300)	(0.1229)	(0.0644)	(0.3049)	(0.2067)
market	0.0665*	−0.1862	−0.0103	−0.1121	0.2243***	0.0288
	(0.0342)	(0.1392)	(0.1044)	(0.1274)	(0.0539)	(0.0745)
Lev	−0.0016	−0.0093	−0.0070***	0.0009	−0.0704***	−0.0225*
	(0.0079)	(0.0072)	(0.0013)	(0.0007)	(0.0239)	(0.0135)
Size	0.0059**	0.0033	0.0019	0.0073**	0.0101*	0.0026
	(0.0029)	(0.0028)	(0.0038)	(0.0036)	(0.0053)	(0.0038)
ROA	0.0011	0.0003	0.0021	−0.0010	0.0002	−0.0007*
	(0.0007)	(0.0014)	(0.0015)	(0.0008)	(0.0009)	(0.0004)
Fix	−0.0031***	0.0038***	0.0682***	0.1016	0.9922*	0.7568***
	(0.0007)	(0.0007)	(0.0202)	(0.0651)	(0.5309)	(0.2783)
Age	−0.0042***	−0.1272***	0.0020**	0.0029**	0.0246***	0.0153***
	(0.0006)	(0.0010)	(0.0010)	(0.0013)	(0.0027)	(0.0020)
_Cons	0.8310***	2.3915***	0.8444***	0.7250***	0.3972***	0.6770***
	(0.0645)	(0.0630)	(0.0813)	(0.0702)	(0.1234)	(0.0974)
id	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes
N	29,402	29,402	8070	8070	8180	8180

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

APPENDIX 12

MARKET SHARE TRANSMISSION MECHANISM OF COVID-19 IMPACT ON RESOURCE ALLOCATION BY INDUSTRIES AND OWNERSHIP

	High-tech industry		Medium-low-tech industry		State-owned enterprise		Non-state-owned enterprise	
Variables	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
Epid · market	0.0263	0.2347**	0.0179**	0.0297	0.0223**	0.0234	−0.0744*	0.2186
	(0.0709)	(0.1179)	(0.0081)	(0.0218)	(0.0101)	(0.0348)	(0.0384)	(0.1768)
market	−0.1389	−0.5842**	0.0956***	−0.1302	0.0987*	−0.4241*	0.0645*	0.0111
	(0.1239)	(0.2548)	(0.0347)	(0.1210)	(0.0572)	(0.2424)	(0.0338)	(0.0361)
Lev	−0.0044***	−0.0034***	−0.0131	−0.0066	−0.0215*	−0.0179*	−0.0065***	−0.0008
	(0.0010)	(0.0013)	(0.0105)	(0.0056)	(0.0119)	(0.0095)	(0.0024)	(0.0015)
Size	0.0022	−0.0033	0.0056**	0.0072***	0.0026	0.0086***	0.0088***	−0.0002
	(0.0035)	(0.0044)	(0.0028)	(0.0024)	(0.0036)	(0.0033)	(0.0025)	(0.0023)
ROA	0.0017	−0.0005	0.0009*	0.0008	0.0021***	0.0004	−0.0005	0.0004
	(0.0015)	(0.0018)	(0.0005)	(0.0010)	(0.0007)	(0.0009)	(0.0010)	(0.0018)
Fix	−2.3186**	4.7480***	−0.0027***	0.0048***	0.1407**	0.2335*	−0.0022***	0.0035***
	(1.0944)	(1.0261)	(0.0007)	(0.0007)	(0.0647)	(0.1372)	(0.0006)	(0.0006)
Age	0.0029***	0.0063***	−0.0043***	−0.1246***	0.0027***	0.0020	−0.0038***	−0.1256***
	(0.0008)	(0.0013)	(0.0010)	(0.0036)	(0.0006)	(0.0012)	(0.0009)	(0.0037)
_Cons	0.8298***	0.8604***	0.8341***	2.2396***	0.8212***	0.7093***	0.7608***	2.4415***
	(0.0698)	(0.0930)	(0.0587)	(0.0707)	(0.0722)	(0.0655)	(0.0526)	(0.0737)
id	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	13,854	13,851	27,586	27,581	25,412	25,408	16,028	16,024

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

APPENDIX 13

THE METHOD AND ESTIMATED RESULTS BASED ON HSIEH AND KLENOW (2009)

If the framework is Hsieh and Klenow (2009), then the enterprise production function is $Y_{it} = A_{it}K_{it}^{\alpha}L_{it}^{1-\alpha}$, whereas the enterprise production function in this article is $Y_{it} = K_{it}^{\alpha}\left(A_{it}L_{it}\right)^{1-\alpha}$.

In the following derivation, we find that the expressions of output distortion and capital distortion index under the two frameworks are identical, which are

$$\tau_{Y_{si}} = 1 - \frac{\sigma}{\sigma-1}\frac{1}{1-\alpha_s}\frac{wL_{si}}{P_{si}Y_{si}}, \tag{13-1}$$

$$\tau_{K_{si}} = -1 + \frac{\alpha_s}{1-\alpha_s}\frac{wL_{si}}{RK_{si}}. \tag{13-2}$$

The difference is that in Hsieh and Klenow (2009), the technical progress is:

$$TFPR'_{it} = \frac{\sigma}{\sigma-1}\left(\frac{MRPK_{it}}{\alpha}\right)\left(\frac{MRPL_{it}}{w_{it}(1-\alpha)}\right)^{1-\alpha} = \left(\frac{r_{it}}{\alpha}\right)^{\alpha}\left(\frac{1}{1-\alpha}\right)^{1-\alpha}\frac{\left(1-\tau_{Kit}\right)^{\alpha}}{1-\tau_{Yit}}. \tag{13-3}$$

The technical progress in this paper is positively related to the technical progress in Hsieh and Klenow (2009). The expression is as follows: $TFPR_{it} = TFPR'^{\frac{1}{1-\alpha}}_{it}$.

So, a descriptive statistical comparison of the Harrold Neutral A and the Cobb Douglas A_1 production function is shown in Table 13-1. Since capital intensity is less than 0, Harrold's neutral progress was greater than that in the Cobb–Douglas production function, with logarithmic averages of 7.4254 and 9.1266, respectively.

In this paper, we reapply the Hsieh and Klenow (2009) framework to the empirical test of technological progress in the study of the positive conduction mechanism of the resource allocation distortion caused by the impact of Covid-19 pneumonia, the empirical results and heterogeneity results are robust.

To sum up, our study posits a different technological advance than Hsieh and Klenow's (2009), but the output distortion index and the resource misallocation index are consistent. Thus, the impact of Covid-19 on resource misallocation is the same in this study and in Hsieh and Klenow's (2009) framework. Of course, the reason we chose Harrold for neutral technological progress is that the Chinese economy is shifting from high-speed growth driven by traditional factors and investment to high-quality growth driven by innovation and talent. It is more in line with the long-term dynamic growth of Harold's neutral technological progress in human capital, from 'Output growth' to 'Labour growth', and empirical data show that the Chinese economy is relatively more advanced, which are more consistent with the reality of China (Tables 13-2–13-5).

TABLE 13-1 Descriptive statistics of variables for the full sample.

Variables	Mean	Standard deviation	Minimum	Maximum
A	6.7614	2.4076	−10.8504	17.7986
A_1	4.4324	1.7380	−8.3234	12.4185

TABLE 13-2 Positive transmission of technological progress.

	A_1		A	
Variables	τ_Y	τ_K	τ_Y	τ_K
$Epid \cdot \Omega$	0.0004***	0.0008***	0.0003***	0.0006***
	(0.0001)	(0.0002)	(0.0001)	(0.0001)
Ω	−0.0080***	−0.0247***	−0.0065***	−0.0201***
	(0.0005)	(0.0010)	(0.0004)	(0.0008)
Lev	−0.0071**	−0.0013	−0.0071**	−0.0013
	(0.0029)	(0.0018)	(0.0029)	(0.0018)
Size	0.0090***	0.0113***	0.0090***	0.0113***
	(0.0023)	(0.0018)	(0.0023)	(0.0018)
ROA	0.0014**	0.0007	0.0014**	0.0007
	(0.0006)	(0.0009)	(0.0006)	(0.0009)
Fix	−0.0031***	0.0025***	−0.0031***	0.0025***
	(0.0006)	(0.0005)	(0.0006)	(0.0005)
Age	0.0032*	−0.0049***	0.0032*	−0.0049***
	(0.0017)	(0.0015)	(0.0017)	(0.0015)
_Cons	0.7308***	0.8927***	0.7308***	0.8927***
	(0.0511)	(0.0471)	(0.0511)	(0.0471)
id	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes
N	41,437	41,429	41,437	41,429

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

APPENDIX 14

THE ESTIMATION PROCESS OF ROBUST STANDARD ERROR

For the example of the main regression model (15), we set it to

$$X_{it} = \alpha + \beta_1 Epid_{it} + \beta_2 M_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \tag{14-15}$$

where $i = 1, \ldots, N, t = 1, \ldots, T, E(\varepsilon_{it}) = 0$.

Taking the Covid-19 epidemic as an example, in general, the coefficient variance can be expressed as

$$V\left[\hat{\beta}_1\right] = E\left[\left(\hat{\beta}_1 - \beta_1\right)^2\right] = V\left[\sum_i Epid_{it}\varepsilon_{it}\right] / \left(\sum_i Epid_{it}^2\right)^2. \tag{14-16}$$

TABLE 13-3 Technological progress transmission mechanism of Covid-19 impact on resource allocation by industries.

Variables	Primary industry τ_Y	Primary industry τ_K	Secondary industry τ_Y	Secondary industry τ_K	Tertiary industry τ_Y	Tertiary industry τ_K
$Epid \cdot A_1$	0.0027***	0.0096	0.0003***	0.0005***	0.0003***	0.0011***
	(0.0008)	(0.0083)	(0.0001)	(0.0001)	(0.0001)	(0.0003)
A_1	−0.0039	−0.0623**	−0.0090***	−0.0234***	−0.0090***	−0.0268***
	(0.0039)	(0.0262)	(0.0006)	(0.0012)	(0.0006)	(0.0019)
Lev	0.1133	0.0429	−0.0060**	−0.0001	−0.0060**	−0.0165
	(0.0883)	(0.0950)	(0.0029)	(0.0017)	(0.0029)	(0.0105)
Size	−0.0251	0.0293	0.0120***	0.0120***	0.0120***	0.0134***
	(0.0452)	(0.0503)	(0.0020)	(0.0019)	(0.0020)	(0.0039)
ROA	0.0103	0.1089	0.0017**	0.0000	0.0017**	−0.0002
	(0.0128)	(0.0979)	(0.0007)	(0.0009)	(0.0007)	(0.0018)
Fix	−7.1110	5.2153	−0.0025***	0.0026***	−0.0025***	0.5520***
	(7.4974)	(9.0737)	(0.0005)	(0.0005)	(0.0005)	(0.1608)
Age	0.0047	−0.0491	0.0305***	0.0094***	0.0305***	−0.0066***
	(0.0057)	(0.0607)	(0.0047)	(0.0027)	(0.0047)	(0.0023)
_Cons	1.3492	1.1787	0.3556***	0.7075***	0.3556***	0.8783***
	(0.8860)	(0.8684)	(0.0801)	(0.0577)	(0.0801)	(0.0984)
id	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes
N	596	596	28,870	28,865	28,870	11,968

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

If the error terms are autocorrelated, then $V\left[\sum_i Epid_{it}\varepsilon_{it}\right]$ can be expressed as

$$V\left[\sum_i Epid_{it}\varepsilon_{it}\right] = \sum_i \sum_j Cov\left[Epid_{it}\varepsilon_{it}, Epid_{jt}\varepsilon_{jt}\right] = \sum_i \sum_j Epid_{it}Epid_{jt}E\left[\varepsilon_{it}, \varepsilon_{jt}\right], \quad (14\text{-}17)$$

$$V_{cor}\left[\hat{\beta}_1\right] = \sum_i \sum_j Epid_{it}Epid_{jt}E\left[\varepsilon_{it}, \varepsilon_{jt}\right] / \left(\sum_i Epid_{it}^2\right)^2, \quad (14\text{-}18)$$

A direct idea is to extend White (1980) to use $\hat{\varepsilon}_{it}\hat{\varepsilon}_{jt}$ instead of $E\left[\varepsilon_{it}, \varepsilon_{jt}\right]$, but because of $\sum_i Epid_{jt}\hat{\varepsilon}_{jt} = 0$, also $V_{cor}\left[\hat{\beta}_1\right] = \sum_i \sum_j Epid_{it}Epid_{jt}\hat{\varepsilon}_{it}\hat{\varepsilon}_{jt} / \left(\sum_i Epid_{it}^2\right)^2$ is 0.

For time series data, White (1980) can extend the generation of heteroscedastic- and autocorrelation-consistent (HAC) estimates by assuming that the error term has autocorrelation and heteroscedastic problems during the interval M, as detailed in Newey and West (1986).

TABLE 13-4 Technological progress transmission mechanism of Covid-19 impact on resource allocation by regions.

	East region		Central region		Western region	
Variables	τ_Y	τ_K	τ_Y	τ_K	τ_Y	τ_K
$Epid \cdot A_1$	0.0004***	0.0013***	0.0002	0.0001	0.0040	0.0056***
	(0.0001)	(0.0003)	(0.0001)	(0.0001)	(0.0033)	(0.0020)
A_1	−0.0079***	−0.0265***	−0.0079***	−0.0210***	−0.0098***	−0.0219***
	(0.0006)	(0.0014)	(0.0012)	(0.0015)	(0.0014)	(0.0015)
Lev	0.0011	−0.0021	−0.0075***	−0.0005	−0.0666***	−0.0175
	(0.0082)	(0.0082)	(0.0013)	(0.0008)	(0.0236)	(0.0120)
Size	0.0099***	0.0120***	0.0038	0.0120***	0.0164***	0.0118***
	(0.0031)	(0.0025)	(0.0040)	(0.0030)	(0.0055)	(0.0036)
ROA	0.0011	0.0002	0.0022	−0.0007	0.0010	0.0004
	(0.0008)	(0.0014)	(0.0015)	(0.0009)	(0.0008)	(0.0009)
Fix	−0.0033***	0.0022***	0.0577**	0.0715	1.0368**	0.7305***
	(0.0007)	(0.0006)	(0.0234)	(0.0533)	(0.5216)	(0.2222)
Age	0.0025***	−0.0045**	0.0039***	0.0080***	0.0203***	0.0059**
	(0.0005)	(0.0019)	(0.0010)	(0.0015)	(0.0030)	(0.0027)
_Cons	0.7243***	0.8876***	0.8374***	0.7186***	0.3833***	0.7424***
	(0.0672)	(0.0636)	(0.0864)	(0.0605)	(0.1320)	(0.0914)
id	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes
N	28,614	28,606	6754	6754	6069	6069

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Similar to the above approach to solve the problem of both autocorrelation and heteroscedasticity, cluster errors can be obtained when samples I and J are not in the same group, $E\left(\varepsilon_{it}\varepsilon_{jt}\right)=0$:

$$V_{clu}\left[\hat{\beta}_1\right]=\sum_i\sum_j Epid_{it}Epid_{jt}E\left[\varepsilon_{it},\varepsilon_{jt}\right]I\left[i,j\ in\ same\ cluster\right]/\left(\sum_i Epid_{it}^2\right)^2. \tag{14-19}$$

Further, substituting $\hat{\varepsilon}_{it}\hat{\varepsilon}_{jt}$ for $E\left[\varepsilon_{it},\varepsilon_{jt}\right]$ yields:

$$V_{clu}\left[\hat{\beta}_1\right]=\sum_i\sum_j Epid_{it}Epid_{jt}\hat{\varepsilon}_{it}\hat{\varepsilon}_{jt}I\left[i,j\ in\ same\ cluster\right]/\left(\sum_i Epid_{it}^2\right)^2, \tag{14-20}$$

where, $I[\cdot]$ is the indicating function, at the time of the event, is equal to 1, otherwise equal to 0. The standard error here is the clustering robust standard error.

TABLE 13-5 Technological progress transmission mechanism of Covid-19 impact on resource allocation by industries and ownership.

Variables	High-tech industry τ_Y	High-tech industry τ_K	Medium-low-tech industry τ_Y	Medium-low-tech industry τ_K	State-owned enterprise τ_Y	State-owned enterprise τ_K	Non-state-owned enterprise τ_Y	Non-state-owned enterprise τ_K
$Epid \cdot A_1$	0.0005***	0.0007***	0.0003***	0.0008***	0.0005***	0.0009***	0.0002*	0.0005**
	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)
A_1	−0.0109***	−0.0313***	−0.0071***	−0.0220***	−0.0082***	−0.0248***	−0.0077***	−0.0245***
	(0.0008)	(0.0017)	(0.0006)	(0.0013)	(0.0007)	(0.0014)	(0.0007)	(0.0014)
Lev	−0.0039***	−0.0021**	−0.0107	−0.0015	−0.0166	−0.0087	−0.0065**	−0.0009
	(0.0010)	(0.0011)	(0.0109)	(0.0062)	(0.0122)	(0.0086)	(0.0026)	(0.0018)
Size	0.0054	0.0051	0.0092***	0.0131***	0.0065*	0.0139***	0.0125***	0.0093***
	(0.0033)	(0.0041)	(0.0029)	(0.0021)	(0.0039)	(0.0030)	(0.0026)	(0.0022)
ROA	0.0018	−0.0003	0.0011**	0.0013	0.0025***	0.0009	−0.0004	0.0007
	(0.0015)	(0.0019)	(0.0005)	(0.0010)	(0.0007)	(0.0009)	(0.0010)	(0.0018)
Fix	−4.3911***	−1.1726	−0.0028***	0.0032***	0.1030*	0.0997	−0.0024***	0.0024***
	(1.1471)	(0.9779)	(0.0007)	(0.0006)	(0.0594)	(0.0673)	(0.0006)	(0.0005)
Age	0.0046***	0.0118***	0.0031*	−0.0029	0.0043***	0.0072***	0.0035**	−0.0044*
	(0.0008)	(0.0014)	(0.0016)	(0.0020)	(0.0006)	(0.0013)	(0.0016)	(0.0024)
_Cons	0.8316***	0.8735***	0.7220***	0.8154***	0.7801***	0.7099***	0.6504***	0.9136***
	(0.0687)	(0.0886)	(0.0619)	(0.0555)	(0.0764)	(0.0624)	(0.0546)	(0.0615)
id	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
quarter	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	13,854	13,851	27,583	27,578	25,412	25,408	16,025	16,021

Notes: The values in parentheses are heteroscedasticity-robust standard errors; *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.