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CORPORATE REAL ESTATE RISK INFLUENCE INVESTMENT AND FINANCING DURING A PERIOD OF EXTERNAL SHOCK–EVIDENCE BY COVID-19 PANDEMIC

Shu-Ching CHOU, Ming-Chu CHIANG *, Sih-Jie CHEN, Chi-Yu LIN

Department of Finance, National Yunlin University of Science and Technology, Douliu, Yunlin, Taiwan

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Abstract. In addition to the collateral effect of corporate real estate, recent studies highlight that the crowding effect and irreversibility of corporate real estate may pose risks to capital allocation. This study uses the 2020 COVID-19 pandemic as a black swan event to analyze how the corporate real estate risks and different real estate components relate to investment and leverage during the COVID-19 pandemic. This study further examines potential structural changes in capital expenditure and debt financing across four industry groups in the post-pandemic period. The results indicate that real estate risk negatively affects both investment and leverage, and this effect becomes more pronounced during the COVID-19 pandemic. Both land and building holdings are found to negatively influence leverage during the non-COVID-19 period; however, their effects are not statistically significant during the pandemic period. Manufacturing firms, particularly those in the electronics sector, show reduced capital expenditures, while firms in the tourism & others category increase leverage in the post-COVID-19 period under high real estate risk. The findings highlighting how industries with different asset structures may be exposed to varying levels of real estate risk and adopt distinct strategies in response to external shocks.

Keywords: corporate real estate risk, collateral effect, firm resilience, investment, debt financing, COVID-19 pandemic.

*Corresponding author. E-mail: *mingchuc@yuntech.edu.tw*

1. Introduction

Corporate real estate plays a dual role within firms, serving not only as a key asset for production and service delivery but also as a critical instrument for financing. As collateral, real estate facilitates access to commercial real estate mortgages, enhancing firms' financing capability. Prior research underscores the significance of this collateral function, demonstrating a positive relationship between the value of corporate real estate and firms' fixed asset investments, and refers to this as the "collateral channel" by real estate (Gan, 2007; Deng et al., 2018; Fougère et al., 2019).

Recent scholars have increasingly focused on the inherent risks associated with corporate real estate holdings. From a portfolio theory perspective, diversifying asset types can help reduce overall portfolio risk. Corporate real estate is often a substantial component of firms' physical investments made to support operational needs and is typically larger in value with longer duration compared to other assets. However, real estate is relatively illiquid, and its investment is often irreversible. This lack of flexibility makes it challenging for firms to adjust their real estate assets in the short term when faced with external economic shocks (Tuzel, 2010; Deng et al., 2018). Moreover, the significant capital committed to real estate investments can crowd out other potential uses of funds. In addition, the volatility of real estate values may lead banks to perceive higher risks associated with these assets, resulting in reduced lending. Such constraints can adversely impact corporate investments and borrowings (Campello et al., 2022). These factors collectively heighten the risks of corporate real estate holdings.

In the face of rapid environmental changes, the ability of firms to formulate adaptive strategies and adjust their real estate to enhance production efficiency is considered a key managerial competency for building competitive advantage (McGrath, 2013). The global outbreak of COVID-19 in 2020, marked as a black swan event due to its abrupt, pathogenic, and contagious nature, prompted many governments to implement quarantine measures to curb its spread, significantly impacting global economic activities (Antipova, 2021). In response to quarantine measures, many firms adopted remote working arrangements (Working from Home, WFH), potentially altering the allocation and use of corporate real estate in response to external shocks (Oladiran et al., 2023). This context gives rise to the research question of this study: During the pandemic, did corporate real estate holdings facilitate increased investment and borrowing through the collateral

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channel? Or, conversely, did the real estate risk exposure during the pandemic lead to reduced financing capacity and diminished investment opportunities of firms? This study also investigates industry-specific heterogeneities, hypothesizing differential pandemic impacts across four industry categories: non-electronics manufacturing, electronics, shipping, and tourism & others. We also examine changes in land and building holdings before and after the COVID-19 pandemic, as well as variations in investment and debt responses across these industry categories.

This study utilizes a sample of publicly listed firms in Taiwan from 2013 to 2024. Taiwan offers a compelling context for this investigation due to its export-oriented economy, with a strong emphasis on the electronics sector, which was particularly vulnerable to disruptions during the COVID-19 pandemic because of its critical role in the global supply chain. Furthermore, Taiwan's industrial landscape comprises a diverse range of 37 sectors, as classified by the Taiwan Stock Exchange (TWSE). This industrial diversity facilitates a comparative analysis of the differential impacts of real estate risk across sectors. The empirical results indicate that real estate risk negatively affects both investment and leverage, and this effect becomes more pronounced during the COVID-19 pandemic. Both land and building holdings are found to negatively influence leverage during the non-COVID-19 period; however, their effects are not statistically significant during the pandemic period. Among the four industry categories, manufacturing firms, particularly those in the electronics sector, show reduced capital expenditures, while firms in the tourism & others category increase leverage in the post-COVID-19 period when facing higher real estate risk. The endogeneity and robustness tests are consistent with the main findings.

This study makes some contributions to the literature. First, prior research on corporate real estate holdings has focused on the collateral effect and its implications for firms' investment and financing decisions (Berger & Udell, 1990; Gan, 2007; Chaney et al., 2012; Fougère et al., 2019). In contrast, studies examining the risks associated with corporate real estate holdings remain limited (Deng et al., 2018; Campello et al., 2022). Given the rapid pace of environmental changes in recent years, the ability of managers to build resilience through devise adaptive strategies to mitigate the impact of external shock is addressed (Kim et al., 2024; Choi, 2025; Fung et al., 2025). In addition to investigating the influence of corporate real estate exposure on investment and borrowing decisions during the COVID-19 period through the collateral effect, this study also examines potential structural changes in capital expenditure and debt financing associated with real estate risk in the post-COVID-19 period by applying the Chow test. The results enrich the existing literature on real estate risk by exploring firm resilience through adaptive adjustments in investment, debt financing, and real estate holdings.

Second, this study adopts the COVID-19 pandemic as a crisis period. Unlike the 2008 financial crisis, the COVID-19 pandemic prompted widespread quarantine measures and remote working practices, which directly affected the demand for factory facilities and buildings (Oladiran et al., 2023). In addition to measuring total real estate risk relative to market returns (Deng et al., 2018), this study distinguishes itself by disaggregating real estate into land and factory buildings, and by using the corresponding ownership structure as a proxy for adjustment costs to examine their impact on investment and leverage during and after the COVID-19 pandemic. This approach offers valuable insights into the sources of real estate risk and firms' adjustment strategies toward different asset types.

Finally, in recent years, many countries have adjusted their economic policies to strengthen investment in domestic manufacturing (Wraight, 2019). This study categorizes the sample into four major industry groups: non-electronics manufacturing, electronics and information technology (Electronics), transportation and shipping (Shipping), and tourism, trade, and others (Tourism & Others). An interesting finding is that electronics firms with high real estate risk tend to reduce investment during COVID-19 pandemic. In contrast, firms in the tourism & others group, which were heavily impacted by lockdown policies during the pandemic, increase debt financing when facing higher real estate risk. The findings of this study offer valuable insights for both practitioners and policymakers, highlighting how industries with different asset structures may be exposed to varying levels of real estate risk and adopt distinct strategies in response to external shocks.

The remainder of this paper is structured as follows: First, a concise review of corporate real estate holding risk is presented, followed by a literature review that examines the potential impacts of external shocks on corporate real estate holdings, investment, and financing decisions. Based on this review, hypotheses are developed and the analytical framework is established. Regression analyses are conducted using the full sample, followed by subsample analyses across different industries, non-COVID-19 and COVID-19 periods, pre- and post-COVID-19 periods. The endogeneity and robustness tests are also conducted. The findings are discussed in detail, and the paper concludes with a summary of key insights and implications.

2. Corporate real estate holding risk

The current literature presents inconsistent views regarding the impact of corporate real estate on firm investment. Campello et al. (2022) argue that assets used as collateral should possess four characteristics: tangibility, verifiability, alienability, and redeployability. Real estate, due to its long useful life, verifiability in legal proceedings, and the presence of secondary markets for asset transactions and transfers, is better suited as collateral for credit agreements compared to liquid or intangible assets. As a result, the higher the value of real estate, the lower the cost of debt, which enhances a firm's borrowing capacity and

increases investment opportunities. This phenomenon is called the "collateral effect of real estate" (Chaney et al., 2012; Gan, 2007; Deng et al., 2018).

However, some scholars contend that certain characteristics of real estate may negatively influence corporate investment and financing. Corporate real estate typically includes land, plants, and buildings essential for operations, which often constitute a significant portion of a firm's assets coupled with its illiquidity and the irreversibility of investments, real estate's nature makes it challenging for firms to adjust their holdings flexibly in response to external economic shocks in the short term (Tuzel, 2010). Consequently, firms with substantial real estate holdings may struggle to optimize asset and capital allocation. Based on these characteristics, Deng et al. (2018) consider asset adjustment costs as a risk for firms. They argue that under the assumption of asset diversification, a higher proportion of high-risk assets and the correlated risks among different asset types elevate the firm's overall risk and impair its investment opportunities.

3. Effect of COVID-19 and hypothesis development

3.1. Real estate risk, COVID-19 and investment

Deng et al. (2018) find that firms do not generally reduce investments during the subprime crisis period (2007–2009). They propose that while the value of real estate remains positively correlated with investment, firms with higher real estate risks are more sensitive to external shocks, leading to a significant reduction in investment levels during the crisis. Similarly, Zhao and Sing (2015) find that firms reduce their real estate holdings when faced with production uncertainties to mitigate external shocks. Deng et al. (2018) further posit that higher real estate risk leads to higher required rates of return from asset holders or stakeholders, raising the threshold for investment decisions and consequently lowering investment amounts.

The global COVID-19 pandemic of 2020–2022 presents a different set of challenges compared to the 2007–2009 subprime crisis. To understand how these challenges impact corporate strategy, it is essential to first understand the mechanisms through which real estate risks are transmitted. Regarding financial and investment decision-making, real estate risks during the pandemic are primarily transmitted to firms through the collateral channel and the liquidity channel.

First, regarding the collateral channel, the classic study by Chaney et al. (2012) indicates that corporate investment is highly sensitive to collateral value; on average, a one-dollar change in collateral value leads to a change of approximately 0.06 dollars in corporate investment. This correlation is even more significant among financially constrained firms, implying that fluctuations in real estate values can significantly amplify the impact of economic shocks on aggregate investment through this multiplier effect. Aretz et al. (2020) further point out that the function of collateral extends beyond merely determining financing amounts to affecting the efficiency of capital allocation. They suggest that expanding the scope and access to collateral can facilitate the "democratization" of credit, allowing small, young, and constrained firms to obtain funds for investment. However, Hossain et al. (2023) emphasize that corporate real estate assets are key collateral for obtaining debt financing; fluctuations in asset value directly alter a firm's borrowing capacity. If external shocks cause asset price declines, the firm's collateral value is weakened, restricting financing capacity via the collateral channel. Wang (2023) also notes that when external shocks (such as natural disasters) cause asset values to fall and trigger severe "collateral constraints", firms significantly shift toward using operating leases as an alternative financing solution.

Second, regarding the liquidity channel, Balemi et al. (2021) point out that high uncertainty increases investors' required risk premiums, leading to rising capitalization rates and falling asset valuation estimates. Simultaneously, the drying up of funding liquidity further restrict collateral channel in the capital market during COVID-19 period. The related hypothesis is established as the following:

H1: *The collateral effect was limited during the COVID-19 period*.

The operation of these collateral and liquidity mechanisms produced specific impacts on real estate investment during the COVID-19 pandemic. Due to the rapid global spread of the virus, many countries implemented lockdowns and mandated stay-at-home policies. These quarantine measures disrupted international supply chains and significantly increased transportation costs. Such structural shocks fundamentally altered patterns of space demand. According to Chong and Phillips (2022), the compounding effects of restrictive policies severely hit commercial real estate market, causing significant declines in US REIT prices during the pandemic. Using French firms as a sample, Bergeaud et al. (2023) found that during the pandemic, office asset valuations dropped more significantly in areas with higher telecommuting potential, accompanied by rising vacancy rates. Oladiran et al. (2023) specifically show that a positive work from home (WFH) experience increases the likelihood that firms will reduce their total space quantity, reduce their density of occupation, and negotiate shorter leases in the medium term. Kennedy et al. (2021) argue that these impacts may persist, leading to structural changes in the corporate real estate market.

Against this backdrop, fluctuations in collateral value directly influenced investment strategies. Research by Seger and Pfnür (2021) indicates that as remote work and supply chain restructuring increased uncertainty regarding the valuation of specific real estate types (such as city-center offices), firms faced risks of asset devaluation and reduced collateral capacity. Under pressure from the collateral channel, affected firms, particularly those with financing constraints, tended to shift from asset ownership

to leasing, seeking sale-and-rent-back arrangements to alleviate financial pressure and preserve liquidity.

However, the pandemic also introduced counter-forces. Governments worldwide implemented stimulus measures, and inflation-driven price increases simultaneously elevated real estate values. Physical assets are perceived as effective instruments for mitigating inflationary impacts in the post-pandemic period (Amundi Asset Management, 2021), thereby potentially reducing the overall risk of asset holdings. Furthermore, given the logistical challenges, companies may utilize the collateral effect of real estate to enhance local investments to reduce reliance on international supply chains.

Drawing on the existing literature and the specific mechanisms of the collateral and liquidity channels, it is plausible that during the COVID-19 pandemic, firms reduce investments due to heightened real estate risks and funding constraints. Alternatively, they may have increased investments by leveraging the collateral value of real estate. The hypotheses are formulated as follows:

H2(a): *During the COVID-19 pandemic, corporate real estate risks reduce investment.*

H2(b): *During the COVID-19 pandemic, corporate real estate risks increase investment.*

3.2. Real estate risk, COVID-19 and leverage

Corporate real estate serves not only as a means for production and service delivery but also as a critical source of collateral for financing. It facilitates firms' access to secured loans that will increase available capital (Campello et al., 2022). Some studies show that the value of corporate real estate positively influences fixed asset investment and borrowing levels through the collateral effect (Chaney et al., 2012; Fougère et al., 2019).

Corporate real estate holdings may also have adverse effects on borrowing capacity. Shleifer and Vishny (1992) suggest that asset quality influences both the liquidation value of assets and the level of borrowing. Rampini and Viswanathan (2013) argue that expenditures that do not contribute to a firm's profitability can crowd out other investment opportunities. They propose that firms acquire fixed assets through leasing to minimize capital outlay, thereby preserving borrowing capacity for future investment opportunities. Similarly, Cook et al. (2021) find that firms with higher sales volatility often prefer operating leases over purchasing fixed assets. They contend that operating leases allow firms to access necessary assets without incurring large, one-time capital expenditures, thus preserving cash reserves.

Furthermore, based on the literature mentioned above, the collateral channel or the real estate–based financing mechanism, may be constrained during the COVID-19 pandemic due to heightened uncertainty surrounding real estate values. On the other hand, firms that are more severely affected by the pandemic may exhibit a greater reliance on real estate–based financing to alleviate short-term liquidity pressures, thereby potentially increasing their borrowing capacity. Accordingly, we propose the following hypothesis.

H3(a): *During the COVID-19 pandemic, corporate real estate holdings reduce debt financing.*

H3(b): *During the COVID-19 pandemic, corporate real estate holdings increase debt financing.*

4. Methodology

4.1. Samples

This study examines listed companies in Taiwan as the sample, covering the period from 2013 to 2024. Since the research focuses on corporate real estate, companies involved in commercial real estate investment and those in the financial services industry are excluded due to their distinct asset and financial structures. Macroeconomic indicators, stock returns, fixed assets, real estate investment amounts, and other financial data are obtained from the Taiwan Economic Journal (TEJ).

4.2. Models and variables

Collateral effect during the COVID-19 pandemic

To examine whether the COVID-19 pandemic shock affected the collateral channel provided by corporate real estate, we construct a collateral-based financing model following Deng et al. (2018) and Campello et al. (2022). Specifically, we incorporate an interaction term between firms' real estate holdings and the COVID-19 pandemic indicator to investigate whether the pandemic shock mediates the collateral effect of real estate (H1).

$$Capex_{i,t} = \alpha_0 + \alpha_1 REweight_{i,t} + \alpha_2 COVID19 + \alpha_3 REweight_{i,t} * COVID19 + \theta Controls_{i,t} + Sector\ FE + Year\ FE + \varepsilon_{i,t}. \quad (1)$$

The variables in Eq. (1) are explained as follows:

Capex – Capital expenditures, calculated as the annual expenditure on fixed assets divided by the total fixed assets from the previous year (Deng et al., 2018); *REweight* – The ratio of real estate to total fixed assets; *COVID*19 – A dummy variable equal to 1 if the sample period is 2020 or 2022, and 0 otherwise; *Controls* – Control variables include the natural logarithm of total assets (*Logasset*), company age (*Firmage*), operating profit margin (*Profitr*) and the ratio of debt to assets (*Leverage*); *Sector FE* – The 37 sector fixed effects based on industry classifications from the Taiwan Stock Exchange (TWSE); *Year FE* – Year 2013–2024 to control for year fixed effect.

Real estate risk exposure and capital expenditures

The corporate real estate risk exposure is estimated using Eq. (1). This equation is based on the model proposed by Deng et al. (2018), which extends the Capital Asset Pricing Model (CAPM) by incorporating real estate market returns as a second factor influencing individual stock returns.

$$R_{i,t} - R_{ft} = \alpha_{it} + \beta_{i,t}^{mt}\left(R_{mt} - R_{ft}\right) + \beta_{i,t}^{re}\left(R_{re} - R_{ft}\right)_i + \varepsilon_{i,t}. \quad (2)$$

In Eq. (2), $R_{i,t}$ represents the return of stock *I* at time *t*; R_{ft} is the risk-free rate, proxied by the interest rate on 3-month government bonds; R_{mt} denotes the stock market return, proxied by the weighted average return of the Taiwan Stock Exchange (TWSE) Index; R_{re} represents the real estate market return, proxied by the Tsinghua Anfu Real Estate Price Index (Tsihwa). The Tsinghua Anfu index is utilized due to its comprehensive coverage of domestic real estate price and its incorporation of actual transaction data starting from 2013. This study employs monthly returns of the aforementioned variables to conduct regression analysis. The regression coefficient $\beta_{i,t}^{re}$ represents the risk exposure of stock *i* to real estate market risk. A positive $\beta_{i,t}^{re}$ indicates an increase of the risk of company relative to real estate market risk.

We then employ the difference-in-differences (DID) method to examine the impact of corporate real estate risk exposure on capital expenditures during the COVID-19 pandemic. To control for endogeneity, all the independent variables are one-year lagged. Sector and Year fixed effects are applied to control the influence of the unobserved factors on coefficient estimation.

$$Capex_{i,t} = \alpha_0 + \alpha_1 RErisk_{i,t} + \alpha_2 COVID19 + \alpha_3 RErisk_{i,t} * COVID19 + \theta Controls_{i,t} + Sector\ FE + Year\ FE + \varepsilon_{i,t}. \quad (3)$$

The variables in Eq. (3) are explained as follows:

Capex – Capital expenditures, calculated as the annual expenditure on fixed assets divided by the total fixed assets from the previous year (Deng et al., 2018); *RErisk* – Corporate real estate risk, estimated by Eq. (2); *COVID*19 – A dummy variable equal to 1 if the sample period is 2020 or 2022, and 0 otherwise; *Controls* – Control variables include the ratio of real estate to total fixed assets (*REweight*), operating profit margin (*Profitr*), corporate growth proxied by the market-to-book ratio (M/B), and liquidity measured as cash and short-term investments divided by total assets (*Cashr*). Leverage is the ratio of debt to assets (*Leverage*). Inflation is measured by the consumer price index in terms of the annual growth rate to capture the potential impact on firm investment (Inflation). According to Deng et al. (2018), operating profit margin, corporate growth, and liquidity are expected to have a positive relationship with capital expenditures, but leverage is negatively related to capital expenditures. Additionally, to capture the potential influences of prior-period capital expenditures, $Capex_{t-1}$ are included as a control variable; *Sector FE* – The 37 sector fixed effects based on industry classifications from the Taiwan Stock Exchange (TWSE); *Year FE* – Year 2013–2024 to control for year fixed effect.

Corporate real estate risk and debt financing

This study further examines the relationship between corporate real estate risk exposure and debt financing during the COVID-19 pandemic. The analysis uses debt growth rate (*Debtgrowth*) and leverage ratio (*Leverage*) as dependent variables as proxy of debt financing. The models are specified as follows.

$$Debtgrowth_{i,t} = \alpha_0 + \alpha_1 RErisk_{i,t} + \alpha_2 COVID19 + \alpha_3 RErisk_{i,t} * COVID19 + \theta Controls_{i,t} + Sector\ FE + Year\ FE + \varepsilon_{i,t}; \quad (4)$$

$$Leverage_{i,t} = \alpha_0 + \alpha_1 RErisk_{i,t} + \alpha_2 COVID19 + \alpha_3 RErisk_{i,t} * COVID19 + \theta Controls_{i,t} + Sector\ FE + Year\ FE + \varepsilon_{i,t}. \quad (5)$$

This study further investigates whether the real estate value and asset components enhance debt financing capacity through collateral channels during the COVID-19 period. Based on Chaney et al. (2012) and Deng et al. (2018), we utilize the real estate value divided by prior-year fixed asset amount as the proxy of real estate value (*REweight*). We also calculate the ratio of land holdings (*Landweight*) and the ratio of plant and building holdings (*Buildingweight*) to examine how the adjustment costs of each type of real estate impact debt financing. The models are specified as follows:

$$Leverage_{i,t} = \alpha_0 + \alpha_1 REweight_{i,t} + \alpha_2 COVID19 + \alpha_3 REweight_{i,t} * COVID19 + \theta Controls_{i,t} + Sector\ FE + Year\ FE + \varepsilon_{i,t}; \quad (6)$$

$$Leverage_{i,t} = \alpha_0 + \alpha_1 Landweight_{i,t} + \alpha_2 Buildweight_{i,t} + \alpha_3 COVID19 + \alpha_4 COVID19 * Landweight_{i,t} + \alpha_5 COVID19 * Buildweight_{i,t} + \theta Controls_{i,t} + Sector\ FE + Year\ FE + \varepsilon_{i,t}, \quad (7)$$

where the Control variables include the operating profit margin (*Profitr*), firm size (*LnAsset*)), and the total amount of cash and short-term investments (*Cashr*).

4.3. Differences across industries

Becchetti et al. (2008) argue that firms in different industries exhibit markedly heterogeneous investment strategies when facing external shocks, owing to differences in stakeholder structures, risk-taking patterns, and resource allocation inertia. Under the heightened uncertainty induced by the COVID-19 pandemic, the shock was not limited to short-term demand disruptions but may have triggered a structural reconfiguration of real estate markets (Balemi et al., 2021). Traditional retail, catering, and tourism-related properties, whose demand is highly dependent on foot traffic and physical interaction, suffered from low asset liquidity and high demand elasticity, leading to rising vacancy rates, downward rent adjustments, and declining asset values during the COVID-19 pandemic period. Tanrıvermiş (2020), using the tourism and hotel industries as an example, further illustrates that pandemic containment measures and travel bans directly compressed revenue sources, rapidly transforming high fixed-cost real estate investments into financial burdens and consequently dampening subsequent investment incentives.

In contrast, logistics and warehouse properties benefited from the surge in e-commerce and supply-chain reorganization, becoming relative winners during the pandemic and exhibiting increased demand for operational fixed assets. Amankwah-Amoah et al. (2021) note

that industries with higher levels of digitalization and more adaptable supply chains are better able to reduce their reliance on specific physical spaces through remote collaboration, product transformation, and business model reconfiguration. This characteristic led many firms during the pandemic to substitute traditional real estate investment with digital investment, reallocating resources toward research and development, information systems, and flexible production networks (Kodama et al., 2024). Moreover, the widespread adoption of working-from-home (WFH) arrangements and the implementation of remote learning in educational institutions (Oladiran et al., 2023) substantially increased global demand for digital products, including laptops, iPads, and internet services. Consequently, amid accelerated corporate digital transformation and surging demand for electronic products, the electronics industry may have experienced counter-cyclical growth during the pandemic period.

Recognizing that differences in industry characteristics result in varying asset and liability structures, the impact of real estate holdings on investment and debt financing may differ across industries. Accordingly, we divided the sample into four subgroups: non-electronics manufacturing (non-Electronics), electronics (Electronics), transportation and shipping (Shipping), and tourism, leisure, trading, and others (Tourism & others). Regression and the comparison of the change in real estate holdings, investment, as well as debt financing after the COVID-19 pandemic, are performed separately for each subgroup.

4.4. Additional test: pre-and post-COVID-19 analysis

Given the impact of COVID-19, particularly the rise of remote work driven by lockdown and quarantine policies, this study examines whether firms have systematically adjusted their working arrangements and, in turn, whether such changes have reduced corporate demand for real estate and fixed assets. Conversely, firms may have increased investment in fixed assets to localize production and mitigate the potential impact of future supply chain disruptions. To test for structural changes in corporate investment and debt financing behavior and the influence by real estate risk, this study employs the Chow test (Wooldridge, 2016) using the following model specification:

$$Capex_{i,t} = \alpha_0 + \alpha_1 RErisk_{i,t} + \alpha_2 PostCOVID19 + \alpha_3 RErisk_{i,t} * PostCOVID19 + \theta Controls_{i,t} + Sector\ FE + Year\ FE + \varepsilon_{i,t}; \quad (8)$$

$$Leverage_{i,t} = \alpha_0 + \alpha_1 RErisk_{i,t} + \alpha_2 PostCOVID19 + \alpha_3 RErisk_{i,t} * PostCOVID19 + \theta Controls_{i,t} + Sector\ FE + Year\ FE + \varepsilon_{i,t}, \quad (9)$$

where the variable definitions are the same as Eqs. (3) and (5) except *PostCOVID*19 below.

- PostCOVID19: A dummy variable equal to 1 if the sample period is between 2020 to 2024, and 0 otherwise.

5. Results

5.1. Sample distribution and descriptive statistics

Table 1 presents the annual distribution of real estate holdings among publicly listed companies in Taiwan from 2013 to 2024. Column 3 reports the average real estate value (*REvalue*) per firm, which increased from TWD$ 1,914.45 million in 2013 to TWD$ 2,479.71 million in 2024, representing a growth of 29.53%. The proportion of real estate value to total assets (*REvalue%*) ranged between 14.08% to 15.54%. Notably, prior to the COVID-19 outbreak in 2020, the corporate real estate holding ratio generally exceeded 15%. However, after 2020, this ratio declined to below 15%, suggesting that the pandemic may have had an adverse impact on firms' investment in real estate.

Table 1. Sample distribution and real estate holding

Year	No. of firms	REvalue (%)-all	Non-electronics	Electronics	Shipping	Tourism & others
2013	794	1,914,451.932 (15.54%)	21.43%	9.98%	17.48%	27.09%
2014	812	1,930,641.718 (15.32%)	20.86%	10.15%	17.73%	24.63%
2015	822	1,937,024.236 (14.71%)	20.34%	9.82%	16.72%	24.42%
2016	840	1,965,678.891 (15.20%)	20.72%	10.28%	17.49%	24.48%
2017	852	1,991,208.178 (15.32%)	20.43%	10.62%	17.34%	24.47%
2018	859	2,062,886.635 (15.31%)	20.05%	10.93 %	17.23%	24.59%
2019	871	2,021,384.842 (15.03%)	19.67%	10.63%	14.82%	24.45%
2020	876	2,049,988.194 (14.75%)	19.91%	10.61%	11.74%	22.74%
2021	878	2,148,242.907 (14.80%)	19.92%	10.70%	12.09%	22.22%
2022	880	2,222,973.868 (14.08%)	18.81%	10.20%	11.15%	21.25%
2023	880	2,340,890.918 (14.22%)	18.96%	10.36%	10.99%	21.39%
2024	878	2,479,705.954 (14.65%)	19.25%	11.01%	11.00%	21.44%

Notes: REvalue is the Real estate average amount in thousands of Taiwan dollars (TWD). Percentage (%) is the average ratio of real estate amount divided by total assets of each firm. The 4 industry categories are based on the Taiwan Stock Exchange (TWSE).

Columns 4 through 7 of Table 1 display real estate holdings across four industry categories. The results indicate that non-Electronics has the highest real estate holding (*REvalue%*), approximately 20%, followed by Tourism & others and Shipping, while Electronics exhibits the lowest, ranging from 9.38% to 10.53%. These findings highlight industry-specific characteristics. Traditional industries, such as steel, cement, plastics, and textiles, generally require substantial land and facilities for production, contributing to their higher real estate holding. Similarly, in Tourism, Trade & Others, hotels and restaurants rely heavily on real estate as their primary business premises, resulting in a higher real estate holding. In contrast, the electronics industry invests heavily in machinery and equipment for production, making the proportion of real estate holdings in the electronics sector is lower. For example, Taiwan Semiconductor Manufacturing Company (TSMC), a global leader in electronics manufacturing, reported that its machinery and equipment accounted for 48.34% of property, plant, and equipment (PP&E) in 2024, while real estate holdings comprised only 6.05% of PP&E only (TSMC, 2024).

Table 2 reports the summary statistics of variables. The statistics show the sample firms have an average real estate holding value about 2,079,547 million. The average capital expenditure is about 23.4% relative to total fixed assets. The average debt ratio is 36.38% with growth rate of 4.48%. The variable definitions are listed in the Appendix Table A1.

Figure 1 illustrates the trends in capital expenditure (*Capex*), leverage (*Leverage*), and real estate holdings relative to total assets (*RE_asset*) from 2013 to 2024. As shown in the figure, among the three variables, real estate holdings exhibit a slight decline after the COVID-19 pandemic, leverage peaks in 2020 at the onset of the pandemic, and the ratio of capital expenditure decreases after 2021. This figure suggests that the COVID-19 pandemic may have had an impact on capital expenditure, debt financing, and real estate holdings.

Table 2. Descriptive statistics

Variables	Mean	Median	Std. Deviation	Maximum	Minimum
REvalue (mil.)	2,079,547	661,932	4,593,110	33,970,000	0.000
REweight	1.141	0.834	1.214	5.396	0.000
Landweight	0.353	0.344	0.276	1.000	0.000
Buildweight	0.248	0.219	0.202	0.998	–0.011
Capex (%)	0.234	0.081	0.561	4.322	0.000
Growthdebt (%)	4.475	1.738	26.199	70.576	–31.591
Leverage (%)	37.509	36.595	18.126	85.000	2.800
Profitr	0.025	0.023	0.084	0.296	–0.144
M/B	1.802	1.370	1.448	9.000	0.500
Cashr	0.106	0.070	0.107	0.532	0.001
LnAsset	15.850	15.693	1.408	22.521	4.615
Inflation	1.310	1.360	0.966	2.950	–0.31

Notes: Variable definitions are in the Appendix Table A1.

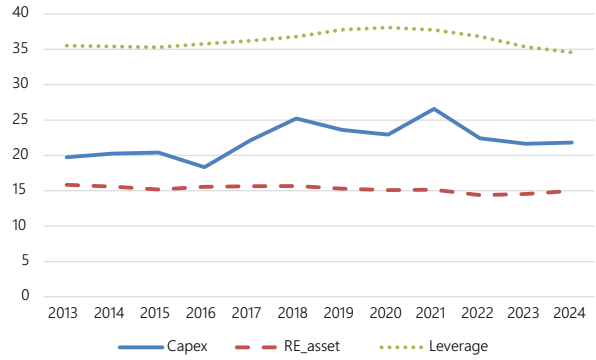

Figure 1. Capital expenditure, leverage and real estate holding from 2013–2024

5.2. Collateral effect during COVID-19 pandemic

Table 3 presents the regression results of real estate holdings (*REweight*) on fixed asset investment (*Capex*). Model (1) shows that the coefficient of *REweight* is significantly positive (0.1191, 1% significance level), indicating that firms with a higher proportion of real estate tend to have higher ixed asset investment. This suggests a potential financing mechanism by the real estate to enhance investment via collateral channel, as mentioned in Chaney et al. (2012), Deng et al. (2018) and Campello et al. (2022). Models (2) show that a significantly positive coefficient of *REweight* (0.1247, 1% significance level), while the coefficients of interaction terms *REweight* COVID19* are significantly negative (–0.0683, 1% significance level). The findings of Models (2) shows that the collateral effect of real estate holding might be weakened during the COVID-19 pandemic.

Table 3. Collateral effect during COVID-19 pandemic

	Estimate	t-stat.	Estimate	t-stat.
Intercept	0.7323***	7.73	0.6987***	7.1
REweight	0.1191***	10.21	0.1247***	9.13
Covid19	–0.0097	–0.37	0.0715**	2.37
*REweight** Covid19			–0.0683***	–3.94
LnAsset	–0.0279***	–6.27	–0.0257***	–5.72
Firmage	–0.0061***	–11.1	–0.0057***	–10.23
Profitr	0.8866***	7.87	0.8297***	7.42
Leverage	0.0013***	3.68	0.0012***	3.22
Sector FE	V		V	
Year FE	V		V	
Obs.	10169		9278	
Adj. R^2	0.11		0.11	

Notes: The dependent variable Capex is a firm's capital expenditure (investment). Variable definitions are in the Appendix Table A1. ***p < 0.01, **p < 0.05.

5.3. Real estate risk exposure

Table 4 presents the regression results of Eq. (2) for real estate exposure. The Tsinghua Real Estate Index (Tsinghua) is employed as the proxy for Taiwan's real estate market returns. The first column uses the sample for the whole period. The estimated coefficient for the market return (R_{mt}), calculated using a rolling five-year monthly return, is 0.875, indicating a positive correlation between individual stock returns and market returns. The coefficient for real estate market returns (R_{re}) is –0.007, significant at the 1% level.

The third and fifth columns of Table 4 report the regression results of Non–COVID19 and COVID-19 periods. The regression coefficients of R_{re} in the third and fifth columns are –0.010 and 0.018 with 1% significant level, respectively. The results indicate that the real estate market returns in Non–COVID19 period do not increase individual stock returns, while the real estate risk in COVID-19 period lowers the individual stock returns.

Table 4. Real asset risk exposure

RE index	All sample		Non-COVID19		COVID19	
	Estimate	t-stat.	Estimate	t-stat.	Estimate	t-stat.
Intercept	1.396***	9.67	1.642***	11.62	–1.862***	–2.88
R_{mt}	0.875***	123.44	0.808***	77.65	0.940***	84.26
R_{re}	–0.007***	–6.99	–0.010***	–10.15	0.018***	4.28
Obs.	120,412		84,081		31,331	
Adj. R^2	0.112		0.063		0.191	

Notes: Variable definitions are in the Appendix Table A1. ***P < 0.01.

5.4. The impact of real estate risk exposure on investment

Table 5 reports the regression results examining the impact of corporate real estate exposure (*RErisk*) on investment (*Capex*). Model (1) presents the results for the full sample, where the coefficient of *RErisk* is negative at 5% significance level. This indicates that higher real estate exposure is associated with lower capital expenditures, suggesting a negative relationship between real estate exposure and investment in fixed assets.

Model (2) incorporates the impact of the COVID-19 pandemic in the regression analysis. The coefficient of *RErisk* remains significantly negative, and the interaction term of *RErisk* and *COVID19* (*RErisk*COVID19*) yields a negative coefficient of –0.008, significant at the 5% level. Models (3) and (4) further divide the sample into two subperiods: non-COVID-19 and COVID-19. The coefficients of *RErisk* in non-COVID-19 period and COVID-19 period are –0.004 and –0.014, respectively, with significance at 1% level. Table 5 suggests that the real estate risk exposure will reduce a firm's capital expenditure, and this influence is intensified during the COVID-19 period. Overall, the findings in Table 5 supports Hypothesis H1(a).

Regarding the control variables, the coefficient of *REweight* is significantly negative, indicating that a higher proportion of real estate holdings is associated with lower capital expenditures. Meanwhile, the coefficients for profitability (*Profitr*), growth opportunities (*M/B*), and cash holdings (*Cashr*) are significantly positive, suggesting that firms with higher profitability, greater growth potential, and more cash reserves tend to invest more in capital expenditures. These findings align with the existing literature.

Table 5. Real estate risk and capital expenditure – COVID-19 and non-COVID-19 periods

	Full sample (M1)		COVID-19 effect (M2)		non-COVID-19 period (M3)		COVID-19 period (M4)	
	Estimate	t-stat.	Estimate	t-stat.	Estimate	t-stat.	Estimate	t-stat.
Intercept	0.255	1.24	0.251	1.21	0.315	1.45	0.088	0.93
RErisk	–0.005***	–4.70	–0.004***	–3.57	–0.004***	–3.36	–0.014***	–3.96
COVID19			0.020	0.37				
RErisk* COVID19			–0.008**	–2.11				
REweight	–0.022***	–2.61	–0.021***	–2.58	–0.029***	–3.05	–0.002	–0.13
Profitr	0.316**	2.46	0.309**	2.39	0.394**	2.47	0.088	0.40
M/B	0.010*	1.82	0.011*	1.93	0.010	1.49	0.012	1.26
Cashr	0.526***	6.32	0.516***	6.25	0.519***	5.51	0.519***	3.02
Leverage	0.001	1.61	0.001	1.55	0.001	1.44	0.000	0.67
Inflation	–0.047	–0.57	–0.045	–0.55	–0.052	–0.62	–0.020	–0.75
$Capexp_{t-1}$	0.231***	9.56	0.229***	9.45	0.256***	8.34	0.162***	4.42
Sector FE	V		V		V		V	
Year FE	V		V		V		V	
Obs.	9299		9299		6694		2605	
Adj. R^2	0.11		0.11		0.12		0.10	

Notes: The dependent variable Capex is a firm's capital expenditure (investment). Variable definitions are in the Appendix Table A1. ***p < 0.01, **p < 0.05, *p < 0.1.

5.5. The impact of real estate risk exposure on debt financing

Table 6 presents the regression results examining the effects of corporate real estate risk exposure (*RErisk*) on debt growth (*Debtgrowth*) and leverage (*Leverage*). Models (1) and (2) have the debt growth (*Debtgrowth*) as dependent Variable. The coefficients of *RErisk* in both Model (1) and Model (2) are significantly negative, indicating that higher real estate exposure is associated with lower increases in debt. In Model (2), the coefficient for COVID-19 is significantly positive (2.127, 10% significance level), suggesting that firms experienced an increased demand for debt during the pandemic. The coefficient of interaction term between *RErisk* and *COVID19* (*RErisk*COVID19*) is –0.221 and statistically negative, indicating that real estate risk exposure does not significantly increase the debt growth during the pandemic.

Models (3) and (4) use Leverage as the dependent variable. The coefficients of *RErisk* in both Model (3) and Model (4) are significantly negative, demonstrating that higher real estate exposure is associated with lower leverage. In Model (4), the coefficient for COVID-19 is significantly positive (2.675, 1% significance level), and the interaction term *RErisk*COVID19* is significantly negative (–0.150, 5% significance level). These results in Table 6 indicate that firms had higher debt needs during the COVID-19 period, but corporate real estate risk exposure results in lower financing. For the control variables, higher profitability (*Profitr*) and greater cash reserves (*Cashr*) are associated with lower leverage, while larger firm size is positively associated with leverage. These findings are consistent with the existing literature. Overall, the findings in Table 6 supports Hypothesis H2(a).

5.6. The impact of real estate holdings risk on leverage

Different types of real estate

Table 7 explores the influence of different types of real estate holdings, land and buildings, on leverage. The independent variable is the proportion of real estate holdings to the previous year's fixed assets (*REweight*) that is utilized to proxy the adjustment cost on real estate holdings. The coefficient of *REweight* in the first column is significantly negative (–1.275, 1% significance level), indicating that firms with a higher proportion of real estate in their fixed assets tend to have lower leverage. This suggests that substantial real estate holdings reduce the firm's capacity or willingness to take on additional debt. Model (2) presents that the proportions of land (*Landweight*) and building (*Buildingweight*) are both significantly and negatively related to the firm's leverage. These findings suggest that real estate holdings, due to their substantial investment scale, may exert a capital crowding-out effect on additional borrowing.

Models (3) and (4) of Table 7 show that the coefficients of *COVID19* are positive and significant at the 1% level. The interaction terms *REweight *COVID19* and *Buildweight *COVID19* are not statistically significant, whereas the coefficient of *Landweight * COVID19* is negative and marginally significant. Overall, the results in Table 7 suggest that higher ownership of real estate, including both land and buildings, exhibits a crowding-out effect on debt capacity. However, this effect does not appear to intensify during the COVID-19 period.

Table 6. Real estate risk and debt financing – COVID-19 and non-COVID-19 periods

Dependent variables	Debtgrowth				Leverage			
	All samples (M1)		COVID-19 effect (M2)		All sample (M3)		COVID-19 effect (M4)	
	Estimate	t-stat.	Estimate	t-stat.	Estimate	t-stat.	Estimate	t-stat.
Intercept	18.327***	4.62	18.136***	4.57	13.930***	4.80	13.800***	4.75
RErisk	–0.167***	–3.89	–0.133***	–2.94	–0.255***	–9.70	–0.232***	–8.25
COVID19			2.127*	1.84			2.675***	3.40
RErisk*COVID19			–0.221*	–1.73			–0.150**	–2.11
Profitr	18.534***	4.12	18.378***	4.08	–23.991***	–9.42	–24.097***	–9.45
Cashr	0.824	0.26	0.660	0.21	–28.749***	–15.94	–28.861***	–15.99
LnAsset	–0.930***	–4.66	–0.918***	–4.60	1.970***	13.80	1.978***	13.85
Sector FE	V		V		V		V	
Year FE	V		V		V		V	
Obs.	10363		10363		10363		10363	
Adj. R^2	0.04		0.04		0.02		0.02	

Notes: The dependent variables are debt growth (Debtgrowth) and debt ratio (Leverage). Variable definitions are in the Appendix Table A1. ***p < 0.01, **p < 0.05, *p < 0.1.

Table 7. Real estate holding and leverage – COVID-19 and non-COVID-19 periods

	Without COVID-19 effect				With COVID-19 effect			
	(M1)		(M2)		(M3)		(M4)	
	Estimate	t-stat.	Estimate	t-stat.	Estimate	t-stat.	Estimate	t-stat.
Intercept	17.105***	5.83	21.638***	7.56	17.133***	5.84	21.515***	7.49
REweight	–1.275***	–7.03			–1.301***	–6.46		
Landweight			–6.507***	–9.28			–5.963***	–7.58
Buildingweigh			–3.098***	–3.57			–3.469***	–3.54
COVID19					2.786***	3.21	3.168***	2.84
REweight*COVID19					0.090	0.27		
Landweight*COVID19							–2.054	–1.45
Buildweight*COVID19							1.511	0.77
Profitr	–22.017***	–8.50	–22.255***	–8.79	–21.996***	–8.48	–22.364***	–8.83
Cashr	–29.132***	–15.56	–31.337***	–17.21	–29.131***	–15.56	–31.303***	–17.19
LnAsset	1.825***	12.89	1.664***	12.06	1.825***	12.89	1.666***	12.06
Sector FE	V		V		V		V	
Year FE	V		V		V		V	
Obs.	9299		10133		9299		10133	
Adj. R^2	0.20		0.21		0.20		0.21	

Notes: The dependent variables are debt ratio (Leverage). Variable definitions are in the Appendix Table A1. ***$p < 0.01$.

Impacts in different industries

Table 8 categorizes the full sample into four major industry groups, non-electronics, electronics, shipping, tourism & others, to examine the impact of real estate risk exposure on investment (Panel A) and the relationship between real estate holding and leverage (Panel B). In Panel A, Columns (1) to (4) demonstrate that, during the whole sample period, the coefficient of *RErisk* is significantly negative for electronics, non-electronics and tourism & others industries, while it is insignificant for the shipping industry. Columns (5) to (8) show that the coefficient of *RErisk*COVID19* turns significantly negative for electronics firms only, but remains insignificant for other industries. The results explain the results in Table 5 which a negative impact of real estate market risk on capital expenditure during COVID-19 pandemic majorly reflect in electronics industries.

In Panel B, Columns (1) to (4) reveal that the coefficient of *REweight* is significantly negative for all four types of industries. This finding suggests that holding more real estate is detrimental to increasing leverage. Columns (5) to (8) indicate that the coefficients of *COVID19* are all positive, while those of *REweight*COVID19* are insignificant across all four industries, implying that the negative impact of real estate holdings on leverage is not significant during the pandemic. The results indicate an increased demand for leverage in these sectors during the pandemic. However, the insignificant coefficients for *REweight*COVID19* across all industries suggest that the increased funding demand during the pandemic was not achieved through real estate collateralization.

Overall, the results show that the real estate risk of most industries except shipping sector hinder fixed assets investment and borrowings. During the COVID-19 period, manufacturing firms significantly increased their leverage. However, the COVID-19 shock only marginally intensified the negative effect of real estate holding risk on investment for firms in the electronics industry, while no significant interaction effects were observed for other industries or for leverage.

Table 8. Real estate risk, investment and leverage – different industries

Industry	Without COVID-19 effect				With COVID-19 effect			
	Non-electronics	Electronics	Shipping	Tourism & others	Non-Electronics	Electronics	Shipping	Tourism & others
Panel A: Real estate risk and investment								
Intercept	0.173	0.168	–0.192	–0.892	0.173	0.162	–0.218	–0.892
RErisk	–0.004***	–0.007***	–0.004	–0.007**	–0.004***	–0.005***	–0.002	–0.007*
COVID19					0.034	0.000	0.162	–0.336
RErisk* COVID19					0.001	–0.013*	–0.010	0.003

End of Table 8

Industry	Without COVID-19 effect				With COVID-19 effect			
	Non-electronics	Electronics	Shipping	Tourism & others	Non-Electronics	Electronics	Shipping	Tourism & others
REweight	0.003	–0.072***	–0.034	0.024	0.003	–0.072***	–0.037	0.024
Controls	V	V	V	V	V	V	V	V
Sector FE	V	V	V	V	V	V	V	V
Year FE	V	V	V	V	V	V	V	V
Obs.	3100	4307	254	717	3100	4307	254	717
Adj. R^2	0.09	0.12	0.26	0.09	0.09	0.12	0.26	0.09
Panel B: Real estate holding and leverage								
Intercept	47.392***	11.018***	–27.878	–54.306***	47.342***	11.110***	–28.572	–54.689***
REweight	–0.821**	–1.208***	–8.069***	–4.237***	–0.759*	–1.312***	–6.906***	–3.928***
COVID19					3.278**	2.148*	7.905	4.453
REweight* COVID19					–0.198	0.368	–4.025	–1.143
Controls	V	V	V	V	V	V	V	V
Sector FE	V	V	V	V	V	V	V	V
Year FE	V	V	V	V	V	V	V	V
Obs.	3100	4307	254	717	3100	4307	254	717
Adj. R^2	0.20	0.16	0.28	0.24	0.20	0.17	0.29	0.25

Notes: The dependent variables in Panel A and B are capital expenditure (Investment) and debt ratio (Leverage), respectively. The 4 industry categories are based on the Taiwan Stock Exchange (TWSE). Variable definitions are in the Appendix Table A1. ***p < 0.01, **p < 0.05, *p < 0.1.

5.7. Additional test: Impact in pre- and post- COVID-19 periods

Panel A of Table 9 shows the test for structural changes of real estate risk on corporate investment and debt financing after the outbreak of COVID-19 pandeminic based on Equation (8). Table 9 shows that when the dependent variable is investment (*Capex*), the coefficient of *RErisk *Post-COVID19* is significantly negative only for the electronics industry, while it is not statistically significant for other industries. When the dependent variable is leverage, the coefficient of *RErisk* PostCOVID19* is positive and marginally significant only for tourism & others sectors, with no significant results for other industries.

Panel B compares real estate holdings, investment, and leverage between the pre- and post-COVID-19 periods using *t*-tests. If the mean value in post-COVID-19 period is significantly higher or lower than that of the pre-COVID-19 period at the 10% significance level, a "+" or "−" symbol is appended, respectively. The results show that firms in the shipping industry exhibited higher capital expenditure (*Capex*) after the COVID-19 outbreak. Both electronics and tourism & other firms reported higher leverage in the post-COVID-19 period. Regarding real estate holdings, electronics firms tended to increase land holdings (*Landweight*) but reduce their holdings of buildings (*Buildweight*), while non-electronics firms generally reduced their building holdings.

Table 9. Real estate holding risk, investment and leverage—pre- and post-COVID-19

Panel A: Impact of real estate risk by post-COVID-19								
Industry	Non-Electronics	Electronics	Shipping	Tourism & others	Non-Electronics	Electronics	Shipping	Tourism & others
Dependent variable	Investment				Leverage			
Intercept	0.010	0.179**	0.091	–0.088	49.258***	8.969***	–67.247***	–43.998***
RErisk	–0.004**	–0.004**	0.000	–0.008**	–0.063	–0.256***	–0.886***	–0.635***
PostCOVID19	0.164	–0.026	–0.163	–0.797	–3.377***	–2.959***	–13.916**	–4.874
RErisk* PostCOVID19	–0.001	–0.013**	–0.011	0.005	–0.038	–0.084	–0.388	0.495*
Controls	V	V	V	V	V	V	V	V
Sector FE	V	V	V	V	V	V	V	V
Year FE	V	V	V	V	V	V	V	V
Obs.	3100	4307	254	717	3465	4731	279	814
Adj. R^2	0.10	0.12	0.27	0.09	0.20	0.17	0.36	0.16

End of Table 9

Panel B: Real estate holding, investment and leverage in pre- and post-COVID-19								
	Non-Electronics		Electronics		Shipping		Tourism & others	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
Capex	0.151	0.151	0.263	0.282	0.163	0.308 (+)***	0.216	0.244
Leverage	35.370	33.770 (–)***	35.789	36.934 (+)**	47.003	48.678	37.482	41.197 (+)**
REweight	1.127	1.161	0.988	1.080 (+)***	0.951	0.947	0.718	0.652
Landweight	0.404	0.416	0.298	0.330 (+)***	0.310	0.303	0.363	0.331
Buildingweight	0.222	0.210 (–)**	0.296	0.271 (–)***	0.111	0.135	0.221	0.220
Obs.	2281	1483	3115	2025	180	125	527	360

Notes: Panel A conduct regression based on Eqs. (8)–(9). Panel B compares real estate holdings, investment, and leverage between the pre- and post-COVID-19 periods using *t*-tests. Only differences that are statistically significant at the 5% level are reported; non-significant results are omitted for brevity. The 4 industry categories are based on the Taiwan Stock Exchange (TWSE). Variable definitions are in the Appendix Table A1. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Overall, the findings in Table 9 reveal an interesting pattern: following the outbreak of the COVID-19 pandemic, firms in the electronics industry adopted a more conservative investment stance, particularly with respect to buildings, in response to real estate risk. In contrast, firms in the trading, tourism, and other sectors (Tourism & others) appeared to maintain higher levels of debt as a strategy to manage the risks associated with real estate.

5.8. Endogeneity and robustness tests

Considering the potential endogeneity between real estate risk and firms' investment and leverage decisions, this study employs the industry-level average real estate risk as an instrumental variable and conducts the analysis using the Two-Stage Least Squares (2SLS) regression approach. The empirical results of *RErisk* on *Capex* and *Leverage* (Eq. (3) and Eq. (5)) are reported in Table 10. Panel A indicates that, after controlling for endogeneity bias, the coefficients of real estate risk (*RErisk*) on capital expenditures and leverage remain significantly negative. In addition, the interaction terms of real estate risk and the COVID-19 indicator (*RErisk*COVID-19*) are also significantly negative, which is consistent with the main findings (Table 5 and Table 6).

We further conduct several robustness tests: (1) adding firm fixed effects; (2) including revenue (*LogSales*) and firm age (*FirmAge*) as additional control variables (Deng et al., 2018; (3) using log (*Capex/Sales*) as an alternative measure of capital expenditure (*Capex*) and the five-year moving average of *RErisk* as an alternative measure of real estate risk; and (4) conducting a placebo test by using the year 2017 (Year2017) instead of the COVID-19 period (2020–2022). The results are reported in Panel B of Table 10. Tests (1) and (2) show that the coefficients of *RErisk* and *RErisk*COVID-19* remain negative and consistent with the main findings. Test (3) indicates that the results using alternative measures of capital expenditure and *RErisk* remain consistent with the main results of investment regressions. Test (4) shows a positive coefficient of *RErisk*COVID19* on *Capex* and an insignificant one on *Leverage*, supporting the validity of the placebo test and further reinforcing our main findings.

Table 10. Endogeneity and robustness tests

Panel A: Impact of real estate risk during COVID-19 – Endogeneity								
Dependent variable	Capex				Leverage			
	Estimate	t-stat.	Estimate	t-stat.	Estimate	t-stat.	Estimate	t-stat.
RErisk	–0.004***	–5.28	–0.003***	–3.88	–0.046***	–2.85	–0.042***	–2.58
COVID19			–0.036	–0.96			6.148***	10.01
RErisk*COVID19			–0.008***	–3.61			–0.054*	–1.68
Controls	V	V	V	V	V	V	V	V
Sector FE	V	V	V	V	V	V	V	V
Year FE	V	V	V	V	V	V	V	V
Obs.	9299		9299		10363		10363	
Wald chi^2	720.11***		739.26***		1124.06***		1126.48***	

End of Table 10

Panel B: Robustness tests								
Dependent variable	(1) Firm fixed effects		(2) More control variables		(3) Alternative measurement		(4) Placebo tests	
	Capex	Leverage	Capex	Leverage	(a) Capex	(b) Capex	Capex	Leverage
RErisk	–0.004**	–0.097***	–0.003***	–0.06***	–0.000**	–0.009***	–0.0082***	–0.1378***
COVID19	–0.007	1.295***	–0.006	1.330***	0.006	0.003		
RErisk*COVID19	–0.008**	–0.236**	–0.007***	–0.200***	–0.001**	–0.004**		
Year2017							0.0204	1.1393
RErisk*Year2017							0.0084***	0.0066
Controls	V	V	V	V	V	V	V	V
Sector FE	V	V	V	V	V	V	V	V
Year FE	V	V	V	V	V	V	V	V
Firm FE	V							
Obs.	9299	10363	9288	10351	9263	9299	9299	10363
Adj. R^2	0.10	0.09	0.11	0.09	0.28	0.11	0.10	0.09

Notes: Panel A shows 2SLS regression results that control endogeneity. Panel B adopts 4 robustness tests: (1) adding firm fixed effect; (2) adding more control variables (logsales, firmage); (3) (a) using log (Capex/sales) as an alternative measurement of capital expenditure (Capex), (b) using the 5-year moving average RErisk value as an alternative measurement of RErisk; (4) conducting placebo test by using COVID-19 as interacted term. The tables only report the coefficients of RErisk, COVID-19 and RErisk*COVID-19 for brevity. Variable definitions are in the Appendix Table A1. ***p < 0.01, **p < 0.05, *p < 0.1.

6. Discussions

Hypothesis testing and implication

Tables 5 and 6 show that the risk associated with corporate real estate holdings negatively affects both investment and leverage, and this effect becomes more pronounced during the COVID-19 pandemic. Table 7 further analyzes the differentiated impacts of the proportions of land and buildings. The results indicate that both land and building holdings negatively affect leverage in the non-COVID-19 period. These findings suggest that, rather than facilitating investment and borrowing through collateral effects, corporate real estate holdings risk during the COVID-19 pandemic constrains firms' investment and financing activities. The results support Hypotheses H2(a) and H3(a), which posit that corporate real estate risk reduces both investment and leverage during the COVID-19 period.

We propose several possible explanations for these results. Most countries adopted lockdown and working-from-home policies during the COVID-19 pandemic (Oladiran et al., 2023). These policies, as shown in Panel (B) of Table 8, result in insignificant changes in investments in fixed assets and real estate for most firms. The stagnation of investment activities renders the collateral effects of real estate insignificant during the pandemic. As shown in Table 3, a weakened collateral channel of corporate real estate during the COVID-19 pandemic is evidenced in our sample. Deng et al. (2018) propose that the real estate risk negatively affects investment and access to external financing, and the negative influence is severe during the 2008 financial crisis. Our findings stand on Deng et al. (2018) that real estate risks may hinder a firm's investment and borrowing. However, we find that during an external shock like the COVID-19 pandemic, real estate holding risk rather than collateral effect influences the investment and leverage decision a lot.

Additionally, we find a significant increase in leverage among our sample firms during the pandemic. In Taiwan, many firms retained employees by reducing working hours instead of layoffs, necessitating the continued payment of basic wages and maintenance costs for facilities and equipment. Our findings imply that borrowing during the pandemic is likely driven by the need for operating funds rather than the expansion of fixed asset investments.

Furthermore, government financial subsidies during the pandemic may explain the insignificance of Hypotheses H2(b) and H3(b). Following the outbreak of the pandemic, the Executive Yuan provided approximately TWD$50 billion in subsidies in February 2020 to some industries, including food services, tourism, and transportation (Executive Yuan, 2020). The Ministry of Economic Affairs also implemented the "Relief and Revitalization Measures for Businesses Affected by Severe Pneumonia with Novel Pathogens" on January 15, 2020. This program offered subsidies to manufacturing, service, and other industries whose average monthly revenue for any two consecutive months or any single month between January 2020 and December 2021 decreased by 15% or more compared to the same period before the pandemic, subject to regulatory approval (Ministry of Economic Affairs, 2020). Compared to collateral-based loans, which require bank approval and incur interest expenses, the government's subsidy programs offer direct assistance for wages and operational expenses that provide an alternative financial resource. This may have reduced firms' incentives to obtain collateral-based loans using real estate.

Industry difference and remote working

Table 8 categorizes the sample into four major industry groups: non-electronics, electronics, shipping, and tourism & others. Panel A indicates that during the pre-COVID-19 period, the risk associated with real estate holdings

significantly and negatively affects capital investment in the manufacturing sector and the tourism & others group. In contrast, shipping firms appear less sensitive to real estate risk. However, electronics firms with higher real estate risk exhibit lower capital investment during the COVID-19 period compared to the pre-COVID-19 period, a pattern not observed in the other three industries. This finding reflects the capital-intensive nature of Taiwan's manufacturing sector, which inherently entails high asset risk and tends to curtail capital expenditures under heightened uncertainty, such as during the COVID-19 period.

An interesting observation emerges in Table 9, which shows that, in the post-COVID-19 period, tourism & others firms with higher real estate holdings tend to increase leverage, while electronics firms reduce investment. Notably, the leverage ratio for the tourism & others industry experienced the most significant increase among all sectors, rising from 37.482% to 41.197%. These findings suggest that firms in the tourism & others sector, heavily impacted by lockdown policies during the pandemic, relied more on borrowing in the aftermath of COVID-19.

During the 2020 COVID-19 pandemic, many companies adopted working-from-home (WFH) practices in compliance with lockdown mandates. As illustrated in Table 9, this study finds a decline in building holdings (Buildingweight) in both non-electronics and electronics sectors after the pandemic. Meanwhile, the electronics industry experienced a significant increase in land holdings in the post-COVID-19 period, possibly in preparation for operational expansion to meet heightened demand for 3C products and the growing relevance of AI-related developments. These findings suggest that the electronics industry made notable real estate adjustments and improved profitability in response to the pandemic. In contrast, consistent with the observations of Cooke et al. (2019), other industries appear less responsive in adjusting their asset structures when facing external shocks.

7. Conclusions

In addition to the collateral effect of corporate real estate, the impact of real estate risks on corporate operations has garnered increasing attention in recent years. This study examines publicly listed companies in Taiwan from 2013 to 2024, using the 2020 COVID-19 pandemic as a black swan event to analyze the effects of corporate real estate risks on investment and leverage during the pandemic. Using the CAPM model, this study incorporates a real estate price index to estimate the real estate exposure of the sample companies. Subsequently, it evaluates the effects of corporate real estate exposure on investment and leverage during both the non-COVID-19 and COVID-19 periods. Furthermore, the study investigates whether the rise of remote work during the pandemic has triggered structural changes in corporate investment and debt financing behavior.

The empirical results show that corporate real estate risk negatively impacts both investment and leverage in the non-COVID-19 period, and this adverse effect becomes more pronounced during the pandemic. While most firms exhibit increased demand for debt financing during the COVID-19 period, there is no corresponding increase in investment or in the overall proportion of real estate holdings. These findings suggest that corporate managers did not substantially exploit the collateral value of real estate during the crisis. Instead, the risks associated with real estate may have heightened concerns among investors and creditors, thereby negatively influencing firms' investment and debt financing decisions.

Notably, post-COVID-19 investment and financing behavior varies across four major industry groups: non-electronics, electronics, shipping, and tourism & others. The electronics industry exhibits distinct behavior, increasing its land holdings while reducing its building holdings after the pandemic. In contrast, firms in the tourism & others category increased their leverage rather than reducing investment. This divergence highlights the electronics industry's unique capacity to adjust asset structures in response to external shocks and underscores significant inter-industry differences.

The findings of this study provide new empirical evidence on the role of corporate real estate during the COVID-19 pandemic, contributing to the literature on real estate risk, resilience theory and asset alignment theory. However, the effects of the pandemic on capital expenditure and real estate investment may persist for several years, particularly given the lumpy nature of such investments. Future research could consider extending the post-pandemic observation period to capture these longer-term dynamics more accurately.

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Author contributions

Shu-Ching Chou: conceptualization, methodology, formal analysis, writing & editing, funding acquisition, Ming-Chu Chiang: formal analysis, review & editing, Sih-Jie Chen: data curation, formal analysis, Chi-Yu Lin: data curation, formal analysis.

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APPENDIX

The Table A1 provides variable definitions.

Table A1. Variable definitions

Variables	Definitions
R_{mt}	Represents stock market returns, proxied by the return of the Taiwan Stock Exchange Capitalization Weighted Index
R_{re}	Represents the real estate market return index, proxied by Tsihwa index
RErisk	Measures a firm's exposure to real estate holdings by using Eq. (1)
REvalue (mil.)	REvalue is the Real estate average amount in thousands of Taiwan dollars (TWD)
REweight	The value of real estate holdings divided by the total fixed assets from the previous year
Landweight	The value of land holdings divided by the total fixed assets from the previous year
Buildweight	The value of building holdings divided by the total fixed assets from the previous year
Capex (%)	Capital expenditures, calculated as the firm's annual fixed asset expenditure divided by the total fixed assets from the previous year
Growthdebt (%)	The change in debt over two consecutive years, divided by the total debt balance of the previous year
Leverage (%)	The ratio of total liabilities to total assets
Profitr	The operating profit margin, calculated as operating profit divided by net sales
M/B	The market value of equity divided by book value of equity
Cashr	The sum of cash and short-term investments divided by total assets
Logasset	The natural logarithm of total assets
Inflation	Inflation is measured by the consumer price index (CPI) in terms of the annual growth rate