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The nonlinear relationship between financial flexibility and enterprise risk-taking during the COVID-19 pandemic in Taiwan's semiconductor industry

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Keywords: *COVID-19, financial flexibility, risk-taking, semiconductor industry*

Abstract

Research background: Risk-taking is the basis for sustainable development of enterprise. It was clear that the influence COVID-19 epidemic on the global market economy has increased operational risks for businesses. The semiconductor industry has high operating risks and financial risks. Moderate financial flexibility (FF) can improve the ability of semiconductor enterprises to acquire financial resources in real time, calmly cope with the impact of uncertainties in operation, improve investment opportunities, and enhance sustainable operation. It is therefore interesting to study the influence of FF on enterprise risk-taking (ERT).
Purpose of the article: The aim of the contribution is to explore the effect of FF on ERT within Taiwan's semiconductor industry amid the COVID-19 pandemic period, and investigate whether ERT varies with semiconductor industry characteristic.
Methods: Data from first three quarters of 2020, from multinational semiconductor firms listed on the Taiwan Stock Exchange (TSE), were collected and analyzed. Fixed effects regression with heteroscedasticity adjustment used to evaluate the influence of FF on the ERT of Taiwan's semiconductor industry. Furthermore, in order to corroborate and support the reliability of the results,

this research also used the different measures of ERT and Quantile regression (median regression) in the research model to check the robustness.

Findings & value added: Empirical results indicate that FF has a U-shaped effect on ERT for multinational semiconductor firms listed on the TSE, particularly within the integrated circuits (IC) manufacturing industry. Additionally, FF also has a U-shaped effect on ERT for the asset-light semiconductor and IC manufacturing industries. This article also suggests that for the asset-light semiconductor and IC manufacturing industries, the optimal inflection points are 1.1397 and 0.9729, respectively. Based on the consequences of this study, it is suggested that Taiwan's semiconductor industry should reasonably maintain FF and focus on the liquidity risk management for the long term value added, even after the COVID-19 pandemic period.

Introduction

Worldwide, governments have enforced stringent border control measures in a bid to control the ongoing COVID-19 pandemic. As a result, some economic activities have been suspended or reduced. In major countries, production activity has slowed down and supply chain procurement has been delayed. However, due to COVID-19-related operational risks, the number of business professionals and students working from home has increased. Thus, there has been a surge in demand for products such as computers, notebooks, game consoles and related processors, and smartphones. As semiconductors are integral to all computing and smart devices, this industry sector is set to capitalize on an increasingly digitized and virtually connected world.

The key products of the semiconductor industry are chips with various computing and transmission functions, which are the core components of the upper, middle and downs streams of the global electronic industry. The products of semiconductor industry directly affect the production of electronic products and their derivatives, so they play a critical role in the development of the electronic industry and electronic derivative applications in various countries. Chips are used in new business environments such as new generation mobile phones, big data analysis, high-speed computing, autonomous vehicles (self-driving car), commercial satellites, intelligent production, etc. Thus, it is critical for international readers to learn more about research information related to the semiconductor industry.

In addition, the continuous introduction of new technology applications, such as 5G infrastructure, Industry 4.0, and artificial intelligence (AI), are creating a higher demand for semiconductors, which is expected to generate new business opportunities for Taiwan's semiconductor industry amid the COVID-19 crisis. According to the World Semiconductor Trade Statistics organization (WSTS), during the third quarter of 2020, worldwide semiconductor revenue reached US$113.6 billion. This is a year-over-year growth of 5.8% and an increase of 11.0% quarter-on-quarter during the COVID-19 pandemic (TSIA, 2020). A survey conducted by the Taiwan Semiconductor Industry Association (TSIA) has showed that during the third quarter of 2020, Taiwan's semiconductor industry revenue as a whole totaled NT$867 billion (US$28.1 billion) (20.1% growth from 2019), with NT$243.5 billion (US$7.9 billion) in design (30.9% increase), and NT$480.5 billion (US$15.6 billion) in manufacturing (19.3% increase) (TSIA, 2020). Taiwan's semiconductor industry, which accounts for 15% of Taiwan's gross domestic product (GDP) 2020, makes the greatest contribution to Taiwan's economy.

The effect of the COVID-19 epidemic on the global market economy has increased operational risks for businesses. Changes to policies and the international economic environment have prompted enterprises to raise awareness of potential risks and increase their risk-taking. Enterprise risk-taking (ERT) refers to a decision-making behavior orientation, which reflects the attitude of enterprise management toward 'risky' projects when making investment decisions. As the fundamental driving force of long-term sustainable economic growth, ERT is of great significance to the promotion of enterprise value and its social and economic growth as a whole (Acemoglu & Zilibotti, 1997; Liu & Chang, 2019). Faced with dynamic environmental changes, enterprises need to adopt a variety of methods to avoid risks. However, the effectiveness of any method used to reduce risk is always limited.

Financial flexibility (FF) refers to the intrinsic strength of enterprises to make effective use of financial resources and reduce financial risks when faced with extreme or unprecedented financial environmental changes. During periods of uncertainty, FF is a key factor in enterprise strategic adjustment (Hayward *et al.*, 2017). During a crisis, enterprises with FF have greater access to capital markets, in order to raise funds for new development opportunities at much lower costs (Arslan-Ayaydin *et al.*, 2014; Islam *et al.*, 2020). The higher the level of FF, the more flexible an enterprise can be when faced with an emergency (Denis & McKeon, 2012). This helps to improve the ability of an enterprise to withstand negative financial impacts during crisis periods, thus reducing idiosyncratic risks. There is also evidence that financially flexible enterprises are more likely to survive in periods of economic stress (DeAngelo & DeAngelo, 2007; Gamba & Triantis, 2008; Meier *et al.*, 2013; Mittoo *et al.*, 2011).

For non-pandemic periods, there are several studies on the relationship between FF and ERT. Some studies report that FF positively influences ERT (Gu & Yuang, 2020; Liu & Chang, 2019; Wang & Shi, 2014; Zhang & Geng, 2018), whereas some articles suggest that FF has a negative influence on the ERT (Bancel & Mittoo, 2011; Zhou L. B. *et al.*, 2020). However, there is no empirical study to analyze whether FF can provide a competitive advantage for the semiconductor industry and how FF affects the ERT of semiconductor industry.

The semiconductor industry belongs to the knowledge- and technology-intensive economy and is highly competitive. In response to a rapid change in demand for electronic terminal products, the semiconductor industry has evolved into an innate entity in constant pursuit of leading technology. Every year there are huge capital expenditures, low total asset turnover rates, and long payback periods, which could cause major and sustained recession, and an overcapacity situation. As a whole, the semiconductor industry has high operating risks and financial risks. Moderate FF can improve the ability of semiconductor enterprises to acquire financial resources in real time, calmly cope with the impact of uncertainties in operation, improve investment opportunities, and enhance sustainable operation.

as According to the authors' knowledge, there have been no studies examining the relationship between FF and ERT within the semiconductor industry, particularly in the COVID-19 pandemic context. Thus, the main research question of this study is to determine the impact of FF on the ERT for the semiconductor enterprises in Taiwan. More specifically, what are the effects of FF on the ERT of Taiwan's semiconductor industry? In this study, the fixed effects regression with heteroscedasticity adjustment used to examine the non-linear relationship between FF and ERT amid the COVID-19 epidemic period in Taiwan's semiconductor industry, and identifies the optimal inflection point. Furthermore, in order to corroborate and support the reliability of the results, this research also used the different measures of ERT and quantile regression in the research model to check the robustness. This study also explores whether ERT varies with different semiconductor industry characteristics (IC design and IC manufacturing), and which one constitutes a basis for corporate competitiveness.

Following the introduction, the remainder of the article is organized as follows. Section 2 presents the literature on financial flexibility and enterprise risk-taking. We describe the method adopted and data utilized in this study in Section 3. The results and discussion are in Section 4 and 5, respectively, and the conclusion in Section 6.

Literature review

Theory of capital structure

Capital Structure became a topic of interest among academics and practitioners in corporate financial management. The literature discusses several theories of the relationship between financial flexibility (FF) and performance, including trade-off theory (TOT), pecking order theory (POT) and so on.

The classical M&M irrelevance theory (Modigliani & Miller, 1958) assumed that capital markets are perfect with no financing frictions. In this case, companies don't need to have FF. However, in reality, capital markets are not perfect and the associated costs of financing from external sources have risen, so FF has become an important concept (Bilyay-Erdogan, 2020). After the M&M theory, TOT and POT have predominated the literature on capital structure.

Based on the TOT, enterprises consider a trade-off between the costs and benefits of cash-holding to maximize the shareholder wealth (Dittmar *et al.*, 2003). However, TOT ignores the importance of FF, resulting in empirical under-performance, and it is being criticized due to its inability to explain observed debt ratios (Denis & McKeon, 2012). POT proposes that the information asymmetry between managers and investors makes external financing costly (Myers, 1984; Myers & Majluf, 1984). Bases on the POT, instead of targeting cash levels, companies use cash as a buffer between retained earnings and investment needs. More liquid enterprises are inclined to finance their activities primarily through their capital. Higher liquidity translates into FF and opens up the possibility of obtaining debt at lower cost (Kedzior *et al.*, 2020).

Academics empirically explain underperforming capital structure theories, citing the propensity of firms to want to maintain FF as additional borrowing capacity (Bilyay-Erdogan, 2020; DeAngelo & DeAngelo, 2007; Denis & McKeon, 2012; Gamba & Triantis, 2008; Marchica & Mura, 2010). Thus, the concept of FF provides an explanation for the dilemmas raised in the capital structure literature, suggesting that FF can constitute an important "missing link" that links the propositions of existing capital structure theories to the observational behavior of firms (Bilyay-Erdogan, 2020).

Definition and measure of financial flexibility

FF can be defined as “an enterprise's ability to access funds to finance positive net present value projects and to withstand financial risk” (Bonaimé *et al*., 2014; Ferrando *et al*., 2017). To be more specific, FF is the “ability of a firm to effect resilience when faced with unexpected events or crises, timely acquire or invoke resources, seize opportunities to invest” (Bates *et al*., 2009; Cherkasova & Kuzmin, 2018; DeAngelo *et al*., 2011; Denis & Mckeon, 2012; Graham & Harvey, 2001; He *et al*., 2020; Ma & Jin, 2016; Opler *et al*., 1999; Yi, 2020; Zhang *et al*., 2020). FF plays a vital role in the financial decision-making of enterprises. It helps to maintain the enterprise's debt capacity and future financing capacity, and assists with selecting lucrative investments (Marchica & Mura, 2010). This greatly enhances an enterprise’s competitiveness and solidifies its place in the market (Guo *et al*., 2020).

Existing studies measure FF with either the single indicator method, which analyzes FF using a single indicator such as debt capacity or cash holdings (Billett & Garfinkel, 2004; Byoun, 2008; Marchica & Mura, 2010), the multi-indicator combination method, the use of financial leverage and cash holdings (Arslan-Ayaydin *et al*., 2014; DeAngelo & DeAngelo, 2007; He *et al*., 2020; Zeng *et al*., 2013). As there is no standard way of measuring FF, this research refers to the studies by Al-Slehat (2019) and Teng *et al.* (2021), FF measures and calculates as follows. That is: *FF = Cash flexibility + Debt flexibility*[1]. Both cash and debt flexibility are measured based on stock financial information at the end of an accounting period.

Financial flexibility and enterprise risk-taking

ERT refers to the analysis and choice of uncertain investment projects that can bring expected earnings and future cash flow, reflecting the willingness or commitment of enterprises to pay a high price to obtain high returns (Wiklund & Shepherd, 2005). ERT is a resource-consuming activity and as such, has a strong dependence on the enterprise’s resources (Liu & Chang, 2019). Without resource support, ERT activities are difficult to maintain. Therefore, the amount, quality, and acquisition ability of enter-

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[1] Cash flexibility is “an enterprise’s ability to make use of internal funds and calculates as Cash flexibility = (cash + cash equivalent)/total assets”. Debt flexibility is “an enterprise’s ability to obtain external funds and calculates as Debt = 1 - corporate debt ratio”, while corporate debt ratio is the ratio of total liabilities to total assets (Teng *et al*., 2021).

prise resources will affect ERT behavior (Liu & Chang, 2019; Wang *et al.*, 2019).

FF is considered to be “the optimal allocation of financial resources, the making of valuable investments during a crisis, and the control of financial risks” (Cherkasova & Kuzmin, 2018). Theoretically, enterprises with FF can respond more quickly when faced with external financial shocks, and call on or raise financial resources to prevent negative repercussions. There is evidence that financially flexible companies are more likely to survive in periods of economic stress (DeAngelo & DeAngelo, 2007; Gamba & Triantis, 2008; Meier *et al.*, 2013; Mittoo *et al.*, 2011). Enterprises are currently forced to take much greater risks as they are operating within a complex business market.

The existing academic literatures have competing views on the effects of FF on ERT. The trade-off theory states that when enterprises face financial difficulty, sufficient cash reserves help to reduce risks. Moderate FF can ensure an enterprise’s supply of funds, improve their ability to cope with risks, and provide options to fully grasp appropriate investment opportunities (Gu & Yuang, 2020).

Based on the Resource Dependence Theory, Liu and Chang (2019) sampled the A-share non-financial enterprises listed on the Chinese Stock Exchange from 2014 to 2018, and established a fixed-effect model to study the impact of FF on ERT. The research found that FF can significantly promote ERT. Other studies have also revealed that FF is positively related to ERT (Wang & Shi, 2014; Zhang & Geng, 2018).

In accordance with the Resource Constraint Theory, resource constraint will directly affect an enterprise's resource acquisition and the implementation effect of economic activities. More importantly, through the expectations of enterprise managers, it will induce inefficient decision-making behaviors and affect the business performance of enterprises; however, having FF can alleviate resource constraints. The accumulation of financial resources can improve the FF of enterprises, and the use of financial resources and risk hedging can reduce an enterprise’s overall risk. Bancel and Mittoo (2011) investigated FF and its level of impact on enterprises, and showed that the stronger the FF of an enterprise, the less it would suffer during a financial crisis.

Derived from the aforementioned theories and arguments, the literature of the relationships between FF and ERT is still inconclusive. A series research report found a positive relationship between FF and ERT (Gu & Yuang, 2020; Liu & Chang, 2019; Wang & Shi, 2014; Zhang & Geng, 2018), the other indicates a negative relationship (Bancel & Mittoo, 2011; Zhou L. B. *et al.*, 2020). Although, the linear relationship between FF and

ERT has been conducted, one cannot ignore the fact that this relationship can be nonlinear. Thus, this article tries to fill this gap by studying whether the nonlinear impact of FF on the ERT of semiconductor enterprises in Taiwan.

According to the discussed literature and using data from semiconductor companies listed on the TSE, this study uses the fixed effects regression with heteroscedasticity adjustment to examine the nonlinear relationship between FF and ERT amid the COVID-19 pandemic period in Taiwan's semiconductor industry, and identifies the optimal inflection point. This study argues that appropriate improvement of FF can reduce ERT, but when it exceeds the level that enterprises can control, excessive FF can lead to an increase in ERT.

Research methodology

Data source

Our study targets semiconductor firms listed on the TSE from the Taiwan Economic Journal (TEJ) databases (https://www.finasia.biz). TEJ database is well designed and is one of the most accurate financial and economic databases in Taiwan at present. It includes listed company's information, stock market information, financial information, macroeconomics & commodity, Asia data bank etc.

The study samples are from listed companies in Taiwan's capital market, they are all corporate organization types. Semiconductor companies are capital intensive industries with huge assets and revenues. Semiconductor companies contribute the most to the Taiwan Capital Market Weighted Index and are also the most important investment objects for the international investors. In addition, the semiconductor industry (includes IC design and IC manufacturing) contributes approximately 15% of its GDP, as it is important to Taiwan's economic development. Out of all the semiconductor firms sampled, this study selected 405 firm-quarters from the first three quarters of 2020 as the objects of study. All sample statistics were minorized at the 1st and 99th percentiles on a quarterly basis (Baker *et al.* 2003) in order to minimize the effect of the extreme value of an outlier.

Measure of variables

Table 1 reports the description of all the variables used in this article. The first set of variables relate to enterprise risk-taking (ERT) measures. In this research, we use two different methods to calculate ERT. ERT is the company earnings volatility (Boubakri *et al.*, 2013) and is calculated as the standard deviation of return on equity (ROE) adjusted by industry (subdivided into the IC design and IC manufacturing industries), and by previous 5 quarterly periods. In calculating the volatility, we first adjusted the ROE of an enterprise for each quarter by the industry average, and then calculated the standard deviation of ROE adjusted by the industry during each observation period. The calculation formula is as follows:

$$ERT = \sqrt{\frac{1}{T-1}\sum_{t=1}^{T}\left(AdjROE_{ijt} - \frac{1}{T}\sum_{t=1}^{T} AdjROE_{ijt}\right)^2}, T = 5 \tag{1}$$

$$AdjROE_{ijt} = ROE_{ijt} - \frac{1}{n_{jt}}\sum_{i=1}^{n_{jt}} ROE_{ijt} \tag{2}$$

where, ROE_{ijt} is the return on equity of enterprise *i* in industry *j* at the end of *t* quarter, $AdjROE_{ijt}$ is the return on equity adjusted by the quarterly average of the industry (Boubakri *et al.*, 2013). ERT_1 is the another assessment of enterprise risk-taking (Boubakri *et al.*, 2013) and equal to

$$ERT_1 = Max\left(AdjROE_{ijt}\right) - Min\left(AdjROE_{ijt}\right), T = 5 \tag{3}$$

In the remaining specifications, ERT_1 was used for the robustness tests (Boubakri *et al.*, 2013).

The second set of variables used relate to FF. Based on the previously discussed literature, there is no standard way of measuring FF. This research refers to the studies by Al-Slehat (2019) and Teng *et al.* (2021), FF measures and calculates as *FF= Cash flexibility + Debt flexibility*.

For control variables, this study measured five factors: Revg, Rdd, Bnig, Oeg and Ard (see Table 1), is found by previous studies that may determine firm value (Boisjoly *et al.,* 2020; Rahayu, 2019; Sardo & Serrasqueiro, 2018; Zeidan & Shapir, 2017). Lastly, we control for quarterly fixed as well as industry differences in our sample.

Research model and methods

This paper establishes the following econometric model for an empirical test:

$$ERT_{it} = \beta_0 + \beta_1 FF_{it} + \beta_2 FF2_{it} + \beta_3 CON_{it} + \mu_t + \gamma_i + \varepsilon_{it} \tag{4}$$

where ERT_{it} is enterprise risk-taking; FF_{it} is the financial flexibility of i enterprise in t quarter; $FF2_{it}$ is the square of financial flexibility for i enterprise in t quarter; CON_{it} is the control variable in the model; μ_t denotes the unobservable firm and time effects; γ_i is an industry unobservable effect; ε_{it} represents error terms.

Panel data is used when researchers want to combine both cross-sectional and time series data, which provides many advantages. As the research data was taken from multiple companies and multiple financial quarters, and each variables' research model is numerical, hence, this study uses the panel regression data analysis to evaluate the FF-ERT relations. Thus, this study employs the above-mentioned regression model to study the relationship between FF and ERT within individual industries and financial quarters after heteroscedasticity adjustment with cluster at firm level.

Results

Descriptive statistics

Table 2 presents a summary of the statistics for all variables in the model. The minimum ERT value is 0.3, the maximum is 21.818, and the mean value is 2.065. The average ERT of the semiconductor companies listed on the TSE during the COVID-19 pandemic is relatively small. The average level of FF of listed semiconductor companies in Taiwan is 0.945, which is slightly low. Additionally, we also examine whether multi-collinearity among independent variables may exist. Variance inflation factor (VIF) of 0.2 and lower or 5 and higher indicates the presence of multi-collinearity (Hair *et al.*, 2017). Table 3 documents that the values of variance inflation factor values are less than 3, which means the multi-collinearity problem is not obvious (Hair *et al.*, 2017).

Empirical results

This study used the Hausman test (1978) to determine whether the data is suitable for the fixed effect model or the random effect model. The results show that the chi-square value is 17.53 and p-value is 0.0075<0.05, indicating that the data is suitable for the fixed effect model in this study. Then, the fixed effect regression model with controls for quarterly fixed as well as industry differences has been suggested and used. The panel data fixed effects regression result (including the heteroscedasticity adjustment) is summarized in the Tables 4–13 given below.

From the perspective of the semiconductor companies listed on the TSE as a whole, the coefficients of FF and FF2 both have a significant influence on ERT at the 10% level with heteroscedasticity adjustment (Table 4, column 1). The t-test rejects the FF as zero at the 10% level, and FF2 is zero at the 10% level. The coefficient of FF (-11.7712) is negative and FF2 (4.7037) is positive, which reveals that the effect of FF on ERT has a U-shaped relationship for the semiconductor industry.

In terms of the IC design firms as a whole, the coefficients of FF and FF2 both have an insignificant influence on ERT (Table 4, column 2). Moreover, for the IC manufacturing firms listed on the TSE as a whole, it appears that the coefficients of FF and FF2 both have a significant influence on ERT at the 5% level (Table 4, column 3). The t-test rejects the FF as zero, and FF2 is zero at the 5% level. The coefficient of FF (-19.7632) is negative and FF2 (10.1021) is positive, which reveals that FF has a U-shaped effect on ERT for the IC manufacturing industry.

With regard the control variables, Revg has positive impact on ERT at the 5% significance level for IC-manufacturing industry, but has no significant effect on ERT for semiconductor and IC-design industries. Rdd has negative impacts on ERT for semiconductor firms listed on the TSE, particular within the IC-design and IC-manufacturing industries. This implies that the higher of density of research and development (Rdd), the lower of enterprise risk-taking (ERT) for the semiconductor industry (includes IC-design and IC-manufacturing industry). This finding agrees with the propositions of Dewett (2007). Both Bnig and Oeg have no significant effect on ERT. Ard has negative effect on ERT for the IC-design industry, while semiconductor and IC-manufacturing industries have not. That is, the longer it takes to collect accounts receivable, the greater the risk of bad debts due to an increase in the balance of accounts receivable and a decrease in the recovery rate of accounts receivable for IC-design industry. This finding agrees with the propositions of Rahayu *et al.* (2020).

On the other hand, it is possible to distinguish between asset-heavy business model (AHBM) and asset-light business model (ALBM) in the semiconductor industry. For this reason, companies have different activity structures and potentially different ways to earn revenue, despite operating in the same market. In addition, there is research that evidences that asset-light enterprises have higher competitive efficiency and lower operating risks (Wen *et al.*, 2012; Zhou Z. *et al.*, 2020). Thus, this study further subdivides the semiconductor, IC design and IC manufacturing industries, into

AHBM and ALBM sub-industries for reanalysis. Tables 5 to 8 show the regression results.

Table 5 shows that the ALBM semiconductor industry's FF and FF2 has a significant influence on ERT at the 10% level (column 3). It reveals that FF has a U-shaped effect on ERT for the ALBM semiconductor industry. However, the FF and FF2 values of the AHBM semiconductor industry have not significant impact on ERT (column 2).

Table 6 reports that the AHBM and ALBM IC design industry's FF and FF2 has no significant impact on ERT. That is, FF has no risk aversion effect on the IC design industry, regardless of the asset tangibility. A possible reason for this is that the IC design industry has more intangible assets, such as patent rights or licensing fees.

Table 7 documents that the ALBM IC manufacturing industry's FF and FF2 has a significant influence on ERT at the 10% level (column 3). It reveals that FF has a U-shaped effect on ERT for the ALBM IC manufacturing industry. Nevertheless, the FF and FF2 values of the AHBM IC manufacturing industry have an insignificant influence on ERT (column 2).

In summary, the empirical results evidence that FF has a U-shaped effect on ERT for the whole semiconductor and IC manufacturing industries (Table 8). That is, within a certain range, FF reduces ERT, but beyond this range it is not conducive to the reduction of ERT. From the perspective of tangible assets, FF has a U-shaped effect on ERT for the ALBM semiconductor and IC manufacturing industries.

To obtain more information relevant to decision-making, Stata statistical software was applied to find the optimal point and value of the U-shaped curve, as shown in Table 9 and Figure 1. The results confirm that for the ALBM semiconductor industry, the optimal inflection point of the U-shaped relationship between FF and ERT is 1.1397, beyond which FF will have a positive effect on ERT (Table 9). The ALBM IC manufacturing industry had a similar result, with an optimal inflection point of 0.9729. Again, on exceeding the optimal inflection point, FF will have a positive impact on ERT for the ALBM IC manufacturing industry (Table 9). Table 9 also outlines the optimal values of FF and RT for the ALBM semiconductor and IC manufacturing industries. The ALBM-IC manufacturing industry had the lowest ERT during the COVID-19 pandemic.

Robustness test

To corroborate and support the reliability of the results, multiple key variables were replaced for the stability tests. ERT_1 replaces ERT, as ERT_1

is another measure of enterprise risk-taking. Tables 10 list the re-estimated results which are similar to the main findings.

We also employed the measures by FF with industry adjustment (FF-ind) (Arslan-Ayaydin *et al.*, 2014) to replace FF in this study. Table 11 lists the re-estimated results which are analogous to the main consequences. The FF-ind of the IC design industry still has insignificant influence on ERT (column 2) and FF-ind has a U-shaped effect on ERT for the IC manufacturing industry (column 3).

Moreover, this paper also explores the FF-ERT relations of the semiconductor industry in different quarters, respectively. Table 12 displays that the estimated results which are very analogous to the main outcomes. Additionally, we also use the quantile regression approach to check the robustness. Table 13 displays the results of the quantile regression, which are again similar to the main findings.

Discussion

This study evaluates the influence of FF on ERT in Taiwan's semiconductor during the COVID-19 pandemic. Fixed-effect panel regression analysis within individual industries and financial quarters after heteroscedasticity adjustment with cluster at firm level was applied to data from semiconductor companies listed on the TSE during first three quarters 2020.

The observed results reveal that during the COVID-19 pandemic, FF has a U-shaped effect on ERT for the semiconductor industry, particularly in IC-manufacturing. Unlike extant research that suggested either a positive (Gu & Yuang, 2020; Liu & Chang, 2019; Wang & Shi, 2014; Zhang & Geng, 2018) or negative linear FF-ERT relationship (e.g. Agha & Faff, 2014; Al-Slehat, 2019; Ali & Siddiqui, 2020), the U-shaped FF-ERT relationship becomes apparent during the COVID-19 pandemic period.

Moreover, when the semiconductor industry is subdivided into the AHBM and ALBM semiconductor industries, FF has an insignificant effect on ERT for AHBM semiconductor firms as well as IC design and IC manufacturing. The reason for this may be due to the comparison with asset-light operations, as heavy asset operations mostly rely on large-scale investment or acquisition of fixed assets to obtain income. Asset-heavy enterprises often have less operating cash flow (less FF), so financing constraints cannot be alleviated, so their risk-taking effect is not obvious. On the other hand, the results document that FF still has a U-shaped impact on ERT for the ALBM semiconductor as well as IC manufacturing firms. However, FF has an insignificant effect on ERT for the ALBM IC design company. This finding agrees with the propositions of Wen *et al.* (2012), and Zhou Z. *et al.* (2020).

As a whole, the empirical results of this study fill in the gap of relevant literature, or promote the diversity of relevant literature

Conclusions

This study investigates the impact of FF on the Taiwanese semiconductor industry's ERT using the fixed effect panel regression method. The empirical results reveal that during the COVID-19 pandemic, FF has a U-shaped effect on ERT for the semiconductor industry, particularly in IC-manufacturing. This relationship was proved valid after several robustness checks. Moreover, when the semiconductor industry is subdivided into AHBM and ALBM firms, FF has a U-shaped impact on ERT for ALBM semiconductor firms as well as IC manufacturing firms.

This study offers a critical theoretical and practical contributions. Academically, to the best of authors' knowledge, this study is one of the earliest to explore the relationship between FF and ERT for the semiconductor industry, particularly in the COVID-19 pandemic context. Second, unlike extant research that suggested either a positive or negative linear FF-ERT relationship, the curvilinear (U-shaped) FF-ERT relationship becomes apparent during the COVID-19 pandemic period. Third, this article further examines whether the effect of FF on ERT varies with asset-heavy business model (AHBM) or asset-light business model (ALBM) semiconductor firms. Moreover, due to the repeatable applicability and execution of the research procedures presented in this paper, future researchers can duplicate the research procedures in this paper to any industry or company they want to study, and obtain similar results.

This research has practical implications for semiconductor industry owners and/or managers. In terms of practicality, ALBM semiconductor (including IC manufacturing) firms listed on the TSE need to enhance rational capture and optimization of FF to ensure minimal ERT. In addition, in terms of corporate governance, the chief financial officers of enterprises, particularly in the semiconductor industry, should focus on dynamic control of FF. In other words, in order to maintain minimal ERT small fluctuations could be made whilst keeping within the range of optimum FF. Additionally, adequate corporate cash liquidity should be maintained to guarantee a company's continued sustainable operation, regardless of the economic circumstances.

This research has several limitations. The major limitation of this study is the relatively short period of research. Further analysis should include several countries and observations, as well as a longer period of study. In the future, the study can explore more market economy issues arising from the COVID-19 pandemic, such as the multiple impacts of the third wave of global pandemic caused by the mutated virus that the world has recently faced. Next, the article can further explore the interactive effect of COVID-19 pandemic and US-China trade war on enterprise risk-taking for Taiwan's semiconductor industry.

In terms of FF measurement, there is no consistent standard way of measuring FF in the literature. Future research may consider other important variables that affect ERT (such as dynamic capability or sustainability), then the FF measured by dummy variables (Ferrando *et al.*, 2017) can be used to conduct interaction or moderating analysis to increase the richness of the research. In addition, from the methodology perspective, the empirical findings are, mostly, documented on static panel data methods (regression analysis) and correlation analysis. Further analysis should comprise a longer period (more quarters) of study, then generalized method of moments could be used (GMM) developed by Arellano and Bond (1991) to solve this dilemma between efficiency and bias, or used the dynamic panel model for the robust check.

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Annex

Table 1. Definitions of variables

Variable	Acronym (units)	Description
Dependent variable		
Enterprise risk-taking	ERT (numerical)	Standard deviation of industry-adjusted ROE for five consecutive quarters, as shown in formula (1)
Independent variables		
Financial flexibility	FF (ratio)	Cash flexibility + Debt flexibility
Financial flexibility squared	FF2 (ratio)	FF*FF
Control variables		
Growth rate of revenue	Revg (%)	the quarter-over-quarter percentage increase in revenue
Density of research and development	Rdd (ratio)	Research and development expenditure divided by net sales of a company
Growth rate of net profit before taxes	Bnig (%)	net profit before taxes of current period minus net profit before tax of prior period divided by net profit before tax of prior period
Growth rate of owner's equity	Oeg (%)	owner's equity of current period minus owner's equity of prior period divided by owner's equity of prior period
Average collection days	Ard (days)	Average collection days

Table 2. Descriptive statistics of main variables.

Variable	N	Mean	Std. Dev.	Min	Max
ERT	405	2.065	2.627	0.3	21.818
FF	405	0.945	0.251	0.378	1.501
Revg	405	13.211	32.083	-58.11	127.42
Rdd	405	0.144	0.198	0	1.506
Bnig	405	42.075	211.783	-750.23	920.7
Oeg	405	4.942	25.183	-46.07	162.59
Ard	405	60.509	24.952	10.1	148.41

Note. See Table 1 for definitions of variables.

Table 3. Pearson correlations matrix

Variables	1	2	3	4	5	6	7
1. ERT	–						
2. FF	-0.211*	–					
3. Revg	0.045	-0.016	–				
4. Rdd	-0.084	0.291*	-0.199*	–			
5. Bnig	-0.000	0.043	0.459*	-0.089	–		
6. Oeg	0.030	0.093	0.289*	0.003	0.120*	–	
7. Ard	-0.151*	-0.166*	-0.178*	-0.121*	-0.109*	-0.076	–
VIF	1.13	1.45	1.16	1.27	1.10	1.08	

Note: (1) * statistical significance level α = 0.1; **statistical significance level α = 0.05; *** statistical significance level α = 0.01; (2) See Table 1 for definitions of variables.

Table 4. Regression results of the semiconductor industry

Variables	ERT		
	(1) Semiconductor	(2) IC design	(3) IC manufacturing
FF	-11.7712*	-11.7372	-19.7632**
	(6.1617)	(10.4789)	(7.9601)
FF2	4.7037*	4.4098	10.1021**
	(2.7173)	(4.4538)	(4.2565)
Revg	-0.0024	-0.0137	0.0206**
	(0.0076)	(0.0108)	(0.0078)
Rdd	-2.2395*	-2.5755*	-7.9713**
	(1.2855)	(1.3836)	(2.9903)
Bnig	-0.0001	0.0003	0.0001
	(0.0006)	(0.0009)	(0.0007)
Oeg	0.0056	0.0093	-0.0183
	(0.0165)	(0.0176)	(0.0168)
Ard	-0.0175	-0.0283*	0.0005
	(0.0108)	(0.0147)	(0.0133)
Constant	10.0726***	11.6892*	10.8365***
	(3.8463)	(6.7982)	(3.6086)
Sample size	405	243	162
Adjusted R-square	0.1257	0.1205	0.2626
Industry Fixed Effect	Yes	No	No
Quarter Fixed Effect	Yes	Yes	Yes
F-value	1.960	1.239	2.248
P-value	0.0651*	0.292	0.0444**

Note: (1) Cluster-robust standard errors at firm level in parentheses; (2) * statistical significance level α = 0.1; **statistical significance level α = 0.05; *** statistical significance level α = 0.01; (3) See Table 1 for definitions of variables.

Table 5. Baseline results of the AHBM and ALBM semiconductor industry

Variables	ERT		
	(1)Semiconductor	**(2)AHBM-semiconductor**	**(3)ALBM-semiconductor**
FF	-11.7712*	-11.6853	-13.7358*
	(6.1617)	(10.0855)	(7.4579)
FF2	4.7037*	3.9818	5.9705*
	(2.7173)	(4.2610)	(3.5308)
Revg	-0.0024	0.0139	-0.0010
	(0.0076)	(0.0092)	(0.0102)
Rdd	-2.2395*	-2.2704	-1.9855
	(1.2855)	(2.2642)	(1.4625)
Bnig	-0.0001	-0.0004	-0.0003
	(0.0006)	(0.0007)	(0.0006)
Oeg	0.0056	-0.0818	0.0198
	(0.0165)	(0.0584)	(0.0136)
Ard	-0.0175	-0.0340**	0.0011
	(0.0108)	(0.0167)	(0.0076)
Constant	10.0726***	11.2656*	9.6057**
	(3.8463)	(6.2416)	(4.0408)
Number of samples	405	173	232
Adjusted R-square	0.1257	0.2911	0.1522
Quarter Fixed Effect	Yes	Yes	Yes
F-value	1.960	1.001	2.553
P-value	0.0651*	0.439	0.0199**

Note: (1) Cluster-robust standard errors at firm level in parentheses; (2) * statistical significance level α = 0.1; **statistical significance level α = 0.05; *** statistical significance level α = 0.01; (3) See Table 1 for definitions of variables.

Table 6. Baseline results of the AHBM and ALBM IC design industry

Variables	ERT		
	(1) IC design	**(2) AHBM-IC design**	**(3) ALBM-IC design**
FF	-11.7372	-19.6075	-9.9301
	(10.4789)	(18.0871)	(10.0820)
FF2	4.4098	7.3193	4.4055
	(4.4538)	(7.6325)	(4.5827)
Revg	-0.0137	0.0079	-0.0088
	(0.0108)	(0.0124)	(0.0141)
Rdd	-2.5755*	-1.6374	-2.5378
	(1.3836)	(2.3672)	(1.6260)
Bnig	0.0003	-0.0003	-0.0004
	(0.0009)	(0.0009)	(0.0010)
Oeg	0.0093	-0.1021*	0.0254*
	(0.0176)	(0.0584)	(0.0136)
Ard	-0.0283*	-0.0390	-0.0045
	(0.0147)	(0.0231)	(0.0071)
Constant	11.6892*	16.6359	8.1207
	(6.7982)	(10.9230)	(5.9622)

Table 6. Continued

Sample size	243	86	157
Adjusted R-square	0.1205	0.3263	0.1379
Quarter Fixed Effect	Yes	Yes	Yes
F-value	1.239	0.929	1.534
P-value	0.292	0.498	0.176

Note: (1) Cluster-robust standard errors at firm level in parentheses; (2) * statistical significance level α = 0.1; **statistical significance level α = 0.05; *** statistical significance level α = 0.01; (3) See Table 1 for definitions of variables.

Table 7. Baseline results of the AHBM and ALBM IC manufacturing industry

	RT		
Variables	**(1)IC manufacturing**	**(2)AHBM-IC manufacturing**	**(3)ALBM-IC manufacturing**
FF	-19.7632**	-6.6350	-27.5864**
	(7.9601)	(4.8732)	(10.3858)
FF2	10.1021**	3.1698	14.1764**
	(4.2565)	(2.5903)	(5.6339)
Revg	0.0206**	0.0089	0.0232**
	(0.0078)	(0.0126)	(0.0090)
Rdd	-7.9713**	-7.8120***	-4.2949
	(2.9903)	(2.5894)	(8.0947)
Bnig	0.0001	-0.0002	0.0002
	(0.0007)	(0.0012)	(0.0010)
Oeg	-0.0183	0.0542**	-0.0328**
	(0.0168)	(0.0259)	(0.0147)
Ard	0.0005	-0.0151	0.0105
	(0.0133)	(0.0095)	(0.0159)
Constant	10.8365***	5.5635**	14.0307***
	(3.6086)	(2.1349)	(4.8893)
Sample size	162	87	75
Adjusted R-square	0.2626	0.3395	0.3662
Quarter Fixed Effect	Yes	Yes	Yes
F test	2.248	3.348	2.381
P-value	0.0444**	0.00895***	0.0506*

Note: (1) Cluster-robust standard errors at firm level in parentheses; (2) * statistical significance level α = 0.1; **statistical significance level α = 0.05; *** statistical significance level α = 0.01; (3) See Table 1 for definitions of variables.

Table 8. Consolidated results

Variables	ERT					
	Semiconductor		IC design		IC manufacturing	
FF	– (*)		n.s.		– (**)	
FF2	+ (*)		n.s.		+ (**)	
	AHBM	ALBM	AHBM	ALBM	AHBM	ALBM
FF	n.s.	– (*)	n.s.	n.s.	n.s.	– (**)
FF2	n.s.	+ (*)	n.s.	n.s.	n.s.	+ (**)

Note: (1) n.s. denotes no significance statistically; + denotes positive effect; – denotes negative effect; (2) * statistical significance level $\alpha = 0.1$; **statistical significance level $\alpha = 0.05$; *** statistical significance level $\alpha = 0.01$.

Table 9. Optimal values of FF and ERT for ALBM semiconductor and IC manufacturing industries

	ALBM-Semiconductor	**ALBM-IC manufacturing**
Optimal value of FF	1.1397	0.9729
Lowest ERT	1.6274	1.2652

Table 10. Regression results: using the ERT_1

Variables	**ERT_1**		
	(1) Semiconductor	**(2) IC design**	**(3) IC manufacturing**
FF	-12.8487**	-12.6749	-19.5750**
	(6.4766)	(10.7419)	(8.3779)
FF2	5.4687*	4.7682	9.8146**
	(2.9423)	(4.5647)	(4.5088)
Revg	0.0004	-0.0152	0.0206**
	(0.0069)	(0.0110)	(0.0080)
Rdd	-1.1339	-3.1790**	-7.9417**
	(0.8441)	(1.5455)	(3.2194)
Bnig	0.0001	0.0005	0.0004
	(0.0006)	(0.0010)	(0.0007)
Oeg	0.0055	0.0093	-0.0186
	(0.0176)	(0.0175)	(0.0184)
Ard	-0.0185	-0.0268*	-0.0005
	(0.0119)	(0.0153)	(0.0133)
Constant	10.2558**	12.3300*	10.9767***
	(3.9285)	(6.9751)	(3.6827)
Sample size	405	243	162
Adjusted R-square	0.0920	0.1289	0.2639
Industry Fixed Effect	Yes	No	No
Quarter Fixed Effect	Yes	Yes	Yes
F test	1.909	1.155	2.299
P-value	0.0728*	0.338	0.0402**

Note: (1) Cluster-robust standard errors at firm level in parentheses; (2) * statistical significance level $\alpha = 0.1$; **statistical significance level $\alpha = 0.05$; *** statistical significance level $\alpha = 0.01$; (3) See Table 1 for definitions of variables.

Table 11. Regression result: using FF-ind

Variable	**ERT**		
	(1) Semiconductor	**(2) IC design**	**(3) IC manufacturing**
FF_ind	-4.1587	-3.7331	-7.0274**
	(2.5484)	(3.1209)	(2.9704)
FF_ind2	5.1172	2.9681	18.5032**
	(5.6198)	(6.0659)	(8.6771)
Revg	-0.0024	-0.0132	0.0218***
	(0.0076)	(0.0111)	(0.0081)
Rdd	-2.5786*	-2.9358*	-10.7674**
	(1.4690)	(1.6363)	(4.0418)
Bnig	-0.0002	-0.0000	-0.0000
	(0.0006)	(0.0008)	(0.0008)
Oeg	0.0038	0.0075	-0.0284
	(0.0173)	(0.0186)	(0.0208)
Ard	-0.0188	-0.0288*	-0.0040
	(0.0114)	(0.0155)	(0.0141)
Constant	3.6883***	4.8163***	2.2165**
	(1.0488)	(1.5801)	(0.9884)
Sample size	405	243	162
Adjusted R-square	0.0778	0.0762	0.2056
Industry Fixed Effect	Yes	No	No
Quarter Fixed Effect	Yes	Yes	Yes
F test	1.752	1.129	1.859
P-value	0.102	0.354	0.0951*

Note: (1) Cluster-robust standard errors at firm level in parentheses; (2) * statistical significance level α = 0.1; **statistical significance level α = 0.05; *** statistical significance level α = 0.01; (3) See Table 1 for definitions of variables.

Table 12. Regression results from the first three quarters of 2020

Variables	ERT								
	SI Q1	**SI Q2**	**SI Q3**	**ICD Q1**	**ICD Q2**	**ICD Q3**	**ICM Q1**	**ICM Q2**	**ICM Q3**
FF	-14.0091**	-12.8462*	-10.4963	-14.5557	-12.7593	-9.4709	-21.5436**	-16.8561**	-23.8680*
	(6.5594)	(6.8379)	(7.1170)	(11.7850)	(13.0663)	(10.3655)	(8.1812)	(7.3189)	(12.0576)
FF2	5.8144**	5.1257	4.2155	5.7763	4.7875	3.4404	10.9286**	8.2815**	13.1573*
	(2.8410)	(3.1352)	(3.3189)	(4.9156)	(5.7728)	(4.6317)	(4.3427)	(3.8907)	(6.8611)
Revg	0.0125	-0.0106	-0.0048	0.0023	-0.0209	-0.0156	0.0230*	0.0099*	0.0360*
	(0.0108)	(0.0098)	(0.0112)	(0.0174)	(0.0133)	(0.0140)	(0.0134)	(0.0058)	(0.0204)
Rdd	-2.0264	-2.2634*	-1.9990	-2.2900	-2.5609*	-2.3154	-8.0996**	-9.1286**	-6.3796
	(1.4615)	(1.3313)	(1.3884)	(1.6640)	(1.4859)	(1.4687)	(3.3721)	(3.7829)	(5.2427)
Bnig	-0.0021**	0.0010	0.0014	-0.0017	0.0012	0.0016	-0.0018*	0.0023	0.0010
	(0.0010)	(0.0007)	(0.0014)	(0.0017)	(0.0009)	(0.0018)	(0.0011)	(0.0014)	(0.0017)
Oeg	0.0048	0.0093	0.0028	0.0057	0.0129	0.0095	-0.0017	-0.0167	-0.0363
	(0.0202)	(0.0217)	(0.0167)	(0.0203)	(0.0213)	(0.0193)	(0.0222)	(0.0282)	(0.0235)
Ard	-0.0140	-0.0176	-0.0232*	-0.0214	-0.0281*	-0.0365**	-0.0004	-0.0003	-0.0109
	(0.0112)	(0.0115)	(0.0124)	(0.0152)	(0.0145)	(0.0174)	(0.0139)	(0.0128)	(0.0144)
Constant	10.8866***	10.6875***	9.5729**	12.6390	12.2255	10.6812	11.7448***	9.8601***	12.8161**
	(4.1042)	(4.0784)	(4.1479)	(7.6842)	(7.7638)	(6.5886)	(3.9179)	(3.3384)	(5.0450)
Observations	135	135	135	81	81	81	54	54	54
Adjusted R-square	0.1422	0.1239	0.0761	0.0894	0.0974	0.0710	0.2882	0.3092	0.2232
Industry Fixed Effect	Yes	Yes	Yes	No	No	No	No	No	No
Quarter Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-value	2.112	1.068	1.914	1.276	0.786	1.110	1.967	2.167	1.539
P-value	0.0469**	0.388	0.0725*	0.274	0.601	0.366	0.0804*	0.0549*	0.178

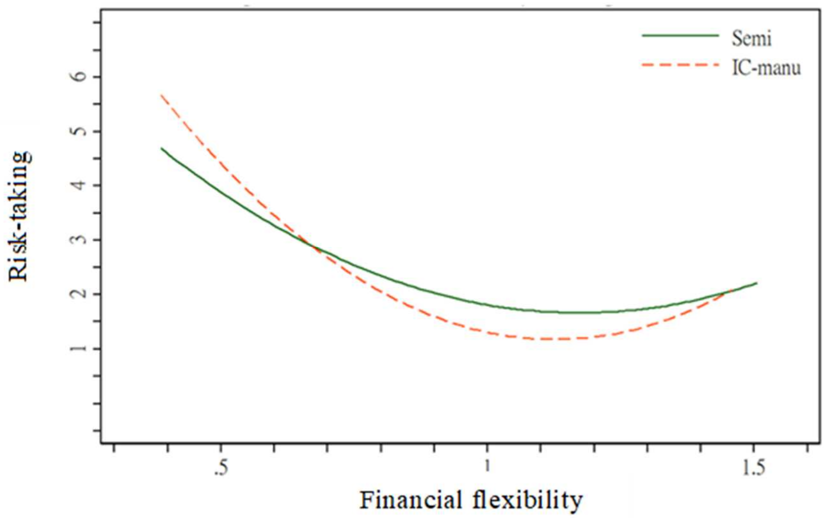
Note: (1) SI = total semiconductor industry; ICD = IC design industry; ICM = IC manufacturing industry; (2) Cluster-robust standard errors at firm level in parentheses; (3) * statistical significance level α = 0.1; **statistical significance level α = 0.05; *** statistical significance level α = 0.01; (4) See Table 1 for definitions of variables.

Table 13. Quantile regression results

Variables	ERT		
	(1) Semiconductor	(2) IC design	(3) IC manufacturing
FF	-5.4700***	-3.1406	-12.8845***
	(1.4544)	(2.1393)	(2.7203)
FF2	2.5870***	1.4802	6.5075***
	(0.7702)	(1.0888)	(1.5874)
Revg	0.0053**	0.0023	0.0051
	(0.0023)	(0.0033)	(0.0035)
Rdd	0.0525	-0.3187	-3.1537
	(0.3652)	(0.4873)	(2.2806)
Bnig	-0.0002	-0.0002	0.0006
	(0.0003)	(0.0004)	(0.0005)
Oeg	0.0025	0.0029	-0.0064
	(0.0027)	(0.0035)	(0.0064)
Ard	-0.0061**	-0.0044	-0.0041
	(0.0025)	(0.0036)	(0.0041)
Constant	4.2477***	3.1854***	7.5643***
	(0.6750)	(1.0473)	(1.1147)
Sample size	405	243	162
Quarter Fixed Effect	Yes	Yes	Yes

Note: (1) Cluster-robust standard errors at firm level in parentheses; (2) * statistical significance level α = 0.1; **statistical significance level α = 0.05; *** statistical significance level α = 0.01; (3) See Table 1 for definitions of variables.

Figure 1. U-shaped relationship between financial flexibility and enterprise risk-taking



Note: Semi = Semiconductor industry; IC-manu= IC-manufacturing industry.