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CONCAVE EFFECT OF FINANCIAL FLEXIBILITY ON SEMICONDUCTOR INDUSTRY PERFORMANCE: QUANTILE REGRESSION APPROACH

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Abstract. To survive increasingly uncertain and competitive markets, technology and capital-intensive semiconductor companies need to be more agile, responsive and flexible than ever before. This study investigates the impact financial flexibility on firm performance within Taiwan's semiconductor industry and whether the impact on FP differs depending on the semiconductor industry characteristics. Using quantile regression analysis, data from semiconductor companies listed on the Taiwan Stock Exchange during the COVID-19 shock was investigated. The results evidence an inverted U-shaped relationship between FF and FP in the lower and median return on equity quantiles of the semiconductor industry. For the asset heavy business model companies, FF has a concave impact on FP for IC-design and IC-manufacturing companies but not the semiconductor companies. For the asset light business model companies, FF has a concave impact on FP in the lower and median quantiles for semiconductor companies, in the upper quantiles for IC-design companies and in all except the 90th quantile for IC-manufacturing companies. The results of this research significantly contribute to extant literature as with such specific knowledge regarding the impact of FF on FP, managers are able to make decisions based on a firm's individual FF-FP relationship and identify the most lucrative business trajectory.

Keywords: financial flexibility, firm performance, return on equity, semiconductor industry, quantile regression, COVID-19.

JEL Classification: G18, G28, G31, G32.

Introduction

Due to its advanced technology and research and development capabilities, Taiwan's semiconductor industry (SI) is the most advantageous industry in Taiwan and is believed to have the world's most comprehensive semiconductor companies. Taiwan's SI is integral within international supply chains and has a strong market influence and export contribution, making it essential to the economy (Cheng et al., 2021). The SI produces the majority of Taiwan's

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total exports, accounting for nearly 30%, according to the Ministry of Economic Affairs and Taiwan's Bureau of Foreign Trade (Cheng et al., 2021). In 2020, the SI made the greatest contribution to Taiwan's economy by accounting for 15% of the gross domestic product.

The COVID-19 pandemic began in 2020, after the US-China trade war. During this time, and amidst ongoing US-China trade tensions, most leading indexes of major economies declined; however, Taiwan's SI has benefited substantially. Conversely, some export-oriented Taiwanese IC manufacturers based in China are struggling to cope with high tariffs due to the US-China trade war (Kuo & Klingler-Vidra, 2021). This has had adverse effects on Taiwan's semiconductor companies, especially for those not manufacturing in Taiwan.

The impact of the COVID-19 pandemic has increased remote working and online learning, thus significantly increasing the demand for notebooks, tablets, computers, monitors and internet-related communication devices, all of which contain semiconductors. The need for epidemic prevention-related integrated circuits (IC), including microcontrollers, temperature sensors and respirator chips has also surged. The growing popularity of 5G infrastructure, artificial intelligence, Internet of Things and Smart Applications has also created more demand for semiconductors during the ongoing COVID-19 pandemic.

As the emphasis on sustainable development increases, interest in environmental innovation (Hizarci-Payne et al., 2021; Ardito et al., 2016; Aldieri, 2013) and financial flexibility practices and has risen among scholars and practitioners (Chang & Wu, 2021, 2022; Teng et al., 2021; Gu & Yuan, 2020; Yi, 2020). Financial flexibility (FF) is the capability of a financial enterprise to obtain and restructure the required finance for minimum cost (Gamba & Triantis, 2008) and can help firms respond to market changes affecting investment, performance and business growth. Even in a crisis, companies with adequate FF have greater cash reserves to economically raise capital in order to fund new growth opportunities and further improve performance (Arslan-Ayaydin et al., 2014). To be more competitive in a dynamic business environment, corporate managers pay increasing attention to FF when making financial decisions (Graham & Harvey, 2001). Recently, enterprises worldwide have looked to increase their FF to avoid uncertainty and seize growth opportunities (Yun et al., 2021; La Rocca & Cambrea, 2019).

Several researchers have explored the challenges faced by the SI (Park et al., 2021) and its corporate response to the COVID-19 shock (Kempf et al., 2021; Rumbaugh et al., 2021; Thorbecke, 2021); nevertheless, there is no empirical research that evaluates the effect of the COVID-19 pandemic on the SI's firm performance (FP). This study not only offers additional empirical evidence on the effect of COVID-19 epidemic but also contributes to a deeper understanding how FF affect FP amid a COVID-19 crisis. The literature concerning the relationship between FF and FP is inconclusive. There are numerous studies on the FF-FP relationship for non-epidemic periods and in companies from China (Chun & Yanbo, 2016), East Asia (Arslan-Ayaydin et al., 2014), Iran (Hooshyar et al., 2017), Jordan (Al-Slehat, 2019) and Pakistan (Ali & Siddiqui, 2020) it was found to be positive. Conversely, some articles argue that high FF leads to overinvestment (Agha & Faff, 2014).

Recent research has shown that firms with FF experienced greater stock performance in the initial stages of the COVID-19 epidemic (e.g., Fahlenbrach et al., 2020; Ramelli & Wagner, 2020). In addition, the scholar verified that FF has a positive impact on FP for manufacturing industry in Taiwan amid the COVID-19 epidemic (Teng et al., 2021). More recently, mixed results on the effect of FF on FP has led to doubt surrounding the linear relationship between the two variables, thus instigating the adoption of nonlinear models. Some studies have focused on the nonlinear concave relationship between FF and FP (Gu & Yuan, 2020; Yi, 2020). The inverted U-shaped curve demonstrates that initially FP rises as FF increases; however, on reaching the FF threshold, FP declines as FF increases. Thus far, there is no consensus as to whether FF increases or decreases FP. Prompted by the ongoing debate, this research's primary enquiry is whether FF impacts FP and more specifically, how it effects FP.

This research contributes to extant literature by empirically exploring the FF-FP relationship for semiconductor companies listed on the Taiwan Stock Exchange (TSE), considering a non-linear concave relationship. Using the quantile regression (QR) method, the research focusses on FP tail information (proxied by ROE) and highlights how FF impacts different FP quantiles.

This research elicits several important findings. The first analysis evidences a concave relationship between FF and FP in TSE listed semiconductor firms from Q1 2020 to Q1 2021. The QR approach verifies there is a concave FF-FP relationship in the lower and median ROE quantile firms. These results evidence that FF is significant to a companies' decision making and empirically supports the trade-off theory. Taiwan's semiconductor companies should aim for optimal FP whilst balancing FF benefits and costs. Similarly, there is also a concave relationship between FF and FP in the lower ROE quantiles of IC-design firms and all the ROE quantiles of IC-manufacturing firms.

Dividing the SI (including IC-design & IC-manufacturing) into the AHBM and ALBM companies confirmed the FF-FP relationship is different for each. The second analysis revealed a concave FF-FP relationship in ALBM semiconductor companies, whereas there is no significant relationship between FF and FP in the AHBM semiconductor companies. Additionally, there is a concave FF-FP relationship in the AHBM and ALBM IC-design and IC-manufacturing companies. These results reinforce that the advantages and disadvantage of AHBM and ALBM are essential to understanding the FF-FP relationship.

The rest of this article is organized as follows: Section 1 offers a literature review and hypotheses development; Section 2 presents the materials, research model and method; Section 3 details the QR and analyzes the results; Section 4 discusses the results; and finally, the last Section summarizes the study and offers implications and future research suggestions.

1. Literature review and hypothesis development

1.1. Capital structure

Capital structure has attracted much attention from academics and practitioners in corporate finance management. Current literature discusses several theories on the FF and FP nexus, which include trade-off theory (TOT) and pecking order theory (POT).

From a TOT perspective, firms consider the trade-off between the benefits and costs of cash-holding to maximize shareholder wealth (Dittmar et al., 2003). Nevertheless, TOT disregards the significance of FF, resulting in empirical under-performance (Denis & McKeon, 2012).

According to POT, companies have no target cash levels, but cash is used as a buffer between retained earnings and investment needs (Yun et al., 2021). Based on POT, more liquid companies tend to finance their activities primarily through capital, as higher liquidity translates into FF and opens up the possibility of acquiring debt at a lower cost (Kedzior et al., 2020).

Fama and French (2005) indicated that neither TOT nor POT can shed light on real-world debt choices of firms. Later, the academics have made an empirical explanation for the under-performing capital structure theory, citing the propensity of firms to maintain FF as an additional capacity for additional borrowing (Denis & McKeon, 2012; Marchica & Mura, 2010; Gamba & Triantis, 2008; DeAngelo & DeAngelo, 2007). Therefore, the concept of FF offers an explanation for the dilemmas raised in the capital structure literature (Bilyay-Erdogan, 2020).

1.2. Financial flexibility and firm performance

According to the trade-off theory (Modigliani & Miller, 1963), when firms experience financial difficulties, sufficient cash reserves help reduce risks (Gu & Yuan, 2020). The resource-based view also argues that enterprises with idle (or surplus) resources can use these resources to obtain external opportunities and promote enterprise growth (Nohria & Gulati, 1997). The agency theory (Jensen, 1986), however, predicts that when a firm has extra cash, managers may waste it or invest in detrimental projects. Additionally, excessive FF could lead to excessive idle cash, rendering the profitability of corporate cash relatively weak. Conversely, however, low debt and low leverage have no incentive effect and will reduce FP (Gu & Yuan, 2020).

There are competing views on the relationship between FF and FP in existing academic literatures. Chun and Yanbo (2016) examined whether investment scale or efficiency guides the FF-FP relationship for companies listed on the SSSE (Shanghai and Shenzhen stock exchanges) and showed that FF significantly positively impacts FP. Arslan-Ayaydin et al. (2014), from 1994 to 2009, assessed the impact of FF on FP of East Asian firms and indicated that corporations with optimal FF perform better in a financial crisis. Al-Slehat (2019), from 2010 to 2017, explored the impact of FF on FP of service industries in Jordan and found it had a positive influence. Ali and Siddiqui (2020), from 2009 to 2018, reported that FF had a positive influence on the FP of Pakistan Stock Exchange listed enterprises. Teng et al. (2021) evidenced that FF had a positive impact on FP for TSE listed manufacturing firms, from Q1 2020 to Q2 2020.

Contrastingly, some studies suggest that high FF leads to overinvestment from an agency costs perspective (Agha & Faff, 2014). More recently, mixed results on the impact of FF on FP has led to doubt surrounding the linear relationship between the two variables, thus instigating the adoption of nonlinear models. Some studies concentrating on the nonlinear FF-FP relationship evidence it has a convex (U-shaped) or concave (inverted U-shaped) pattern. For example, Yi (2020) explores the impact of FF on the FP of SSSE listed manufacturing companies, from 2011 to 2017, and found the relationship to be concave. Gu and Yuan (2020), from 2015 to 2018, investigated the associations among internal control, FF and FP of SSSE listed Chinese information technology companies, and confirmed that FF has a concave effect on FP. In contrast, Chang and Wu (2022) applied QR to analyze the effect of FF on FP for TSE listed hospitality firms, from Q1 2020 to Q4 2020, and evidenced a convex FF-FP nexus. Given the above discussion, the first hypothesis is:

Hypothesis 1. There is a nonlinear FF-FP relationship which is either a concave (inverted U-shaped) or convex (U-shaped) pattern.

Research evidence that companies with increased asset tangibility will have reduced FP (proxied by return on assets [ROA]) (Ali & Siddiqui, 2020). However, a positive correlation between asset tangibility and ROA was discovered by Chang and Ma (2019). More recently, Teng et al. (2021) explored the effect of FF on the FP of Taiwan's manufacturing industry and discovered FF significantly positively influenced FP in AHBM manufacturing firms. Conversely, Chang and Wu (2022) reported a nonlinear convex relationship between FF and FP in AHBM hospitality firms.

Additionally, Sohn et al. (2013) verified a positive correlation between the ALBM, operating profitability and enterprise value, indicating that ALBM improved FP. Seo et al. (2021) also indicated a positive relationship between ALBM and FP for US loading firms. More recently, Chang and Wu (2022) reported a concave nexus between FF and FP relationship for ALBM hospitality firms. Based on the above discussion, the second and third hypothesis are:

Hypothesis 2. For AHBM semiconductor firms, there is a nonlinear FF-FP relationship which is either a concave (inverted U-shaped) or convex (U-shaped) pattern.

Hypothesis 3. For ALBM semiconductor firms, there is a nonlinear FF-FP relationship which is either a concave (inverted U-shaped) or convex (U-shaped) pattern.

1.3. Research gap in extant literature

To summarize the literature review, one argument suggests there is a linear (positive or negative) FF-FP relationship, yet the opposing argument states there is a nonlinear (convex or concave) FF-FP relationship. Thus far, empirical studies addressing the FF-FP relationship are still inconclusive. This investigation fills the gap in extant literature by addressing the nonlinear effect of FF on the SI's FP.

2. Material and methods

2.1. Data source

The sample included 137 publicly traded semiconductor companies in according to the TSE classification. The sample firms provided financial data from the first quarter of 2020 to the first quarter of 2021. Taiwan Economic Journal (TEJ) database provides the data of firms' financial and accounting data in order to measure firm performance. Two firm-quarter values were missing from Q4 2020 due to the recompilation of their financial reports, as a result 683 quarterly sample observations were available.

2.2. Variables

Dependent variable. As assessing FP is multi-dimensional, this study includes two measurements: ROE and ROA. ROE is the net income divided by average shareholder equity. ROA, used for the robustness test, is the net income divided by average total assets.

Independent variable. FF is the independent variable and is measured as follows: *FF = cash flexibility + debt flexibility* (Teng et al., 2021; Al-Slehat, 2019). Cash flexibility calculates as (*cash + cash equivalent*) / *total assets*. Debt flexibility calculates as *1-corporate debt ratio*[1] (Teng et al., 2021).

Control variables. The control variables are the growth rate of revenue (REVG), research and development intensity (RDD), growth rate of net profit before taxes (BNIG), growth rate of owner's equity (OEG), average collection days (ARD) and firm size (SIZE), as previous studies found they determined FP (Song et al., 2021; Teng et al., 2021; Boisjoly et al., 2020). REVG is the quarter-over-quarter percentage increase in revenue; RDD is calculated as (research and development expenditures)/sales; BNIG calculates as (net profit before tax of current period-net profit before tax of prior period)/net profit before tax of prior period; OEG is captured as the percentage change in owner's equity over the prior period; ARD measures as 365 days in a year divided by accounts receivable turnover ratio; SIZE as measured by the natural logarithm of total assets.

2.3. Research model and methods

QR allows a full range of conditional quantile functions (Chiang et al., 2010), is more robust and provides more efficient estimations. This research utilizes Koenker and Bassett's (1978) QR model:

$$Q_\theta\left(ROEq_{it}|X_{it}\right)=\beta_i+\beta_{1\theta}FF_{it}+\beta_{2\theta}FF2_{it}+\beta_{3\theta}CON_{it}+\mu_{\theta t}+\gamma_{\theta t}+\varepsilon_{\theta it},$$

where $Q_\theta\left(ROEq_{it}|X_{it}\right)$ is the θ-th QR function. $ROEq_{it}$ is the FP for firm i at quarter t; FF_{it} is the FF for firm i at quarter t; $FF2_{it}$ is the square of FF for firm i at quarter t; CON_{it} are the control variables in the research model; $\mu_{\theta t}$ denotes the unobservable firm and time effects at the θ-th quantile; $\gamma_{\theta t}$ denotes an industry unobservable effect at the θ-th quantile; $\varepsilon_{\theta it}$ represents error terms for firm i at quarter t at the θ-th quantile. The aforementioned QR model explores the nonlinear FF-EP relationship within financial quarters, after heteroscedasticity adjustment with cluster at firm level.

3. Results

3.1. Descriptive statistics

Table 1 reveals the statistics for key variables in our sample. The average level of FF for semiconductor firms is 0.956. For ROE, the mean value is 3.275, median 3.28, minimum –37.75 and maximum 68.09. The mean value is slightly lower than the median and there is a wide range between the minimum and maximum values. The skewness value is 0.887 and the

[1] Corporate debt ratio is the ratio of total liabilities to total assets.

Table 1. Descriptive statistics

Variable	ROE	FF	REVG	RDD	BNIG	OEG	ARD	SIZE
Semiconductor industry								
Mean	3.275	0.956	20.718	0.143	433.103	13.354	58.787	15.439
St. deviation	5.737	0.26	39.566	0.234	5809.381	49.395	25.455	1.716
Min	–37.75	0.103	–76.55	–0.051	–1286.93	–71.16	0	11.265
Max	68.09	1.92	372.19	2.86	142000	535.91	221.37	21.795
10th percentile	–1.66	0.615	–14.56	0.013	–69.83	–8.16	29.65	13.452
25th percentile	0.84	0.762	–1.48	0.031	–12.07	–2.51	41.34	14.207
50th percentile	3.28	0.969	15.44	0.092	40.87	4.09	57.23	15.287
75th percentile	5.57	1.141	34.52	0.182	137.34	13.355	73.22	16.385
90th percentile	8.23	1.269	63.4	0.278	352.51	29.43	88.65	17.722
Skewness	0.887	–0.179	2.46	6.955	22.289	6.384	1.038	0.693
Kurtosis	34.151	3.063	17.763	66.62	528.441	54.545	6.737	3.906
Sample sizes	683	683	683	683	683	683	683	683
IC-design								
Mean	3.874	1.033	26.319	0.209	658.951	18.555	54.675	14.824
St. deviation	5.921	0.246	45.577	0.28	7459.825	60.88	27.798	1.429
Min	–16.44	0.377	–76.55	–0.051	–1286.93	–49.71	0	11.265
Max	68.09	1.92	372.19	2.86	142000	535.91	221.37	20.191
10th percentile	–1.96	0.717	–17.41	0.044	–62.41	–9.71	25.94	13.230
25th percentile	0.73	0.888	–0.2	0.098	–2.29	–3.95	36.16	13.875
50th percentile	3.77	1.062	23.09	0.152	58.66	5.19	50.49	14.677
75th percentile	6.64	1.193	42.76	0.243	156.04	17.17	68.15	15.714
90th percentile	9.6	1.326	77.42	0.340	402.69	40.57	88.65	16.488
Skewness	2.99	–0.289	2.231	6.022	17.342	5.338	1.335	0.637
Kurtosis	36.017	3.278	14.906	47.62	319.928	37.054	7.206	4.285
Sample sizes	413	413	413	413	413	413	413	413
IC-manufacturing								
Mean	2.353	0.837	12.15	0.041	87.639	5.378	65.107	16.385
St. deviation	5.321	0.235	25.798	0.037	366.227	19.973	19.804	1.693
Min	–37.75	0.103	–73.44	0	–934.15	–71.16	25.19	13.257
Max	18.06	1.46	162.58	0.19	3690.35	162.59	172.67	21.795
10th percentile	–0.975	0.565	–12.605	0.005	–79.97	–6.245	41.1	14.235
25th percentile	1.04	0.680	–2.79	0.014	–26.68	–1.29	51.37	15.366
50th percentile	2.865	0.841	8.385	0.29	18.475	3.375	64.06	16.156
75th percentile	4.27	1.014	24	0.054	93.82	9.41	77.16	17.389
90th percentile	6.22	1.143	35.195	0.095	299.915	18.435	88.75	18.510
Skewness	–3.636	–0.172	1.569	1.566	5.854	3.247	0.841	0.667
Kurtosis	26.753	3.21	10.686	5.477	50.248	31.033	6.002	3.652
Sample sizes	270	270	270	270	270	270	270	270

kurtosis value is 34.151, which illustrates the ROE distribution is skewed and heavily left-tailed. The normality test confirms the Jacque-Bera statistic (=28,000, $p < 0.001$) rejects the normally distributed hypothesis. The ROE histrgoram (Figure 1) shows the non-normal, skewed and heavily left-tailed distribution.

For the IC-design industry, the statistic value of Jacque-Bera (=19000, p-value < 0.001) and the ROE histrogram (Figure 2) demonstrate the skewed to right and heavily tailed distribution. For IC-manufacturing, the mean value of ROE is lower than the median and there is a wide range between the minimum and maximum values. The statistic value of Jacque-Bera (=6943, p-value < 0.001) and the ROE histrogram (Figure 3) show a skewed and heavily left-tailed distribution in the IC-manufacturing industry (Table 1). These findings further support the need for a QR approach.

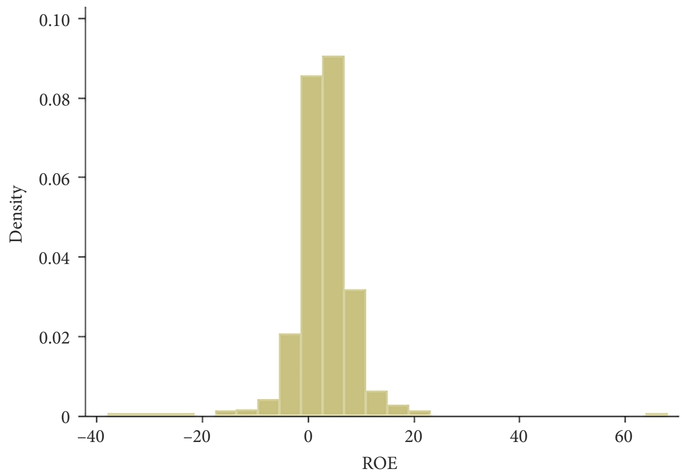

Figure 1. ROE histogram: SI

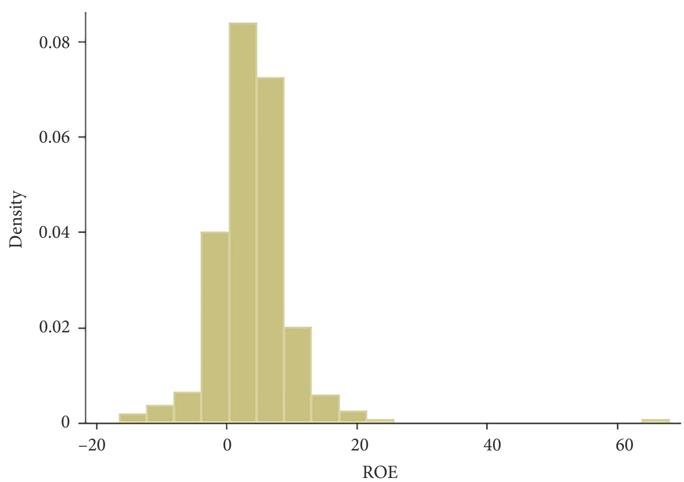

Figure 2. ROE histogram: IC-design industry

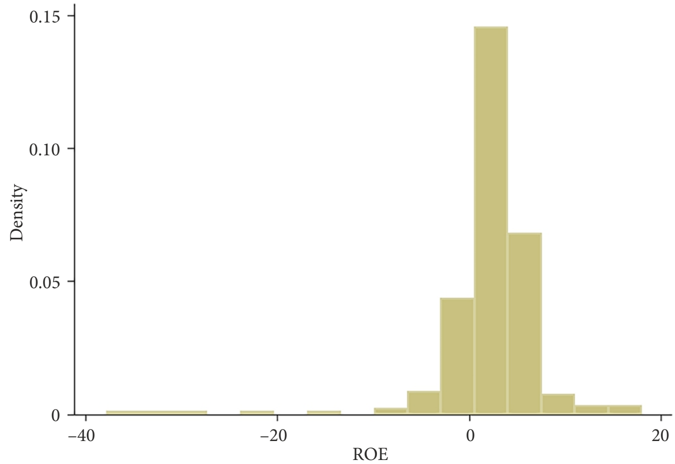

Figure 3. ROE histogram: IC-manufacturing industry

Whether multi-collinearity exists among the independent variables was investigated. Table 2 contains the results of variance inflation factor (VIF) on the independent variable with the mean VIF of 1.05. For the SI, the highest value of is 1.09, which is far below the cut-off value of 10, suggested by Hair et al. (2017). Therefore, no multicollinearity problem is suspected. The IC-design and IC-manfacturing industry have similar results.

Table 2. Pearson's correlation

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	VIF
(1) FF	1							
(2) REVG	0.146*	1						1.09
(3) RDD	0.293*	0.023	1					1.05
(4) BNIG	–0.063	0.191*	–0.121*	1				1.01
(5) OEG	0.163*	0.018	0.099*	0.015	1			1.07
(6) ARD	0.297*	0.167*	0.184*	0.051	0.028	1		1.07
(7) SIZE	–0.175*	–0.207*	–0.184*	–0.102*	–0.064	–0.164*	1	1.02

Note: $^{*}p < 0.1$.

3.2. Mean difference of main variables: IC-design vs. IC-manufacturing

The independent t-test was applied to confirm the difference in means of the IC-design industry and IC-manufacturing industry and whether the variables have any significance.

IC-design's ROE is 3.874%, which is significantly higher than IC-manufacturing (2.353%), at the 1% significance level (Table 3). FF, REVG, RDD and OEG are also higher in IC-design than in IC-manufacturing at the 1% level. However, IC-design's ARD and SIZE are lower than IC-manufacturing's. Therefore, the motivation to assess the model on the basis of two separate samples is justified.

Table 3. Independent t-test for mean difference

	IC-design		IC-manufacturing		t-test
	Mean	Std. Dev.	Mean	Std. Dev.	
ROE	3.874	5.921	2.353	5.321	4.019***
FF	1.033	0.246	0.837	0.235	4.484***
REVG	26.319	45.577	12.15	25.798	4.993***
RDD	0.209	0.28	0.041	0.037	9.789***
BNIG	658.951	7459.825	87.639	366.227	1.258
OEG	18.555	60.88	5.378	19.973	3.547***
ARD	54.675	27.798	65.107	19.804	–2.886**
SIZE	14.824	1.429	16.385	1.693	–1.93*

Note: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

3.3. Nonlinear FF-FP relationship: semiconductor industry

The ordinary least squares (OLS) estimation results show that the coefficient of FF and FF2 are not statistically significant at the 10% level, suggesting the relationship between FF and FP is not significant. Table 4 summarizes the QR estimation results for the different ROE quantiles. For FP, the coefficient of FF is positive and significant in the 10th, 25th and 50th quantiles, and the coefficients between FF and FP significantly decrease from 59.6666 in the 10th ROE quantile to 11.3813 in the 50th ROE quantile.

The coefficient of FF2 becomes negative, which verifies the concave impact of FP. These results support Hypothesis 1, which states FF will have a concave impact on the SI's FP. The results imply that improvement to the level of FF will assist enterprises to obtain optimum FP; however, when the optimal inflection point is surpassed, FF has a negative impact on FP (Table 4). These results concur with those of Gu and Yuan (2020) and Yi (2020), who also confirm there is a concave FF-FP relationship.

With regards to the control variables, OLS and QR analysis evidence that REVG significantly positively effects FP. The OLS results show that RDD significantly negatively effects FP, whereas the QR results reveal RDD negatively effects FP in the lower and 75th quantiles. BNIG has a significant effect in the OLS model but not in the QR model. For OEG, the OLS results reveal there is a positive impact on FP, but the QR results show that FF has a positive impact on FP in all quantiles except 10th and 90th quantiles. OLS estimates evidence ARD has no significant effect on FP, whereas the QR results reveal ARD negatively effects FP in the upper quantiles. Finally, the OLS results show SIZE significantly positively effects FP, whereas QR results show it has a positive effect on FP in all quantiles except the 90th (Table 4).

3.3.1. Inter-quantile difference

Confirmed by the results, the impact of FF (including its components) on FP is heterogeneous across the ROE distributions. Inter-quantile regression was employed to test whether the slope of the entire quantile is equal to verify that the difference is statistically significant

Table 4. OLS and QR results for the SI

	OLS	SI				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	16.1395	59.6666***	25.0062*	11.3813***	10.7118	−3.4913
	(10.3073)	(18.2696)	(12.8171)	(4.0086)	(6.9246)	(7.9575)
FF2	−7.3856	−28.1917***	−11.3451*	−5.0233**	−5.3078	1.1518
	(5.2493)	(9.4312)	(6.3940)	(2.2422)	(3.4411)	(4.2565)
REVG	0.0281**	0.0223***	0.0289***	0.0367***	0.0576***	0.0670***
	(0.0072)	(0.0078)	(0.0065)	(0.0081)	(0.0105)	(0.0151)
RDD	−6.0482**	−4.8935***	−3.2355**	−1.2163	−1.0130*	−1.1520
	(1.5231)	(1.8058)	(1.2564)	(1.4542)	(0.5434)	(1.8240)
BNIG	0.0019*	0.0001	0.0001	0.0001	0.0003	0.0003
	(0.0008)	(0.0004)	(0.0006)	(0.0005)	(0.0012)	(0.0019)
OEG	0.0278**	0.0102	0.0163**	0.0210*	0.0337**	0.0414
	(0.0089)	(0.0073)	(0.0083)	(0.0118)	(0.0149)	(0.0345)
ARD	−0.0116	0.0057	0.0019	−0.0039	−0.0207**	−0.0268***
	(0.0113)	(0.0095)	(0.0065)	(0.0065)	(0.0088)	(0.0073)
SIZE	0.8195**	0.7879***	0.6600***	0.5237***	0.2715**	0.1658
	(0.1913)	(0.1454)	(0.1213)	(0.0983)	(0.1245)	(0.1880)
Constant	−17.2437**	−43.4529***	−22.4442***	−11.5787***	−3.8438	7.0294
	(6.1433)	(8.6598)	(6.8590)	(2.3270)	(3.7645)	(4.9192)
Sample size	683	683	683	683	683	683
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.3489	0.2673	0.1747	0.1584	0.1615	0.2296

Note: (1) FE – fixed effect; (2) Standard errors are shown in parentheses; (3) $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

(Koenker & Bassett, 1978). F statistic value was employed to test the equality of the coefficient across various quantile pairings. The inter-quantile results for FP, the F-test results and the corresponding p-values after 200 replications using the bootstrap method to test the uniformity of the coefficients between the upper (90th and 75th) and the lower (10th and 25th) quantiles are all shown in Table 5. For the SI, there are statistically significant differences in the parameter estimates of FF and FF2 for the symmetrical quantiles (Quantile (90/10)).

Figure 4 identifies how the effects of each covariable differ between quantiles and how they compare to the OLS regression results for each independent variable. QR and OLS estimates give 95% confidence intervals, respectively. QR estimations are significantly different from OLS estimations, particularly in the symmetrical quantiles (Quantile (90/10)).

Table 5. Inter-quantile regression results for FF

		SI	
		Quantile (90/10)	Quantile (75/25)
FF	F-statistics	3.44	0.02
	Sig.	0.0642*	0.8833
FF2	F-statistics	2.92	0.13
	Sig.	0.0879*	0.7208
REVG	F-statistics	9.14	5.19
	Sig.	0.0026**	0.0231**
RDD	F-statistics	0.66	2.05
	Sig.	0.4156	0.1524
BNIG	F-statistics	0.08	0.02
	Sig.	0.7773	0.8814
OEG	F-statistics	6.67	2.24
	Sig.	0.01**	0.1348
ARD	F-statistics	13.08	12.97
	Sig.	0.0003***	0.0003***
SIZE	F-statistics	4.45	6.19
	Sig.	0.0352**	0.0131**

Note: Quantile (90/10) = 90th Quantile(y) – 10th Quantile(y); Quantile (75/25) = 75th Quantile(y) – 25th Quantile(y); *p < 0.1; **p < 0.05; ***p < 0.01.

3.4. Nonlinear FF-FP relationship: IC-design industry vs. IC-manufacturing industry

This section examines the nonlinear effect of FF on FP for the IC-design and IC-manufacturing industries. For IC-design, the OLS results reveal a concave FF-FP relationship at the 10% significance level. QR reveals FF has a concave influence on FP in the lower quantiles (Table 6).

Regarding the control variables, QR analysis reveals REVG positively affects FP at the 1% significance level for all ROE quantiles; nevertheless, this is insignificant in OLS estimates. OLS estimation results reveal that RDD insignificantly impacts FP, while the QR estimation results evidence that RDD has a positive impact in all quantiles except 75th quantile. BNIG is only significant in the OLS estimate model, not the QR estimate model. OEG positively affects FP at the 10% significance level only in the 10th quantile but is not significant in OLS estimate model. OLS results evidence ARD significantly negatively impacts FP, whereas QR results reveal ARD negatively effects FP in the lower quantiles. The OLS results show SIZE has no significant effect on FP, whereas the QR results show it has a positive effect in all quantiles (Table 6).

For IC-manufacturing, OLS estimation results show FF has an insignificant effect on FP; however, the QR results identify a concave effect in all quantiles. These findings again verify there is a concave FF-FP relationship (Table 6). Among the control variables, REVG

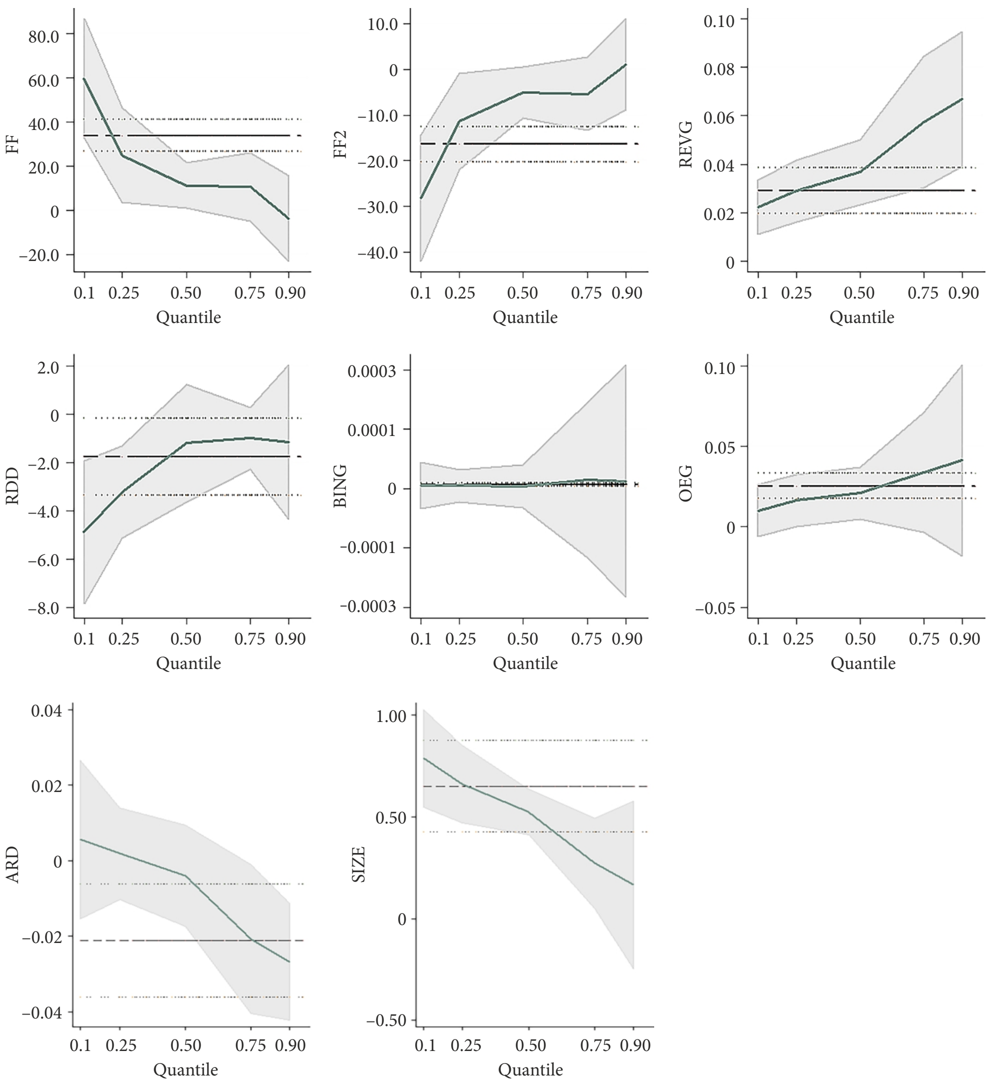

Figure 4. Graphical representation of OLS and QR estimates for the SI

positively affects FP at the 5% significance level in the 25th quantile. RDD negatively affects FP in the 25th, 50th and 90th quantiles. BNIG does not have a significant relationship with FP in any of the ROE quantiles. OEG positively affects FP in the lower and upper quantiles. ARD negatively affects FP at the 5% significance level for all ROE quantiles expect the 10th and SIZE affects FP positively in the lower and median ROE quantiles (Table 6).

Table 6. OLS and QR results for IC-design and IC-manufacturing

	OLS	IC-design				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	17.1431*	27.6677***	15.2591**	5.0127	4.1327	–10.5386
	(8.8811)	(10.3473)	(7.2404)	(7.2169)	(6.0208)	(13.1628)
FF2	–7.9923**	–9.5550*	–5.5138*	–2.0546	–2.6989	5.1537
	(3.7428)	(5.0757)	(3.3121)	(3.3850)	(3.0528)	(6.5987)
REVG	0.0067	0.0250***	0.0290***	0.0345***	0.0589***	0.0617***
	(0.0075)	(0.0070)	(0.0087)	(0.0102)	(0.0142)	(0.0145)
RDD	–9.6329	–6.9015***	–4.3148*	–3.1702*	–1.5753	–1.4439*
	(6.5685)	(2.6553)	(2.3652)	(1.9159)	(1.0100)	(0.7401)
BNIG	0.0031***	0.0001	0.0001	0.0001	0.0003	0.0002
	(0.0009)	(0.0006)	(0.0005)	(0.0006)	(0.0015)	(0.0018)
OEG	–0.0064	0.0087*	0.0070	0.0124	0.0221	0.0306
	(0.0151)	(0.0047)	(0.0065)	(0.0109)	(0.0136)	(0.0358)
ARD	–0.0664***	0.0322***	0.0156**	–0.0033	–0.0135	–0.0184
	(0.0190)	(0.0070)	(0.0068)	(0.0088)	(0.0084)	(0.0131)
SIZE	1.6125	0.9289***	0.9642***	1.1374***	0.7429***	0.8717***
	(2.6024)	(0.2347)	(0.2263)	(0.2941)	(0.2142)	(0.3114)
Constant	–24.0401	–33.5639***	–23.5372***	–16.5135***	–6.5822	–0.0180
	(41.7555)	(5.5157)	(4.6296)	(4.6071)	(4.6147)	(7.7652)
Sample size	413	413	413	413	413	413
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.7177	0.2588	0.2203	0.1930	0.1969	0.2514
	OLS	IC-manufacturing				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	–1.8952	79.4209***	62.7989***	40.5569***	26.4380***	35.2711**
	(18.3790)	(13.2357)	(17.3991)	(8.6915)	(10.1853)	(13.9233)
FF2	–4.0848	–40.9974***	–34.4441***	–23.2528***	–15.0892**	–20.9305***
	(9.9263)	(7.2617)	(9.1467)	(4.8199)	(6.0468)	(7.7370)
REVG	–0.0180	0.0122	0.0186**	0.0143	0.0245	0.0275
	(0.0111)	(0.0238)	(0.0088)	(0.0101)	(0.0152)	(0.0253)
RDD	–66.8837***	–9.3023	–13.1071***	–15.4336**	–2.9113	–11.1932*
	(17.3209)	(6.9053)	(4.7006)	(6.1332)	(7.9135)	(6.7577)
BNIG	0.0027**	0.0003	–0.0003	–0.0004	–0.0010	0.0056
	(0.0010)	(0.0012)	(0.0007)	(0.0015)	(0.0022)	(0.0036)
OEG	0.0015	0.0634**	0.0669*	0.0556	0.0914**	0.0896*
	(0.0305)	(0.0263)	(0.0344)	(0.0367)	(0.0402)	(0.0526)
ARD	–0.0097	–0.0250	–0.0220**	–0.0245***	–0.0421***	–0.0535***
	(0.0174)	(0.0153)	(0.0093)	(0.0089)	(0.0107)	(0.0182)
SIZE	9.4010**	0.9099***	0.7990***	0.5802***	0.1988	0.1119
	(3.5696)	(0.1916)	(0.0831)	(0.1233)	(0.1439)	(0.2156)

End of Table 6

	OLS	IC-manufacturing				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
Constant	−143.1798**	−50.2733***	−37.5339***	−21.7819***	−7.7626	−7.0085
	(57.4586)	(6.5484)	(8.5232)	(4.6001)	(5.3225)	(7.8553)
Sample size	270	270	270	270	270	270
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.7399	0.4801	0.2953	0.2096	0.1639	0.2016

Note: (1) FE – fixed effect; (2) Standard errors are shown in parentheses; (3) *p < 0.1; **p < 0.05; ***p < 0.01.

3.4.1. Inter-quantile difference: IC-design vs. IC-manufacturing

Table 7 presents the inter-quantile ROE results for IC-design and IC-manufacturing. For IC-design, the coefficients between FF and FP significantly decrease from 27.6677 to −15.2591 when ROE changes from the 10th to the 25th quantile. At the highest ROE level, FF negatively effects FP (Table 6). For FF, there was a positive statistical difference, indicating that FF in the 10th quantile had a greater positive impact on FP than FF in the 90th quantile (Table 6). However, the negative effect of FF2 on FP in the 10th quantile was significantly greater than that in the 90th quantile (Table 6). These results clearly verify the heterogeneous behavior of their relationship with FP in IC-design.

For the control variables (Table 7), BNIG, OEG and SIZE do not cross the significance level for the two symmetrical quantiles. REVG, RDD and ARD cross the significance level after a certain percentile level, particularly in Quantile (90/10) of the symmetrical quantiles.

Table 7. Inter-quantile regression results for FF: IC-design and IC-manufacturing

		IC-design		IC-manufacturing	
		Quantile (90/10)	Quantile (75/25)	Quantile (90/10)	Quantile (75/25)
FF	F-statistics	4.61	3.05	5.68	4.40
	Sig.	0.0323**	0.0814*	0.0179**	0.0370**
FF2	F-statistics	2.99	0.90	3.59	4.00**
	Sig.	0.0847*	0.3438	0.0591*	0.0467**
REVG	F-statistics	5.32	7.56	0.30	0.18
	Sig.	0.0216**	0.0062***	0.5816	0.6747
RDD	F-statistics	6.07**	1.52	0.05	1.65
	Sig.	0.0142**	0.2188	0.8265	0.2002
BNIG	F-statistics	0.00	0.38	1.69	0.15
	Sig.	0.9549	0.5357	0.1942	0.6958
OEG	F-statistics	0.26	1.51	0.15	0.37
	Sig.	0.6114	0.2193	0.6958	0.5415
ARD	F-statistics	18.22	7.92	1.98	2.62
	Sig.	0.0000***	0.0051***	0.1604	0.1066
SIZE	F-statistics	0.02	1.47	22.12	23.59
	Sig.	0.8783	0.2258	0.0000***	0.0000***

Note: *p < 0.1; **p < 0.05; ***p < 0.01.

For IC-manufacturing, the coefficients between FF and FP significantly decrease from 79.2049 to 26.4380 when ROE changes from the 10th to the 75th quantile (Table 6). There are statistically significant differences in the parameter estimates of FF and FF2 for the two symmetrical quantiles (Table 7). For FF, there is a positive and statistically significant difference, which suggests FF has a significantly greater positive impact on FP in the lower quantiles than in the upper quantiles. However, the negative effect of FF2 on FP was significantly greater in lower quantiles than in upper quantiles (Table 6). Regarding the control variables, only SIZE crosses the significance level for the two symmetrical quantiles (Table 7).

3.5. Effect of AHBM and ALBM

This section further subdivides the SI (including IC-design and IC-manufacturing) into AHBM and ALBM firms for re-analysis. Tables 8 to 10 show the OLS and QR results.

OLS and QR reveals FF has not significant impact on FP for AHBM semiconductor companies (Table 8). These results do not support Hypothesis 2; however, the findings are similar to Chang and Wu's (2021) who state FF has not significant effect on risk taking for the AHBM semiconductor companies. In terms of ALBM semiconductor companies (Table 8), QR estimation results suggest FF has a convex (inverted U-shaped) impact on FP. These results support Hypothesis 3 which states FF will have a concave effect on FP in ALBM semiconductor firms. The findings concur with Chang and Wu (2022) who evidence a concave FF-FP relationship in ALBM hospitality firms.

Furthermore, for AHBM IC-design firms, the OLS estimation results show that FF has an insignificant effect on FP, whereas QR shows FF has a concave impact on FP in the lower quantiles (Table 9). For ALBM IC-design firms (Table 9), the OLS estimation results indicate FF2 has a negative effect on FP. QR reveals a concave relationship in the upper quantiles, suggesting FF has a concave impact on FP.

For AHBM IC-manufacturing firms, OLS estimation results report a concave relationship between FF and FP, while QR reveals this is in the lower and median (25th and 50th) quantiles (Table 10). For ALBM IC-manufacturing firms, OLS estimation results show FF has not significant influence on FP, whereas QR identifies a concave effect in all quantiles except the 90th. This again suggests there is a concave FF-FP relationship (Table 10).

Table 8. OLS and QR results of AHBM and ALBM semiconductor firms

	OLS	AHBM semiconductor firms				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	8.2549	22.7426	8.1350	5.2835	4.7912	−7.1272
	(10.5889)	(14.4048)	(10.1220)	(5.3113)	(8.0201)	(12.7464)
FF2	−2.0362	−9.1111	−2.0097	−1.3343	−1.2180	2.8270
	(5.6987)	(7.3455)	(5.3465)	(2.7268)	(4.3995)	(6.1148)
REVG	0.0279***	0.0048	0.0174*	0.0145	0.0097	−0.0088
	(0.0099)	(0.0119)	(0.0098)	(0.0093)	(0.0133)	(0.0187)
RDD	−2.4694	−4.5124	−4.7237*	−3.3138	−1.0983	5.5244
	(2.5219)	(3.1942)	(2.7296)	(2.4926)	(2.5037)	(5.0843)

End of Table 8

	OLS	AHBM semiconductor firms				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
BNIG	0.0012	0.0001	0.0001	0.0001	0.0001	0.0001
	(0.0009)	(0.0006)	(0.0007)	(0.0008)	(0.0013)	(0.0013)
OEG	0.0733***	0.0809**	0.0885***	0.1245**	0.1769**	0.2567***
	(0.0214)	(0.0343)	(0.0288)	(0.0500)	(0.0828)	(0.0683)
ARD	0.0051	0.0271*	0.0048	–0.0073	–0.0227**	–0.0460**
	(0.0105)	(0.0139)	(0.0081)	(0.0088)	(0.0092)	(0.0184)
SIZE	0.5975***	0.5870**	0.6402***	0.4887***	0.2481	–0.2027
	(0.1820)	(0.2817)	(0.1740)	(0.1344)	(0.1837)	(0.2365)
Constant	–13.5792**	–24.5070***	–14.9631**	–8.7970**	–2.6631	14.6814*
	(5.9520)	(9.0585)	(6.4395)	(4.0275)	(5.6511)	(8.3348)
Sample size	295	295	295	295	295	295
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.4484	0.2655	0.2485	0.2671	0.2736	0.3719
	OLS	ALBM semiconductor firms				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	11.8485*	78.0918***	39.3872*	18.9078**	8.8713	10.2416
	(6.7158)	(16.3049)	(23.6664)	(9.0584)	(6.8691)	(11.0264)
FF2	–5.3150*	–37.8929***	–18.3879	–9.6749**	–5.9687*	–6.3519
	(2.7931)	(8.4872)	(11.1787)	(4.8037)	(3.4893)	(5.4277)
REVG	0.0374***	0.0234	0.0357***	0.0519***	0.0645***	0.0807***
	(0.0114)	(0.0169)	(0.0090)	(0.0137)	(0.0098)	(0.0109)
RDD	–3.8213***	–5.0262***	–3.1255*	–0.9450	–1.0783*	–1.1986
	(1.3420)	(1.7970)	(1.7866)	(1.3148)	(0.5957)	(1.4178)
BNIG	0.0028**	0.0004	0.0004	0.0003	0.0003	0.0003
	(0.0011)	(0.0016)	(0.0011)	(0.0009)	(0.0013)	(0.0019)
OEG	0.0241**	0.0080	0.0076	0.0116	0.0150*	0.0183**
	(0.0100)	(0.0068)	(0.0075)	(0.0074)	(0.0076)	(0.0087)
ARD	–0.0270	–0.0057	–0.0109	–0.0148	–0.0195*	–0.0248**
	(0.0175)	(0.0181)	(0.0074)	(0.0153)	(0.0116)	(0.0125)
SIZE	0.5754**	0.5901**	0.3609	0.4320**	0.3586**	0.3066*
	(0.2699)	(0.2323)	(0.2198)	(0.1951)	(0.1728)	(0.1708)
Constant	–10.5717*	–47.8080***	–23.8952**	–11.7733***	–1.8276	–0.3941
	(5.7180)	(8.1280)	(10.2380)	(3.8267)	(4.3100)	(6.3679)
Sample size	388	388	388	388	388	388
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.3098	0.3260	0.1978	0.1663	0.2023	0.2655

Note: (1) FE – fixed effect; (2) Standard errors are shown in parentheses; (3) *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table 9. OLS and QR results of AHBM and ALBM IC-design firms

	OLS	IC-design (AHBM)				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	10.9253	42.3510***	27.7502**	11.6290	–19.0920	–62.3149***
	(13.7412)	(13.4872)	(11.1616)	(13.0230)	(17.2941)	(20.9825)
FF2	–2.3692	–14.6023**	–9.4862*	–3.1350	9.6413	27.6443***
	(7.0060)	(6.7596)	(5.3814)	(5.9200)	(7.7441)	(9.2664)
REVG	0.0290***	0.0127	0.0124	0.0171	0.0239	–0.0121
	(0.0105)	(0.0089)	(0.0103)	(0.0124)	(0.0173)	(0.0230)
RDD	–0.6202	–8.0836*	–5.0149	–3.6674	–0.9208	1.3323
	(2.2786)	(4.5235)	(4.3626)	(3.2615)	(2.8075)	(6.7484)
BNIG	0.0018*	0.0001	0.0001	0.0001	0.0001	0.0000
	(0.0010)	(0.0007)	(0.0008)	(0.0011)	(0.0015)	(0.0012)
OEG	0.0490**	0.0689***	0.0702**	0.0599	0.1582	0.3252***
	(0.0182)	(0.0236)	(0.0328)	(0.0706)	(0.1006)	(0.1126)
ARD	0.0052	0.0174	0.0062	–0.0013	–0.0100	–0.0518***
	(0.0120)	(0.0118)	(0.0104)	(0.0091)	(0.0104)	(0.0153)
SIZE	1.0042**	1.6510***	1.3029***	1.3506**	0.9971	0.3402
	(0.3920)	(0.3494)	(0.4454)	(0.5440)	(0.6029)	(0.7917)
Constant	–22.4321***	–53.1372***	–36.8536***	–26.3243**	–1.8753	37.5725**
	(7.9532)	(7.5976)	(9.2369)	(12.2689)	(13.0483)	(18.0808)
Sample size	154	154	154	154	154	154
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.4987	0.3712	0.3293	0.2906	0.2891	0.4339
	OLS	IC-design (ALBM)				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	7.6836	25.6161	13.0875	7.5658	11.2207**	17.3268*
	(5.0028)	(19.1513)	(10.7075)	(8.1537)	(4.6356)	(8.9724)
FF2	–3.9554*	–9.4946	–5.8820	–4.3807	–7.2241***	–9.7007**
	(2.1094)	(8.3781)	(5.1328)	(4.0827)	(2.4010)	(4.3624)
REVG	0.0350***	0.0301*	0.0302**	0.0406**	0.0534***	0.0766***
	(0.0123)	(0.0158)	(0.0128)	(0.0157)	(0.0096)	(0.0140)
RDD	–6.7392***	–7.5011*	–5.4848**	–3.4880	–1.7170	–1.2774
	(1.4911)	(3.9900)	(2.6213)	(2.9511)	(1.1388)	(0.8434)
BNIG	0.0026***	0.0004	0.0003	0.0003	0.0003	0.0002
	(0.0010)	(0.0015)	(0.0013)	(0.0014)	(0.0009)	(0.0009)
OEG	0.0187**	0.0056	0.0063	0.0087	0.0090	0.0156
	(0.0090)	(0.0056)	(0.0058)	(0.0065)	(0.0059)	(0.0111)
ARD	–0.0013	0.0173	0.0037	–0.0017	–0.0096	0.0088
	(0.0158)	(0.0217)	(0.0142)	(0.0169)	(0.0115)	(0.0188)
SIZE	0.6256**	0.5581**	0.4548	0.6183**	0.4781***	0.5604*
	(0.2998)	(0.2675)	(0.2767)	(0.2503)	(0.1728)	(0.3105)
Constant	–8.4797*	–24.1574**	–11.7273**	–7.8809	–4.1573	–8.9036
	(5.0442)	(11.2926)	(4.9434)	(5.4473)	(4.4438)	(6.9783)
Sample size	259	259	259	259	259	259
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.4187	0.2388	0.2345	0.1951	0.2573	0.3177

Note: (1) FE – fixed effect; (2) Standard errors are shown in parentheses; (3) *p < 0.1; **p < 0.05; ***p < 0.01.

Table 10. OLS and QR results of AHBM and ALBM IC-manufacturing firms

	OLS	IC-manufacturing (AHBM)				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	23.4617*	13.4553	21.1849*	27.0115**	11.2934	25.6012*
	(11.7162)	(15.9015)	(12.5289)	(12.4700)	(12.8263)	(14.1695)
FF2	–12.4945*	–6.7195	–11.6687*	–15.2842**	–5.2308	–12.3303
	(6.7457)	(8.4907)	(6.9631)	(7.0807)	(7.6146)	(8.1476)
REVG	0.0183	0.0085	0.0189	0.0163	0.0215	–0.0045
	(0.0126)	(0.0155)	(0.0144)	(0.0151)	(0.0188)	(0.0209)
RDD	–7.6852	–5.4483	–12.2412	–10.1198	4.3626	–15.6242
	(9.5121)	(9.9477)	(7.8786)	(9.4395)	(9.3934)	(11.1355)
BNIG	–0.0009	–0.0005	–0.0007	–0.0011	–0.0010	–0.0021
	(0.0009)	(0.0017)	(0.0017)	(0.0015)	(0.0021)	(0.0027)
OEG	0.1567***	0.1685***	0.1286***	0.1328***	0.1461**	0.2520***
	(0.0303)	(0.0463)	(0.0358)	(0.0411)	(0.0676)	(0.0756)
ARD	–0.0218	0.0084	–0.0065	–0.0232	–0.0416	–0.0955***
	(0.0165)	(0.0245)	(0.0171)	(0.0174)	(0.0259)	(0.0325)
SIZE	0.2962*	0.4362*	0.4733**	0.3928**	0.1236	0.2035
	(0.1686)	(0.2355)	(0.1961)	(0.1763)	(0.2013)	(0.2559)
Constant	–11.4567*	–13.8948	–15.0144**	–13.9279**	–1.8789	–3.7386
	(5.8492)	(9.6482)	(7.4717)	(6.2269)	(7.7115)	(9.8233)
Sample size	141	141	141	141	141	141
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.4932	0.2371	0.2771	0.2688	0.2890	0.4389
	OLS	IC-manufacturing (ALBM)				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	16.0734	85.2314***	75.3017***	38.8660*	33.4115**	16.5095
	(26.3421)	(14.6923)	(17.3179)	(22.8299)	(16.3454)	(28.1016)
FF2	–6.8013	–45.1767***	–38.9714***	–22.0220*	–17.5550*	–11.3556
	(14.5693)	(8.4281)	(9.7514)	(13.7045)	(9.6384)	(16.3657)
REVG	0.0034	–0.0425	0.0126	0.0121	0.0261	0.0321
	(0.0124)	(0.0275)	(0.0261)	(0.0162)	(0.0198)	(0.0435)
RDD	–24.2077	–28.3749*	–17.1863	–16.4916	–24.2731	–15.5801
	(18.5914)	(15.9568)	(14.3061)	(16.8113)	(17.6984)	(20.2811)
BNIG	0.0019	0.0008	0.0012	0.0003	0.0033	0.0063
	(0.0016)	(0.0020)	(0.0021)	(0.0028)	(0.0042)	(0.0044)
OEG	0.0386	0.0952***	0.0665*	0.0449	0.0265	0.0108
	(0.0411)	(0.0321)	(0.0363)	(0.0450)	(0.0525)	(0.0557)
ARD	–0.0676*	–0.0065	–0.0304*	–0.0326**	–0.0437**	–0.0493*
	(0.0390)	(0.0179)	(0.0173)	(0.0158)	(0.0184)	(0.0276)
SIZE	1.6237***	1.2290***	0.7286**	1.1957**	1.1806***	0.1071
	(0.5738)	(0.3602)	(0.3032)	(0.4637)	(0.3903)	(0.7220)
Constant	–27.7005*	–58.4066***	–43.9714***	–30.2131***	–26.4750***	2.4943
	(15.9576)	(7.8164)	(7.9658)	(9.7549)	(8.5331)	(16.0777)
Sample size	129	129	129	129	129	129
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.3100	0.61140	0.3987	0.2297	0.1721	0.1980

Note: (1) FE – fixed effect; (2) Standard errors are shown in parentheses; (3) *p < 0.1; **p < 0.05; ***p < 0.01.

To summarize, QR evidences the effect of FF on FP is concave in the SI (including IC-design and IC-manufacturing) (Table 11). More specifically, the impact of FF on FP increases initially, then starts to decline after reaching the optimal FF value. From a tangible assets' perspective, QR shows the effect of FF on FP is a concave pattern in ALBM semiconductor, IC-design and IC-manufacturing firms. For AHBM firms, QR reveals the effect of FF on FP is concave in both IC-design and IC-manufacturing.

Table 11. Consolidated consequences

	EP											
	Semiconductor				IC-design				IC-manufacturing			
	OLS		QR		OLS		QR		OLS		QR	
FF	n.s.		+ (*)		+ (*)		+ (**)		n.s.		+ (**)	
FF2	n.s.		– (*)		– (**)		– (*)		n.s.		– (**)	
	AHBM		ALBM		AHBM		ALBM		AHBM		ALBM	
	OLS	QR	OLS	QR	OLS	QR	OLS	QR	OLS	QR	OLS	QR
FF	n.s.	n.s.	+ (*)	+ (**)	n.s.	+ (**)	n.s.	+ (*)	+ (*)	+ (*)	n.s.	+ (**)
FF2	n.s.	n.s.	– (*)	– (**)	n.s.	– (*)	– (*)	– (**)	– (*)	– (*)	n.s.	– (*)

Note: (1) n.s. – not significant; (2) *p < 0.1; **p < 0.05; ***p < 0.01.

3.6. Robustness check

To support the findings, stability tests were performed where multiple key variables were replaced. As ROA is a fundamental measure of FP, it replaced ROE. The re-estimates correspond to the main findings in the SI (including IC-design & IC-manufacturing) (Table 12 and 13).

In addition, financial flexibility with industry-adjustment (FF-ind) (Arslan-Ayaydin et al., 2104) replaced FF. Table 14 reveals a concave relationship between FF-ind and FP in the SI in all but the 90th quantile. FF-ind also has a concave impact on FP for IC-design in the 10th quantile and for IC-manufacturing in all quantiles (Table 15). These results align with the main results for the SI (including IC-design and IC-manufacturing) (Table 14 and 15).

Table 12. OLS and QR results for the SI using ROA

	OLS	SI				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	6.9655	8.6789***	7.7738***	7.4337***	7.8709***	7.0816*
	(4.1043)	(3.1269)	(2.0197)	(2.1374)	(2.3686)	(3.9438)
FF2	−2.6176	−3.5473**	−3.1533***	−2.8097**	−3.1735**	−2.6758
	(2.3502)	(1.7208)	(1.1358)	(1.2117)	(1.4357)	(2.2330)
REVG	0.0217***	0.0150**	0.0208***	0.0251***	0.0407***	0.0474***
	(0.0039)	(0.0073)	(0.0041)	(0.0063)	(0.0067)	(0.0058)

End of Table 12

	OLS	SI				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
RDD	–4.3242**	–2.5707***	–2.4076***	–0.9576	–0.7516*	–0.5836
	(1.0872)	(0.9832)	(0.8705)	(0.8531)	(0.4365)	(0.6884)
BNIG	0.0011*	0.0001	0.0001	0.0000	0.0002	0.0002
	(0.0005)	(0.0003)	(0.0003)	(0.0005)	(0.0006)	(0.0010)
OEG	0.0176**	0.0091***	0.0065	0.0140***	0.0149**	0.0244**
	(0.0048)	(0.0029)	(0.0042)	(0.0047)	(0.0075)	(0.0114)
ARD	–0.0002	0.0147***	0.0050	–0.0003	–0.0120**	–0.0156***
	(0.0065)	(0.0054)	(0.0055)	(0.0037)	(0.0048)	(0.0056)
SIZE	0.4317**	0.5285***	0.3512***	0.2834***	0.1076*	0.0470
	(0.1019)	(0.0692)	(0.0641)	(0.0753)	(0.0645)	(0.0679)
Constant	–8.6941**	–15.0197***	–9.8435***	–7.5551***	–3.0439**	–0.4481
	(2.4908)	(2.0397)	(1.7359)	(1.3393)	(1.3509)	(2.0358)
Sample size	683	683	683	683	683	683
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.4016	0.2214	0.1988	0.1946	0.2279	0.2952

Note: (1) FE – fixed effect; (2) Standard errors are shown in parentheses; (3) *p < 0.1; **p < 0.05; ***p < 0.01.

Table 13. OLS and QR results for IC-design and IC-manufacturing using ROA

	OLS	IC-design				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	9.5483*	17.0818**	11.2836***	6.0430*	9.4102**	–0.6109
	(4.2362)	(7.0189)	(3.9232)	(3.2318)	(4.2706)	(8.5587)
FF2	–3.8709**	–6.2230*	–3.9362**	–2.2745	–3.9848*	1.3395
	(1.3743)	(3.5220)	(1.9687)	(1.6746)	(2.1537)	(4.4467)
REVG	0.0055	0.0187**	0.0216***	0.0236***	0.0384***	0.0430***
	(0.0055)	(0.0080)	(0.0056)	(0.0070)	(0.0094)	(0.0069)
RDD	–9.7816*	–6.1284***	–3.5458**	–2.5118*	–1.3048	–0.8510
	(4.2217)	(2.0812)	(1.6142)	(1.2957)	(0.8076)	(0.5487)
BNIG	0.0018**	0.0001	0.0001	0.0000	0.0002	0.0002
	(0.0005)	(0.0005)	(0.0003)	(0.0004)	(0.0006)	(0.0010)
OEG	–0.0022	0.0079**	0.0066*	0.0118*	0.0114	0.0169
	(0.0081)	(0.0038)	(0.0039)	(0.0070)	(0.0092)	(0.0109)
ARD	–0.0365*	0.0228***	0.0097**	–0.0002	–0.0058	–0.0145**
	(0.0156)	(0.0068)	(0.0041)	(0.0048)	(0.0053)	(0.0056)

End of Table 13

	OLS	IC-design				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
SIZE	1.2824	0.6868***	0.6606***	0.5989***	0.3945***	0.4620**
	(1.2933)	(0.1708)	(0.1715)	(0.1125)	(0.1140)	(0.1867)
Constant	–18.4589	–21.8260***	–16.6070***	–10.2685***	–7.3752***	–2.3978
	(20.6568)	(4.1986)	(3.0916)	(2.8345)	(2.6344)	(4.3965)
Sample size	413	413	413	413	413	413
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.7594	0.2405	0.2328	0.2140	0.2132	0.2724
	OLS	IC-manufacturing				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	3.3784	6.3424	12.0072***	10.9121***	9.3594**	8.8115*
	(10.0892)	(4.6345)	(2.5274)	(3.2344)	(4.1297)	(4.9430)
FF2	–4.4632	–2.9896	–6.7193***	–5.4588***	–3.8874	–3.8937
	(5.6197)	(2.6411)	(1.4217)	(1.9206)	(2.7385)	(2.8094)
REVG	–0.0064	0.0082	0.0135**	0.0177***	0.0292***	0.0269**
	(0.0070)	(0.0117)	(0.0058)	(0.0063)	(0.0104)	(0.0126)
RDD	–43.9336***	–14.9961***	–13.4220***	–10.3380***	–5.3128	0.3402
	(8.9285)	(3.7895)	(3.1265)	(3.5650)	(5.2072)	(4.2383)
BNIG	0.0014**	0.0004	–0.0000	0.0003	–0.0003	0.0033*
	(0.0006)	(0.0005)	(0.0007)	(0.0008)	(0.0012)	(0.0020)
OEG	0.0101	0.0149	0.0214***	0.0087	0.0032	0.0117
	(0.0179)	(0.0107)	(0.0081)	(0.0095)	(0.0177)	(0.0203)
ARD	–0.0098	–0.0079	–0.0095***	–0.0088	–0.0277***	–0.0295***
	(0.0105)	(0.0113)	(0.0036)	(0.0063)	(0.0098)	(0.0104)
SIZE	4.0850**	0.5945***	0.4244***	0.3222***	0.1499	0.0164
	(1.7399)	(0.1084)	(0.0717)	(0.0847)	(0.1324)	(0.1052)
Constant	–62.2033**	–11.9705***	–10.2125***	–7.9638***	–2.9406	0.2620
	(29.6339)	(3.0770)	(1.7886)	(1.9081)	(2.4959)	(3.0639)
Sample size	270	270	270	270	270	270
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.6241	0.2828	0.2343	0.1740	0.1462	0.2105

Note: (1) FE – fixed effect; (2) Standard errors are shown in parentheses; (3) *p < 0.1; **p < 0.05; ***p < 0.01.

Table 14. OLS and QR results for the SI using FF-ind

	OLS	SI				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	2.4929**	8.6789***	7.7738***	7.4337***	7.8709***	7.0816*
	(0.8308)	(3.1269)	(2.0197)	(2.1374)	(2.3686)	(3.9438)
FF2	−3.5582	−3.5473**	−3.1533***	−2.8097**	−3.1735**	−2.6758
	(4.7440)	(1.7208)	(1.1358)	(1.2117)	(1.4357)	(2.2330)
REVG	0.0217***	0.0150**	0.0208***	0.0251***	0.0407***	0.0474***
	(0.0040)	(0.0073)	(0.0041)	(0.0063)	(0.0067)	(0.0058)
RDD	−4.3242**	−2.5707***	−2.4076***	−0.9576	−0.7516*	−0.5836
	(1.1521)	(0.9832)	(0.8705)	(0.8531)	(0.4365)	(0.6884)
BNIG	0.0011*	0.0001	0.0001	0.0000	0.0002	0.0002
	(0.0005)	(0.0003)	(0.0003)	(0.0005)	(0.0006)	(0.0010)
OEG	0.0177**	0.0091***	0.0065	0.0140***	0.0149**	0.0244**
	(0.0047)	(0.0029)	(0.0042)	(0.0047)	(0.0075)	(0.0114)
ARD	−0.0000	0.0147***	0.0050	−0.0003	−0.0120**	−0.0156***
	(0.0063)	(0.0054)	(0.0055)	(0.0037)	(0.0048)	(0.0056)
SIZE	0.4315**	0.5285***	0.3512***	0.2834***	0.1076*	0.0470
	(0.1003)	(0.0692)	(0.0641)	(0.0753)	(0.0645)	(0.0679)
Constant	−6.8669**	−15.0197***	−9.8435***	−7.5551***	−3.0439**	−0.4481
	(1.9033)	(2.0397)	(1.7359)	(1.3393)	(1.3509)	(2.0358)
Sample size	683	683	683	683	683	683
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.3991	0.1771	0.1592	0.1489	0.1573	0.2294

Note: (1) FE – fixed effect; (2) Standard errors are shown in parentheses; (3) *p < 0.1; **p < 0.05; ***p < 0.01.

Table 15. OLS and QR results for IC-design and IC-manufacturing using FF-ind

	OLS	IC-design				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	2.5861	14.5448***	7.3853***	2.2857	−0.7155	−2.7084
	(1.9545)	(3.5282)	(2.6673)	(1.9282)	(1.9677)	(2.3409)
FF2	−6.4550	−17.4316*	−8.3189	−3.4185	−0.7559	18.2784**
	(4.0240)	(10.3246)	(6.5230)	(6.5566)	(9.1937)	(8.5159)
REVG	0.0052	0.0234**	0.0293***	0.0340***	0.0588***	0.0636***
	(0.0046)	(0.0094)	(0.0082)	(0.0089)	(0.0149)	(0.0122)
RDD	−9.7489**	−5.6788**	−5.8332**	−3.1711	−1.6405	−1.5324**
	(4.3551)	(2.6724)	(2.3867)	(1.9430)	(1.1921)	(0.6280)

End of Table 15

	OLS	IC-design				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
BNIG	0.0018***	0.0001	0.0001	0.0001	0.0003	0.0002
	(0.0006)	(0.0005)	(0.0005)	(0.0005)	(0.0012)	(0.0018)
OEG	–0.0011	0.0098	0.0091	0.0126	0.0230	0.0330
	(0.0094)	(0.0060)	(0.0057)	(0.0090)	(0.0147)	(0.0269)
ARD	–0.0368***	0.0304***	0.0160**	–0.0011	–0.0080	–0.0121
	(0.0116)	(0.0091)	(0.0070)	(0.0092)	(0.0095)	(0.0127)
SIZE	1.0548	0.8883***	0.8694***	1.1171***	0.7143***	0.8160***
	(1.5276)	(0.2341)	(0.1970)	(0.2356)	(0.1952)	(0.3017)
Constant	–12.0249	–15.4109***	–12.4910***	–13.4866***	–5.1336*	–5.2607
	(23.4220)	(3.4284)	(3.0838)	(3.7268)	(3.0506)	(4.4906)
Sample size	413	413	413	413	413	413
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.7594	0.2433	0.2091	0.1919	0.1925	0.2593
	OLS	IC-manufacturing				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	3.7719***	34.7850***	13.0401**	10.3303***	7.4088***	10.4727***
	(0.5846)	(12.5297)	(6.2150)	(3.0672)	(2.4955)	(3.0569)
FF2	–14.6546**	–122.1948***	–48.3419**	–38.6391***	–26.2759***	–29.5665***
	(4.7592)	(42.7519)	(19.9512)	(10.0797)	(8.8560)	(1 0.1190)
REVG	0.0120	–0.0210	0.0130	0.0144	0.0181	–0.0013
	(0.0087)	(0.0227)	(0.0130)	(0.0102)	(0.0168)	(0.0211)
RDD	–8.3288	–2.2158	–13.4071**	–9.0809	0.4396	–11.0501
	(5.5924)	(11.5834)	(5.8269)	(5.7885)	(6.9957)	(7.7626)
BNIG	0.0008	0.0006	–0.0002	0.0003	0.0006	0.0051
	(0.0011)	(0.0018)	(0.0012)	(0.0015)	(0.0021)	(0.0047)
OEG	0.0270	0.1907***	0.0919**	0.0718*	0.0981**	0.1041*
	(0.0149)	(0.0620)	(0.0447)	(0.0430)	(0.0382)	(0.0611)
ARD	–0.0099	–0.0132	–0.0163*	–0.0237**	–0.0359***	–0.0480***
	(0.0083)	(0.0250)	(0.0084)	(0.0097)	(0.0127)	(0.0163)
SIZE	0.3230**	0.7674***	0.8623***	0.5549***	0.2031	0.2847
	(0.1025)	(0.2094)	(0.1449)	(0.1196)	(0.1597)	(0.2264)
Constant	–5.6422**	–12.8552***	–11.4620***	–4.8511**	2.7611	3.8018
	(1.5901)	(4.0878)	(2.5370)	(2.2498)	(3.0855)	(4.5781)
Sample size	270	270	270	270	270	270
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R–square/ Pseudo R^2	0.2751	0.3176	0.2164	0.1788	0.1701	0.2230

Note: (1) FE – fixed effect; (2) Standard errors are shown in parentheses; (3) *p < 0.1; **p < 0.05; ***p < 0.01.

4. Discussion

This empirical investigation of the nonlinear FF-FP relationship uses OLS and QR analysis on data from TSE listed semiconductor firms. The results elicit several findings regarding the relationship between FF and FP.

First, the QR estimation results expose that FF has a concave influence on FP in the lower and median ROE quantiles of Taiwan's SI. This finding concurs with the propositions of Gu and Yuan (2020) and Yi (2020); nevertheless, it is inconsistent with Al-Slehat (2019), Ali and Siddiqui, (2020) and Teng et al. (2021), who all suggest there is a positive FF-FP relationship, and Agha and Faff (2014), who propose there is a negative FF-FP relationship. There could be two reasons for this discrepancy. Prior studies analyze the relationship between FF and FP in non-pandemic periods, whilst this research claims the concave FF-FP relationship depends upon pandemic circumstances. The second reason could be due to the different sample industry (semiconductor vs. non-semiconductor industry). Furthermore, when the sampled firms are divided into IC-design and IC-manufacturing, FF also has a concave effect on FP in the lower quantiles for IC-design and in all ROE quantiles for IC-manufacturing. Consequently, the concave relationship is prominent in Taiwan's SI (including IC-design and IC-manufacturing) amid the COVID-19 pandemic.

Second, on dividing the SI (including IC-design & IC-manufacturing) into AHBM and ALBM firms, this research identifies a concave FF-FP nexus in the lower quantiles of AHBM IC-design firms and in the lower and median quantiles of AHBM IC-manufacturing companies; nevertheless, FF has an insignificant influence on FP in AHBM semiconductor companies. The results support the trade-off theory which proposes companies should maintain an optimal FF level to balance the disadvantages and advantages of FF. The research results highlight the need for AHBM IC-design and IC-manufacturing firms to optimize their FF to ensure they reach the optimal FP, especially in the lower and median ROE quantiles. This knowledge can support and motivate firms to consistently implement policies to maintain FF levels.

Third, there is a concave relationship between FF and FP in ALBM SI lower and median quantiles, IC-design upper quantiles and in all IC-manufacturing quantiles except the 90th. These findings are similar to Chang and Wu (2022) who validated a concave FF-FP relationship in ALBM hospitality companies. These results confirm that FF is significant to decision-making for ALBM hospitality companies and empirically sustains the trade-off theory. ALBM companies should strive to achieve their optimal FF based on the marginal benefits and costs of FF.

Fourth, further OLS regression of the 2019 period reveals the FF-FP relationship is not curvilinear for the SI (including IC-design and IC-manufacturing); however, amid the COVID-19 epidemic period, FF has a significant concave relationship in the IC-design industry (Table 4, 6, 16, and 17). This suggests that in terms of FF, there was a structural change in the IC-design industry as a result of the COVID-19 shock.

Table 16. Summary of OLS and QR analysis for the SI in 2019

	OLS	SI				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	55.8621	58.5542***	19.3585**	6.7866	10.3152***	9.8748
	(30.5708)	(20.9044)	(9.5368)	(4.4900)	(3.5247)	(6.7062)
FF2	−24.0337	−24.9412**	−7.5106	−2.2697	−4.9191***	−4.8730
	(13.3614)	(10.0908)	(4.7140)	(2.2481)	(1.7564)	(4.1242)
REVG	−0.00004	0.0199*	0.0276***	0.0306***	0.0371***	0.0473***
	(0.0121)	(0.0120)	(0.0100)	(0.0093)	(0.0117)	(0.0154)
RDD	−8.6415	−4.4989***	−3.9779***	−3.0258***	−2.8110***	−1.6656
	(2.6097)	(1.6896)	(1.2257)	(0.7988)	(0.8956)	(1.1055)
BNIG	0.0005	0.0008	0.0011	0.0014	0.0013***	0.0016**
	(0.0008)	(0.0024)	(0.0015)	(0.0014)	(0.0005)	(0.0007)
OEG	0.0023	−0.0190	0.0332	0.0532**	0.0675***	0.0939***
	(0.0070)	(0.0244)	(0.0218)	(0.0223)	(0.0219)	(0.0251)
ARD	−0.0664	0.0133	−0.0032	−0.0101*	−0.0230***	−0.0261**
	(0.0181)	(0.0116)	(0.0060)	(0.0055)	(0.0068)	(0.0105)
SIZE	12.3688*	0.7974***	0.7053***	0.5214***	0.4020***	0.3360**
	(1.1176)	(0.1584)	(0.1729)	(0.1316)	(0.1238)	(0.1492)
Constant	−212.4983**	−46.7337***	−21.0817***	−9.3556***	−5.7976**	−2.8173
	(0.2930)	(11.3472)	(5.4318)	(3.3948)	(2.5355)	(3.7270)
Sample size	533	533	533	533	533	533
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.7768	0.2673	0.1747	0.1584	0.1615	0.2296

Note: (1) FE – fixed effect; (2) Standard errors are shown in parentheses; (3) *p <0.1; **p < 0.05; ***p < 0.01.

Table 17. Summary of OLS and QR results for ICdesign and IC-manufacturing in 2019

	OLS	IC-design				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	84.4382	28.4059	3.5435	1.1390	8.8847	4.6679
	(65.2871)	(18.4480)	(8.0654)	(6.9599)	(6.2100)	(15.8636)
FF2	−35.8374	−9.8056	0.3180	0.0818	−4.5420	−2.3068
	(29.4161)	(7.9938)	(3.6767)	(3.0396)	(3.0214)	(7.9120)
REVG	−0.0164	0.0169	0.0265**	0.0253**	0.0357**	0.0529**
	(0.0245)	(0.0118)	(0.0104)	(0.0118)	(0.0167)	(0.0213)
RDD	−9.2412	−8.3156***	−4.9482***	−3.2994**	−4.3189***	−4.1850***
	(4.1003)	(2.0074)	(1.8325)	(1.3206)	(1.1973)	(1.3013)
BNIG	0.0013	0.0025	0.0012	0.0015*	0.0012**	0.0014**
	(0.0013)	(0.0027)	(0.0012)	(0.0007)	(0.0006)	(0.0007)

End of Table 17

	OLS	IC-design				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
OEG	0.0031	−0.0233	0.0127	0.0420	0.0647***	0.0879***
	(0.0201)	(0.0255)	(0.0278)	(0.0269)	(0.0246)	(0.0278)
ARD	−0.0580	0.0137	0.0044	−0.0089	−0.0243***	−0.0249
	(0.0350)	(0.0124)	(0.0084)	(0.0071)	(0.0094)	(0.0208)
SIZE	11.1043**	0.8163***	1.0131***	0.9485***	0.7273***	0.9920**
	(3.4367)	(0.2544)	(0.2842)	(0.2479)	(0.2072)	(0.4106)
Constant	−202.9335	−31.1349**	−18.1787***	−12.1262***	−8.8616**	−9.0093
	(86.2900)	(12.5138)	(6.4517)	(4.4121)	(4.2296)	(8.5953)
Sample size	319	319	319	319	319	319
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R–square/ Pseudo R^2	0.7449	0.2588	0.2203	0.1930	0.1969	0.2514
	OLS	IC-manufacturing				
		Lower quantiles		Median	Upper quantiles	
		10th	25th	50th	75th	90th
FF	−22.8701	105.3806***	63.8813**	10.0445	21.4155**	23.7072***
	(16.3994)	(29.5939)	(27.0121)	(13.5368)	(8.5897)	(7.8244)
FF2	10.6330	−54.0137***	−33.2857**	−4.4599	−11.0545**	−13.0434***
	(6.1078)	(15.9317)	(14.6361)	(7.2526)	(4.9286)	(4.3937)
REVG	−0.0080	0.0020	0.0125	0.0228	0.0116	0.0097
	(0.0152)	(0.0172)	(0.0160)	(0.0150)	(0.0140)	(0.0133)
RDD	−83.8957	−32.3345*	−14.2528*	−12.4131	−2.6227	−5.8270
	(39.8860)	(17.4214)	(7.9427)	(9.0050)	(8.0842)	(4.9450)
BNIG	0.0004	0.0007	0.0013	0.0012	0.0025	0.0026
	(0.0004)	(0.0020)	(0.0025)	(0.0026)	(0.0023)	(0.0023)
OEG	0.0873*	0.0134	0.0583*	0.0748**	0.0589	0.0908**
	(0.0295)	(0.0343)	(0.0308)	(0.0352)	(0.0445)	(0.0420)
ARD	−0.0760	−0.0294	−0.0181	−0.0186*	−0.0437***	−0.0339*
	(0.0360)	(0.0240)	(0.0128)	(0.0108)	(0.0148)	(0.0178)
SIZE	2.5191	0.9163***	0.8730***	0.6188***	0.3384*	0.2965*
	(2.0061)	(0.2600)	(0.2137)	(0.1958)	(0.1844)	(0.1676)
Constant	−19.6478	−62.5893***	−41.2809***	−11.5581	−8.5791	−7.9031
	40.0197	(13.1422)	(12.7164)	(7.4030)	(5.5212)	(5.2863)
Sample size	214	214	214	214	214	214
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
R-square/ Pseudo R^2	0.8914	0.4801	0.2953	0.2096	0.1639	0.2016

Note: (1) FE – fixed effect; (2) Standard errors are shown in parentheses; (3) *p < 0.1; **p < 0.05; ***p < 0.01.

Conclusions, implications and future research

This study adds to current literature by evidencing the relationship between FF and FP has a concave pattern in Taiwan's SI (including IC-design & IC-manufacturing) amid the COVID-19 shock. On dividing the SI (including IC-design & IC-manufacturing) into AHBM and ALBM firms, the research reveals a concave FF-FP relationship in both AHBM and ALBM IC-design and IC-manufacturing firms. Overall, the findings confirm that FF adds value during difficult market conditions, particularly the COVID-19 pandemic period.

The empirical results of this study elicit several practical implications. First, policymakers should develop FF policies that enable companies to respond positively amid a crisis, such as financial difficulty during an epidemic, and maintain effective investment policies. SI (including IC-design & IC-manufacturing) managers of lower and median ROE quantile firms should focus on dynamic control and optimization of FF to obtain the greatest FP, as external financing is more difficult in comparison to firms with greater FP. Second, from the perspective of investors, the results can be used as a reference for SI portfolio evaluation. Analysts or investors can compare a company's FF against the proposed thresholds to predict their possible future performance.

This study is not free from limitations. Despite the ongoing COVID-19 pandemic, the data only analyzed data from Q1 2020 to Q1 2021, from TSE listed firms and after the outbreak of the pandemic. Ongoing research should include longer periods of study across several countries. From a methodology perspective, the empirical findings are predominantly documented using static panel data methods (OLS and QR) and correlation analysis. To use the Generalized Method of Moments for the robustness check, analysis should take place over a longer period (more quarters).

Lastly, as the emphasis on sustainable development increases, interest in environmental innovation practices has risen among scholars and practitioners (Hizarci-Payne et al., 2021; Ardito et al., 2016; Aldieri, 2013). The meta-analysis of Hizarci-Payne et al. (2021) indicates that organizational environmental innovation has the greatest impact on FP. Thus, future studies should discuss the role of environmental innovation on the relationship between FF and FP.

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