

THE QUIET REVOLUTION

THE RISE OF INDEX FUNDS AND THEIR IMPACT ON INNOVATION

ROBIN CAMINGER

EDVIN NILSSON

Master Thesis

Stockholm School of Economics

2024



The Quiet Revolution: The Rise of Index Funds and Their Impact on Innovation

Abstract

Using a sample of 3,133 US-listed firms from 2011 to 2019, we examine if the level of index fund ownership impacts firm innovation. We find a positive relationship between index fund ownership, R&D spending, and the number of patents granted on a firm level, indicating that index funds positively influence corporate governance in their portfolio firms. The effect is stronger examining high-technology firms in isolation, suggesting that the impact of index fund ownership depends on the relative importance that innovation holds for industry-level competition. Finally, blockholder fund management company ownership exerts no marginal influence on index fund ownership and innovation, implying that ownership size does not explain index funds' incentives for stewardship. This paper contributes to the literature by demonstrating the positive influence of passive institutional ownership, and more specifically that of index funds, on corporate governance.

Acknowledgements:

We would like to thank our supervisor Paula Roth for her support and guidance

Keywords:

Innovation, index funds, passive ownership, patents, R&D

Authors:

Robin Caminger (24886)

Edvin Nilsson (24752)

Tutor:

Paula Roth, Postdoctoral Researcher, Department of Finance

Examiner:

Anders Anderson, Associate Professor, Department of Finance

Master Thesis

Master of Science in Finance

Stockholm School of Economics

© Robin Caminger & Edvin Nilsson, 2024

I. Introduction

Index funds offer clear benefits to investors in the form of accessibility, low expense ratios, and a diversified exposure to equity markets (Sharpe, 1991). In light of these advantages, it is not surprising that index funds have experienced a surge in popularity. Farizo (2022) reports that total index fund ownership across US-equities has grown from just 3% in 2000, to 21% in 2022. In addition, articles in *Forbes* and *Morningstar* showcase how the popularity of index funds continues to rise (Carosa, 2024; Rekenthaler, 2024). Despite their clear advantages, index funds have not been met with universal praise, where several sources have questioned their impact on corporate governance, arguing that their low-cost structures could imply insufficient incentives to monitor management (e.g., Bebchuk and Hirst, 2019; Schmidt and Fahlenbrach, 2017; Heath et al., 2022). The large and increasing ownership stakes of index funds, combined with corporate governance being a key determinant of firm-value (Ammann, 2011), signify the importance of understanding how index funds impact corporate governance in their portfolio firms.

Despite this, current research on index fund ownership and corporate governance is flawed in several respects. First, most research focuses on institutional ownership as a whole rather than specifically examining index funds. This approach ignores the heterogeneity of investment profiles amongst institutional investors (e.g., Lewellen and Lewellen, 2022; Bena et al., 2017; Boone and White, 2015). Furthermore, literature on institutional ownership and corporate governance is contradictory. Whereas some papers identify a positive effect (e.g., Hartzell & Stark, 2003; Chen et al., 2020; Aghion et al., 2013), others have found a partly negative relationship, where the type of institutional investor (e.g., mutual-, hedge-, or index fund) and the investment horizon of the institutional investor (i.e., short- vs long-term) appear to be important factors in explaining the discrepancy (Harford et al., 2018; Chi et al., 2019). Considering how index funds structurally differ from other types of institutional investors, such as in their inability to exit investments at will, it is evident that simply extrapolating results of current research on institutional ownership to index funds is insufficient to determine its impact on corporate governance. Second, the minority of research focusing specifically on index funds also presents varying results. On the one hand, Bebchuk and Hirst (2019) make a compelling theoretical argument for why index fund ownership is detrimental for corporate governance, which has been substantiated empirically (e.g., Schmidt and Fahlenbrach, 2017; Brav et al., 2018). On the other hand, against this negative view,

theoretical arguments have been made arguing for an opposite, positive effect (Lewellen and Lewellen, 2021). This positive effect has also been validated by several empirical studies (e.g., Fu et al., 2021; Appel et al., 2016; Crane et al., 2016), demonstrating how no definitive conclusion can be drawn regarding the impact of index fund ownership on corporate governance by examining the current literature. In addition, the research also fails to consider how the impact of index fund ownership might vary depending on firm and industry characteristics (Fu et al., 2021). Third, no unison definition of corporate governance has been used when estimating the impact of varying ownership types on innovation. Instead, different research papers study different aspects of corporate governance with mixed results, e.g., management remuneration (Brav et al., 2019), payout policy (Crane et al., 2016) and board structures (Appel et al., 2016).

In accordance with several papers, we argue that firm-level innovation is particularly suitable to determine the effect of ownership structures on corporate governance (e.g., Aghion et al., 2013; Fang et al., 2014; Fu et al., 2021). This is motivated by three factors. First, innovation is generally characterized by some degree of risk and skewed payoff structures and is therefore sensitive to well-functioning corporate governance (Stein, 1988; Holmström, 1989; Manso, 2011). Second, a company's ability to innovate is a major success driver, increasing profitability, creating competitive advantages, and ultimately being an important determinant of firm-value (Hirshleifer et al., 2018; Bedford et al., 2021; Porter, 1985). Third, literature examining index funds' effect on innovation is severely limited. While some papers have examined the role of institutional investors on innovation (e.g., Aghion et al., 2013; Fang et al., 2014) there is only one paper, to the best of our knowledge, that studies index fund ownership and its impact on firm-level innovation. Using a sample of Chinese firms between 2007 and 2017, Fu et al., (2021) find a significant positive relationship between index fund ownership and innovation. However, considering the substantial difference in market efficiency, investor sophistication and institutional ownership levels between the Chinese and U.S stock markets (Carpenter et al., 2021; Allen et al., 2024), we argue that their findings cannot be directly generalized.

In light of these weaknesses, our study contributes to the literature by adding to the small subset of papers that specifically focus on the impact of index fund ownership on innovation. This is achieved by utilizing a comprehensive panel dataset of US-listed firms from 2011 to 2019. Our sample consists of 3,133 firms (22,817 firm-year observations) with a total market capitalization of USD 31,659 billion, covering 93.4% of the total US market capitalization as of December 31, 2019. Innovation is measured at both the input-

(R&D/Assets) and output level (patents granted) and, as a novel contribution to the literature, at the quality level (number of forward citations per patent). To allow for firm-level heterogeneity, following Fu et al., (2021), we also measure the impact on innovation when distinguishing between high- and low-technology industry belonging. Finally, as an additional contribution, we examine the varying impact of index fund ownership by considering the total ownership stake of the fund management company at the firm level, reflecting the stronger monitoring incentives associated with larger shareholdings (Shleifer and Vishny, 1986)

Our results show that index fund ownership is positively related to increases in innovation input and output, whilst its effect on innovation quality is negligible. For a one-unit (percent) increase in index fund ownership, R&D/Assets increase by 0.07 percentage points and patents granted increase by 0.40%. The results are robust to the inclusion of control variables, varying time periods, winsorizing and logarithmic transformation.

The results are consistent with prior research identifying a positive relationship between institutional ownership and innovation (Aghion et al., 2013; Fang et al., 2014), supporting the value-maximizing view of index fund ownership (Lewellen and Lewellen, 2021) while challenging the agency-cost perspective (Bebchuk and Hirst, 2019). It suggests that index funds' incentives to monitor, for instance driven by their significant ownership stakes and lack of exit options, outweigh potential disincentivizing effects, such as their low management fees. In addition, our results indicate an effect in line with Fu et al., (2021). However, in terms of economic magnitude, we document a stronger effect in our US sample, underscoring the importance of accounting for inter-country differences in market characteristics when studying the influence of index fund ownership.

Second, when grouping firms into high- or low-technology industry belonging, we discover that the effect of index fund ownership on innovation varies considerably compared to treating them as a single, homogenous group. For high-technology firms, index fund ownership is associated with a significant positive effect on R&D spending, patents granted, and as a novel finding, the number of forward citations per patent. Conversely, when examining low-technology firms, index fund ownership is related to a decrease in R&D spending and shows no relationship to patents granted or forward citations. For high-technology firms, a one-unit (percent) increase in index fund ownership is associated with a 0.12 percentage point increase in R&D/Assets, whilst we observe a 0.05 percentage point reduction for low-technology firms. The results are robust to the inclusion of control variables, varying time periods, winsorizing and logarithmic

transformation, and in line with Fu et al., (2021) who also identify a larger positive effect for high-technology firms.

We thus conclude that the impact of index fund ownership on firm-level innovation varies depending on the relative importance that innovation holds for industry-level competition. For industries where innovation is more crucial to remain competitive, the marginal impact of index fund ownership is stronger as compared to industries where innovation ability is not as important. The negative coefficient of R&D/Assets for the low-technology subsample also indicates that the effect does not only differ in magnitude but also in sign, where a potential explanation is that index funds, through their monitoring, help bring innovation spending to levels that are appropriate for the firm given its industry belonging. For firms in low-technology sectors, this could mean reducing R&D expenditure to avoid overinvestment, for instance in the form of empire building (Lo & Shaih-Hou, 2022). Importantly, this finding accentuates the significance in accounting for industry belonging, a consideration missing in much of the previous research (e.g., Bena et al., 2017; Aghion et al., 2013; Appel et al., 2016). Third, allowing for differences in fund management company ownership concentration, we identify, opposite to theory and popular marketing messages of the biggest index fund providers (e.g., Blackrock, 2023; Vanguard, 2023; SSGA, 2023), that higher concentration of fund management company ownership is not associated with a marginal increase in the positive effect that index fund ownership exerts on innovation. As such, we conclude that ownership size is not a key determinant for index fund stewardship in their portfolio firms. However, as we are unable to determine which factor, or factors thereof, that govern stewardship activities by index funds, we suggest this as a future area of research.

II. Theoretical Background

The question of how index fund ownership impacts firm innovation and corporate governance is fundamentally related to the principal-agent problem. The principal-agent problem has a long history within the field of corporate governance, highlighting how informational asymmetry and incentive misalignment create conflicting interest between shareholders (the principals) and management (the agents) (Berle & Means, 1932; Jensen & Meckling, 1976). To mitigate this issue, two types of strategies have been suggested. The first focuses on reducing the impact of incentive misalignment between shareholders and managers, for instance by increasing the share of equity-based compensation. The second aims to reduce the effect of informational asymmetry, with solutions covering improved market regulation and monitoring. This paper focuses on the monitoring aspect of mitigating the principal-agent problem.

One issue with utilizing monitoring to mitigate the principal-agent problem is the free-rider problem. In the context of corporate governance, this illustrates how individual shareholders have weak incentives to monitor since the cost of monitoring is incurred by one (or a few) shareholders, whilst the benefits are enjoyed by all. Consequently, shareholders will tend to underinvest in monitoring relative to optimal levels. Since the free-rider problem is reduced by ownership concentration (Grossman and Hart, 1980 & Shleifer and Vishny, 1986), institutional investors' impact on monitoring, given their large and growing ownership stakes, have become subject to extensive research.

However, relative to other institutional investors, index funds differ in several important regards which are hypothesized to induce changes in their incentives for stewardship. On the one hand, index funds have two notable characteristics believed to produce a higher willingness to monitor, denoted as the “value-maximization view” (Lewellen and Lewellen, 2021; Bebchuk and Hirst, 2019). First, by design, index funds lack the possibility to exit investments at will. As such, they are assumed to have relatively stronger incentives to engage in monitoring as this is the only way for them to affect returns. Second, as an effect of their growing popularity, some index funds have accumulated substantial ownership shares in their portfolio companies, exceeding that of their institutional counterparts (Farizo, 2022), implying stronger incentives for stewardship (Grossman and Hart, 1980; Shleifer and Vishny, 1986).

On the other hand, index funds also have two notable characteristics believed to induce a negative effect on their propensity to monitor, named “the agency-cost view”

(Bebchuk and Hirst, 2019). First, compared to other types of institutional investors, index funds have substantially lower management fees, meaning that they capture less of the upside in engaging in stewardship. As such, *ceteris paribus*, their incentives to be engaged shareholders should be lower compared to their active institutional counterparts. Second, index funds may have conflicting interests relative to the fund management company that they belong to. Fund management companies can have business ties to firms included in the index they track, for instance in the form of 401(k) plans. This may act as a disincentive to engage in shareholder activism, since voting against management might imply that the constituent company changes its supplier of 401(k), causing the fund management company to lose out on management fees.

To summarize, the value-maximization view and the agency-cost view both provide compelling arguments as to why index funds should (or should not) have adequate incentives to be engaged stewards. It is thus evident that empirical research is required to bridge this gap in understanding, which, considering the small amount of past literature on the topic, further underscores the contribution of our paper.

III. Data, Variables, and Model Design

A. Data scope and firm selection

Our dataset consists of US-listed firms, with a final sample size of 3,133 firms and a total market capitalization of USD 31,659 billion, covering 93.4% of total US market capitalization as of the 31st of December 2019. Consistent with prior research (e.g., Fu et al., 2021), we exclude companies in the financial industry, other listed financial vehicles (i.e., REITs and other investment vehicles), as well as some firms with missing data.

B. Innovation data

To measure innovation, we collect firm-level patent and R&D expense data. Patent data is gathered from the WRDS US Patents database who parse data directly from the US Patent and Trademark Office (“USPTO”). Individual patents are linked to the Compustat company database using Compustat Link. As patent data is provided for the years of 2011 through 2019, this constitutes the ultimate time horizon of our study. Our final patent sample consists of 741,561 patents granted for the firms in our dataset.

Research & Development (R&D) expense data is collected through the CRSP/Compustat Merged Annual Fundamental database.

C. Index fund data

To calculate the share of index fund ownership in each firm, we obtain mutual fund ownership data through the Thomson Reuters Mutual Fund Holding S12 database. Our sample consists of 119,996 mutual funds and their reported number of stocks owned in each company per each reporting date.

To identify index funds, we replicate the methodology of Busse and Tong (2012), Appel et al., (2016) and Hsieh et al., (2021) by classifying index funds based on whether their names contain a specific character string.¹ The final number of index funds is 11,446. To determine the index fund ownership share in a firm, we calculate the average number of shares held by the index fund in the company per each reporting date for each sample

¹ A fund is categorized as an index fund if its name contains any of the following strings: Index, Idx, Indx, Ind, Ind_ (_ indicating a space), Russell, S & P, S and P, S&P, SandP, S&P, SP, DOW, Dow, DJ, MSCI, Bloomberg, KBW, Nasdaq, FTSE, NYSE, STOXX, Wilshire, Morningstar, ETF, ETFs, 100, 400, 500, 600, 900, 1000, 1500, 2000, 4000, 5000. We also manually examine the largest index funds and correct any incorrect categorization

year, as well as the average number of total shares in that period to account for any changes in the number of shares outstanding. As the reporting periods for index fund ownership and total shares outstanding coincide, we use the following formula to calculate the total ownership of an index fund in a given company, where i denotes firm and t denotes year:

$$\text{Index Fund Ownership (\%)}_{i,t} = \frac{\sum_{i=1}^n \# \text{ of Index Fund Shares}_i}{\sum_{i=1}^n \# \text{ of Total Shares Outstanding}_i}$$

The ownership of each individual index fund is then aggregated to estimate the total fraction of index fund ownership in each firm.

Tables 1 and 2 show that US index fund ownership has increased steadily over the years. The average total index fund ownership per firm increased from 7.9% in 2011 to 16.0% in 2019, in line with the total market index fund ownership found in Farizo (2022).

D. Dependent variables

We use two main dependent variables that reflect the innovation ability of a firm, namely innovation input and output (Fu et al., 2021). R&D scaled by total assets reflects innovation input, whilst patents granted is a proxy for innovation output. R&D is expressed as a percentage of total assets to eliminate the effect of companies having varying R&D expenditures purely due to size. Firms are assumed to decide R&D spending at the beginning of the year, hence R&D/Assets and index fund ownership are regressed in the same year of observation. In other words, for every year t , we use the observed R&D expenditure of total assets and regress against the average index fund ownership observed during the year.

The second dependent variable, patents granted, is measured as the natural logarithm of total patents granted, but one year forward looking. Baranchuk et al., (2014), Fu et al., (2021) and He and Tian (2013) argue the effect of passive ownership is expected to be reflected in the firm's future ability to innovate, hence the patent variable is lagged. We calculate the natural logarithm of patents granted as a mitigator to outlier observations and to facilitate an easier interpretation of the dependent variable in the regressions (Liu et al., 2019).

Table 1: Index Ownership, R&D/Assets and Patents Granted

Year	N	Index Fund Ownership				R&D/Assets ²				Patents Granted ³			
		Mean	Std	Min	Max	Mean	Std	Min	Max	Mean	Std	Min	Max
2011	1,695	7.9%	4.1	0.0%	26.6%	5.8%	10.5	0.0%	88.0%	32	329.5	0	12,506
2012	1,800	8.4%	4.3	0.0%	26.1%	6.1%	11.0	0.0%	107.9%	33	338.4	0	13,092
2013	1,928	9.0%	4.7	0.0%	29.5%	6.2%	11.4	0.0%	140.3%	34	346.7	0	13,788
2014	2,153	9.4%	5.2	0.0%	37.6%	6.7%	10.7	0.0%	77.9%	34	363.2	0	15,324
2015	2,281	10.3%	5.4	0.0%	56.8%	7.0%	10.9	0.0%	100.3%	32	348.2	0	15,012
2016	2,670	10.4%	6.5	0.0%	50.1%	8.8%	16.5	-0.6%	197.5%	34	365.4	0	16,576
2017	2,888	13.8%	6.9	0.0%	39.0%	8.9%	16.4	0.0%	281.7%	35	389.6	0	18,514
2018	2,932	15.0%	7.3	0.0%	45.4%	9.3%	16.7	0.0%	190.6%	37	405.2	0	18,454
2019	2,858	16.0%	7.6	0.2%	50.9%	9.3%	16.5	0.0%	247.3%	41	417.4	0	18,346

Note: Table 1 shows mean, standard deviation, minimum and maximum statistics of index fund ownership, R&D/Assets and Granted Patents data for the years 2011 through 2019. N denotes the number of firms with index fund ownership and patent data per year. The final sample consists of 3,133 unique firms and has a total market value of USD 31,659 billion, covering 93.4% of US market cap. Index ownership data is gathered from the Thomson Reuters S12 Fund Holding database. Patent data is gathered through the WRDS US Patents database. R&D data is collected through CRSP/Compustat Annual Merged database. The “max” and “min” patent columns denote the spread between observed firms with the most and least patents granted.

E. Patent advancedness

It is not inherently evident that increased numbers of patents granted signify a higher degree of firm innovation, as a firm may increase its output of patents while simultaneously reducing their quality (Unsal and Rayfield, 2019). Consequently, as a novel contribution to the literature specifically examining index funds, we study the quality of innovation by measuring the number of forward citations per patent. A forward citation is a reference to a published patent in a later filed patent. According to the European Patent Office (2024), the number of forward citations in a patent is a strong value indicator, suggesting that the patent is more influential and advanced. As such, the number of forward citations a firm’s patents give rise to can be used to quantify the quality of innovation, giving deeper insights into what extent index fund ownership contributes to innovation.

² The negative R&D/Asset observation in 2016 is explained by a firm reporting negative net R&D

³ The high count of patents granted in the “Max” column represents the patents of a single, outlier firm observation. Results are robust to the exclusion and inclusion of this firm, including winsorizing the full sample at the 1% and 99% levels

To quantify this relationship, we calculate the average number of forward citations per year and for each firm in the sample. We then compute the natural logarithm of forward citations to minimize the effect of outliers, as well as facilitating a better interpretation of the regression outcome (Liu et al., 2019).

F. Control variable data

Six control variables are included to control for effects believed to affect a firm's ability to innovate, collected from the CRSP/Compustat Merged Annual Fundamental database. Similar variables are used in Amore et al., (2013), Baranchuk et al., (2014), Fu et al., (2021) and He & Tian (2013).

Size: Larger firms are likely to have more financial resources, allowing them to invest more into R&D. Furthermore, they may invest in long-term, high-risk projects that smaller sized firms cannot take on. Size is therefore controlled for as the natural logarithm of the firm's total assets in its balance sheet.

Market value: We control for market capitalization as it captures the view on the company's future growth abilities. Firms with high market values are likely better at innovating. Market value is thus controlled for by using the firm's market-to-book ratio (market value over book value shareholder's equity).

Capital structure: Firms with higher levels of debt are more likely to be financially constrained and unable to invest as much into R&D as less levered firms. The effect of capital structure is thereby controlled for by calculating leverage, defined as the ratio of assets over liabilities.

Profitability and growth: Profitable and fast-growing companies are likely to spend more on R&D, which is why we control for return on assets (net income divided by total assets of the firm), the ability to generate cash flow (i.e., operating cash flow over total assets), as well as the share of CAPEX of total assets.

G. High vs. low-technology firms

Innovation is generally regarded as a key competence for firms in order to remain competitive and maintain profitability. Not all firms have the same incentives to innovate (Aghion et al., 2005), and it has been shown that the impact of index funds vary depending on how technologically intensive the industry is (Fu et al., 2021). For example, innovation requirements in the retail sector are generally lower than compared to the software or

Table 2: Summary of Key Variables

		(1) N	(2) Mean	(3) SD	(4) Min	(5) Median	(6) Max
<i>Independent variable</i>	Index Ownership _{i,t}	22,817	11.3	6.7	0.0	10.5	56.8
<i>Dependent variables</i>	R&D/A _{i,t}	12,223	7.72	14.05	-0.6	2.34	281.69
	ln Patents Granted _{i,t+1}	22,817	1.0	1.6	0.0	0.0	9.8
	ln Forward Citations _{i,t+1}	22,817	0.5	0.8	0.0	0.0	5.9
<i>Control variables</i>	Size _{i,t}	22,817	7.6	1.9	1.3	7.5	14.8
	BM _{i,t}	21,761	0.5	1.1	-118.4	0.5	30.5
	Leverage _{i,t}	22,782	2.5	3.6	0.2	1.7	126.5
	CFO _{i,t}	22,806	5.2	16.0	-381.9	6.8	175.1
	CapExp _{i,t}	22,752	3.6	5.2	-0.1	2.1	127.4
	RoA _{i,t}	22,813	0.2	19.3	-473.0	2.7	402.3

Note: Table 2 shows summary statistics for the dependent, independent (index fund ownership) and control variables. *N* denotes total firm-year observations (2011 – 2019). The number of observations for R&D/A is lower due to some firms not reporting R&D expenses separately, and therefore missing in the CRSP/Compustat database. ‘Index Ownership’ denotes total index fund ownership in a firm. ‘ln Patents Granted’ denotes the natural logarithm of patents granted per year. ‘ln Forward Citations’ denotes the natural logarithm of average forward citations, per firm and per year. Size is defined as the logarithm of the firm’s total assets. BM denotes the firm’s book-to-market ratio (equity book value divided by market value of equity). CFO denotes operating cash flow as a percentage of total assets. CAPEXP shows CAPEX as a percentage of total assets. ROA stands for return on assets, i.e., net income divided by total assets. Control variable data is collected from the CRSP/Compustat Merged Annual Fundamental database.

pharmaceutical industries (Unsal and Rayfield, 2019). Therefore, we group firms based on the degree of urgency of innovation.

To categorize firms, we use a NAICS-code based approach developed by Hecker (2005), where firms belonging to high-technology industries are grouped for themselves, and non-high-technology firms separated. The classification has been adjusted to consider the 2017 revision of NAICS codes.

H. Fund management company ownership concentration

Our final contribution to the literature is studying whether total ownership at fund management company level, i.e., the aggregate ownership of each of its individual index funds in a given portfolio company, has a marginal influence on the impact of index fund ownership on innovation. This is motivated by considering that the incentives to monitor should rise as a function of ownership concentration (Shleifer and Vishny, 1986).

We quantify this effect by the use of a dummy variable and an interaction term, where a firm, per year, is assigned a 1 if any ownership stake of a fund management company

exceeds 5% or 10% (thresholds for two separate variables). All other firms are assigned a 0. The dummy variable is then interacted with total index fund ownership to examine the marginal impact of fund management company blockholder⁴ ownership.

Examining Table A1 in Appendix, we observe that index fund ownership concentration increases significantly between 2011 and 2019. For example, only 212 firms had at least one blockholder fund management company owner in 2011, compared to 1,954 firms in 2019.

I. Model design

The model is based on panel data, where we control for firm and year fixed effects and use firm-level clustered standard errors. The two main models to test our hypotheses are based on Fu et al., (2021) and are specified as follow:

$$R\&D/A_{i,t} = \alpha_{1i}INDEX_{i,t} + \alpha_{2i}FC_{i,t} + \gamma_t + \delta_i + \varepsilon_{i,t} \quad (1)$$

$$Patents\ G_{i,t+1} = \alpha_{1i}INDEX_{i,t} + \alpha_{2i}FC_{i,t} + \gamma_t + \delta_i + \varepsilon_{i,t} \quad (2)$$

Where $R\&D/A_{i,t}$ in model (1) refers to innovation input, measured as R&D as a percentage of total assets, and $Patents\ G_{i,t+1}$ in model (2) refers to the firm's innovation output, measured as the natural logarithm of patents granted. The $INDEX_{i,t}$ variable is the level of total index fund ownership per firm and per year. $FC_{i,t}$ are the control variables, per firm and per year. γ_t control year fixed effects, and δ_i control firm fixed effects. i is unique for each firm, and t denotes year.

As an extension to Fu et al., (2021) we also include a third model, where *Forward cites* indicates the average number of forward citations for patents granted, per firm and per year.

$$Forward\ cites_{i,t} = \alpha_{1i}INDEX_{i,t} + \alpha_{2i}FC_{i,t} + \gamma_t + \delta_i + \varepsilon_{i,t} \quad (3)$$

As an additional contribution, we test if blockholder fund management company ownership exerts marginal influence on index funds' impact on innovation. We introduce our final models, specified as follows:

⁴ A blockholder is a shareholder owning at least 5% of the firm's common stock (Holderness, 2009)

$$R\&D/A_{i,t} = \alpha_{1i}INDEX_{i,t} + \alpha_{2i}INDEX_{i,t} \times FM\ Dummy + \alpha_{3i}FC_{i,t} + \gamma_t + \delta_i + \varepsilon_{i,t} \quad (4)$$

$$Patents\ G_{i,t+1} = \alpha_{1i}INDEX_{i,t} + \alpha_{2i}INDEX_{i,t} \times FM\ Dummy + \alpha_{3i}FC_{i,t} + \gamma_t + \delta_i + \varepsilon_{i,t} \quad (5)$$

Where *FM Dummy* is interacted with the *INDEX* variable to determine the marginal effect of index fund ownership on innovation for firms with blockholder fund management company ownership.

IV. Discussion of Empirical Results

A. Panel A: Index Fund Ownership Impact on Innovation Input, Output and Quality

Panel A examines the impact of index fund ownership on innovation input (R&D/Assets), innovation output (patents granted) and innovation quality (forward citations per patent). Regressions (1) and (2) regress index fund ownership on innovation input. When including firm control variables, R&D as a share of total assets increase by 0.070 percentage points for each unit (percent) increase in index fund ownership, statistically significant at the 1% level (negative and statistically insignificant when excluding control variables). Regressions (3) and (4) indicate a positive and statistically significant effect on patents granted, with and without control variables included. When index fund ownership increases by one unit (percent), patents granted increase by 0.398%, equating to, on average, 0.14 more patents granted, significant at the 5% level when including firm control variables (0.608% when excluding firm control variables, significant at the 1% level). Regressions (5) and (6) show no statistically significant relationship between index fund ownership and number of forward citations per patent.

As such, Panel A finds a statistically significant positive relationship between index fund ownership and innovation input and output, supporting the value-maximizing view of index fund ownership (Lewellen and Lewellen, 2021). However, since there is no statistically significant relationship for innovation quality, the result partly supports the agency-cost view as proposed by Bebchuk and Hirst (2019). We therefore conclude, when not accounting for industry differences in innovation, that the impact of index fund ownership on innovation is limited to an increase in activity and spending, whilst its influence on quality is negligible.

The results are coherent with prior literature that has identified a positive relationship between institutional ownership and corporate governance, e.g., Hartzell and Stark, (2003) and Tao et al., (2020). Additionally, considering that the economic effect of index fund ownership is significantly larger in terms of patents granted than R&D/Assets, our results support the findings of Aghion et al., (2013) and Harford et al., (2018). That is, the dominant effect of institutional ownership on innovation stems from long-term institutional investors changing the incentives to innovate within their portfolio firms by, for instance, reducing the risk of management being fired in the face of profit downturns, as compared to simply increasing the amount of R&D spending. The results are opposite to the literature documenting a negative effect of institutional ownership on corporate governance and innovation (Schmidt and Fahlenbrach, 2017; Heath et al., 2021; Brav et al., 2019).

Panel A: Index Fund Ownership Impact on Innovation

	<i>Dependent variables:</i>					
	R&D/Assets		Patents Granted		Forward Citations	
	(1)	(2)	(3)	(4)	(5)	(6)
Index Fund Ownership	-0.015 (0.024)	0.070*** (0.023)	0.608*** (0.185)	0.398** (0.199)	0.072 (0.186)	0.008 (0.197)
Size		-3.422*** (0.365)		18.965*** (2.330)		1.945 (2.522)
BM		-0.074 (0.160)		1.308 (1.274)		-1.598 (1.317)
Leverage		-0.318*** (0.058)		-0.639** (0.251)		0.137 (0.291)
CFO		-25.157*** (3.868)		-6.608 (7.585)		-3.390 (7.639)
CapExp		15.469*** (3.184)		-17.888 (13.250)		12.291 (16.561)
ROA		-9.695*** (1.893)		-9.691* (5.199)		1.531 (4.888)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	No	Yes	No	Yes	No	Yes
Observations	12,223	11,769	19,935	18,918	19,935	18,918
R ²	0.004	0.457	0.019	0.032	0.174	0.184

*Note: Panel A examines the effect of index fund ownership on 1) innovation input, measured as a firm's R&D expenses as a share of total assets, 2) innovation output, measured as the natural logarithm of patents granted, and 3) degree of innovation, measured as the natural logarithm of forward citations. Regressions (1) – (6) are fixed effects models with standard errors clustered at firm level. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Parentheses denote standard errors.*

Finally, the results are in line with the positive relationship between index fund ownership and innovation in a Chinese context, as identified by Fu et al., (2021). In terms of magnitude, we report similar coefficients for R&D/Assets (0.070 percentage point increase compared to 0.097 in Fu et al., (2021)). However, in regard to innovation output, Fu et al., (2021) estimate a more modest effect of 0.064% increase in patents granted, compared to our estimated effect of 0.398%. Seeing as our time periods largely coincide (2011 to 2019 versus 2007 to 2017), and considering how the Chinese market differs from the U.S market, e.g., in the form of less market efficiency (Carpenter et al., 2021; Allen et al., 2023), this result indicates that inter-country differences influence the impact of index fund ownership on innovation, further underscoring the contribution of our paper.

B. Panel B: Index Fund Ownership Impact on High- and Low-Technology Firms

Panel B examines the relationship between index fund ownership and innovation by dividing firms into high- and low-technology industry belonging. Regressions (1) – (6) examine high-technology firms, for whom innovation is generally more critical to remain competitive (Aghion et al., 2005). Regressions (1) and (2) find that R&D expenditure as a percentage of assets increase by 0.116% percentage points, significant at the 5% level, when including firm control variables (-0.595% percentage points when excluding firm control variables, significant at the 1% level). Regressions (3) and (4) show that a one-unit (percent) increase in index fund ownership increases patents granted by 1.652%, significant at the 5% level, when including firm control variables (3.373% when excluding firm control variables, significant at the 1% level). For the average firm in our sample, this would equate to 0.57 more patents granted for each additional percentage point in index fund ownership. Furthermore, as a novel finding, regressions (5) and (6) show that the number of forward citations increase by 1.119%, statistically significant at the 1% level, when including firm control variables (1.110% when excluding firm control variables, significant at the 1% level).

Regressions (5) – (8) examine low-technology firms, which generally operate in less innovation-intensive industries (Aghion et al., 2005). Analyzing R&D as a share of total assets in regressions (7) and (8), we find a statistically significant negative relationship between index fund ownership and innovation input, at a magnitude of -0.050 percentage points when including firm control variables, statistically significant at the 1% level (-0.111 percentage points, significant at 1%, when excluding firm control variables). Regressions (9) and (10) find no statistically significant effect on patents granted when including firm control variables, albeit a positive effect of 1.255% at the 1% significance level when excluding firm control variables. Furthermore, regression (12) shows no impact on the number of forward citations when including firm control variables, but regression (11) shows a positive 0.460 percentage point effect, significant at the 5% level, when excluding control variables.

As such, we find that the effect on innovation input and output is significantly stronger for high-technology firms compared to low-technology firms. Furthermore, aside from differences in economic magnitude, the effect on innovation input differs in sign between the two categories, where high-technology firms demonstrate a positive effect, and low-technology firms exhibit a negative effect. This demonstrates that the impact of index fund ownership does not need to be strictly positive (or negative) as proposed by much of the previous literature (e.g., Schmidt and Fahlenbrach, 2017; Appel et al., 2016; Crane et al., 2012).

Instead, our results indicate that index funds influence innovation input by bringing R&D spending closer to levels that are appropriate for the firm, contingent on its industry belonging. That is, for firms operating in technology-intensive sectors, where innovation is particularly important for competition, index funds provide management with incentives to promote innovation, by for example reducing career concerns (Aghion et al., 2013). Conversely, for firms operating in low-technology sectors, index funds seem to have the opposite effect, i.e., they contribute to bringing down the level of spending on innovation, which, prior to their ownership, could be at excessive levels, for example due to management overinvestment as a form of empire building (Lo & Shaih-Hou, 2022).

Moreover, Panel B repeats the pattern found in Panel A, i.e., the strongest effect of index fund ownership relates to the number of patents granted, indicating that the long-term ownership horizon of index funds stimulates management risk-taking, consistent with the findings of Aghion et al., (2013) and Harford et al., (2018).

Finally, the results are in line with Fu et al., (2021), who identify a similar pronounced effect for the high-technology sub-sample. In terms of relative magnitude, Panel B follows the pattern identified in Panel A, i.e., comparable effects in terms of R&D/Assets but a large discrepancy in terms of patents granted. Where Fu et al., (2021) find that a one-unit increase in index fund ownership is associated with a 0.0654% increase in patents granted for the high-technology subsample, we find that the effect in the U.S market is significantly larger at 1.652%. This discrepancy reiterates the significance in accounting for inter-country differences when estimating the impact of ownership on corporate governance, further emphasizing our contribution.

C. Panel C: Fund Management Company Ownership and Impact on Innovation

Panel C measures the relationship between the ownership concentration of the fund management company, i.e., the combined ownership of all of its individual index funds in a given portfolio company, and if this has a marginal influence on the impact that total index fund ownership has on innovation. We perform the same regressions as in Panel A but include an interaction variable between total index fund ownership and a dummy variable for when the aggregate level of index fund ownership at the fund management company level exceeds 5% or 10%, respectively.

Regressions (1) – (6) study the incremental impact of blockholder fund management company ownership (5% ownership threshold). The incremental effect is insignificant across all dimensions of innovation. Regressions (7) – (12) study the incremental impact of index fund

ownership when fund management company ownership exceeds 10%. The marginal effect is, once again, statistically insignificant on R&D spending and patents granted, but positive and significant at the 10%-level when examining innovation quality. In other words, if a fund management company owns more than 10% of a portfolio company, a one percentage point increase in total index fund ownership is associated with a 0.9% increase in the number of forward citations.

Interpreting Panel C in sum, the result partly supports the agency-cost perspective (Bebchuk and Hirst, 2019), in that the large and growing ownership stakes of index fund providers alone do not provide adequate incentives for stewardship. Instead, since the *Index Ownership* variable remains significantly positive after including size interaction variables, Panel C provides support for index funds having reasons to promote innovation, independent of the size of their stake in the company, contrary to the theoretical prediction of Grossman and Hart (1980) and Shleifer and Vishny (1986). As such, this finding motivates future research in distinguishing what the underlying drivers attributable to index fund stewardship are. For example, is it their inability to exit, competition considerations, or economies of scale that provide index funds with incentives to monitor?

Panel B: Index Fund Ownership on Innovation in High and Low-Technology firms

	<i>Dependent variables:</i>											
	R&D/Assets		Patents Granted		Forward Citations		R&D/Assets		Patents Granted		Forward Citations	
	High Tech Firms						Low Tech Firms					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Index Fund	-0.595***	0.116**	3.373***	1.652**	1.110***	1.119***	-0.111***	-0.050***	1.255***	0.387	0.460**	0.271
Ownership	(0.108)	(0.052)	(0.808)	(0.776)	(0.318)	(0.334)	(0.025)	(0.018)	(0.386)	(0.403)	(0.186)	(0.195)
Size		-1.435***		28.999***		2.279		-1.034***		23.893***		6.376***
		(0.231)		(4.064)		(1.782)		(0.182)		(2.681)		(1.143)
BM		-1.327		-20.842***		-4.777**		-0.210		-12.737***		-6.335***
		(0.811)		(6.549)		(2.228)		(0.139)		(2.728)		(1.440)
Leverage		-0.167***		0.023		0.052		-0.134		2.571**		1.689***
		(0.033)		(0.496)		(0.279)		(0.092)		(1.146)		(0.523)
CFO		-35.525***		-30.413*		-15.999*		0.689		117.763***		56.113***
		(4.070)		(15.965)		(9.107)		(2.303)		(24.237)		(16.298)
CapExp		12.011		-347.775***		-141.184***		-1.380		17.370		2.889
		(8.721)		(64.598)		(39.969)		(2.724)		(49.777)		(26.126)
ROA		-13.080***		-24.988*		-11.291*		-4.842***		-91.635***		-36.269***
		(3.294)		(13.452)		(6.300)		(1.579)		(15.663)		(10.028)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	5,871	5,859	6,583	6,553	6,583	6,553	6,352	5,910	13,352	12,365	13,352	12,365
R ²	0.030	0.624	0.017	0.115	0.262	0.275	0.025	0.168	0.007	0.083	0.094	0.120

*Note: Panel B examines the effect of index ownership on 1) innovation input, measured as a firm's R&D expenses as a share of total assets, 2) innovation output, measured as the natural logarithm of patents granted, and 3) degree of innovation, measured as the natural logarithm of forward citations. Regressions (1) – (12) are fixed effects models with standard errors clustered at firm level. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Parentheses denote standard errors.*

Panel C: Index Fund Concentration Ownership Impact on Innovation (5% and 10% Fund Manager Concentration Dummies)

	<i>Dependent variable:</i>											
	5% Concentration						10% Concentration					
	R&D/Assets		Patents Granted		Forward Citations		R&D/Assets		Patents Granted		Forward Citations	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Index Fund Ownership	-0.015 (0.024)	0.070*** (0.023)	0.608*** (0.185)	0.398** (0.199)	0.071 (0.186)	0.006 (0.197)	-0.015 (0.024)	0.070*** (0.023)	0.608*** (0.185)	0.398** (0.199)	0.071 (0.186)	0.006 (0.197)
FM Dummy (5%)	0.04 (0.037)	-0.001 (0.035)	0.004 (0.375)	-0.001 (0.403)	-0.401 (0.509)	-0.483 (0.509)						
FM Dummy (10%)							0.016 (0.019)	0.026 (0.030)	0.003 (0.406)	-0.038 (0.446)	0.841* (0.510)	0.894* (0.523)
BM		-0.074 (0.160)		1.308 (1.274)		-1.601 (1.316)		-0.074 (0.160)		1.308 (1.274)		-1.601 (1.316)
Leverage		-0.318*** (0.058)		-0.639** (0.251)		0.138 (0.291)		-0.318*** (0.058)		-0.639** (0.251)		0.138 (0.291)
CFO		-25.157*** (3.868)		-6.605 (7.584)		-3.451 (7.640)		-25.157*** (3.868)		-6.605 (7.584)		-3.451 (7.640)
CapExp		15.465*** (3.184)		-17.889 (13.250)		12.319 (16.562)		15.465*** (3.184)		-17.889 (13.250)		12.319 (16.562)
ROA		-9.696*** (1.893)		-9.692* (5.199)		1.550 (4.889)		-9.696*** (1.893)		-9.692* (5.199)		1.550 (4.889)
Size		-3.421*** (0.365)		18.965*** (2.330)		1.933 (2.522)		-3.421*** (0.365)		18.965*** (2.330)		1.933 (2.522)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	12,223	11,769	19,935	18,918	19,935	18,918	12,223	11,769	19,935	18,918	19,935	18,918
R ²	0.004	0.457	0.019	0.032	0.174	0.184	0.004	0.457	0.019	0.032	0.174	0.184

*Note: Panel C includes a dummy variable for fund manager ownership concentration. The FM Dummy in regressions (1) – (6) are assigned a 1 if any firm has total fund management company index fund ownership exceeding 5%; regressions (7) – (12) at 10% concentration. Regressions (1) – (12) fixed effects models with standard errors clustered at firm level. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Parentheses denote standard errors.*

V. Robustness Checks

A. Time period robustness checks

Examining variations of time periods is essential in ensuring robustness and validity of our model. Our main model assumes firms decide R&D spending the beginning of the year, implying that the model should lose explanatory power when predicting levels of R&D as a share of total assets in future years. Furthermore, our model specification assumes index fund ownership affects innovation output, *Patents Granted_i* at $t+1$. However, a filed patent application takes, on average, 26.3⁵ months to be granted, suggesting there may be a need for examining the relationship between index fund ownership and patents granted over longer time periods.

Regressions (1) – (2) in Panel A2 (in Appendix) lag R&D as a share of total assets by one year and show that a one-unit (percentage) increase in index fund ownership increases R&D as a share of assets by 0.055 percentage points at the 5% significance level (compared to 0.070 percentage points in Panel A, our main regression). Regressions (3) – (4) lag the variable by two years, with statistically insignificant results. The results suggest that index fund ownership fails to predict levels of innovation input several years ahead, which supports our assumption of R&D spending being decided at the beginning of the year.

Regressions (5) to (8) lag patents granted by two and three years (e.g., index fund ownership in 2011 is regressed against patents granted in 2013 and 2014). The results coincide with our main findings, namely that there is a statistically significant and positive relationship (with and without control variables) between index fund ownership and patents granted in future years. Furthermore, we observe that the effect on innovation output is stronger the more years the variable is lagged, which indicates model robustness considering the above argument of a patent taking at least two years to become granted.

Panel A2 thus confirms our results are robust to variations in time periods and coincide with the findings of Fu et al., (2021).

B. Time period robustness checks, high- and low-technology firms

We also conduct robustness checks on the high and low-technology firm sub-samples. Regressions (1) and (2) in Panel A3 show that index fund ownership in high-technology firms do not predict levels of R&D spending as a share of total assets in future time periods. As for

⁵ Measured as Traditional Total Pendency, the average number of months from the patent application filing date to the date the application has reached final disposition, according to the USPTO as of September 2024

patents granted, we observe that the magnitude increases as we lag the variable more years, reinforcing the notion that the effect on innovation output is stronger in future years.

When examining low-technology firms in Panel A4, we find results are robust to lagging the dependent variables. A noticeable difference, however, is that the *R&D/A* variable is statistically significant at the 1% level also when the variable is lagged, perhaps explained by R&D spending being reduced over a longer time period. As in our main results, we find no relationship between index fund ownership and patents granted for low-technology firms.

C. Discussion on endogeneity

Our paper uses a panel data estimation model and may therefore suffer from endogeneity. However, in line with Fu et al., (2021) and by replicating their methodology, we argue having taken appropriate mitigating actions. The omitted variable bias, i.e., the possibility of relevant variables being left out of the model that simultaneously impact index fund ownership and innovation, has been mitigated in two ways. First, in line with prior relevant research (Amore et al., 2013; Baranchuk et al., 2014; Fu et al., 2021; He & Tian, 2013) our regressions include economically justified control variables. Second, we conduct a fixed effects regression, controlling for unobserved time-invariant heterogeneity between firms, such as corporate culture and management quality, which we otherwise cannot control for.

That being said, our regression may still suffer from time-variant omitted variables producing a bias in our estimates. However, as our dataset represents a relatively short time period (2011 to 2019), we argue that the prevalence of time-variant omitted variables should be limited (Woolridge, 2013).

Reverse causality, i.e., that firm-level innovation determines index fund ownership and not the other way around, is controlled for by using past ownership data to predict future innovation outcomes. Our main regressions use index fund ownership data that is lagged by one year relative to patents granted and find a significantly positive relationship. Excluding the effect of potential omitted variables, this finding provides strong evidence of a causal link between total index fund ownership and firm-level innovation. Reverse causality would only be plausible if a firm's market value, and consequently its likelihood to be included in an index, were strongly correlated with future patenting activity. However, since future patents are inherently difficult to predict *ex ante*, we consider the probability of this to be low. In addition, the positive relationship between index fund ownership and patents granted remains significant over time and, notably, grows stronger, providing further evidence against reverse causality.

Finally, considering the following reasons, we view the likelihood of measurement error to be low. First, we use an established method to calculate index fund ownership (e.g., Busse and Tong 2012; Appel et al., 2016; Hsieh et al., 2021) yielding ownership levels in line with Farizo (2022). Second, in addition to being an established method to measure innovation (e.g., Hirshleifer et al., 2018; He and Tian, 2013; Fu et al., 2021), our dependent variable patents granted should suffer from a low degree of selection bias considering that firms have strong incentives to protect valuable innovations. In addition, our study considers the quality of innovation by measuring forward citations, thereby reducing the likelihood of estimating spurious effects. That being said, we acknowledge that patent counts and forward citations fail to consider non-patented innovations, implying that our estimates are potentially downwardly biased. Third, by also considering innovation input, we argue, in line with Fu et al., (2021), that we are able to further mitigate the risk of erroneous inferences.

However, one weakness with R&D expense data is that it is generally not disclosed as a separate line item by all firms, explaining the low number of R&D/A observations in Table 2. Our results related to innovation input may therefore be biased to firms that already have good innovation capabilities and, for those reasons, report R&D separately in their financial statements. Nevertheless, we argue our results are still robust, noting that the number of firm-year observations for high- and low-technology firms in Panel B are approximately equal, suggesting that high-technology firms, with arguably higher innovation requirements, are not overrepresented in the sample. Furthermore, despite missing R&D data, our sample size is still substantial (12,223 firm-year observations), supporting the generalizability of our findings.

D. The logarithm of R&D/Assets

As a robustness check to the measurement of innovation input, we calculate the natural logarithm of R&D as a share of total assets in Panel A5, as it introduces robustness to the distribution of observations by reducing skewness, as well as allowing for an interpretation of the variable's elasticity. Panel A5 shows results are robust when introducing $\log R\&D/A_{i,t}$ as dependent variable, with results coinciding with our main results in Panel A and B.

E. Fund management company concentration robustness checks

Panels A6 and A7 perform robustness checks on Panel C by calculating the effect of blockholder fund management company ownership also on the high-and low-technology sub-

samples to rule out any effect in these sub-groups. The interaction variables are statistically insignificant across all regressions, providing further evidence for fund management ownership concentration having no marginal impact on index funds' engagement in stewardship.

F. Removing outliers and winsorizing

Table 1 in Section III shows that our data sample exhibits large differences in minimum and maximum values for patents granted. In particular, there is an outlier firm-observation standing out in terms of patents, with nearly 12,500 – 18,300 patents granted per year. To rule out this observation having any effect on our final results, we exclude it from our regressions in Panels A8 and A9 and show that our results are unaffected.

Furthermore, we winsorize our dependent variables at the 1% and 99% levels in Panels A10 and A11 (running the same regressions as in Panels A and B) and conclude all results are robust when excluding the effect of extreme values.

VI. Conclusion

Our paper examines the impact of index fund ownership on innovation input, output and quality, using a sample of 3,133 US-listed firms from 2011 to 2019. We find a positive relationship between index fund ownership, R&D spending and the number of patents granted, suggesting that the passive ownership nature of index funds encourages managers to behave in a value-maximizing manner by increasing investments in long-term, innovative projects. When dividing firms into high- and low-technology industry belonging, we find evidence for the effect being stronger in high-technology firms, where they simultaneously increase R&D spending and generate more patents than their low-technology counterparts. Furthermore, we contribute a novel finding to the literature by providing evidence for high-technology firms also producing more advanced patents. As such, our results indicate that index fund ownership has a more pronounced effect in industries where innovation is more critical to remain competitive. Finally, by exploring the incremental effect of fund management company blockholder ownership, we find, contrary to popular belief, that this does not influence the positive relationship between index fund ownership and innovation. This finding points to ownership size being insufficient to explain the positive effect of index fund ownership on innovation, suggesting that future research could explore what causes index funds to engage in stewardship activities. In sum, our paper contributes to the notion of passive institutional ownership having a positive impact on corporate governance by specifically studying the effect of index funds.

VII. References

- Aghion, P., Bloom, N., Blundell, R., Griffith, R., & Howitt, P. (2005). Competition and Innovation: an Inverted-U Relationship. *The Quarterly Journal of Economics*, 120(2).
- Aghion, P., van Reenen, J., & Zingales, L. (2013). Innovation and institutional ownership. *American Economic Review*, 103(1).
- Allen, F., Qian, J., Shan, C., & Zhu, J. L. (2024). Dissecting the Long-Term Performance of the Chinese Stock Market. *Journal of Finance*, 79(2).
- Ammann, M., Oesch, D., & Schmid, M. M. (2011). Corporate governance and firm value: International evidence. *Journal of Empirical Finance*, 18(1).
- Amore, M. D., Schneider, C., & Žaldokas, A. (2013). Credit supply and corporate innovation. *Journal of Financial Economics*, 109(3).
- Appel, I. R., Gormley, T. A., & Keim, D. B. (2016). Passive investors, not passive owners. *Journal of Financial Economics*, 121(1).
- Baranchuk, N., Kieschnick, R., & Moussawi, R. (2014). Motivating innovation in newly public firms. *Journal of Financial Economics*, 111(3).
- Bebchuk, L., & Hirst, S. (2019). Index funds and the future of corporate governance: Theory, evidence, and policy. *Columbia Law Review*, 119(8).
- Bedford, A., Ma, L., Ma, N., & Vojvoda, K. (2021). Future profitability and stock returns of innovative firms in Australia. *Pacific Basin Finance Journal*, 66.
- Bena, J., Ferreira, M. A., Matos, P., & Pires, P. (2017). Are foreign investors locusts? The long-term effects of foreign institutional ownership. *Journal of Financial Economics*, 126(1).
- Ballantine, H. W., Berle, A. A., & Means, G. C. (1932). The Modern Corporation and Private Property. *California Law Review*, 21(1).
- BlackRock. (2023). Investment Stewardship Report.
- Boone, A. L., & White, J. T. (2015). The effect of institutional ownership on firm transparency and information production. *Journal of Financial Economics*, 117(3).
- Brav, A., Jiang, W., & Li, T. (2018). Picking Friends Before Picking (Proxy) Fights: How Mutual Fund Voting Shapes Proxy Contests. *SSRN Electronic Journal*.
- Bushee, B. J. (1998). The influence of institutional investors on myopic R&D investment behavior. *Accounting Review*, 73(3).
- Busse, J. A., & Tong, Q. (2012). Mutual fund industry selection and persistence. In *Review of Asset Pricing Studies* (Vol. 2, Issue 2).

- Carpenter, J. N., Lu, F., & Whitelaw, R. F. (2021). The real value of China's stock market. *Journal of Financial Economics*, 139(3).
- Carosa, C. (2024, April). Index funds surge in popularity but pose risks for the market. *Forbes*
- Chen, T., Dong, H., & Lin, C. (2020). Institutional shareholders and corporate social responsibility. *Journal of Financial Economics*, 135(2).
- Chi, J., Liao, J., & Yang, J. (2019). Institutional stock ownership and firm innovation: Evidence from China. *Journal of Multinational Financial Management*, 50.
- Crane, A. D., Michenaud, S., & Weston, J. P. (2016). The Effect of Institutional Ownership on Payout Policy: Evidence from Index Thresholds. *Review of Financial Studies*, 29(6).
- European Patent Office. (2024), What are good indicators of patent value? *epo.org*.
- Fang, V. W., Tian, X., & Tice, S. (2014). Does stock liquidity enhance or impede firm innovation? *Journal of Finance*, 69(5).
- Farizo, J. D. (2022). (Black)Rock the vote: Index funds and opposition to management. *Journal of Corporate Finance*, 76.
- Fu, L., Pan, L., & Wu, F. (2021). Does passive investment have a positive governance effect? Evidence from index funds ownership and corporate innovation. *International Review of Economics and Finance*, 75.
- Grossman, S. J., & Hart, O. D. (1980). Takeover Bids, The Free-Rider Problem, and the Theory of the Corporation. *The Bell Journal of Economics*, 11(1).
- Harford, J., Kecskés, A., & Mansi, S. (2018). Do long-term investors improve corporate decision making? *Journal of Corporate Finance*, 50.
- Hartzell, J. C., & Starks, L. T. (2003). Institutional Investors and Executive Compensation. In *Journal of Finance* (Vol. 58, Issue 6).
- Heath, D., MacCiochi, D., Michaely, R., & Ringgenberg, M. C. (2022). Do Index Funds Monitor? *Review of Financial Studies*, 35(1).
- He, J. (Jack), & Tian, X. (2013). The dark side of analyst coverage: The case of innovation. *Journal of Financial Economics*, 109(3).
- Hecker, D. E. (2005). High-technology employment: A NAICS-based update. In *Monthly Labor Review* (Vol. 128, Issue 7).
- Hirshleifer, D., Hsu, P. H., & Li, D. (2018). Innovative originality, profitability, and stock returns. *Review of Financial Studies*, 31(7).
- Holderness, C. G. (2009). The myth of diffuse ownership in the United States. *Review of Financial Studies*, 22(4).

Holmstrom, B. (1989). Agency costs and innovation. *Journal of Economic Behavior and Organization*, 12(3).

Hshieh, S., Li, J., & Tang, Y. (2021). How do passive funds act as active owners? Evidence from mutual fund voting records 1. *Journal of Corporate Finance*, 66.

Jensen, M. C., & Meckling, W. H. (1976). Theory of the firm: Managerial behavior, agency costs and ownership structure. *Journal of Financial Economics*, 3(4).

Lewellen, J., & Lewellen, K. (2022). Institutional Investors and Corporate Governance: The Incentive to Be Engaged. *Journal of Finance*, 77(1).

Likitapiwat, T., Treepongkaruna, S., Jiraporn, P., & Uyar, A. (2022). Corporate Culture, Innovation, and Female Board Representation: Evidence from Earnings Conference Calls. *Quarterly Journal of Finance*, 12(4).

Liu, Y., Shen, Y., Wang, J., & Wang, Q. (2019). Passive Institutional Investors and Corporate Innovation. *SSRN Electronic Journal*.

Lo, H. C., & Shiah-Hou, S. R. (2022). The effect of CEO power on overinvestment. *Review of Quantitative Finance and Accounting*, 59(1).

Manso, G. (2011). Motivating Innovation. *Journal of Finance*, 66(5).

Porter, M. E. (1985). Competitive strategy: Creating and sustaining superior performance. *Creating and Sustaining Competitive Advantage*.

Rekenthaler, J. (2024, February). Index funds have officially won. *Morningstar*.

Schmidt, C., & Fahlenbrach, R. (2017). Do exogenous changes in passive institutional ownership affect corporate governance and firm value? *Journal of Financial Economics*,

Sharpe, W. F. (1991). The Arithmetic of Active Management. *Financial Analysts Journal*, 47(1).

Shleifer, A., & Vishny, R. W. (1986). Large Shareholders and Corporate Control. *Journal of Political Economy*, 94(3, Part 1).

State Street Global Advisors. (2023). Asset Stewardship Report.

Stein, J. C. (1988). Takeover Threats and Managerial Myopia. *Journal of Political Economy*, 96(1).

Unsal, O., & Rayfield, B. (2019). Institutional investors and medical innovation. *Quarterly Review of Economics and Finance*, 74.

Vanguard. (2023). Investment Stewardship: Annual Report.

Wooldridge, J. M. (2013). Introductory Econometrics A Modern Approach, Fifth Edition. *Cengage Learning, South-Western*

VIII. Appendix

A1. Development of Blockholder Ownership Sample Size

Year	5% Blockholder Ownership	10% Blockholder Ownership
	<i>N</i>	<i>N</i>
2011	212	14
2012	320	50
2013	627	69
2014	793	90
2015	1,155	107
2016	1,438	141
2017	1,833	242
2018	1,979	595
2019	1,954	682

Note: Table A1 shows the number of firms with blockholder fund management company ownership, per year. A blockholder is defined as a shareholder owning at least 5% of shares outstanding (Holderness, 2007). We also calculate the blockholder ownership with a 10% threshold.

A2. Time Period Variations for R&D/Assets and Patents Granted (Full Sample)

	<i>Dependent variable:</i>							
	R&D/A (t+1)		R&D/A (t+2)		Patents Granted (t+2)		Patents Granted (t+3)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Index Ownership	0.044** (0.020)	0.055** (0.022)	0.040 (0.027)	0.031 (0.027)	0.640*** (0.207)	0.499** (0.225)	0.947*** (0.310)	0.778** (0.337)
Size		-0.435 (0.380)		0.328 (0.467)		17.452*** (2.408)		14.436*** (2.519)
BM		0.174 (0.171)		0.261 (0.215)		1.129 (0.978)		1.743 (1.680)
Leverage		-0.182*** (0.065)		-0.013 (0.115)		-0.243 (0.282)		0.277 (0.246)
CFO		0.031 (1.981)		7.109** (2.970)		10.609 (7.543)		3.688 (8.641)
CapExp		9.918*** (2.791)		3.246 (3.401)		-22.829 (16.568)		-35.277** (17.095)
ROA		0.073 (1.191)		0.538 (1.322)		-8.241 (5.790)		-1.216 (7.021)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	10,511	10,102	8,866	8,501	16,906	16,007	14,061	13,272
R ²	0.005	0.011	0.004	0.020	0.015	0.025	0.014	0.020

Note: Panel A2 is a robustness check on 1) the R&D/Asset variable by leading the observations 1 and 2 years ahead ($t+1$, $t+2$), and 2) the Patents Granted variable by leading it forward 2 and 3 years ahead ($t+2$, $t+3$). Regressions (1) – (8) are fixed effects models with standard errors clustered at firm level. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Parentheses denote standard errors.

A3. Time Period Variations for R&D/Assets and Patents Granted (High-Tech Firms)

	<i>Dependent variable:</i>							
	R&D/A (t+1)		R&D/A (t+2)		Patents Granted (t+2)		Patents Granted (t+3)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Index	-0.448***	-0.041	-0.363***	-0.064	4.088***	2.408***	4.261***	2.682**
Ownership	(0.105)	(0.070)	(0.115)	(0.092)	(0.950)	(0.897)	(1.294)	(1.211)
Size		-2.029***		-2.172***		29.982***		29.218***
		(0.328)		(0.440)		(4.498)		(4.946)
BM		0.151		-0.284		-23.607***		-26.186***
		(0.955)		(0.992)		(8.283)		(9.214)
Leverage		0.043		0.189**		0.450		0.382
		(0.046)		(0.084)		(0.506)		(0.541)
CFO		-15.644***		-7.005		-33.054**		-25.223
		(4.166)		(6.052)		(16.324)		(24.371)
CapExp		-6.377		-23.475**		-417.859***		-469.594***
		(11.613)		(11.912)		(67.151)		(82.825)
ROA		-7.920**		-5.794*		-17.334		-17.631
		(3.187)		(3.451)		(11.192)		(19.404)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control Var.	No	Yes	No	Yes	No	Yes	No	Yes
Observations	4,976	4,965	4,137	4,126	5,491	5,462	4,494	4,468
R ²	0.017	0.198	0.011	0.107	0.020	0.123	0.017	0.120

*Note: Panel A3 is a robustness check on the high-technology firm sub-sample, looking at 1) the R&D/Asset variable by leading the observations 1 and 2 years ahead (t+1, t+2), and 2) the Patents Granted variable by leading it forward 2 and 3 years ahead (t+2, t+3). Regressions (1) – (8) are fixed effects models with standard errors clustered at firm level. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Parentheses denote standard errors.*

A4. Time Period Variations for R&D/Assets and Patents Granted (Low-Tech Firms)

	<i>Dependent variable:</i>							
	R&D/A (t+1)		R&D/A (t+2)		Patents Granted (t+2)		Patents Granted (t+3)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Index	-0.111***	-0.057***	-0.097***	-0.052***	1.361***	0.343	1.466**	0.301
Ownership	(0.025)	(0.018)	(0.026)	(0.019)	(0.443)	(0.468)	(0.590)	(0.631)
Size		-0.956***		-0.758***		25.437***		25.483***
		(0.198)		(0.199)		(3.042)		(3.818)
BM		-0.355*		-0.217		-16.660***		-20.171***
		(0.214)		(0.168)		(5.246)		(5.776)
Leverage		-0.070		0.106		4.348***		6.037***
		(0.111)		(0.111)		(1.277)		(1.847)
CFO		-1.332		1.101		121.945***		80.077***
		(2.238)		(1.414)		(26.419)		(29.386)
CapExp		-1.915		-2.382		-18.822		-46.914
		(3.312)		(4.068)		(57.595)		(63.242)
ROA		-1.988		-2.321*		-98.314***		-73.525***

		(1.304)		(1.242)		(19.476)		(20.823)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control Vars.	No	Yes	No	Yes	No	Yes	No	Yes
Observations	5,535	5,137	4,729	4,375	11,415	10,545	9,567	8,804
R ²	0.025	0.120	0.019	0.089	0.008	0.090	0.008	0.088

Note: Panel A4 is a robustness check on the low-technology firm sub-sample, looking at 1) the R&D/Asset variable by leading the observations 1 and 2 years ahead ($t+1$, $t+2$), and 2) the Patents Granted variable by leading it forward 2 and 3 years ahead ($t+2$, $t+3$). Regressions (1) – (8) are fixed effects models with standard errors clustered at firm level. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Parentheses denote standard errors.

A5. Log R&D/A Robustness Checks

	Dependent variable:					
	Log R&D/A					
	All firms		High Tech Firms		Low Tech Firms	
	(1)	(2)	(3)	(4)	(5)	(6)
Index Ownership	-0.008 (0.016)	0.057*** (0.016)	-0.424*** (0.071)	0.078* (0.040)	-0.101*** (0.022)	-0.046*** (0.009)
Size		-2.926*** (0.240)		-1.501*** (0.177)		-0.933*** (0.043)
BM		-0.007 (0.094)		-0.956* (0.562)		-0.195*** (0.050)
Leverage		-0.262*** (0.042)		-0.128*** (0.023)		-0.106*** (0.020)
CFO		-14.037*** (1.741)		-21.945*** (2.601)		0.683 (0.596)
CapExp		11.824*** (2.199)		4.060 (6.437)		-1.588 (1.180)
ROA		-6.335*** (1.218)		-8.923*** (2.338)		-4.198*** (0.410)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	No	Yes	No	Yes	No	Yes
Observations	12,223	11,769	5,871	5,859	6,352	5,910
R ²	0.005	0.448	0.032	0.593	0.027	0.172

Note: Panel A5 is a robustness check on the dependent R&D-variables by examining the natural logarithm of R&D expenses as a share of total assets ("log R&D/A"). Regressions (1) – (6) are fixed effects models with standard errors clustered at firm level. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Parentheses denote standard errors.

Panel A6: High-Technology Firms: Fund Management Company Ownership Concentration Impact on Innovation (5% and 10% FM-Dummy)

	<i>Dependent variable:</i>											
	5% Fund Manager Concentration						10% Fund Manager Concentration					
	R&D/Assets (1)	(2)	Patents Granted (3)	(4)	Forward Citations (5)	(6)	R&D/Assets (7)	(8)	Patents Granted (9)	(10)	Forward Citations (11)	(12)
Index Ownership	-0.595*** (0.108)	0.114** (0.052)	3.409*** (0.813)	1.672** (0.779)	1.131*** (0.321)	1.133*** (0.338)	-0.596*** (0.108)	0.116** (0.052)	3.373*** (0.809)	1.652** (0.777)	1.109*** (0.319)	1.118*** (0.336)
FM Dummy	0.0002 (0.169)	0.042 (0.121)	-0.984 (1.931)	-0.560 (1.704)	-0.585 (0.735)	-0.403 (0.744)	0.028 (0.142)	0.006 (0.137)	0.004 (0.992)	-0.050 (0.868)	0.046 (0.741)	0.108 (0.735)
Firm & Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	5,871	5,859	6,583	6,553	6,583	6,553	5,871	5,859	6,583	6,553	6,583	6,553
R ²	0.030	0.624	0.017	0.115	0.262	0.275	0.030	0.624	0.017	0.115	0.262	0.275

Panel A7: Low-Technology Firms: Fund Management Company Ownership Concentration on Innovation (5% and 10% FM-Dummy)

	<i>Dependent variable:</i>											
	5% Fund Manager Concentration						10% Fund Manager Concentration					
	R&D/Assets (1)	(2)	Patents Granted (3)	(4)	Forward Citations (5)	(6)	R&D/Assets (7)	(8)	Patents Granted (9)	(10)	Forward Citations (11)	(12)
Index Ownership	-0.110*** (0.025)	-0.050*** (0.018)	1.270*** (0.386)	0.399 (0.403)	0.467** (0.187)	0.278 (0.197)	-0.111*** (0.025)	-0.050*** (0.018)	1.260*** (0.386)	0.391 (0.404)	0.461** (0.186)	0.271 (0.195)
FM Dummy	-0.071 (0.065)	-0.047 (0.046)	-0.537 (0.952)	-0.420 (1.023)	-0.234 (0.477)	-0.221 (0.528)	-0.143 (0.126)	-0.072 (0.076)	-1.310 (1.333)	-1.054 (1.470)	-0.159 (0.577)	0.072 (0.636)
Firm & Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	6,352	5,910	13,352	12,365	13,352	12,365	6,352	5,910	13,352	12,365	13,352	12,365
R ²	0.026	0.169	0.007	0.083	0.094	0.120	0.027	0.169	0.008	0.083	0.094	0.120

Note: Panels A6 and A7 are robustness checks on Panel C, but with high-and low-technology firm sub-samples. Control variable results are omitted from the output. Regressions (1) – (12) are fixed effects models with standard errors clustered at firm level. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Parentheses denote standard errors.

Panel A8: Exclude Observation with Most Patents (Panel A Replication)

	<i>Dependent variable:</i>					
	R&D/Assets		Patents Granted		Forward Citations	
	(1)	(2)	(3)	(4)	(5)	(6)
Index Ownership	-0.015 (0.024)	0.070*** (0.023)	0.608*** (0.185)	0.399** (0.199)	0.070 (0.186)	0.006 (0.197)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	No	Yes	No	Yes	No	Yes
Observations	12,213	11,759	19,926	18,909	19,926	18,909
R ²	0.004	0.457	0.019	0.032	0.173	0.184

*Note: Panel A8 is a robustness check on Panel A by removing the firm with most patents granted (outlier). Control variable results are omitted from the output. Regressions (1) – (6) are fixed effects models with standard errors clustered at firm level. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Parentheses denote standard errors.*

Panel A9: Exclude Observation with Most Patents (Panel B Replication)

	<i>Dependent variable:</i>											
	R&D/Assets.		Patents Granted		Forward Citations		R&D/Assets		Patents Granted		Forward Citations	
			High Tech Firms						Low Tech Firms			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Index Ownership	-0.594*** (0.109)	0.121** (0.054)	3.369*** (0.827)	1.599** (0.788)	1.109*** (0.318)	1.133*** (0.332)	-0.098*** (0.025)	-0.045** (0.019)	1.086*** (0.372)	0.073 (0.390)	0.353** (0.179)	0.148 (0.192)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control Var	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	5,861	5,849	6,574	6,544	6,574	6,544	6,352	5,910	13,352	12,365	13,352	12,365
R ²	0.030	0.626	0.016	0.114	0.261	0.275	0.020	0.133	0.008	0.082	0.091	0.111

*Note: Panel A9 is a robustness check on Panel B by removing the firm with most patents granted (outlier). Control variable results are omitted from the output. Regressions (1) – (6) are fixed effects models with standard errors clustered at firm level. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Parentheses denote standard errors.*

Panel A10: Winsorizing at the 1% / 99% Levels (Panel A Replication)

	Dependent variable:					
	R&D/Assets		Patents Granted		Forward Citations	
	(1)	(2)	(3)	(4)	(5)	(6)
Index Ownership	-0.003 (0.017)	0.070*** (0.017)	0.607*** (0.184)	0.400** (0.198)	0.069 (0.181)	-0.007 (0.191)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	No	Yes	No	Yes	No	Yes
Observations	12,223	11,769	19,935	18,918	19,935	18,918
R ²	0.005	0.354	0.019	0.032	0.175	0.186

*Note: Panel A10 is a robustness check on Panel A by winsorizing the full data sample at the 1%/ 99% levels (replacing the 1% most extreme values at either end). Control variable results are omitted from the output. Regressions (1) – (6) are fixed effects models with standard errors clustered at firm level. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Parentheses denote standard errors.*

Panel A11: Winsorizing at the 1% / 99% Levels; High- and Low-Technology Firms (Panel B Replication)

	Dependent variable:											
	R&D/Assets		Patents Granted		Forward Citations		R&D/Assets		Patents Granted		Forward Citations	
	High-Technology Firms						Low-Technology Firms					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Index	-0.439***	0.068	3.412***	1.768**	1.067***	1.047***	-0.111***	-0.050***	1.286***	0.444	0.462**	0.271
Ownership	(0.072)	(0.049)	(0.796)	(0.761)	(0.307)	(0.318)	(0.025)	(0.018)	(0.381)	(0.396)	(0.185)	(0.194)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control Var	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	5,871	5,859	6,583	6,553	6,583	6,553	6,352	5,910	13,352	12,365	13,352	12,365
R ²	0.030	0.488	0.018	0.112	0.269	0.282	0.025	0.168	0.008	0.082	0.094	0.120

*Note: Panel A11 is a robustness check on Panel B by winsorizing the high/low-tech sub-data samples at the 1%/ 99% levels (replacing the 1% most extreme values at either end). Control variable results are omitted from the output. Regressions (1) – (12) are fixed effects models with standard errors clustered at firm level. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Parentheses denote standard errors.*

Generative Artificial Intelligence Disclosure

As part of the thesis creation process, generative artificial intelligence (“generative AI”) was utilized to aid in developing advanced code, with the aim of improving the precision and efficiency of our scripts. Generative AI has not in any way been used to generate writing, and all analysis and interpretation of results is our own work.

The following bullet points briefly describe how generative AI was used, and measures taken to reduce potential risks:

- **Coding assistance:** Due to large data sets used, generative AI helped in suggesting ways to construct and simplify prompts of code, speeding up the processing of complex data structures. For example, the use of many different data sources requires advanced merging of datasets, whereby generative AI can suggest data-processing friendly solutions. This also enhanced the precision of our code, improving the accuracy of our outputs and thereby contributing to more reliable results.
- **Code error identification:** In the code developing process, generative AI was able to quickly identify and suggest solutions to any coding errors that we came across, reducing time spent on data processing, allowing us to spend more time on interpreting results, developing deeper insights and improving the quality of our paper.
- **Mitigation of risks:** Several measures were taken to avoid any potential errors or inaccurate outputs whilst using generative AI. We have manually verified the results of all individual outputs in the data processing stage, as well as carefully considering the reasonableness of such outputs. We are confident the use of generative AI has improved the accuracy and quality of our code.

The only generative AI tool that has been used is ChatGPT, by OpenAI (OpenAI, 2024).