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Does Innovation impact the Financial Performance of High-Tech Firms during Different Life Cycle Stages? Evidence from S&P500 Firms

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ABSTRACT

There has been some resurgence of interest in high-tech firms like Google, Amazon, Facebook, and Apple in the era of IoT. The study extends the literature by examining the impact of innovation on firm performance of high-tech firms in the context of firm life cycle stages. Based on the patents and R&D data of 149 high-tech firms from four sectors like communication services, information technology, healthcare and consumer discretionary from 2002 to 2019, our results show that: First, Innovation has a significant relationship with firm performance. Second, patents have a significant and positive relationship with firm performance. Third, R&D is negatively related to firm performance as it is seen as an expenditure. Fourth, the impact of Innovation on firm performance is strongly observed in the decline stage. Fifth, the firm life cycle enhances the impact of Innovation on financial performance more in the information technology and healthcare sectors. Overall, the fixed-effect model is preferred across all estimations, and firm size and age explain firm performance. Our findings provide some stylised facts of high-tech firms on Innovation and firm performance over their life cycle.

Keywords: Cash Flow Patterns, Innovation, Patents, R&D Expenditures, Firm Life Cycle, Performance, High-Tech Firms
JEL Classification: D22, G3, O31, O32, O34

1. INTRODUCTION

In an ever-changing environment, Innovation drives growth for firms globally in the so-called first-mover advantage (Lieberman and Montgomery, 1988). In the era of severe competition due to technological transformation, Innovation serves as a mastermind behind businesses' success, particularly when focusing on enhancing profits (Carayannis et al., 2020). Hence, it is pertinent to understand how firms' innovation capability provides a competitive advantage even in critical market conditions (Ko and Lu, 2010). This capability needs the firm's strategies, systems and infrastructure (Gloet and Samson, 2016). Innovation positively impacts firm performance because it provides competitive advantages in additional income sources and reduces costs from improving products and processes (Terjesen and Patel, 2017; Paula and Rocha, 2020).

Similarly, the firm life cycle is also critical to understanding the firm, but most of the literature developed is conceptual instead of empirical. The literature of various life cycle models developed earlier says that firms usually follow a sequential and consistent process of their development which means that firms monotonically follow the sequence of stages from introduction to decline during their life cycle (Gray and Ariss, 1985; Quinn and Cameron, 1983). This assumption fails to cover the firm reinvention and restructuring strategies that help it move back to the introduction or growth stage once they have reached their maturity or decline stage.

In a subsequent development, the impact of corporate restructuring and reinvention strategies during the firm life cycle has been justified by Dickinson's famous work (2011). It has enabled the researchers to classify the firm life cycle stages based on the different signs of cash flows from the firm operating, investment, and financing activities. An essential conceptual advantage of classification developed by Dickinson (2011) is that a firm life cycle does not have to follow a strict sequence of stages across their life. Instead, it allows the firm to move back and forth across these stages based on their strategies. Later on, various studies like Drobetz et al. (2015), Hasan et al. (2015), Koh et al. (2015), Faff et al. (2016), Hasan and Cheung (2018) and Yoo et al. (2019) have confirmed the strength of Dickinson (2011) life cycle approach.

Literature suggests that there has been a lack of study on the impact of Innovation on high-tech firms, especially from the perspective of the firm life cycle (Shahzad et al., 2022). For instance, does Innovation influence the financial performance of high-tech firms? Is there any difference in the impact of Innovation on financial performance between the high-tech firms from different sectors? So, this study is timely and the first attempt that uses cash flows to measure the life cycle for high-tech firms because there has been some recent resurgence of interest in high-tech firms like Google, Amazon, Facebook, and Apple, commonly referred to as "GAFA."

According to Global Innovation Index (2019), the US is among the top three globally leading innovators with the highest research and development (R&D) expenditure. Many high-tech firms like Apple, Amazon, Adobe, Accenture, Abbott, eBay, Google, Harley-Davidson, IBM, Intel, Johnson and Johnson, McDonald, Merck, Microsoft, Netflix, Nike, Oracle, Pfizer, Teleflex and others are listed in S&P 500. According to KPMG (2019), survey internet of things (IoT) is among the top drivers for technological Innovation. These firms also represent the movement of firms across different life cycle stages based on cash flow patterns resulting from their innovative and corporate restructuring strategies. Firms' innovation decisions vary differently during life cycle stages (He et al., 2020). Hence, high-tech firms from Standard and Poor 500 are selected as samples to examine this issue because firms in developed economies rely more on Innovation and creative destruction for their growth (Acemoglu et al., 2006).

This study uses data from 2002 to 2019 on the revised model of Dickinson's (2011) life cycle classification approach. This approach focuses on a 3-year moving average of each type of cash flow instead of fiscal year-end values of cash flows. Panel data regression analysis is used to evaluate the impact of innovation on firm performance across different firm life cycle stages. Two standard measures of Innovation (patents and R&D expenditures) are used in this study to assess their impact on firm performance over the firm's life cycle.

The paper is structured as follows. First, the literature review, which consists of prior comparative studies regarding Innovation and firm's life cycle impact on firm performance and life cycle model's debate, is discussed in section two. Next, the methodology is elaborated in section three, while section four provides the empirical results. Finally, section five concludes the study.

2. LITERATURE REVIEW

2.1. Innovation and Firm Performance

The term innovation was first introduced by Schumpeter, who proposed five indicators of Innovation: product, process, market, new inputs, and new forms of organisation (Artz et al., 2010). Innovation is a long-term focus of many strategy researchers because it is a source of sustainable differentiation. In addition, Innovation provides a competitive advantage in the global economy in future exploitable opportunities because it directly impacts its financial performance (Rajapathirana and Hu, 2018).

Empirical studies show that firms continuously developing innovation strategies have competitive advantages even in crisis times (Zouaghi et al., 2018). Firms' innovation ability depends on multiple factors like competitive pressure; more outsider competition would be more innovative firm will be (Hansen et al., 2014; Kafouros, 2008). Literature related to Innovation also claims that it is fundamental for the survival and success of the firms (Abbing, 2010). Firms engage in Innovation to improve their products and processes, leading them towards enhanced financial performance (Varis and Littunen, 2010). Castillo-Vergara et al. (2024) found that product innovation substantially improves the innovative performance of SMEs.

Similarly, Therrien et al. (2011) have found that product and process innovation significantly and positively affects firm performance. It helps them reap the benefits of early entry into the market and offer novel products. Patents are the vital output of firm innovations that have received serious attention because they lead to developing new products and exploiting technological opportunities (Yuan and Li, 2019; Lee et al., 2019; Maresch et al., 2016).

Several definitions of Innovation are available in the literature, but there is still no agreement on its exact definition among researchers (Amara and Landry, 2005). There are two standard measures of Innovation: Patents and R&D expenditures (Global Innovation Index, 2019). Many studies have used R&D expenditures (Matricano, 2020; Paula and Rocha, 2020; Wang et al., 2019; Alt, 2018, Yeniyurt et al., 2014; Gaba and Bhattacharya 2012) and the number of patents (Matricano, 2020; Paula and Rocha, 2020; Wang et al., 2019; Alt, 2018; Ardito et al., 2018; Pantano et al., 2017) as a measure of Innovation.

Previous literature implies that investment in R&D enhances the firm's absorptive capacity of learning (Cohen and Levinthal, 1990; Zahra and George, 2002). R&DE is one of the main determinants of measuring a firm's innovative ability (Shefer and Frenkel, 2005; Van Beers and Zand, 2014). R&D investments allow the firm to develop new technologies and products to directly affect the firm's performance (Chun et al., 2014). Patens and R&D expenditure encourage Innovation, enhancing firm performance (Wang et al., 2019; Paula and Rocha, 2020; Alt, 2018). Additinaly, Alshuaibi et al. (2024) revealed significant positive relationships between green innovation and sustainable firm performance.

Firms with higher R&D investments and a more significant number of patents result in greater efficiency and financial performance (Aghion et al., 2014). Zhang et al. (2018) found that Innovation in the form of patents increases the performance of high-tech firms and increases their survival rate. Similarly, Aboulnasr et al. (2008) have determined that Innovation starts from applying creative ideas to get patents on their behalf. Amimakmur et al. (2024) found that IT innovation strengthens the relationship between financial performance and company value. High-tech firms are continuously engaged in Innovation by generating new ideas and developing new products and services. Hence, they are the focus of this research.

2.2. Firm Life Cycle

The concept of the firm life cycle is a keen interest of many researchers, but still, there is no consensus on the operational definition. This inconsistency is due to variation in the life cycle stages classification in different models (Jaafar and Abdul Halim, 2016). Anthony and Ramesh (1992) mention that life cycle classification measures used in previous literature are dividend payout as the percentage of income, sales growth, and capital expenditures. They have introduced the firm's age as an alternate measure for classifying its life cycle stages. They argue that in all previous literature, variables chosen are financially related to their reference in management, economics, accounting, and firm's risk, which affect the firm performance without considering the life cycle effect.

Later, De Angelo et al. (2006) contended that retained earnings are appropriate to classify the firm life cycle. Dickinson (2011) has classified the firm life cycle based on cash flows from operating, investment and financing activities. She mentioned that firms do not necessarily have to follow a sequence of life cycle stages; instead, they can irregularly move from one stage to another because of their cash flows.

In another study, Faff et al. (2016) have also stressed that though the firm's age and size indicate its maturity, they are good proxies to measure its life as firms may exist many years before listing. They argued that every firm's learning rate is different from others, so age and size are not appropriate parameters to explain its life cycle. They agreed with the Dickinson (2011) cash flow approach for classifying the firms into different life cycle stages. Hasan et al. (2015) and Koh et al. (2015) have also used the Dickinson (2011) approach with the argument that this approach covers the diversified research areas like production behaviour, learning pace, market inefficiency, investment behaviour, entry/exit barriers.

In a recent study in Korean firms, Yoo et al. (2019) examined the effect of the life cycle on the relationship between Innovation and firm performance. They found that the life cycle affects this relationship because the market response is different in each firm's life cycle stage. They determined that R&D expenditures are the key strategy of any firm as it helps to create high firm value through cost reduction and efficient production. Furthermore, they have found that R&D expenditures have a positive relationship at the maturity stage and an insignificant relationship at other stages.

However, there are a few weaknesses in Yoo et al. (2019). They only used four groups instead of five originally defined under Dickinson (2011). In addition, they do not employ the panel data model. Hence, they do not control for the unobserved heterogeneity, which is essential for the internal validity of this kind of firm-level study. Our study attempts to overcome the weaknesses found in Yoo et al. (2019) and uses panel data analysis.

2.3. Theoretical Framework

The firm's year observations are grouped into five distinct life cycle stages using Dickinson's revised model (2011). Drobetz et al. (2015) have proposed a minor amendment in the Dickinson (2011) model. Firms are classified into distinct life cycle stages based on a 3-year moving average of each type of cash flow instead of using fiscal year-end cash flows values. They proposed this amendment to justify that cash flows might change the sign in a single year but are unrelated to the organization's strategic choice and operational capability, resulting in misleading information about its actual life cycle stage. They mentioned that adjusting the single-year effect is reasonable by taking a moving average of 3-year cash flows. It will also not affect the distributional characteristics of the life cycle measures. Dickinson's (2011) classification criteria based on cash flows from operating, investing, and financing activities are stated below in Table 1.

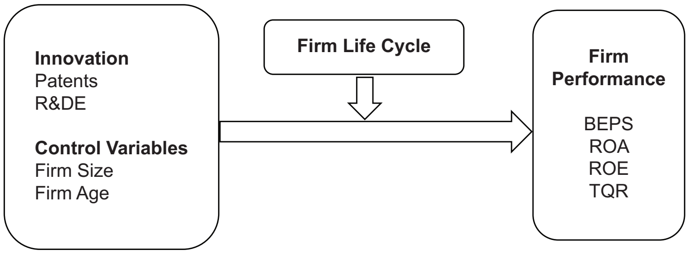
Firms are categorized into the introduction stage because they have no customer base and lack knowledge about their revenue and cost, resulting in negative operating cash flows. At the same time, they have to borrow the funds to make a significant investment in physical assets to grab the growth opportunities that result in negative cash flows from investment activities and positive financing activities. Firms efficiently utilize their investments to maximize their profits in the growth stage, resulting in positive net operating cash flows. Firms earn sufficient profits and pay back their loans in the maturity stage, resulting in favorable operating and negative financing cash flows. In the shakeout stage, growth slows down, prices reduce, which decreases their cash flows, to support firms may sell their useless assets and pay back their finances or take more finances to support the existing operations.

Similarly, in the decline stage, the firm's sales reduce and result in negative operating cash flows. Firms sell their fixed and useless assets that lead to positive investment cash flows, and with external financing, they can support their current operations. Figure 1 below summarises the conceptual framework of the study.

Table 1: Dickinson (2011) life cycle classification criteria

LCS	Introduction	Growth	Maturity	Shakeout			Decline	
Operating cash flows	-	+	+	-	+	+	-	-
Investment cash flows	-	-	-	-	+	+	+	+
Financing cash flows	+	+	-	-	+	-	+	-

Figure 1: Conceptual framework



2.4. Hypothesis Development

The literature concludes that the life cycle has important consideration in explaining the relationship between Innovation and firm performance. Therefore, based on the literature following hypotheses are proposed.

H_1: Patents have a positive impact on firm performance.

H_2: R&D expenditures have a negative impact on firm performance.

H_3: Firm life cycle moderates the relationship between Innovation and firm performance.

H_4: Firm life cycle moderates the relationship between Innovation and firm performance differently across high-tech sectors.

While patents can be capitalised as a future economic benefit (H_1), that is why they are expected to have a positive impact on firm performance. R&D expenditures must be expensed in the incurred accounting period that tends to reduce their current earnings. So, R&D expenditures will negatively impact the firm's performance (H_2).

In this study, the firm life cycle is another focal point. Based on past literature, it is hypothesised that the firm life cycle will moderate the firm performance differently during different life cycle stages, namely introduction, growth, maturity, shakeout, and decline (H_3). In addition, it is also believed that this firm life cycle effect will also be different across high-tech sectors because innovation activity varies across these sectors (H_4). So, this moderation relationship will be expected to vary differently over the firm life cycle across these high-tech sectors.

3. DATA AND METHODOLOGY

This study uses 2002-2019 data of high-tech firms from S&P 500 companies (S&P500) collected from the Bloomberg database. These high-tech firms are from four sectors: Communication services, information technology, healthcare and consumer discretionary. The rationale for selecting data of these high-tech S&P500 firms is that these firms have dynamic cash flows because of their reinventions and restructuring strategies that frequently allow them to move from one life cycle stage to another. The final data set are based on the availability of the cash flows, R&D expenditures and patents data. A total of 149 firms, from which ten are from communication services, 48 firms from information technology, 53 firms from healthcare and 38 firms from the consumer discretionary sector, are selected.

Table 2 shows the sector-wise firm-year observations distribution into five distinct life cycle stages. Most of the observations in this sample are from the maturity stage (1760 observations) and growth stage (641 observations). There are also observations from the introduction (74 observations), shakeout (175 observations) and decline stages (32 observations). There is no single observation from the decline stage in communication services and consumer discretionary sectors. Data also shows that firms have randomly moved across different life cycle stages based on their cash flow patterns.

This study uses two formal innovation measures; several patents received each year and R&D expenditures. In addition to these innovation measures, two variables aligned to previous literature, firm size (Zott and Amit, 2008) and firm age (Maresch et al., 2016), are taken as control variables. Four measures of performance like basic earnings per share (BEPS), return on assets (ROA), return on equity (ROE), and Tobin's Q ratio are used in this study as a robustness check of performance. Table 3 describes the variables used, abbreviations, and proxies to measure them. Four dummy variables are used to mark the five different life cycle stages of introduction, growth, maturity, shakeout and decline. The decline stage is the base group.

Panel regression analysis is used to study the impact of Innovation on firm performance. Overall, the results are in three panels: A, B, and C. In panel A, the only patent is the independent variable. In panel B, only R&DE is the independent variable. In contrast, both patents and R&DE are independent variables in panel C. In addition to independent variables, two control variables of firm size and firm age are also used in each panel. The following equations are used to examine the relationship between Innovation and firm performance in these high-tech firms.

$$BEPS_{it} = \alpha_1 + \alpha_2 LnPatents_{it} + \alpha_3 LnR\&DE_{it} + \alpha_4 F.Size_{it} + \alpha_5 F.Age_{it} + \varepsilon_{it} \quad (1)$$

$$ROA_{it} = \alpha_1 + \alpha_2 LnPatents_{it} + \alpha_3 LnR\&DE_{it} + \alpha_4 F.Size_{it} + \alpha_5 F.Age_{it} + \varepsilon_{it} \quad (2)$$

$$ROE_{it} = \alpha_1 + \alpha_2 LnPatents_{it} + \alpha_3 LnR\&DE_{it} + \alpha_4 F.Size_{it} + \alpha_5 F.Age_{it} + \varepsilon_{it} \quad (3)$$

$$TQR_{it} = \alpha_1 + \alpha_2 LnPatents_{it} + \alpha_3 LnR\&DE_{it} + \alpha_4 F.Size_{it} + \alpha_5 F.Age_{it} + \varepsilon_{it} \quad (4)$$

Equations (5), (6), (7) and (8) deals with patents, dummy variables of life cycle stages and the interaction term of patents and life cycle stages as independent variables.

$$BEPS_{it} = \alpha_1 + \alpha_2 LnPatents_{it} + \alpha_3 F.Size_{it} + \alpha_4 F.Age_{it} + \alpha_5 DLCSI_{it} + \alpha_6 DLCSG_{it} + \alpha_7 DLCSM_{it} + \alpha_8 DLCSS_{it} + \alpha_9 LnPatents_{it}{*}DLCSI_{it} + \alpha_{10} LnPatents_{it}{*}DLCSG_{it} + \alpha_{11} LnPatents_{it}{*}DLCSM_{it} + \alpha_{12} LnPatents_{it}{*}DLCSS_{it} + \varepsilon_{it} \quad (5)$$

$$ROA_{it} = \alpha_1 + \alpha_2 LnPatents_{it} + \alpha_3 F.Size_{it} + \alpha_4 F.Age_{it} + \alpha_5 DLCSI_{it} + \alpha_6 DLCSG_{it} + \alpha_7 DLCSM_{it} + \alpha_8 DLCSS_{it} + \alpha_9 LnPatents_{it}{*}DLCSI_{it} + \alpha_{10} LnPatents_{it}{*}DLCSG_{it} + \alpha_{11} LnPatents_{it}{*}DLCSM_{it} + \alpha_{12} LnPatents_{it}{*}DLCSS_{it} + \varepsilon_{it} \quad (6)$$

Table 2: Sector-wise distribution of the firm-year observations into life cycle stages

Life cycle stages	Communication services	Information technology	Health care	Consumer discretionary	Total
Introduction	6	7	42	19	74
Growth	63	173	283	122	641
Maturity	102	588	558	512	1760
Shakeout	9	88	47	31	175
Decline	0	8	24	0	32
Total	180	864	954	684	2682

Table 3: Variables and their measurement

Variables	Measurement
Basic earnings per share (BEPS)	((Net income - Preferred Dividends)/Weighted average shares outstanding) *100
Return on assets (ROA)	(Net income/Total Assets) *100
Return on equity (ROE)	(Net income/Stockholders' equity) *100
Tobin's Q ratio (TQR)	The market value of the firm/ Assets value of the firm
Patents	Natural log of the number of patents received in each year
R& D Expenditures (R&DE)	Natural log of R&D expenditures
Firm size (F. Size)	Natural log of total assets
Firm age (F. Age)	Number of years from initial public offerings (IPO)
DLCSI	Dummy=1 for Introduction stage, 0 otherwise
DLCSG	Dummy=1 for Growth stage, 0 otherwise
DLCSM	Dummy=1 for Maturity stage, 0 otherwise
DLCSS	Dummy=1 for Shakeout stage, 0 otherwise

$$ROE_{it} = \alpha_1 + \alpha_2 LnPatents_{it} + \alpha_3 F.Size_{it} + \alpha_4 F.Age_{it} + \alpha_5 DLCSI_{it} + \alpha_6 DLCSG_{it} + \alpha_7 DLCSM_{it} + \alpha_8 DLCSS_{it} + \alpha_9 LnPatents_{it}{*}DLCSI_{it} + \alpha_{10} LnPatents_{it}{*}DLCSG_{it} + \alpha_{11} LnPatents_{it}{*}DLCSM_{it} + \alpha_{12} LnPatents_{it}{*}DLCSS_{it} + \varepsilon_{it} \quad (7)$$

$$TQR_{it} = \alpha_1 + \alpha_2 LnPatents_{it} + \alpha_3 F.Size_{it} + \alpha_4 F.Age_{it} + \alpha_5 DLCSI_{it} + \alpha_6 DLCSG_{it} + \alpha_7 DLCSM_{it} + \alpha_8 DLCSS_{it} + \alpha_9 LnPatents_{it}{*}DLCSI_{it} + \alpha_{10} LnPatents_{it}{*}DLCSG_{it} + \alpha_{11} LnPatents_{it}{*}DLCSM_{it} + \alpha_{12} LnPatents_{it}{*}DLCSS_{it} + \varepsilon_{it} \quad (8)$$

In equations (9), (10), (11) and (12) research and development expenditures, firm life cycle dummies and the interaction term of R&DE with life cycle stages are independent variables.

$$BEPS_{it} = \alpha_1 + \alpha_2 LnR\&DE_{it} + \alpha_3 F.Size_{it} + \alpha_4 F.Age_{it} + \alpha_5 DLCSI_{it} + \alpha_6 DLCSG_{it} + \alpha_7 DLCSM_{it} + \alpha_8 DLCSS_{it} + \alpha_9 LnR\&DE_{it}{*}DLCSI_{it} + \alpha_{10} LnR\&DE_{it}{*}DLCSG_{it} + \alpha_{11} LnR\&DE_{it}{*}DLCSM_{it} + \alpha_{12} LnR\&DE_{it}{*}DLCSS_{it} + \varepsilon_{it} \quad (9)$$

$$ROA_{it} = \alpha_1 + \alpha_2 LnR\&DE_{it} + \alpha_3 F.Size_{it} + \alpha_4 F.Age_{it} + \alpha_5 DLCSI_{it} + \alpha_6 DLCSG_{it} + \alpha_7 DLCSM_{it} + \alpha_8 DLCSS_{it} + \alpha_9 LnR\&DE_{it}{*}DLCSI_{it} + \alpha_{10} LnR\&DE_{it}{*}DLCSG_{it} + \alpha_{11} LnR\&DE_{it}{*}DLCSM_{it} + \alpha_{12} LnR\&DE_{it}{*}DLCSS_{it} + \varepsilon_{it} \quad (10)$$

$$ROE_{it} = \alpha_1 + \alpha_1 + \alpha_2 LnR\&DE_{it} + \alpha_3 F.Size_{it} + \alpha_4 F.Age_{it} + \alpha_5 DLCSI_{it} + \alpha_6 DLCSG_{it} + \alpha_7 DLCSM_{it} + \alpha_8 DLCSS_{it} + \alpha_9 LnR\&DE_{it}{*}DLCSI_{it} + \alpha_{10} LnR\&DE_{it}{*}DLCSG_{it} + \alpha_{11} LnR\&DE_{it}{*}DLCSM_{it} + \alpha_{12} LnR\&DE_{it}{*}DLCSS_{it} + \varepsilon_{it} \quad (11)$$

$$TQR_{it} = \alpha_1 + \alpha_2 LnR\&DE_{it} + \alpha_3 F.Size_{it} + \alpha_4 F.Age_{it} + \alpha_5 DLCSI_{it} + \alpha_6 DLCSG_{it} + \alpha_7 DLCSM_{it} + \alpha_8 DLCSS_{it} + \alpha_9 LnR\&DE_{it}{*}DLCSI_{it} + \alpha_{10} LnR\&DE_{it}{*}DLCSG_{it} + \alpha_{11} LnR\&DE_{it}{*}DLCSM_{it} + \alpha_{12} LnR\&DE_{it}{*}DLCSS_{it} + \varepsilon_{it} \quad (12)$$

4. EMPIRICAL ANALYSIS

4.1. Descriptive Statistics

Table 4 shows the descriptive statistics of all the variables used in this study. Research and development expenditures and total assets figures are in a million dollars; patents are in numbers, firm age is in years from IPO while performance is in percentage. Patents have a mean value of 184, a standard deviation of 628.07, a minimum of 0 and a maximum of 9210. R&DE has a mean value of $1039.67 million, a minimum of 0 and a maximum of $35931 million. Similarly, total assets have a mean value of $25326.45 million and a maximum value of $551669 million. BEPS, ROA, and ROE are percentages, while TQR is in several times.

4.2. Pearson Correlation

Pearson correlation analysis matrix was used to see the multicollinearity among the independent variables. The value of Pearson correlation coefficients of all independent variables is <0.6, indicating that they are not highly correlated, so there is no multicollinearity problem. Table 5 below shows the results of the Pearson correlation matrix.

4.3. Panel Regression Analysis

Panel regression analysis is used to analyse the impact of Innovation on firm performance over their life cycle because most life cycle studies have used panel regression (Chuang, 2017; Kansil and Singh, 2018). Four financial performance proxies are used, including BEPS, ROA, ROE, and TQR. In addition, the Hausman test is used to select between the fixed effect and random effect model. Results show that the fixed effect model is applicable in all cases.

Table 6 shows the overall panel regression results in panels A, B and C. Only patents and control variables are used as independent variables in panel A. Only R&DE and control variables are used in panel B as independent variables. However, in panel C, patents and R&DE and control variables are independent variables.

Panel A shows that patents have a significant and positive relationship with ROA and ROE while a significant but negative relationship with BEPS. In Panel B, R&DE has a significant and positive relationship with only BEPS. Panel C also confirms a similar relationship. Firm Size has a significant and positive relationship with BEPS but a negative relationship with ROE and

Table 4: Descriptive statistics

Variable	Mean	Standard deviation	Minimum	Maximum	Skewness	Kurtosis
Patents	184.58	628.07	0	9210	8.01	88.39
R&DE	1039.67	2410.01	0	35931	5.08	43.81
TA	25326.45	50095.42	59.16	551669	4.16	25.61
Firm Age	24.83	17.40	0	132	2.26	11.03
BEPS	2.53	4.86	−28.01	112.93	8.57	151.32
ROA	7.70	10.02	−99.94	61.07	−2.14	17.76
ROE	17.90	32.68	−201.15	370.45	0.96	31.82
TQR	2.74	1.84	0.24	20.92	3.04	17.93

Table 5: Pearson correlation matrix

Variable	Patents	R&DE	Firm size	Firm age
Patents	1			
R&DE	0.538**	1		
Firm size	0.329**	−0.041*	1	
Firm age	0.188**	0.011	0.462**	1

**P<0.01, *P<0.05

TQR. Finally, firm age shows a significant and positive relationship with all performance measures.

Table 7 shows the results of panel regression analysis where patents and firm life cycle stages are taken as independent variables. Life cycle stages are used as dummy variables to examine whether they moderate the impact of Innovation on financial performance. There are five stages in the firm life cycle: Introduction, growth, maturity, shakeout, and decline. Four dummies are employed with decline as the base group.

Patents show a significant and positive relationship with ROA and ROE. From the firm life cycle perspective, only the decline stage shows a reduction in the BEPS. In the second model, all life cycle stages except decline are positive and significant to ROA. In the third model, all life cycle stages are positive and significant to ROE. In the final model, all life cycle stages except introductory are positive and significant to TQR. From the interaction effect, it is observed that having a patent at all life cycle stages except decline contributes to reducing the ROA, while in the decline stage, it contributes to a higher ROE.

Firm size is significant and negative with all performance measurements except BEPS. Moreover, it shows that firms with a more considerable asset tend to have slightly lower ROA, ROE and TQR. In contrast, firm age shows a positive and significant relationship with all measures of firm performance. The longer the firms exist in the marketplace after their IPO, the better the firm performance.

Table 8 shows the results of panel regression where R&DE, firm age, firm size, and firm life cycle are taken as independent variables. R&DE shows a significant and negative relationship between ROA and ROE. In terms of an interaction effect, it is found that R&DE and firm life cycle have interacted in all life cycle stages except the introductory stage with ROA and ROE. This interaction term provides a positive impact on both ROA and ROE. Lastly, it is found that the decline stage of the firm life cycle reduces the BEPS significantly at 1%. In contrast, having R&DE at decline contributes to higher TQR.

Firm size shows a significant but negative relationship with ROA. ROE and TQR are positively related to BEPS. In contrast, firm age shows a positive and significant relationship with all firm performance measurements of BEPS, ROA, ROE and TQR.

Table 9 shows the sector-wise results of panel regression where patents and firm life cycle stages are independent variables. From the firm life cycle perspective, there is no observation from the decline stage in communication services and consumer discretionary sectors, so constant in these sectors represent the shakeout stage results.

There is no direct relationship of patents with any performance measure in the communication services sector. In contrast, the interaction effect results show that having a patent at the shakeout stage reduces the BEPS. ROE increases in the shakeout stage because services are offered to reap the maximum benefit due to its good recognition by the customers with minimum investment. Similarly, TQR in the introductory and shakeout stages is also higher because new services are added to the portfolio, which positively signals to the firm's investors, increasing firm value.

In the information technology sector, patents show a significant and positive relationship with ROE while a significant but negative relationship with TQR. In the second model, all life cycle stages are positive and significant to ROA. In the third model, growth, maturity, and shakeout stages are positive and significant to ROE, while in the final model, all life cycle stages are significant to TQR. For the interaction effect, only the decline stage reduces the BEPS due to the underutilisation of firm products because many competitors are now offering similar products at competitive prices. Having patents at the introduction and decline stage contribute to higher ROA because additions of new patents enhance the returns. In model 3, having patents at the growth, maturity and shakeout stage reduces ROE due to less earning available to their stockholders.

In contrast, the decline stage contributes to higher ROE because more earnings motivate investors. All life cycle stages in the information technology sector contribute to a higher TQR. A greater number of patents reflects positive performance, which augurs well with investors.

Patents show a significant and positive relationship with only ROA in the healthcare sector. Growth, maturity, and shakeout stage are positively related to ROA. In the third model, all stages except the decline stage are significantly and positively related to ROE.

Table 6: Overall panel regression analysis

Variable	Panel A			
	BEPS	ROA	ROE	TQR
LnPatents	−0.25** (0.09)	0.57* (0.22)	3.40** (0.69)	0.01 (0.04)
Firm size	1.36** (0.14)	0.53 (0.34)	−4.25** (1.08)	−0.60** (0.06)
Firm age	0.15** (0.02)	0.21** (0.05)	1.20** (0.15)	0.08** (0.01)
Constant	−31.67** (2.96)	13.16 (6.94)	75.78** (21.86)	14.54** (1.15)
R^2	0.04	0.01	0.01	0.01
F test	167.79**	14.90**	45.73**	42.71**
Hausman Chi^2	126.31**	22.23**	77.84**	83.87**
Variable	**Panel B**			
	BEPS	**ROA**	**ROE**	**TQR**
LnR&DE	0.08* (0.03)	0.07 (0.08)	0.03 (0.24)	−0.01 (0.01)
Firm size	1.29** (0.15)	−0.21 (0.37)	−2.35* (1.11)	−0.58** (0.06)
Firm age	0.16** (0.02)	0.25** (0.05)	1.28** (0.15)	0.08** (0.01)
Constant	−32.04** (3.12)	5.15 (7.37)	38.40 (22.19)	13.97** (1.20)
R^2	0.03	0.01	0.01	0.01
F test	152.75**	14.68**	35.10**	37.96**
Hausman Chi^2	125.01**	22.13**	51.46**	97.21**
Variable	**Panel C**			
	BEPS	**ROA**	**ROE**	**TQR**
LnPatents	−0.27** (0.10)	0.56* (0.23)	3.63** (0.70)	0.01 (0.04)
LnR&DE	0.08* (0.03)	0.07 (0.08)	0.02 (0.24)	−0.01 (0.01)
Firm size	1.39** (0.16)	−0.42 (0.38)	−3.75** (1.13)	−0.58** (0.06)
Firm age	0.16** (0.02)	0.23** (0.05)	1.18** (0.15)	0.08** (0.01)
Constant	−33.67** (3.17)	8.73 (7.52)	62.69** (22.56)	14.03** (1.23)
R^2	0.04	0.01	0.01	0.01
F test	116.61**	12.46**	33.37**	28.48**
Hausman Chi^2	128.07**	24.26**	62.60**	94.84**

**P<0.01, *P<0.05, the values in parenthesis indicate robust standard error

Table 7: Panel regression with patents and dummy variable of firm life cycle

Variable	BEPS	ROA	ROE	TQR
LnPatents	−0.61 (0.47)	3.07** (1.01)	6.81* (3.25)	0.12 (0.17)
Firm size	1.41** (0.15)	−1.49** (0.33)	−7.02** (1.06)	−0.68** (0.06)
Firm age	0.14** (0.02)	0.21** (0.04)	1.29** (0.14)	0.08** (0.01)
DLCSI	−1.76 (1.51)	13.26** (3.27)	51.99** (10.47)	−0.12 (0.56)
DLCSG	−2.01 (1.39)	31.40** (3.00)	82.40** (9.61)	2.20** (0.52)
DLCSM	−0.57 (1.40)	32.56** (3.02)	86.87** (9.67)	2.01** (0.52)
DLCSS	−0.55 (1.47)	34.07** (3.18)	89.04** (10.19)	1.93** (0.55)
lnPatents*DLCSI	0.25 (0.51)	−2.44* (1.10)	−2.07 (3.52)	0.12 (0.19)
lnPatents*DLCSG	0.43 (0.46)	−2.84** (0.99)	−3.80 (3.19)	−0.15 (0.17)
lnPatents*DLCSM	0.30 (0.46)	−2.53* (1.00)	−3.82 (3.21)	−0.11 (0.17)
lnPatents*DLCSS	0.30 (0.48)	−2.54* (1.03)	−2.74 (3.30)	−0.05 (0.18)
Constant	−31.35** (3.14)	3.49 (6.89)	53.58* (22.30)	14.34** (1.20)
R^2	0.05	0.13	0.04	0.01
F test	49.81**	40.92**	34.59**	21.55**
Hausman Chi^2	97.20**	84.64**	101.09**	158.55**

**P<0.01, *P<0.05, the values in parenthesis indicate robust standard error

In contrast, all life cycle stages in the final model are significantly and positively related to TQR. The interaction effect shows that having patents at the growth and maturity stage reduces ROA due to less productivity of their assets. While having patents at the introductory and decline stages contributes to a higher TQR.

In the consumer discretionary sector, patents only show a direct and positive relationship with ROE. Interaction effect results show that having patents in the decline stage reduces BEPS because more spending is needed. Having patents in the introductory and decline stage enhances ROA due to better utilisation of those patents, while in the decline stage, it also enhances TQR.

Firm size is significant and negative with all performance measures except BEPS, positively affecting communication services and consumer discretionary sectors. Moreover, it shows that firms with a more considerable asset tend to lower ROA, ROE and TQR. In contrast, firm age shows a positive and significant relationship in all sectors. The longer the firms exist in the marketplace after their IPO, the better the firm performance.

Table 10 shows the sector-wise results of panel regression where R&DE, firm age, size, and life cycle are taken as independent variables. There is no significant relationship in the communication services sector, either directly or through interaction with any

Table 8: Panel regression with R&DE and dummy variable of firm life cycle

Variable	BEPS	ROA	ROE	TQR
LnR&DE	−0.05 (0.20)	−1.28** (0.43)	−3.19* (1.32)	−0.08 (0.07)
Firm size	1.32** (0.16)	−1.60** (0.35)	−6.12** (1.09)	−0.69** (0.06)
Firm age	0.14** (0.02)	0.27** (0.05)	1.41** (0.15)	0.09** (0.01)
DLCSI	−1.44 (3.66)	0.49 (7.90)	27.97 (24.18)	−0.09 (1.35)
DLCSG	−2.67 (3.62)	3.74 (7.81)	22.83 (23.90)	0.44 (1.34)
DLCSM	−2.14 (3.61)	4.61 (7.79)	25.45 (23.83)	0.48 (1.33)
DLCSS	−2.02 (3.72)	4.90 (8.04)	22.74 (24.60)	0.34 (1.38)
LnR&DE*DLCSI	0.02 (0.20)	0.25 (0.43)	0.85 (1.32)	−0.01 (0.07)
LnR&DE*DLCSG	0.09 (0.20)	1.24** (0.43)	3.01* (1.31)	0.09 (0.07)
LnR&DE*DLCSM	0.13 (0.20)	1.32** (0.43)	3.13* (1.30)	0.08 (0.07)
LnR&DE*DLCSS	0.12 (0.20)	1.38** (0.44)	3.60** (1.34)	0.10 (0.08)
Constant	−29.69** (4.78)	33.48** (10.40)	99.98** (32.06)	16.04** (1.79)
R^2	0.04	0.14	0.06	0.01
F test	45.25**	42.20**	33.79**	19.97**
Hausman Chi^2	103.28**	62.86**	83.27**	184.10**

**P<0.01, *P<0.05, the values in parenthesis indicate robust standard error

performance measure. In the information technology sector, R&DE shows a significant and positive relationship with ROE due to greater returns resulting from R&DE and negative with TQR because more investment in R&DE signals negatively to the investors. All stages are significantly related to ROA. Growth, maturity, and shakeout stages are significant to ROE, while in the final model, all life cycle stages are significant to TQR. From the interaction effect, it is observed that R&DE at the introduction stage contributes to higher ROA due to greater performance of its assets. R&DE reduces ROE in all life cycle stages except the introduction stage, which is insignificant due to lesser earnings available to the stockholders. The firm positive prospects contribute to a higher TQR in all life cycle stages in the information technology sector.

In the healthcare sector, a positive relationship with TQR because having more investment in R&DE signals a positive image of the firm to contribute to the society in terms of developing solutions through R&DE while negative because these R&DE reduces firm earnings. Growth, maturity, and shakeout stages are significantly related to TQR. The interaction effect shows that R&DE at growth, maturity and shakeout stage contributes to higher BEPS due to greater benefits derived from those spending. R&DE contributes to higher ROA only in the introduction stage while higher ROE in all life cycle stages except the introduction stage due to returns generated from the productive investment in R&DE. In contrast, R&DE reduces TQR in the growth, maturity, and shakeout stage because investors do not make those investments positively.

There is no direct relationship of R&DE in the consumer discretionary sector with any performance measure. R&DE interaction term with only shakeout stage contributes to higher ROA and TQR and reduces BEPS.

Firm size shows a significant but negative relationship with ROA, ROE and TQR in all sectors except the communication services sector. A positive relationship with BEPS in all sectors except health care. In contrast, firm age shows a positive and significant relationship with all performance measures in all four sectors

These results show that patents significantly impact firm performance, as evidenced by the positive relationship of patents with ROA and ROE. These results are consistent with the findings of Paula and Rocha (2020), Wang et al. (2019), Alt (2018) and Rajapathirana and Hu (2018). R&DE has a significant negative relationship with ROA and ROE because investors perceive R&DE as a sunk cost, which negatively signals the market that reduces firm value. These results are consistent with Subramanian and Nilakanta (1996) and Yoo et al. (2019) findings. Therefore, our hypothesis H_1 is accepted as patents positively affect firm performance while H_2 is rejected as R&DE negatively affects firm performance.

The firm life cycle effect is strongly observable in the decline stage because patents and R&DE have a significant and positive relationship with ROA, ROE, and TQR but negatively with BEPS. It is a critical stage where firms' earnings become stagnant, and firms must make crucial decisions. These results are consistent with the findings of McGahan and Silverman (2001) and Dickinson (2011), who stated that firms in the decline stage have more internal inefficiencies and to recover from those inefficiencies, firms spend more on Innovation to come back in the market.

If decisions are in the form of Innovation, it will bring the firm back into the competition. At the same time, if spending on research and development increases, their BEPS will decrease because those R&DE are treated as expenses. These results are consistent with Yoo et al. (2019) and He et al. (2020), who said that Innovation impacts performance differently during the firm life cycle. Similarly, except the introduction stage, all life cycle stages moderate Innovation with ROA and ROE. So, our hypothesis H_3 is accepted, which indicates that the firm life cycle moderates the relationship between Innovation and firm performance.

The moderating impact of the firm life cycle on the relationship between Innovation and performance is strongly observable in the information technology and healthcare sectors. More cash flow variation is observed in these sectors because firms have a more significant number of patents and spend more on research and development activities. These results are consistent with Zhang et al. (2018). They determined that patents in high-tech firms enhance their performance and increase their survival rate.

Table 9: Sector wise panel regression with patents and dummy variable of firm life cycle

Variables	Communication services				Information technology				Health care				Consumer discretionary			
	BEPS	ROA	ROE	TQR	BEPS	ROA	ROE	TQR	BEPS	ROA	ROE	TQR	BEPS	ROA	ROE	TQR
LnPatents	−0.46	2.66	3.24	0.43	−0.08	1.69	39.78**	−1.28**	−0.40	3.61*	4.92	0.32	−0.02	0.92	7.97**	−0.03
	(0.95)	(1.71)	(4.76)	(0.30)	(0.48)	(2.09)	(7.07)	(0.29)	(0.67)	(1.73)	(4.08)	(0.31)	(0.54)	(0.55)	(2.72)	(0.13)
Firm size	2.16**	−1.26	−6.89*	−1.13**	0.25	−3.49**	−13.6**	−0.93**	−0.29	−2.4**	−4.9**	−0.94**	5.28**	−0.83	−3.37	−0.59**
	(0.47)	(0.98)	(2.83)	(0.19)	(0.15)	(0.66)	(2.23)	(0.09)	(0.24)	(0.64)	(1.50)	(0.11)	(0.46)	(0.47)	(2.45)	(0.11)
Firm age	0.31**	0.02	0.95	−0.04	0.15**	0.43**	1.68**	0.09**	0.27**	0.24**	0.75**	0.12**	−0.08	0.08	1.40**	0.05**
	(0.12)	(0.22)	(0.63)	(0.04)	(0.02)	(0.08)	(0.29)	(0.01)	(0.03)	(0.09)	(0.20)	(0.01)	(0.05)	(0.05)	(0.27)	(0.01)
DLCSI	0.55	−10.46	−27.35	−0.89	−2.62	−62.1**	50.52	−7.08**	−0.45	6.27	31.4**	−1.89*	−3.02	−4.93	−5.24	0.02
	(4.32)	(7.76)	(21.5)	(1.38)	(2.80)	(12.22)	(41.46)	(1.72)	(1.76)	(4.57)	(10.8)	(0.83)	(5.35)	(5.46)	(27.2)	(1.28)
DLCSG	2.27	6.12	4.47	−0.48	−0.83	19.95*	235.1**	−5.28**	0.17	42.7**	84.7**	4.28**	−1.37	−1.21	−0.56	0.43
	(2.20)	(3.98)	(11.1)	(0.71)	(2.02)	(8.82)	(29.91)	(1.24)	(1.59)	(4.12)	(9.71)	(0.75)	(5.22)	(5.33)	(26.5)	(1.25)
DLCSM	4.10	6.21	4.99	0.20	−0.41	21.88*	249.2**	−5.46**	0.82	45.1**	88.9**	4.24**	0.85	−0.10	0.07	0.21
	(2.18)	(3.92)	(10.9)	(0.70)	(2.02)	(8.81)	(29.89)	(1.24)	(1.61)	(4.16)	(9.80)	(0.76)	(5.20)	(5.30)	(26.4)	(1.25)
DLCSS					0.53	27.22**	259.4**	−5.09**	0.67	44.1**	87.5**	3.96**				
					(2.09)	(9.11)	(30.91)	(1.28)	(1.71)	(4.44)	(10.5)	(0.81)				
lnPatents*DLCSI	−1.55	2.32	8.37	1.27*	0.72	15.26**	11.79	1.37**	0.06	−0.85	−2.65	0.70*	1.26	10.04*	21.01	0.48
	(1.59)	(2.87)	(7.96)	(0.51)	(0.65)	(2.84)	(9.63)	(0.40)	(0.69)	(1.78)	(4.19)	(0.32)	(4.39)	(5.48)	(22.3)	(1.05)
lnPatents*DLCSG	−1.03	−2.68	−1.99	0.22	0.21	−1.37	−34.3**	1.25**	0.60	−3.78*	−4.13	−0.37	0.65	0.39	−1.45	−0.05
	(1.01)	(1.82)	(5.09)	(0.32)	(0.46)	(2.02)	(6.87)	(0.28)	(0.67)	(1.73)	(4.08)	(0.32)	(0.46)	(0.46)	(2.32)	(0.11)
lnPatents*DLCM	−1.45	−2.33	−2.19	0.08	0.30	−1.37	−36.6**	1.31**	0.67	−3.52*	−4.01	−0.37	0.17	0.52	0.95	0.01
	(0.96)	(1.72)	(4.79)	(0.31)	(0.47)	(2.04)	(6.91)	(0.29)	(0.67)	(1.74)	(4.09)	(0.32)	(0.47)	(0.48)	(2.42)	(0.11)
lnPatents*DLCSS					0.13	−2.07	−37**	1.30**	0.76	−2.43	−1.14	−0.31				
					(0.48)	(2.08)	(7.07)	(0.29)	(0.71)	(1.84)	(4.33)	(0.33)				
Constant	−52**	28.58	155.5*	28.7**	−7.54*	55.89**	31.80	27.22**	0.53	11.94	16.42	16.86**	−116**	24.59*	53.57	14.3**
	(10.7)	(22.25)	(63.3)	(4.41)	(3.46)	(15.11)	(51.26)	(2.12)	(4.71)	(12.2)	(28.7)	(2.22)	(10.95)	(11.2)	(57.8)	(2.63)
R^2	0.15	0.01	0.02	0.10	0.25	0.02	0.06	0.02	0.02	0.40	0.30	0.01	0.02	0.01	0.01	0.01
F test	10.6**	1.45	1.30	7.55**	25.8**	13.37**	18.48**	14.67**	20.62**	42.33	30.2**	19.01**	23.39**	4.75**	9.48**	3.25**
Hausman Chi^2	33.1**	85.32**	35.4**	94.3**	50.4**	48.97**	37.56**	43.31**	91.48**	40.9**	97.7**	147.8**	58.57**	23.3**	90.4**	24.2**

**P<0.01, *P<0.05, the values in parenthesis indicate robust standard error

Table 10: Sector wise panel regression with R&DE and dummy variable of firm life cycle

Variables	Communication services				Information technology				Health care				Consumer discretionary			
	BEPS	ROA	ROE	TQR	BEPS	ROA	ROE	TQR	BEPS	ROA	ROE	TQR	BEPS	ROA	ROE	TQR
LnR&DE	−0.73	0.44	5.71	−0.40	−0.19	1.77	32.16**	−1.17**	−1.39	−2.46	−10.51*	0.94**	0.05	−0.15	−0.18	−0.04
	(2.03)	(3.21)	(7.14)	(0.61)	(0.42)	(1.85)	(5.61)	(0.25)	(0.71)	(1.86)	(4.38)	(0.34)	(0.15)	(0.15)	(0.78)	(0.03)
Firm size	1.73**	0.54	1.69	−0.62	0.40*	−3.36**	−11.3**	−0.83**	−0.19	−1.36**	−3.65*	−0.99**	6.09**	−1.37*	−6.35*	−0.61**
	(0.28)	(1.76)	(1.02)	(0.35)	(0.16)	(0.71)	(2.16)	(0.10)	(0.24)	(0.62)	(1.46)	(0.11)	(0.55)	(0.55)	(3.09)	(0.13)
Firm age	0.13*	0.07	−0.60	0.09*	0.16**	0.44**	1.82**	0.09**	0.27**	0.05*	0.67**	0.12**	0.02	0.20**	1.96**	0.05**
	(0.05)	(0.22)	(0.19)	(0.04)	(0.02)	(0.09)	(0.26)	(0.01)	(0.03)	(0.09)	(0.21)	(0.02)	(0.06)	(0.06)	(0.34)	(0.01)
DLCSI	−12.30	−66.57	−200.1	−22.63	−10.97	−246**	−89.87	−24.3**	−5.99	−90.9**	−134.51	−2.01	−2.63	0.52	11.85	0.29
	(61.49)	(75.1)	(216)	(14.4)	(12.15)	(53.43)	(162)	(7.26)	(13.47)	(35.03)	(82.61)	(6.40)	(5.51)	(5.54)	(28.9)	(1.28)
DLCSG	−14.49	56.67	154.1	8.55	−4.12	47.26	704.8**	−22.9**	−25.23	−10.35	−121.59	19.91**	0.74	−0.91	2.05	0.14
	(40.24)	(51.1)	(141)	(9.78)	(8.12)	(35.71)	(108)	(4.85)	(13.11)	(34.11)	(80.44)	(6.23)	(5.48)	(5.51)	(28.7)	(1.28)
DLCSM	−16.62	57.97	129.9	8.64	−3.66	48.40	722.5**	−22.9**	−24.61	−9.19	−118.14	19.97**	1.16	−0.61	−4.33	0.16
	(40.27)	(50.9)	(142)	(9.76)	(8.12)	(35.70)	(108)	(4.85)	(13.11)	(34.12)	(80.46)	(6.23)	(5.44)	(5.47)	(28.5)	(1.27)
DLCSS					−2.49	52.90	722.8**	−22.9**	−24.83	−11.42	−121.35	19.96**				
					(8.22)	(36.14)	(109)	(4.91)	(13.16)	(34.23)	(80.72)	(6.25)				
LnR&DE*DLCSI	0.62	3.19	10.03	1.26	0.57	12.48**	8.88	1.18**	0.29	5.29**	8.67	0.11	0.82	−1.13	−9.51	−0.03
	(3.06)	(3.77)	(10.8)	(0.72)	(0.62)	(2.73)	(8.27)	(0.37)	(0.72)	(1.89)	(4.45)	(0.34)	(5.77)	(5.81)	(30.3)	(1.34)
LnR&DE*DLCSG	0.87	−2.77	−7.48	−0.45	0.21	−1.72	−31.5**	1.16**	1.46*	2.43	10.74*	−0.89**	−0.03	−0.04	−0.85	0.01
	(2.03)	(2.59)	(7.16)	(0.50)	(0.42)	(1.85)	(5.60)	(0.25)	(0.71)	(1.85)	(4.37)	(0.34)	(0.14)	(0.14)	(0.73)	(0.03)
LnR&DE*DLCSM	0.99	−2.78	−6.09	−0.42	0.23	−1.67	−32.2**	1.17**	1.47*	2.59	10.82*	−0.90**	0.13	0.06	−0.10	−0.01
	(2.03)	(2.58)	(7.15)	(0.49)	(0.42)	(1.85)	(5.60)	(0.25)	(0.71)	(1.85)	(4.37)	(0.34)	(0.13)	(0.13)	(0.69)	(0.03)
LnR&DE*DLCSS					0.17	−1.79	−31.7**	1.19**	1.48*	2.75	11.28*	−0.91**				
					(0.43)	(1.87)	(5.66)	(0.25)	(0.72)	(1.86)	(4.39)	(0.34)				
Constant	−22.40	−32.90	−137.3	18.50	−7.76	25.49	−485**	42.56**	23.48	45.84	195.3*	1.59	−139.4**	36.5**	122.53	15.38**
	(39.84)	(53.3)	(140)	(10.3)	(8.55)	(37.63)	(114)	(5.11)	(13.50)	(35.12)	(82.82)	(6.41)	(12.83)	(12.9)	(71.7)	(2.99)
R^2	0.28	0.02	0.22	0.13	0.24	0.02	0.07	0.02	0.02	0.47	0.34	0.02	0.01	0.01	0.01	0.02
F test/Wald Chi2	55.13	1.37	38.8**	5.50**	24.46**	11.09	19.94**	11.82**	19.73**	623.4**	30.06**	19.10**	26.69**	2.17*	4.95**	4.54**
Hausman Chi^2	3.22	21.1**	15.42	61.2**	49.45**	30.73**	37.54**	38.24**	77.98**	1.18	39.58**	88.46**	140.85**	25.1**	33.72**	32.79

**P<0.01, *P<0.05, the values in parenthesis indicate robust standard error

Table 11: Summary of sector wise significant relationships over the firm life cycle

Sector Wise DV	Introduction		Growth		Maturity		Shakeout		Decline	
	Patents	R&DE	Patents	R&DE	Patents	R&DE	Patents	R&DE	Patents	R&DE
Communication										
Services BEPS							-			
ROA										
ROE							+			
TQR	+						+			
Information										
Technology BEPS									-	
ROA	+	+							+	
ROE			+	-	+	-	+	-		-
TQR	+	+	+	+	+	+	+	+	+	+
Health care										
BEPS				+		+		+		
ROA		+	-		-					
ROE				+		+		+		+
TQR	+			-		-		-	+	
Consumer										
Discretionary BEPS							-	-		
ROA	+						+	+		
ROE										
TQR							+	+		

Therefore, our hypothesis H_4 is also accepted, indicating that the firm life cycle moderates the relationship across high-tech sectors.

Firm size has a significant and positive relationship with BEPS while a significant but negative relationship with ROA, ROE and TQR. Finally, firm age shows a significant positive relationship with all performance measures of BEPS, ROA, ROE and TQR. These results are consistent with the findings of Francis et al. (2005), Zott and Amit (2008) and Maresch et al. (2016). Table 11 below summarises the sector-wise significant relationships with performance over different life cycle stages of the firms.

4.4. Robustness Check

Four performance measures are used in this study, which includes BEPS, ROA, ROE, and TQR. These measures serve as the robustness check of the performance of the firms. Results indicate that firm life cycle significantly moderates the relationship of Innovation with all performance measures, either BEPS, ROA, ROE, or TQR, especially in information technology and health care sectors. Results also confirm the robustness of these performance measures regarding the direction of the relationship, especially with ROE and TQR. All performance measures results are presented in the analysis section to show a side-by-side comparison.

5. CONCLUSION

This study examines the moderating role of the firm life cycle in the relationship between Innovation and firm performance of high-tech firms. This study's primary motivation is the rapidly changing environmental circumstances in which firms are continuously involved in innovative activities to remain competitive in the market. The firm life cycle is also critical because firms have different priorities while passing through different life cycle stages. This study uses the most appropriate and practical life cycle classification approach of Dickinson (2011) based on cash flows from operating, investment, and financing activities. This approach allows the firms to move back and forth across different life cycle stages based on Innovation and corporate restructuring strategies.

Findings determine that the fixed-effect model is applicable in almost all cases. Results show that both measures of Innovation (patents and R&DE) have a significant relationship with firm performance, and this effect is strongly observable in the decline stage. This study validates that innovation impacts firm performance, and the life cycle is also an important factor influencing this relationship. It also validates that this moderating impact of the life cycle is strongly observable in the information technology and health care sectors.

This study extends the literature regarding the validity of life cycle theory which states that life cycle is a critical component in the strategic decision-making processes of the firm. This study has practical implications for managing firms that want to decide on investment in R&DE to remain competitive in the market and enhance their performance, as findings suggest that both patents and R&DE affect firm performance. These decisions will positively impact the decline stage, a crucial stage of the firm.

The findings of this study will also help the investors to view the firm's existing innovation strategy to decide about making long-term investments based on firm strategic plans. This study uses only S&P 500 high-tech firms' data, so it is recommended to extend the study's scope by taking data from high-tech firms of other developed, developing and undeveloped countries.

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