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The Value Relevance of Operational Innovation: Insights from the Perspective of Firm Life Cycle

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Abstract: This study investigates the effect of innovation on firm value at each stage of the firm life cycle (FLC): growth, mature and decline stages. Innovation involves improving the yield of input resources and creating new revenue sources. Thus, we define operational innovation as overall efficiency in business operations and divide the operational innovation into technical innovation and scale innovation. We adopt data envelopment analysis to measure a firm's operational innovation and Dickinson's method to determine the firm's life cycle stage. The findings show that the effect of operational innovation on firm value differs among different stages of the firm life cycle, indicating that firms seeking value maximisation should improve the performance of technical innovation at the growth stage and that of scale innovation at the decline stage. In addition, technical innovation is positively related to the firm's future value at every stage of its life cycle, signifying that the firm's sustainability is associated with technical innovation rather than scale innovation. This study contributes to the existing literature by presenting the value relevance of the operational innovation that firms should pursue in each life cycle stage.

Keywords: operational innovation; firm life cycle; firm value; technical innovation; scale innovation; continuous improvement

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1. Introduction

This study's purpose was to explore whether the value relevance of innovation is different across each stage of the FLC. Contingency theory suggests that firms respond to each market situation to increase their value [1]. The FLC is typically divided into growth, mature and decline stages, which reflect circumstances firms face as they grow in the marketplace. We considered FLC as an indicator concerning the firm's external market environment. In addition, we empirically analysed whether firms increase their future value by pursuing innovation. Prior studies noted that, by carrying out innovation, firms can maintain the growth or mature stage or leap back from the decline stage to a different life cycle stage instead of disappearing from the market [2,3]. By analysing whether innovation affects the future value of firms, we present empirical evidence that innovation ensures the survival of firms.

FLC, derived from product life cycle theory, is the theory that firms have similar patterns, just as products are developed and released to the market, grow in popularity and disappear from the market [4,5]. The FLC is divided into growth, mature and decline, each featuring unique business environments, organisational structures, decision-making processes and performance [2,3]. For example, firms in the growth stage make long-term or large-scale investments and have higher sales growth rates than mature and declining ones. Meanwhile, mature firms experience stable market and sales growth and make fewer investments than growing firms. In the decline stage, firms try to improve their short-term performance by recovering or closing lines of business as profitability declines.

Innovation allows firms to successfully enter new markets and establish barriers to entry to keep competitors out [3,6]. Innovation also enables firms to earn profits by ensuring continuous growth and helps them maintain competitive advantages. Thus, innovation has drawn attention as a strategic way for firms to achieve their goals. Moreover, the success of innovation activities can be affected by firms' current FLC stage because resource allocation, business goals, organisational structure, marketing channels and abilities to achieve goals may differ in each life cycle stage [2].

This study treated the FLC stage as an environmental factor because the life cycle stage reflects how the firm has evolved as it adapts to changes in the market. Firms that successfully innovate in response to changes in the market increase firm value over a more extended period than firms that do not. Therefore, this study compared how innovations affect firm value at each stage of FLC. We also considered whether innovative activities contribute to the survival of firms. Particularly, firms in the decline stage seek short-term goals or reorganise their business units. However, some prior studies indicated that innovation helps firms in the decline stage continue to survive or leap back to other stages [2,3]. Accordingly, this study examined whether declining firms' implementation of innovative activities affects future firm value.

Two significant differences between this study and prior research are as follows: First, most prior studies measured innovation as research and development (R&D) expenditures (e.g., [7–9]). Using R&D as a proxy variable for innovation poses two potential limitations. First, R&D expenditures are necessary for innovation, but not all R&D leads to innovation. The success of R&D is inherently uncertain. Second, it takes a long time for R&D expenditures to lead to innovations; for example, an average of 4–6 years for US firms and 2–4 years for South Korean firms [10,11]. Hence, using R&D expenditures as a proxy for innovation requires a time lag to the analysis, which some argue is not easy to determine. Innovations include developing more efficient production methods and new services or products, implementing more productive organisational structures, acquiring new resources and entering new markets [12]. According to Horngren et al. (2012) [13], innovation generates value by efficiently supplying new or existing products. Thus, we measured innovation as operational efficiency, indicating the extent to which firms can maximise outputs at a given input level. Operational innovation (OPINN) means the degree to which firms maximise their outputs under the given input level and is evaluated by adopting data envelopment analysis (DEA). Yoo et al. (2019) [14] documented that firms can reduce operating costs through efficient production technology by R&D investment; however, uncertainty also exists due to characteristics such as time lag. Unlike R&D expenditure, OPINN is a measure of a posterior outcome of innovation activities; thus, there is an advantage because it is not necessary to consider the time-lag effect of innovation. DEA is a methodology of measuring the relative efficiency of individual firms; thus, it is an integral part of DEA to classify individual firms into several homogeneous groups. This paper selected samples from the manufacturing industry and classified them into sub-industry groups by two-digit standard industrial classification (SIC) codes. We evaluated a firm's OPINN relative to its peers in each sub-industry group.

Second, contingency theory proposes that firms must establish control systems suitable for situational factors, such as their environment, technology and size, to improve performance [1]. Since the 1970s, contingency theory has been popular in management practice, emphasising that firm managers must understand the market environment. Firms can grow by enhancing competitiveness through innovations. This study provides empirical evidence on which innovation activities will improve the firm value the most at different stages of FLC. It suggests that even firms in the decline stage can revive due to ongoing innovation. Specially, we present empirical evidence on what types of OPINN should be pursued for sustainability from a short-term and long-term perspective, respectively.

Following the Introduction section, Section 2 reviews previous studies on innovation, firm value and the FLC and develops the research hypotheses. Section 3 specifies the empirical model to test the hypotheses and describes how the variables were measured. Section 4 presents the empirical results. Section 5 discusses the implications of our findings on which types of innovation affect firm value at each FLC stage. The last section concludes the paper.

2. Review of Prior Research and Hypotheses Development

2.1. Innovation and Firm Value

Prior research on innovation has mainly analysed which factors affect innovation and the innovation's effect on firm value. Kostopoulos et al. (2011) [15] tested the mediating effects of innovation within an organisation. They surveyed Greek firms and analysed the relationships among external knowledge inflows, including a firm's absorptive capacity measured as its R&D expenditures, the number of employees with bachelor's degrees, innovation and financial performance. Their results showed that absorptive capacity directly affects innovation and financial performance, increasing financial performance through innovation performance. Lev and Sougannis (1996) [11] analysed how capitalisation of R&D expenditures affects firm value. They confirmed that there are positive relationships between capitalised R&D expenditures and stock returns. They also revealed that capitalised R&D expenditure has a positive impact on future stock returns. Hendricks and Singhal (1997) [16] demonstrated an unusual change in the market value of firms that delayed the release of newly announced products. They found that the delayed announcement of new products reduces a firm's market value by 5.25%, on average. Chaney et al. (1991) [17] reported that the introduction of new products increases stock prices. Rubera and Kirca (2017) [18] analysed the effect of innovation and customer satisfaction on firm value. They measured innovation with the number of new products, and their analysis showed that a firm's innovation increases firm value through consumer satisfaction. Lee (2020) [19] measured innovation as the number of patents and analysed its relationship with the firm value measured in Tobin's Q. He revealed that patents are weakly associated with firm value, while R&D is related to increased firm value. Cockburn et al. (1988) [20] and Austin (1993) [21] found that patent application disclosure increases firm value, measured by stock returns, showing that patents are a positive factor for a firm's market value. Feldman and Lemley (2015) [22] used the number of patents to measure innovation and reported that it is scarce for patent licensing demands to lead to firm innovation. As reviewed above, previous studies used the number of patents, R&D investments and the number of new products as proxies for innovation, all of which are positively associated with firm value.

Some previous studies used operational efficiency or productivity as a proxy for innovation and analysed the relationship between innovation and firm value. Vassalou and Apedjinou (2003) [23] applied the Cobb–Douglas production function to measure the portion of gross profit changes not explained by changes in capital and labour, which they attributed to innovation. They found that innovation and profitability are the main drivers of stock returns. They also reported that portfolios developed based on innovation have similar characteristics to those developed based on past stock returns. He and Chen (2007) [24] analysed the effects of innovation measured as operational efficiency and R&D expenditures on firm value (Tobin's Q) in Japan's electric machine industry. They found that R&D expenditures affect firm value in the long run; however, their short-term relationship was unclear. On the other hand, operational efficiency has a significantly positive effect on firm value in the short term. As He and Chen (2007) [24] showed, the efficiency measure has the advantage of not considering a time-lag variable when estimating its relationship with firm value.

2.2. FLC

FLC is an extended version of the product life cycle, which holds that firms exhibit different characteristics in each stage of organisational development [2,5].

Miller and Friesen (1984) [2] divided the FLC into birth, growth, maturity, revival and decline stages. They showed that firm strategy, decision-making style, organisational structure and market situation are different in each stage. Accordingly, firms should change their management strategies and organisational structures in response to market changes according to where they are in their life cycle.

Prior research on FLC generally studied how to measure FLC or tested whether firm value varies according to where the firm is in its life cycle. Two representative studies that tried to distinguish between FLC stages are Anthony and Ramesh (1992) [25] and Dickinson (2011) [3]. Anthony and Ramesh (1992) [25] first introduced the FLC concept, using sales growth, dividend pay-outs, capital expenditures and firm age to classify the FLC stage of the firm. They conducted empirical analyses to determine whether the effects of sales growth rate and capital expenditures on stock prices differed over the FLC. They found that unexpected sales and capital expenditures increases are positively correlated with unexpected stock returns in the growth stage. However, the strength of these relationships gradually decreases as the FLC moves from the growth to decline stages. Dickinson (2011) [3] tried to identify FLC stages using cash flow patterns because performance metrics and firm characteristics, such as firm size and age, were non-linearly correlated with the FLC. She divided the FLC into introduction, growth, mature and decline stages by analysing three cash flow patterns arising from operating, investing and financing activities. She found that FLC stages using the patterns of cash flows are consistent with extant economic theories. Recent studies distinguished the firm life cycle stages by applying Dickinson's method (e.g., [26,27]). We defined FLC stages according to the method developed by Dickinson (2011) [3]. Section 3 explains how life cycle stages were classified in more detail.

A body of studies examined the relationship between FLC and firm value. Previous studies argued that, since the FLC stage represents the firm's economic situation, the relevance of FLC to firm value differs for each stage of the life cycle. Anthony and Ramesh (1992) [25] showed that the stock market response to accounting information is different across the FLC stage. Xu (2007) [28] explained that the FLC stage is heterogeneous in individual risk factors and delivers valuable information for investors in evaluating risk factors. Park and Chen (2006) [29] analysed the impact of accounting conservatism and FLC on firm value and found that investors highly evaluate the stock prices of growing firms using conservative accounting practices. Won and Ryu (2016) [30] reported that business strategies affecting performance persistence differ for each life cycle stage. They revealed that differentiation strategy is positively related to the performance persistence at the growth stage. In contrast, cost leadership strategy positively affects the persistence of performance at the mature stage. Yoo et al. (2019) [14] found that R&D expenditure, future performance and uncertainty vary depending on the FLC stages.

Similar to this study, some prior research measured firm value as Tobin's Q and investigated whether the effect of firm-specific variables on firm value differs across the FLC stages. For instance, Shyu and Chen (2009) [31] presented empirical evidence that diversification destroys firm value in the growth stage. In contrast, firms in the mature stage should implement diversification to increase their market value. Phama and Phama (2020) [32] showed that CEO duality, where a CEO is also the board's chairman, has a different effect on firm value in each life cycle stage. Park et al. (2021) [33] argued that R&D expenses negatively affect firm value in the growth stage, and R&D expenses at the mature stage are positively related to firm value. At the decline stage, they found no significant relationship between R&D expenses and firm value. These results explained that the value relevance of R&D expenses appears to be different because firm characteristics differ for each FLC stage. Prior studies examining value relevance at each stage of the FLC were concerned that empirical results without considering firms' FLC stages can be misleading. As the FLC refers to a firm's market circumstance, managers need to make decisions suitable for their FLC stage to increase the firm value. As previous studies explored the factors that increase firm value at each stage of the life cycle, we attempted to empirically analyse the types of innovation that can improve firm value at growth, mature and decline stages.

2.3. Hypotheses Development

This paper tests whether the value relevance of firm innovation varies according to FLC stages. We also investigated the effect of innovation on future firm value to verify if it makes the company sustainable. Most prior studies showed a significant positive relationship between innovation and firm value [11,17,18]. This study extends the existing literature from the perspective of FLC. We expected that the types of innovation affecting firm value will vary by stage of FLC. In addition, unlike prior studies that measured innovation by R&D expenditures, the number of patents and new product announcements, we measured innovation in terms of OPINN, as mentioned in Section 1. This study evaluated two types of OPINN: technical innovation (TECH) and scale innovation (SCALE). TECH pertains to the ability of companies to increase their outputs (or decrease their inputs) while remaining in the variable returns-to-scale (RTS) frontier. SCALE relates to the extent to which companies that reached the variable RTS frontier can increase their output scales (or decrease their input scales) while staying within the constant RTS frontier. Section 3.2 discusses OPINN as a proxy for innovation and details how the OPINN is measured.

According to FLC theory, the market environment and management decisions that firms must make in their growth, mature and decline stages are different. The extent to which TECH and SCALE affect the firm value may vary according to FLC stages. Moreover, even the same innovation type may affect the firm value in each FLC stage.

In the growth stage, firms have the highest proportion of intangible assets, such as R&D expenditures, patents and copyrights, compared to other stages [34]. In addition, the ability to realise revenue using intangible assets is most pronounced in the growth stage. Managers seek innovative ways to achieve TECH to maximise outputs at the same input level. Thus, we hypothesised that TECH is positively related to firm value in the growth stage. On the other hand, a high SCALE score may negatively correlate with firm value in the growth stage. In general, firms in the growth stage expand their production sizes and endeavour to achieve economies of scale. SCALE in the growth stage means that firms have enough production capacity to meet the growing demand for products. Aside from this, the company's mass production capabilities at the growth stage can give investors a good signal about its growth potential. In our analysis, the value of SCALE moved from 0 to 1 as scale efficiency increases. As scale efficiency increases (i.e., as SCALE approaches 1), firms fully utilise production capacity and do not increase production facilities because they are closer to CRS technology. At the growth stage, investors are likely to evaluate low SCALE as having high growth potential. Therefore, we expected a negative relationship between SCALE and firm value in this stage. Taken all together, we predicted that the OPINN that improves firm value in the growth stage is TECH rather than SCALE.

In the mature stage, firms typically have higher operating cash flows and sales that help maintain a stable market share, despite their low overall market growth rate. They sell products to existing customers rather than new ones, making it challenging to create incremental revenue growth. According to Miller and Friesen (1984) [2], a firm's goal in the mature stage is to improve operational efficiency. Managers operate firms efficiently by pursuing technological progress or economies of scale. Firms aim to reduce costs and improve capacity utilisation by focusing on production efficiency [2,3,35]. In addition, firms in the mature stage can make enough profits in competitive markets by achieving technical and scale efficiencies [2,35,36]. Accordingly, we expected that, in the mature stage, TECH and SCALE will positively affect the firm value.

Firms' competitiveness and market share decrease because of entry by rivals with new technologies in the decline stage. Furthermore, as organisational inertia becomes more vigorous, making investments in environmental changes becomes more complex [37]. In this stage, profitability decreases because firms' products or technologies have been transferred to or copied by competitors. Firms in the decline stage make little investment in new equipment assets due to decreased market share of their products or services. Existing assets are not replaced and come to the end of their useful life, which results in low depreciation expenses and reduces fixed costs. According to prior studies, it is appropriate for declining firms to efficiently operate their organisations by selecting strategies to dispose of unnecessary facilities and withdraw from existing businesses in response to a decrease in market demand [2,3,14,25,35,38]. Hence, we expected that SCALE has a positive effect on firm value in the decline stage. Based on the above discussion, this study established the following hypotheses:

Hypothesis 1 (H1). *Operational innovation has a positive effect on firm value.*

Hypothesis 1-1 (H1-1). *Technical innovation in the growth stage has a positive effect on firm value.*

Hypothesis 1-2 (H1-2). *Technical innovation and scale innovation in the mature stage has a positive effect on firm value.*

Hypothesis 1-3 (H1-3). *Scale innovation in the decline stage has a positive effect on firm value.*

In general, firms experience the growth, mature and decline stage sequentially and disappear from the market. However, they may stay at a particular stage or move from the decline (or mature) stage to the mature (or growth) stage. Studies related to FLC argued that innovation can help a firm leap back from decline to the growth or mature stage [2,3]. In other words, they conjectured that innovation can improve or expand the FLC in a sustainable way. Miller and Friesen (1984) [2] and Dickinson (2011) [3] pointed out that innovation leads to a revival or growth stage in the FLC, but they did not provide empirical evidence. In response, we demonstrated whether the innovative activities of firms lead them in a sustainable direction. In other words, by analysing whether innovation activities affect future firm value, we demonstrated whether innovation can be the driving force of continuous growth.

Specifically, we were interested in the relationship between TECH and the future value of firms in the decline stage. Declining firms should seek to enter new markets or merge or diversify their business to survive [39]. Firms, ultimately, aim to survive in the market and further try to remain in the growth stage to maximise their firm value. To achieve these objectives, firms seek innovation across the production process, technology and distribution systems. Previous studies explained that declining firms can revive, and the critical strategy for revival is technological innovation [2,3]. Along with prior studies, we considered TECH to be a more fundamental innovation activity than SCALE to impact long-term firm value. Following the arguments of prior research, we tested whether TECH results in an extension of FLC. The empirical analysis of whether declining firms should innovate so as not to disappear from the market will have practical implications. Following the theoretical arguments of prior research, we tested whether TECH results in an extension of FLC. This study established the following hypothesis:

Hypothesis 2 (H2). *Technical innovation has a positive effect on future firm value in the decline stage.*

3. Research Design

This study investigates whether innovation is related to firm value at each stage of FLC. To achieve our research objectives, we measured OPINN and firm value and grouped firms into one of three FLC stages and tested the relationships between OPINN and firm value in each FLC stage.

3.1. Empirical Model

The purpose of this study was to analyse the value relevance of innovation at each stage of FLC. The following empirical model was used to test this study's hypotheses:

$$\begin{aligned} \text{Tobin's } Q_t = \ & a_1 + a_2\text{OPINN}_t + a_3\text{OCF}_t + a_4\text{LEV}_t + a_5\text{SIZE}_t + a_6\text{ROA}_t \\ & + \sum \text{IND} + \sum \text{YEAR} + \epsilon_t \end{aligned} \quad (1)$$

The dependent variable in Equation (1) is Tobin's Q, calculated as follows:

$$\text{Tobin's Q} = \frac{\begin{array}{c}(\text{the number of common stocks} \times \text{stock price}) \\ +(\text{the number of preferred stocks} \times \text{stock price}) \\ +\text{book value of liabilities}\end{array}}{\text{book value of total assets}} \quad (2)$$

To test H1, H1-1, H1-2 and H1-3, we estimated Equation (1). When testing H2, the dependent variable of Equation (1) was Tobin's Q of the next period.

INNOV was transformed to natural logarithmic values and used for our test. Banker and Natarajan (2008) [40] provided a theoretical framework for a two-stage procedure: the log transformation of DEA-measured values and a regression analysis estimating the relationship between the log-transformed and contextual variables. We describe the methods to measure INNOV in Section 3.2.

Equation (1) includes control variables likely to affect Tobin's Q: OCF indicates cash flows incurred from operating activities. ROA indicates the return on assets that measures a firm's profitability. The OCF and ROA were expected to be correlated positively with firm value. LEV indicates the liabilities-to-assets ratio. Myers and Majluf (1984) [41] documented that LEV positively impacts firm value, while other studies showed that LEV is negatively related to firm value [42,43]. SIZE means firm size measured as total assets that can cause a firm to achieve economies of scale and increase firm value. However, firm size is also associated with political costs, which can negatively affect firm value [44]. The model used in this study also includes industry dummy and year dummy variables to control for events that may affect specific industries or occur in specific years. Table 1 summarises the variables included in the estimation model.

Table 1. Variable measurement.

Variable		Measurement
Tobin's Q		Refer to Equation (2)
INNOV	OPINN	Operational Innov. measured applying the Banker, Charnes and Cooper model (1984) [45]
	TECH	Technical Innov. measured applying the Charnes, Cooper and Rhodes model (1978) [46]
	SCALE	Innovation calculated by dividing OPINN by TECH
Controls	OCF	Operating cash flows divided by average assets
	LEV	Average liabilities divided by average total assets
	SIZE	The logarithm of average total assets
	ROA	Net income divided by average assets

3.2. Innovation: OPINN, TECH and SCALE

Schumpeter (1942) [12] noted that a firm's innovation activities include: introducing efficient production methods, transitioning to highly productive organisations, acquiring new resources, inventing or developing new products and creating new markets. Horngren et al. (2012) [13] defined innovation as generating value by supplying products to markets in an efficient manner. Innovation is regarded as the outcome of an invisible process as measured in terms of productive efficiency [47]. Firm innovation increases the overall productivity or operational efficiency of the firm. Traditional economic analysis regards innovation activity as a production function like any other [48]. Accordingly, operational efficiency can be a proxy for measuring the outcome of corporate innovation. This paper defines innovation as an improvement in the overall efficiency of the firm, i.e., OPINN.

According to Koopmans (1951) [49], a firm attains full efficiency if and only if the firm can increase none of its outputs without reducing some of its other outputs. Farrell (1957) [50] suggested an efficiency measurement calculated using empirically available input and output data. Charnes et al. (1978) [46] proposed a DEA model that calculates the efficiency of a firm relative to its peers. This paper measured OPINN by adopting the

Charnes et al.'s DEA model (1978) [46]. The OPINN score $\hat{\theta}_{kt}$ of an observation k in period t is the reciprocal of $\hat{\Phi}_{kt}$, which is calculated from the following linear programme:

$$\begin{aligned} &\hat{\Phi}_{kt} = \max \Phi_{kt} \\ &\text{subject to}: \sum_{t=1}^{T} \sum_{j=1}^{J} \lambda_{jt} x_{ijt} \le x_{ikt},\ i = 1,\ 2,\ \ldots,\ I \\ &-\sum_{t=1}^{T} \sum_{j=1}^{J} \lambda_{jt} y_{rjt} + \Phi_{kt} y_{rkt} \le 0,\ r = 1,\ 2,\ \ldots,\ R \\ &\lambda_{jt}, \Phi_{kt} \ge 0 \end{aligned} \tag{3}$$

where x_{ijt} is the quantity of input i used by a firm j in period t, y_{rjt} is the quantity of output r produced by a firm j in period t and λ_{jt} is the weight placed on a firm j in period t. x_{ikt} and y_{rkt} indicate inputs and outputs, respectively, for a firm being evaluated. $\hat{\Phi}_{kt}$ is greater than or equal to 1. $\hat{\Phi}_{kt}$ = 1 means that the observation (k, t) is on the efficient frontier and the most innovative. An observation (k, t) with $\hat{\Phi}_{kt} > 1$ is below the frontier and evaluated to be less innovative. For convenience in our analysis, we used the reciprocal of $\hat{\Phi}_{kt}$, i.e., $\hat{\theta}_{kt}$, that has a value between 0 and 1.

RTS pertains to the proportion by which output levels change when we change all input levels in the same ratio. Constant RTS (CRS) refers to when the output levels increase proportionally as the input levels increase. Increasing RTS (IRS) indicates when the output levels increase more significantly than an increase in inputs. In contrast, decreasing RTS (DRT) is when the output levels rise less than an increase in input levels.

Equation (3) assumes that the innovation activities exhibit CRS, implying that the efficient frontier is a straight line that increases from the origin to the right. The CRS restriction on firms' innovation is somewhat misleading because firms' innovation activities may be under the technology of IRS or DRS. Banker et al. (1984) [45] introduced the variable returns-to-scale DEA by adding $\sum_{j=1}^{J} \lambda_{jt}$ = 1 to the constraint of Equation (3) to relax the CRS restriction. Banker et al.'s DEA model (1984) [45] takes into account the scale-size effect, i.e., IRS or DRS, and its efficient frontier is convex toward the axis of output levels. We measured firms' TECH by comparing them with their peers on the efficient frontier with the same scale size. Therefore, the difference between a firm's OPINN and TECH implies the existence of scale inefficiency. We measured the scale efficiency of the innovation activities by dividing OPINN by TECH [51].

$$\text{SCALE} = \frac{\text{OPINN}}{\text{TECH}} \tag{4}$$

From Equation (4), OPINN aggregates TECH and SCALE into a single value. SCALE = 1 indicates that the firm's innovation operates with CRS technology and has no scale inefficiency. SCALE < 1 means that the firm's innovation exhibits IRS or DRS technology and is scale inefficient as much as (1-SCALE).

We determined input and output variables to calculate OPINN, TECH and SCALE by applying the DEA model. Most firms regard sales revenues as a major source of profits and cash flows generated from their business. This study selected sales revenues from selling products to customers as an output variable. Prior studies have commonly measured manufacturing firms' operational efficiency using the three input factors: cost of goods sold (COGS), selling, general and administrative costs (SG&A) and net property, plant and equipment (NPPE) that are utilised in producing products [52–54]. To consider both expenses incurred to generate revenues, as well as capital stocks invested into operations, we chose three inputs: COGS, SG&A and NPPE.

3.3. Methodology of Measuring FLC Stages

This study tested whether the relationship between innovation and firm value varies by the FLC stage. We applied the FLC stage model developed by Dickinson (2011) [3]. This methodology uses cash flow patterns to determine which stage in its life cycle a firm belongs. Table 2 summarises the FLC stages by each cash flow pattern from operating, investing and financial activities. For example, firms in the growth stage have positive cash flows in their operating and financing activities and negative cash flows in their investment activities. On the other hand, mature firms exhibit positive cash flows in operating activities and negative cash flows in investing and financing activities.

Table 2. FLC stages and cash flow patterns.

Source of Cash Flows	Introduction	Growth	Mature	Shake-Out	Decline
Operating activities	−	+	+	+/−	−
Investing activities	−	−	−	+/−	+
Financing activities	+	+	−	+/−	+/−

At first, we divided the FLC into five stages: introduction, growth, mature, shake-out and decline. For instance, if a firm shows positive cash flows in financing activities and negative cash flows in operating and investing activities, then the firm's life cycle is classified as a growth stage. Some prior studies classified FLC stages as growth, mature and decline stages (e.g., Anthony and Ramesh, 1992 [25]; Liu, 2006 [55]; Jaafar, 2016 [56]); others divided them into introduction, growth, mature and decline stages (e.g., Wang et al., 2020 [26]; Ahmed et al., 2021 [57]). Several studies added shake-out between mature and decline stages to their analysis (e.g., Miller and Friesen, 1984 [2]; Dickinson, 2011 [3]). The introduction and growth stages have similar cash flow patterns, market environments and strategic goals, as do the shake-out and decline stages. Many prior studies grouped FLC into growth, mature and decline stages (e.g., [5,25,36]). Therefore, we excluded the introduction and shake-out from the FLC classification. The final FLC stages we selected and used in the analysis were the introduction, mature and decline, from the five stages.

3.4. The Sample

The sample consisted of firms in the manufacturing industry that were publicly traded in the Korea Composite Stock Price Index (KOSPI) market from 2002 to 2019. This paper gathered data from KIS-VALUE, a Korean financial database provided by NICE Information Service Co., Ltd. We removed firm-year observations that satisfied the following criteria from the sample:

(1) Fiscal year-end date not 31 December; or
(2) Firms with impaired capital; or
(3) Firms missing financial data from KIS-VALUE.

About 98% of manufacturing firms listed on the Korean KOSPI market end their fiscal year in December. Most studies using Korean firm data excluded firms whose fiscal year-end date is not 31 December from the sample to enhance the comparability of financial data. In addition, we excluded firms with capital impairments from the sample because they might not have carried out normal business operations. Since we needed to test the impact of innovation on future firm value, we calculated Tobin's Q using the data from 2002 to 2020.

After deleting unqualified observations, we obtained a total of 5468 firm-year observations. Table 3 shows the distribution of samples by the FLC stage. There were 1385 observations from firms in the growth stage, which accounted for 25.3% of the sample. Most firms were in the mature stage and formed 45% of the sample. In the decline stage, there were 355 observations, taking up 6.5% of the sample. The composition ratio of the growth, mature and decline stage by year was consistent.

As discussed in Section 3.2, this paper evaluated a firm's OPINN, TECH and SCALE, relative to its competitors with similar production technology. Prior literature on the application of DEA at the industry level divided sample firms into homogeneous sub-groups using two-digit SIC codes [58–62]. Consistent with prior studies, we classified manufacturing firms into 23 sub-industry groups using two-digit SIC codes and evaluated INNOV for each sub-group. For example, if a firm belonged to the manufacturing industry and its two-digit SIC code was 32, then the firm was classified into the sub-industry of "Manufacture of Furniture" and evaluated relative to its peers in the sub-industry.

Table 3. The number of observations in each FLC stage.

Year	Introduction	Growth	Mature	Decline	Shake-Out	Total
2002	12	33	136	21	46	248
2003	18	62	116	22	50	268
2004	19	69	120	20	40	268
2005	22	73	117	11	36	259
2006	35	67	122	11	35	270
2007	41	70	121	19	32	283
2008	49	86	84	23	32	274
2009	34	76	133	16	30	289
2010	36	105	110	14	38	303
2011	65	101	110	10	21	307
2012	43	75	148	14	35	315
2013	27	71	154	16	48	316
2014	33	83	159	19	28	322
2015	23	74	169	22	40	328
2016	18	90	169	22	47	346
2017	27	96	156	30	36	345
2018	54	70	177	18	40	359
2019	25	84	184	27	48	368
Total	581	1385	2485	355	682	5468

4. Empirical Results

4.1. Descriptive Statistics and Correlations

Table 4 reports the descriptive statistics for the variables included in the regression model. The mean and median of Tobin's Q were 1.078 and 0.911, respectively. This study divided OPINN into TECH and SCALE. The mean (median) of TECH was 0.881 (0.891), and that of SCALE was 0.969 (0.987). The mean and median of OPINN, calculated by multiplying TECH and SCALE, were 0.853 and 0.860.

Table 4. Descriptive statistics.

Variable	Mean	SD	25%	50%	75%
Tobin's Q	1.078	0.714	0.735	0.911	1.180
TECH	0.881	0.092	0.825	0.891	0.953
SCALE	0.969	0.048	0.960	0.987	0.997
OPINN	0.853	0.093	0.800	0.860	0.919
OCF	0.055	0.074	0.015	0.054	0.096
LEV	0.412	0.186	0.261	0.412	0.550
SIZE	26.535	1.458	25.571	26.264	27.153
ROA	0.033	0.082	0.011	0.036	0.067

Note: Refer to Table 1 for descriptions of how variables were measured.

The regression model used in this study included OCF, LEV, SIZE and ROA as control variables. The average and median OCF values were 0.055 and 0.054, respectively, which means that firms had a net cash inflow of 5.55% of their asset value. The mean and median LEV values were 0.412 and 0.412, respectively, which means that the value of firms' liabilities was 41% of their assets. SIZE was the logarithm of a firm's assets, and its mean and median values were 26.535 and 26.264, respectively, implying that firms had assets worth KRW 350 billion, on average. ROA had mean and median values of 0.033 and 0.036, respectively. Except for Tobin's Q, there was no substantial difference between the mean and median values of variables.

Table 5 summarises the mean and standard deviation of major variables by the FLC stage. Firm value, measured as Tobin's Q, was almost the same in the growth and mature stages. The mean of TECH and SCALE was the highest in the mature stage and the lowest in the decline stage.

Table 5. Mean (SD) of major variables by firm life cycle.

Variable	Introduction		Growth		Mature		Shake-Out		Decline	
	Mean	Std Dev	Mean	Std Dev	Mean	Std dev	Mean	Std Dev	Mean	Std Dev
Tobin's Q	1.073	0.561	1.096	0.698	1.096	0.738	1.015	0.812	1.010	0.612
TECH	0.814	0.117	0.857	0.083	0.867	0.080	0.856	0.094	0.799	0.134
SCALE	0.852	0.113	0.884	0.083	0.892	0.080	0.886	0.092	0.833	0.135
OPINN	0.957	0.071	0.970	0.042	0.972	0.040	0.967	0.049	0.959	0.061
OCF	−0.047	0.054	0.057	0.043	0.094	0.057	0.050	0.059	−0.057	0.054
LEV	0.527	0.172	0.448	0.150	0.369	0.181	0.368	0.196	0.465	0.227
SIZE	26.271	1.367	26.648	1.425	26.711	1.534	26.129	1.191	26.048	1.327
ROA	−0.022	0.107	0.035	0.056	0.053	0.058	0.034	0.089	−0.035	0.154

Table 6 shows Pearson's correlation coefficients. Most of the innovation and all of the control variables were highly correlated with Tobin's Q. As expected, TECH and OPINN were positively correlated with Tobin's Q. In contrast, the correlation between SCALE and Tobin's Q was estimated to be negative (−). The correlation presents a linear relationship between two variables; thus, we tested our hypotheses through regression analysis.

Table 6. Correlations.

Variable	TECH	SCALE	OPINN	OCF	LEV	SIZE	ROA
Tobin's Q	0.065 ***	−0.075 ***	0.029 **	0.100 ***	0.024 *	0.099 ***	0.062 ***
TECH		−0.140 ***	0.884 ***	0.250 ***	−0.111 ***	0.110 ***	0.358 ***
SCALE			0.335 ***	0.129 ***	0.037 ***	0.001	0.177 ***
OPINN				0.299 ***	−0.089 ***	0.104 ***	0.424 ***
OCF					−0.213 ***	0.164 ***	0.478 ***
LEV						0.106 ***	−0.308 ***
SIZE							0.142 ***

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Refer to Table 1 for descriptions of how variables were measured.

OCF, LEV, SIZE and ROA positively correlated with Tobin's Q. Most of the correlations between Tobin's Q and the independent and control variables were in the expected direction, which supports the validity of this study's key constructs and metrics.

4.2. The Difference in Innovation Measures between FLC Stages

Before hypothesis testing with regression analysis, we performed a mean difference test of each innovation for each stage of the firm life cycle. The innovations of this study were measured in each industry relative to the firm's competitors.

Table 7 shows the results of the *t*-test. TECH and SCALE and OPINN, which equals the multiplication of TECH and SCALE, showed the highest mean value in the mature stage. In other words, on average, the level of innovation was highest in the mature stage, whereas it was lowest in the decline stage. Moreover, the mean difference between the highest mean value (mature stage) and the lowest mean value (decline stage) was statistically significant. Specifically, between the mature and decline stages, the mean difference of TECH or OPINN was significant at the 1% level, and that of SCALE was significant at the 10% level.

4.3. The Value Relevance of Innovation

We examined the effect of innovation on firm value in each FLC stage. This study divided the whole sample into three sub-samples for the test: growth, mature and decline stages.

Table 7. *t*-test for innovation difference between firm life cycle stages.

FLC	Mean		
	TECH	**SCALE**	**OPINN**
Growth	0.884	0.970	0.857
Mature	0.892	0.973	0.867
Decline	0.833	0.959	0.799
***t*-test**	***t*-value**	***t*-value**	***t*-value**
Growth vs. Mature	−3.180 ***	−1.953 *	−3.825 ***
Mature vs. Decline	11.458 ***	5.271 ***	13.386 ***
Growth vs. Decline	8.616 ***	3.892 ***	10.031 ***

Note: * $p < 0.1$, *** $p < 0.01$. Refer to Table 1 for descriptions of how variables were measured.

Table 8 presents the empirical results for firms in the growth stage. As expected, the coefficient on TECH was 1.017 ($p < 0.01$), indicating that TECH has a positive impact on the value of firms in the growth stage. Meanwhile, the coefficient on SCALE was significantly negative (coefficient = −0.730, *p*-value = 0.073), indicating that the SCALE lessens firm value in the growth stage. We previously anticipated that the SCALE in the growth stage would reduce firm value. The coefficient for the OPINN was 0.833 ($p < 0.01$). These results signify that TECH enhances the value of firms in the growth stage even if SCALE does not. The results presented in Table 8 support our H1-1 that innovation is positively related to firm value. This study's empirical model included four control variables. Most of the coefficients for OCF, LEV and ROA were estimated to be significantly positive. SIZE was negatively related to firm value; however, none was significant except when innovation was measured as SCALE. The variance inflation factor (VIF) was estimated to determine whether multicollinearity exists between the variables. The maximum value of VIF was less than 2, indicating no multicollinearity problems in the model.

Table 8. The value relevance of innovation in the growth stage.

Variable	Expected Sign	TECH	SCALE	OPINN
		Estimate (*t*-Value)	**Estimate (*t*-Value)**	**Estimate (*t*-Value)**
intercept	?	0.672 * (1.859)	0.406 (1.135)	0.536 (1.492)
INNOV	+/−	1.017 *** (4.518)	−0.730 * (−1.793)	0.833 *** (3.594)
OCF	+	2.488 *** (5.661)	2.733 *** (6.223)	2.519 *** (5.708)
LEV	+/−	0.717 *** (5.589)	0.731 *** (5.643)	0.699 *** (5.427)>
SIZE	+/−	−0.004 (−0.327)	−0.005 ** (−0.339)	0.001 (0.006)
ROA	+	0.293 *** (0.769)	0.966 *** (2.639)	0.278 (0.703)
$\sum$IND	?		Included	
$\sum$YR	?		Included	
Adjusted R^2		0.202	0.192	0.198
F-value		9.039 ***	8.530 ***	8.817 ***
VIF(Max)		1.746	1.517	1.951

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Refer to Table 1 for descriptions of how variables were measured.

Table 9 shows the relationship between innovation and firm value for firms in the mature stage. TECH (coefficient = 1.402, $p < 0.01$) was significantly positively related to firm value in this stage. The coefficient for OPINN was also positive (coefficient = 1.479) at the 1% level, and, even in the mature stage, innovation was revealed to affect firm value. Meanwhile, the coefficient for SCALE was estimated to be a negative value, but it turned out to be statistically insignificant. We previously anticipated that the mature stage would be the most SCALE-innovative among the three stages, with SCALE positively impacting firm value. The mature stage is when firms operate with constant RTS technologies; for instance, a 10% increase in the input size increases the output by 10%. The results of this study found that SCALE does not have any incremental impact on firm value, as most firms in the mature stage produce products or services with constant RTS technologies. All the control variables had significantly positive values at a 99% confidence level for firms in the mature stage.

Table 9. The value relevance of innovation in the mature stage.

Variable	Expected Sign	TECH	SCALE	OPINN
		Estimate (*t*-Value)	**Estimate (*t*-Value)**	**Estimate (*t*-Value)**
intercept	?	−0.768 *** (−3.018)	−1.270 *** (−5.060)	−0.889 *** (−3.547)
INNOV	+	1.402 *** (7.613)	−0.009 (−0.028)	1.479 *** (7.815)
OCF	+	1.545 *** (5.723)	1.816 *** (6.700)	1.478*** (5.454)
LEV	+/−	0.644 *** (8.041)	0.584 *** (7.221)	0.624 *** (7.810)
SIZE	+/−	0.045 *** (4.895)	0.055 *** (5.788)	0.053 *** (5.742)
ROA	+	2.448 *** (8.374)	3.129 *** (11.091)	2.336 *** (7.815)
∑IND	?		Included	
∑YR	?		Included	
Adjusted R^2		0.265	0.247	0.266
F-value		21.112 ***	19.330 ***	21.025 ***
VIF(Max)		1.831	1.566	1.768

Note: *** $p < 0.01$. Refer to Table 1 for descriptions of how variables were measured.

Table 10 presents the estimation results of the relationship between innovation and firm value in the decline stage. Unlike in the mature stage, SCALE had a significantly positive impact on firm value. Meanwhile, TECH, with a positive relevance to firm value in the mature stage, was not significant at the decline stage. OPINN also had a significantly positive value, indicating that innovation improves firm value even in the decline stage.

Table 10. The value relevance of innovation in the decline stage.

Variable	Expected Sign	TECH	SCALE	OPINN
		Estimate (*t*-Value)	**Estimate (*t*-Value)**	**Estimate (*t*-Value)**
intercept	?	2.403 *** (3.003)	1.943 ** (2.584)	2.373 *** (3.190)
INNOV	+	0.034 (0.073)	0.926 *** (4.351)	0.871 *** (4.426)
OCF	+	−1.339 ** (−2.221)	−1.492 ** (−2.565)	−1.343 ** (−2.316)
LEV	+/−	0.411 ** (2.553)	0.537 *** (3.387)	0.525 *** (3.324)
SIZE	+/−	−0.071 ** (−2.372)	−0.048 * (−1.682)	−0.063 ** (−2.228)
ROA	+	−0.460 ** (−2.067)	−0.746 *** (−3.314)	−0.735 *** (−3.284)
∑IND	?		Included	
∑YR	?		Included	
Adjusted R^2		0.282	0.326	0.328
F-value		4.075 ***	4.794 ***	4.819 ***
VIF(Max)		1.950	1.896	1.842

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Refer to Table 1 for descriptions of how variables were measured.

To summarise the findings above, the regression results support H1-1 that firms' innovation is positively related to firm value. We confirmed that different types of innovations are associated with firm value by the life cycle stage. We presented empirical evidence that the innovation type positively related to firm value is TECH at the growth and mature stages and SCALE at the decline stage, supporting H1-2 that the types of innovation that increase firm value vary by the life cycle stage.

4.4. The Effect of TECH on Future Value

We further analysed whether technical innovation activities affect future firm value. Firms in the growth and mature stages extend their life cycle, whereas those in the decline stage may have future firm value by leaping back to the growth or mature stage. The purpose of this study was not to track the life cycle of an individual firm. Instead, by presenting the evidence that current innovation activities affect future firm value, we confirmed whether innovation activities guarantee firm sustainability.

Table 11 shows the analysis of whether TECH activities impact the firm value in year t + 1. At the growth stage, by achieving TECH, a firm can have more excellent future value. The estimated coefficient and *t*-value for TECH were 0.727 and 2.925, respectively. Thus, TECH positively affected both current and subsequent firm values (see Table 8). These results imply that growing firms can be sustainable by improving TECH. Moreover, firms in the mature stage, like those in the growth stage, can increase their future firm value through TECH.

Table 11. The effect of TECH on the firm value of year t + 1.

Variable	Expected Sign	Growth	Mature	Decline
		Estimate (*t*-Value)	**Estimate (*t*-Value)**	**Estimate (*t*-Value)**
intercept	?	0.721 ** (1.810)	−0.453 (−1.561)	1.433 (1.250)
INNOV	+	0.727 *** (2.925)	1.029 *** (4.887)	1.056 *** (3.267)
OCF	+	2.842 *** (5.862)	1.537 *** (4.965)	−0.941 (−1.062)
LEV	+/−	0.597 *** (4.212)	0.665 *** (7.266)	0.572 ** (2.376)
SIZE	+/−	−0.007 (−0.516)	0.032 *** (3.023)	−0.026 (−0.603)
ROA	+	−0.012 (−0.028)	2.506 *** (7.307)	−0.026 (−0.603)
∑IND	?		Included	
∑YR	?		Included	
Adjusted R^2		0.175	0.222	0.258
F-value		7.695 ***	16.917 ***	3.728 ***
VIF(Max)		1.751	1.839	1.907

Note: ** $p < 0.05$, *** $p < 0.01$. Refer to Table 1 for descriptions of how variables were measured.

From Table 11, the coefficient of TECH was significantly positive (1.056) at the decline stage. In Table 10, the TECH of declining firms did not affect their current firm value. However, Table 11 presents that technical innovation can increase firm value from a long-term perspective, even for a declining firm. Taken together, the results of these two analyses suggest that TECH in the decline stage does not immediately affect firm value when it occurs. However, it does in the following year. These signify the necessity for firms in the decline stage to innovate to increase their long-term value continuously. The results presented in Table 11 support our H2 that a firm's TECH has a positive relationship with future firm value.

5. Discussion

While prior studies measured innovation as R&D expenditures, the number of patents or the number of new products, this study measured innovation as operational efficiency:

OPINN, TECH and SCALE. We relatively evaluated firm innovation utilising DEA within their peer groups. In addition, this study investigated whether the effects of operational efficiency on firm value vary according to FLC, an indicator of the firm's market environment. To the best of our knowledge, little literature considered the market environment when testing the value relevance of innovation. This study can fill the knowledge gap in this field by proposing operational efficiency as an innovation measure and providing empirical evidence that the innovation type that increases firm value differs depending on the market environment.

We found that OPINN, TECH and SCALE positively affect firm value, signifying that a firm will benefit from innovation. This finding aligns with past literature, showing that innovation increases firm value. Moreover, we showed that the type of innovation affecting firm value differs depending on the firm's market situation. Specifically, TECH in the growth and mature stages and SCALE in the decline stage can enhance firm value. In Table 12, we summarise innovation types that firms should pursue in each FLC stage. For instance, firms in the growth stage should adopt innovative ways to improve TECH by reducing defective units or labour hours and increasing the utilisation of existing production facilities. Firms in the mature stage should adopt the innovative measures of firms in the growth stage to improve TECH. Declining firms need first to identify which production technology they are facing, i.e., increasing, constant or decreasing RTS. They can then improve SCALE by scaling up outputs when they face increasing RTS or reducing inputs when decreasing RTS. TECH of firms in the decline stage is related to the future firm value, not the current firm value. This study's results support the argument [2,3] of previous studies that firms in the decline stage can survive through innovation or leap back to other improved FLC stages. Our empirical evidence showed that declining firms can revive through continuous innovation activities.

Table 12. Types of innovation affecting firm value in each FLC stage.

FLC Stage	Growth	Mature	Decline
Innovation type	TECH	TECH	SCALE

Note: Refer to Table 1 for descriptions of how variables were measured.

As with any study, we need to acknowledge limitations. This study used only Tobin's Q as a proxy for firm value. Some studies found that innovation is related to increased stock prices or stock returns [17,20,21]. One can measure firm value using other variables, such as stock prices or stock returns, in different research settings to extend our study.

Despite these limitations, this study has implications due to the proxy used to measure innovation. Measuring innovation in terms of operational efficiency can be a good proxy for evaluating the outcome of firm innovation. Recently, Banker et al. [63] (2020) argued that the International Financial Reporting Standards (IFRS) accounting regime increases productivity by improving information environments and promoting internal resource allocation decisions. Korea is one of the countries that has adopted IFRS since 2011. We measured FLC stages and innovation using accounting information disclosed by Korean listed companies. In the future, we can apply the research methodology documented in this study to other countries that have introduced IFRS.

6. Conclusions

This paper explored the value relevance of innovation at different stages of FLC. The empirical analysis yielded the following main results. First, by revealing that OPINN positively impacts Tobin's Q, we found that innovation can be a driver of firm value. Second, we documented that TECH makes firms sustainable by presenting empirical results that improving TECH increases firms' future value. Specifically, in the growth and mature stages, TECH is linked closely to the current firm value and the viability of firms in the future. Our study found broad support for the hypothesis that operational, technical and scale innovations positively affect firm value, and the relationship between innovation and firm value differs depending on FLC stages.

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