FRONT-LOADING THE FRONT-END OF INNOVATION

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Abstract: The Stage-Gate process is a tool used by innovation managers to rationalize resource allocation the innovation process by breaking the innovation process into different stages, and determining progress and prospects at gates using pre-determined criteria. This study determines the performance impact of investing financial resources relatively heavily in the front-end or early stages of new product development (NPD) projects. Data was collected for NPD projects for one of the largest consumer electronics firms in the world. Investing relative more resources in front-end activities positively affects performance. The degree of newness of an NPD project positively moderates this relationship.

Keywords: New Product Development (NPD), Front-End of Innovation, Resource Allocation, Stage Gate Model/Process.

INTRODUCTION

Levels of competition and the pressure to innovate increase and so product life cycles decrease in length (Sommer et al., 2015). Managing the development of new products has thus become a top priority in many companies (Mullins & Sutherland, 1998). NPD failure rates remain high at 65% for established firms (Adams et al., 2006; De Medeiros et al., 2014), as firms pursue and invest in inappropriate projects (too long). Worthy projects might be cancelled for the wrong reasons too. Companies increasingly formalize New Product Development (NPD) processes and use tools such as the Stage-Gate procedure to better manage NPD - 88% of U.S. businesses employ a stage-gate model to manage, direct and control their product innovation efforts (APQC benchmark, 2010). We define a stage-gate model following Cooper (2006) as “a conceptual and operational map for moving new product projects from idea to launch and beyond—a blueprint for managing the new product development process to improve effectiveness and efficiency”. Employing a stage-gate process significantly improves a firm’s innovation performance (Sommer et al., 2015).

INVESTING IN THE FRONT-END OF NPD

An important decision in the area of NPD is how much to invest at what stage of a product’s development (Cooper & Kleinschmidt, 1988; Wang et al., 2002). As the number of ideas for new product development tends to be larger than the resources to invest in each (Cooper & Edgett, 2012), firms use a tool such as the stage-gate model to prevent investment in a project that may turn out to fail for reasons that were known (by some), but not fully recognized within the organization (Cooper, 2006; Sommer et al., 2015). By breaking up the NPD process in several stages, and deciding at each gate whether or not to proceed, investment in inappropriate projects can be prevented. A goal of the stage gate model as adopted by many firms is to prevent projects from continuing too long.

There are a number of potential and broadly recognized risks to the use of a stage-gate model. One is that potentially successful projects are prematurely discontinued as they do not meet the criteria for progression defined in a firm. This paper focuses on another, related risk of using a stage-gate model: the model could lead to underinvestment in the early stages of NPD. Likely outcomes of NPD projects are largely assessed in the first stages of the NPD project (Cooper, 1988; Markham, 2013), however, yet most resources for NPD are spent in the final stage. Underinvesting in the early stages might thus lead to NPD projects that are potentially successful being prematurely stopped, particularly for more radical innovation projects.

In view of this, we suggest the following conceptual model (Figure 1) and more fully develop the argument in its support below:

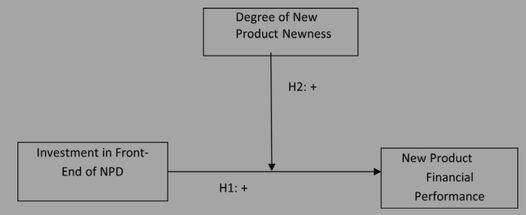

FIGURE 1: CONCEPTUAL MODEL

In line with Kim and Wilemon (2002) we divide the NPD process in two main phases: front-end and back-end (cf Cooper (1990); Menor et al. (2002)). Kim and Wilemon (2002). We define the front-end of innovation as “predevelopment stages consisting of idea generation, product definition, and project evaluation”. In the front-end, the goal is to create and analyze alternative solutions (Markham, 2013). The front-end is the first step in NPD process in which opportunities are identified and concepts are developed (Kim & Wilemon, 2002; Kock et al., 2015). When an innovation project completes the front-end phase and receives approval, it moves into the back-end, which is execution oriented. Here, ideas need to be screened and weeded out (Cooper, 1990). Before moving a NPD project to the back-end, they are examined in terms of expected market performance (Papastathopoulou et al., 2001). The outcome of this stage could be a product concept, business case, or a startup plan.

The front-end of innovation is a decisive phase for NPD, determining the potential for success of a NPD project (Florén & Frishammar, 2012; Kock et al., 2015): “most projects do not fail at the end; they fail at the beginning” (Qingyu & William, 2001). Resource allocation in the front-end is a particularly difficult and risky activity. The front-end includes many critical and decisive activities making it central to new product success (Cooper, 1988). Not much is known about the technical and market potential of a NPD project in this phase (Cooper, 2006; Koen et al., 2001; Sommer et al., 2015). Cristiano et al. (2000) argue that the front-end is the most difficult stage to manage due to its often unstructured nature (Akbar & Tzokas, 2013). Managers are often reluctant to invest large amounts of resources in projects during the front-end and often favor

incremental projects (Koen et al., 2001). The chances of success of a new product development project generally are lower in the front-end than at later stages if only because later stages tend to have fewer projects to compete for limited resources available. Investment of financial resources in the front-end should result in stronger new product performance by increasing relevant technical and market knowledge and thereby reducing uncertainties (Cooper, 1988; Reinertsen & Smith, 1991). When a firm has reduced the market and technical uncertainties in the front-end already, it is less likely to wrongly discontinue a potentially successful project.

We hypothesize:

Hypotheses 1: *The more financial resources are invested in the front-end of an NPD project the better financial new product performance of products that ensue.*

The degree of newness of an NPD project is an important driver of new product performance (Garcia & Calantone, 2002) as novel products promise higher technical and functional performance and offer additional functions and improved benefits to customers and so a higher price can for instance be asked for them (Rothaermel & Hill, 2005). The Degree of Newness could conceivably impact the effect of decisions relating to resource allocation as well (Carbonell et al., 2004; Verworn et al., 2008). In terms of our conceptual model, the degree of newness then moderates the link between front-end investment in NPD and NPD financial performance.

Degree of newness is defined as the extent to which an NPD project aims to develop products that are new to the market and/or new to the developing firm (Langerak & Jan Hultink, 2006). Radical innovation projects may yield higher payoffs but also entail greater risks (Cooper Robert, 1993). Bolumole et al. (2015) found that radical NPD projects require relatively more resources than incremental NPD. A very innovative NPD project is less compatible with the existing knowledge base of a firm (Biazzo, 2009). A firm's understanding of a new technology being developed that is highly novel is smaller than for NPD projects with low newness, which generates more unpredictability and even uncertainty (Green et al., 1995; Poskela & Martinsuo, 2009). A radically new NPD project might require a different and more costly management approach (De Brentani, 2001; Song & Montoya-Weiss, 1998) - more innovative NPD projects need more management attention, research facilities, flexible decision making and creativity (Markham, 2013). Higher investment in the front-end of an NPD project would therefore pay off more for projects that show a higher degree of newness.

Hypothesis 2: *The degree of newness of an NPD project positively moderates the relationship between front-end investment in an NPD project and a new product's financial performance.*

DATA & METHODS

Eisenhardt (1995) identified several shortcomings in the NPD literature which remain unaddressed. Studies in this literature focus on the firm level rather than the project or product level and so cannot identify phases in the NPD process or the performance of individual projects (cf. Markham (2013)). By focusing on a single company we can identify phases for each NPD project, and we can also determine NPD performance. Focusing on a single company allows us to reduce the noise associated with a cross-sectional study (Kock et al., 2011).

Setting. With total revenue of €24 billion in 2015, the focal firm is one of the largest electronic companies in the world, and develops and launches products in different product-market categories worldwide. The focal firm consists of three divisions, each having a number of business units (BU). Each BU has a number of product groups (PG's). A PG is the smallest unit within large firms to which sales responsibility can be delegated (Yoon & Lilien, 1985). A division operates autonomously to a large extent and is directed by a general manager accountable to senior management. We collected data for product groups and business units of a single division in the multi-national focal firm mainly active in consumer electronics and healthcare, ensuring consistency in the data and feasibility of the data collection process since divisions vary in accounting, reporting and data storage processes. This division, active in a market characterized by short product life cycles, contributes around 25% of total revenue of the firm. Being innovative is crucial in this industry (Coman & Ronen, 2007). The focal firm employs a stage-gate NPD process that is divided in two major stages. The first stage takes the maturity of a technology, product or product group into account: when maturity is considered low, i.e. when newness is high, an 'advanced development project' is started to gain knowledge on a baseline technology.

Variables. Dependent Variable. While acknowledging that measuring New Product Performance may not be straightforward (Daniel et al., 2004), the literature distinguishes between operational and market outcomes (Tatikonda & Montoya-Weiss, 2001) - we used the latter (Henard & Szymanski, 2001). Blindenbach-Driessen and Van Den Ende (2010) state that may be difficult to determine which product generated how much profit or even sales, but for the focal firm this data is available. The substantial advantage of this empirical focus on a single firm, as in this case, rather than a focus on an industry (cf Reid and de Brentani (2012)) or a cross-sectional study (Kock et al., 2015; McNally et al., 2011), is that cause-effect relations are more readily established in part due to reduced industry level and firm level noise in the data. The average development time for a new product in the focal firm product is 1 year, with little variation, and so time-to-market differences between newly developed products did not impact the results found (cf McNally et al. (2011)). In the consumer electronics market, the cycle time is high (Mullins & Sutherland, 1998), implying that current sales are generated by products only introduced recently (Ettlie & Subramaniam, 2004). We assume that R&D expenditure in year t=0 contributes to sales increase (decrease) in t+1 (Brush et al., 2000).

Independent variable. In order to be able to compare between NPD projects, over time, and across NPD projects of different scale in terms of overall R&D investment, *Front-end Investment* was measured as the ratio of front-end to total invested financial resources (cf. Griliches (1992)).

Moderator variable. In line with Booz-Allen and Hamilton (1982) we measure the *Degree of Newness* for an NPD project by grouping them as having high, moderate or low degrees of newness (cf Cooper and Kleinschmidt (1988); Kester et al. (2014); Kleinschmidt and Cooper (1991)). See Table 1. The assumption of group variance equality is not violated (Lavene's test, $p>0.05$). A one-way ANOVA test shows means for sales for projects categorized as low, moderate and high degree of newness differ significantly ($p<0.01$). The mean sales of the low degree of newness group differs significantly from both the mean of moderate and high degree of newness group (Tukey Post-Hoc test; $p<0.05$), but there is no statistically significant difference between sales for NPD project with the moderate and high degree of newness ($p>0.05$). Count frequencies and distribution of the variable Degree of Newness are presented in Table 1.

TABLE 1: DEGREE OF NEWNESS COUNT FREQUENCIES

		Frq.	%
Degree of Newness	Low	69	67
	Moderate	24	23.3
	High	10	9.7

Control variables. We include several control variables (cf. Constantopoulos et al. 2015) . First of all, *Division Size,* as the size of an organization can affect innovative and operational performance (Camisón-Zornoza et al., 2004). The number of employees in a division can vary each year. *R&D intensity,* at division level, can vary by year, was measured as the ratio of total R&D expenditures to the division's total sales. *Marketing expenses* as a share of total revenue in t+1, at Business Unit level, is included as a control. Market dynamics will impact the chances of success for a new product, which is why we include *Market growth* as a control, at Business Unit level at t+1 (Bharadwaj et al., 2005). To control for differences in the characteristics of NPD processes and specific market characteristics, we include a *Business Unit* dummy, categorizing product groups as either domestic appliances or personal care products, to capture BU specific effects.

ANALYSIS

For the 2012-2015 period, the division for which data was collected saw a total of 229 NPD projects through to completion. Sales data were not available for 2016 and so NPD projects for 2015 were removed from the sample which reduced the sample size to 172. Cases with zero R&D expenditures were removed from the sample as well, as this indicates that the firm is no longer investing in a PG or a BU, further reducing the sample to 148 NPD projects from 58 product groups (including floor cleaning, shaving, kitchen appliances) in 11 business units. We checked for possible outliers and for normal distribution of the data. The dependent variable is non-normally distributed (skewness Z-value of 51.80 and kurtosis Z-value of 291.22), lying outside of the acceptable range (Aiken & West, 1991). The dependent variable showed heterogeneous variance (Shapiro-Wilk test, $p<0.01$) implying a non-normal distribution as well, and was therefore transformed into a log variable. For the independent variable the Shapiro-Wilk test was significant ($p<0.01$), but the Q-Q plot suggest a normal distribution, and so we believe we can safely assume the data to be normally distributed. Heteroscedasticity was tested for by visually inspecting the scatter plot of the regressions' standardized residual against the regressions' standardized predicted value: heteroscedasticity does not affect the results (cf. Garcia and Calantone (2002)). The final sample size with acceptable measures for the dependent variable (skewness Z–value of -0,735 and Kurtosis Z-value of -0,739; Shapiro-Wilk test of 0,365, $p>0.05$) is 103 (n=103). Our ordinal moderator variable cannot be tested for normal distribution.

To check if the assumption of a linear relation between the independent and dependent variable is satisfied, a scatter plot was visually inspected and quadratic terms for the independent variable were included in the regression model. The latter yielded no significant changes in the R-squares or F-values. We conclude that the assumption of linearity is valid.

We performed hierarchical regression analyses to test our hypotheses (OLS). A Variance Inflation Factor test (VIF) was conducted to test for multicollinearity. For each of the variables the VIF values were lower than or equal to 1.345. The average VIF for the explanatory variables was 0.98, staying well below the limit of 5 (Sine et al. 2006).

In order to triangulate, we brought together a focal group of innovation consultation and management, portfolio management, and accounting and finance experts (Hartman, 2004). The expert panel session validated the results we found, helped interpret these and identified a number of related issues for discussion.

RESULTS

Descriptives and Correlations. Descriptive statistics are presented in Table 2. The table in the Appendix presents the Pearson's correlation matrix.

TABLE 2: DESCRIPTIVE STATISTICS

Variables	Mean	Std. Dev.	Min	Max
1. NPD financial performance	2.157	11.515	-21.481	27.307
2. Front-end Investment	0.205	0.25	0	1
3. Degree of Newness	1.43	0.666	1	3
4. Marketing expenses	0.099	0.047	0.019	0.467
5. Division Size	17255	325.425	16542	17255
6. R&D Intensity	6.089	0.582	5.59	6.69
7. Market Growth	0.062	0.039	-.02	0.16
8. BU Category	0.628	0.447	0	1

A multiple hierarchal regression analysis was performed (see Table 3). None of the control variable reported significant results (Model 1). Model 2 shows that Front-end Investment contributes significantly to NPD financial success, suggesting support for Hypothesis 1. Adjusted R^2 increases significantly for model 2 compared with model 1 ($p<0.01$). Since the Durbin-Watson statistic (1.919) falls within the critical values implying that first order linear auto-correlation does not play a role.

TABLE 3: PEARSON'S CORRELATION MATRIX (PG LEVEL)

Variables	1.	2.	3.	4.	5	6	7.	8.	9.	10.
1. NPD performance	1									
2. Front-end Invest.	0.281**	1								
3. DN Cont. Cont.	0.390**	0.220	1							
4. DN Mod (dummy)	0.203*	0.169	0.448**	1						
5. DN High (dummy)	0.179	0.047	0.693**	-0.181	1					
6. Marketing expenses	0.011	-0.117	-0.079	-0.086	-0.19	1				
7. Business Unit size	-0.251*	-0.039	-0.065	-0.218	0.023	0.221	1			
8. R&D Intensity	0.048	0.113	0.070	0.177	-0.076	-0.078	-0.471*	1		
9. Market Growth	-0.053	-0.143	0.004	-0.056	0.006	0.154	0.105	-0.158	1	
10. BU Category	-0.038	-0.224	-0.024	-0.021	-0.021	-0.570	-0.089	-0.102	-0.085	1

Significant at *.10, ** .05 and *** .01 level.

Model 3 in Table 3 includes the moderation effect to be tested with a view to hypothesis 2 (Aguinis, 2004) - low Degree of Newness is the comparison. The direct effect of Front-end Investment remains significant. Inclusion of the moderation term increases the R^2 ($p<0.10$): in line with Hypothesis 2 a higher degree of newness of projects strengthens the positive effect of Front-end Investment on NPD financial performance.

TABLE 4: FRONT-END INVESTMENT AND NPD FINANCIAL PERFORMANCE

		Model 1	Model 2	Model 3
Constant		6.589	6.577	6.588
Controls:	Marketing expenses	0.044	0.150	0.138
	Division Size	-0.307	-0.316	-0.309
	R&D Intensity	-0.023	-0.104	-0.123
	Market Growth	-0.045	-0.004	-0.002
	Business Unit	-0.051	0.652	0.090
	Degree of Newness	0.375	0.085	0.306
IV:	Front-end Invest.		**0.311****	**0.237****
Moderation:	*Moderate* Degree of Newness * Front-end Invest.			**0.115***
	High Degree of Newness * Front-end Invest.			**0.129***
Model fit	F	1.998*	3.796***	2.824***
	R^2	0.086	0.178	0.215
	Adj. R^2	0.047	0.121	0.183
	N	103	103	103

Significant at * .10 level, ** .05, and *** .01 levels.

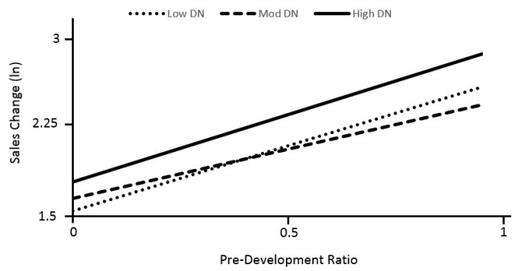

FIGURE 1 PRESENTS THE REGRESSION RESULTS FROM TABLE 3 VISUALLY: THE COEFFICIENT OF THE INTERACTION EFFECT IS STRONGEST WITH A HIGH DEGREE OF NEWNESS.

Robustness checks. In addition to the analysis at the Product Group level, we performed an analysis at the level of the **Business Unit**. Because the sample is small (n= 25 after the usual checks of the data, described above), an analysis for hypothesis 2 was not feasible and these results merely indicative. Results of this analysis, available from the authors upon request, support hypothesis 1. To further increase the validity and understanding of the results, two focal firm expert panels each consisting of 6 members were organized to interpret the results and gather additional insights. Experts unanimously agreed on the fact that front end activities are hugely important for NPD success. Participants endorsed the statement submitted by one participant that "*this phase* [the front-end] *might be the most important stage in the whole NPD process*". One stated additionally that "*the study's results are once more a reason to make the organization even more attentive on the importance of front end activities*." With respect to hypothesis 2 the experts stated that "*more radical innovation projects need relative more resources in terms of management attention, time and monetary funds*". In the words of one participant, the panel interprets the main results as follows: "*investing sufficient financial resources in pre-development activities is not a guarantee for success, but is a genuine precondition to gain success in NPD and ultimately in the market*".

DISCUSSION, IMPLICATIONS & CONCLUSION

Although burgeoning, the literature on the front-end of NPD has focused almost singularly on the firm rather than the project or product level (Daniel et al., 2004). A focus in this study on NPD projects in a single firm allows for a reduction of noise associated with cross-sectional analysis and focus on of the direct link between NPD investment and product performance.

As hypothesized, despite investment in NPD often being a failure and the front-end of NPD is particularly risky, we find a positive relationship between investment in the front-end and new product performance – new product value is created in the front-end. Based on our findings, managers may reconsider their reluctance to invest in the front-end of an NPD project (cf. Markham (2013); Reinertsen and Smith (1991)). Kijkuit and van den Ende (2010) have indicated that managers' personal commitment to a research project is important to that project's organizational survival If that commitment also translates into resource investment, we show here that early commitment also transpires into commercial success. A project's survival in the organization is not just a result of managers being prone to the behavioral sunk cost effect of sticking to a decision once taken. This is in line with what Qingyu and William (2001) state ("most projects do not fail at the end; they fail at the beginning").

Although we find that the degree of newness of an NPD positively moderates the effect of front-end investments on performance (cf. Bolumole et al. (2015)), we have some indication, including what Figure 1 suggests, that the effect might be curvilinear (see Kock et al. (2011)). Data limitations prevent us from studying this possibility empirically. What remains to be studied is the extent to which the findings we can report on are dependent on the wider context of the portfolio of innovation projects that a firm maintains (Cooper, 2013) - the innovation portfolio of the focal firm is skewed towards incremental innovation projects (cf. Frishammar and Ylinenpää (2007)).

We would advise managers of NPD projects to invest relative more financial resources in the front-end of NPD to increase performance. Future research can focus on the extent to which financial resources can be substituted for by other resources such as organizational support. For large investments in the front-end of NPD projects of high novelty might such substitution might not be as straightforward as NPD projects of low novelty.

This study focuses on a single industry, single firm and a single division, reducing the 'noise' that comes with a cross-sectional research design but possibly reducing representativeness. We believe this is both a strength as well as a possible limitation of this paper. A second possible limitation may be that the performance variable in this study is a single construct (sales), while some (e.g., (Kleinschmidt & Cooper, 1991)), argue that sales are an over-simplification of performance. Thirdly, the independent variable (Front-end Investment) potentially is an over-simplification as it focuses on financial resources

spent and does not consider man-hours spent (as well). Finally, the lag between product development on the one hand and sales, on the other hand, we assumed to be one year but the lag might in actual fact be different from that. Furthermore, the sales increase we assume to be due to a newly introduced product might actually be for other reasons (not controlled for).

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