R&D Effort, Effectiveness, and Firm Performance in the Pharmaceutical Sector

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Research exploring the impact of R&D on firm outcomes yields mixed results. The paper draws on an integration of the resource-based view, the capabilities perspective, and accumulation theory to highlight the effectiveness of R&D effort in yielding recognized innovative output as a fundamental, yet underemphasized factor in the role of R&D as a contributor to firm performance. Specifically, innovative output is examined as an intervening factor in the relationship between R&D effort and firm performance. Empirical tests on a sample of 303 firms in the pharmaceutical industry reveal that R&D effort yields increasing returns to R&D effectiveness, which suggests that firms can enhance the value of research activities through increased activity. However, the discovery of innovative output as an important mediating factor between R&D effort and firm performance suggests that the benefit of increased R&D may be limited if this effort is not effective in yielding recognized innovative output. These findings are critical since managers in research-intensive industries often base resource allocation decisions on the assumed influence of R&D effort on firm performance.

Research and development (R&D) represents a critical business function for many high- technology firms. Even during economic downturns, many technology firms (e.g. Sun Microsystems, Microsoft, Computer Associates, etc.) continue to invest heavily in research efforts based on the assumption that innovation represents an important factor that influences firm outcomes (Hunter, 2003; Silverman, 2002; Whiting & Ricadela, 2002). However, academic research addressing the organizational impact of R&D only lends partial support for the assumed relationship between R&D and firm outcomes. This research consistently supports a positive relationship between R&D and innovative

output (e.g. Bierly & Chakrabarti, 1996; Graves & Langowitz, 1993; Griliches, 1990; Henderson & Cockburn, 1996). However, conflicting findings have emerged regarding whether R&D yields increasing (Henderson & Cockburn, 1996) or decreasing returns to scale (Graves & Langowitz, 1993). Furthermore, most studies investigating the relationship between R&D efforts and firm performance find mixed results (Lin et al., 2006; Schoenecker & Swanson, 2002), with Hsieh et al. (2003) representing the only exception. While contributing to the understanding of the organizational role of R&D efforts, this paper will reflect the belief that an integration of these two streams of research provides an opportunity to achieve a more fine-grained understanding of the role of R&D effort and to begin to explain the mixed findings present in the literature. Specifically, an integrated consideration of this work motivates the exploration of the effectiveness of R&D effort to yield recognized innovative output as a salient, yet underemphasized, intervening factor in the relationship between R&D and overall firm performance.

To investigate this relationship, this paper draws on the capabilities perspective (Richardson, 1972; Teece, Pisano & Shuen, 1997; Helfat et al., 2007) and the resource-based view (Penrose, 1959; Barney, 1991) as the theoretical foundation. The resource-based view and the capabilities perspective support a focus on R&D effort as an organizational process and a potential contributor to firm performance and competitive advantage. Second, a return to the roots of resource-based thinking and the capabilities perspective highlights the importance of "skillful manipulation," which drew attention to the competence of an organizational process to achieve a given objective. Hence, the term *effectiveness* will be used to denote the ability or competence of R&D effort in achieving the creation of recognized innovative output, and we focus on the effectiveness of R&D effort as an intervening factor that influences the relationship between R&D effort and firm performance will be examined.

By analyzing the relationship among R&D effort, the effectiveness of R&D effort, and firm performance, a number of important contributions will hopefully be made. This work could provide useful insights for both academics and practitioners by providing a more fine-grained understanding of the factors influencing the relationship between R&D effort and firm performance. Secondly, by highlighting R&D effectiveness as another potential isolating mechanism that enables R&D to represent a source of competitive advantage, a greater understanding of R&D may be achieved, and thirdly, by highlighting the importance of process effectiveness as a relevant and intervening factor and offering a greater understanding of the relationship between organizational processes and overall firm performance.

The progression of the discussion proceeds as follows: First, the theoretical foundation that supports our focus on R&D effort as a contributor to competitive advantage, as well as the focus on the effectiveness of R&D in generating recognized innovative output as a key intervening factor will be discussed. Following the theoretical discussion, the hypotheses will be developed, which address the relationships among R&D, innovative output, and firm performance from a resource-based rationale. After the hypothesis development, the empirical methods and results will be presented, followed by a discussion of the results and their implications, and concluding with limitations and avenues for future research.

Theoretical Background

Drawing from a theoretical foundation of the resource-based view (Penrose, 1959; Barney, 1991) and the capabilities perspective (Richardson, 1972; Teece et al., 1997; Helfat et al., 2007), this paper assumes a process-oriented perspective on R&D effort as a potential contributor to competitive advantage. A process-oriented perspective dates back to the seminal work of Penrose (1959) who suggested that the key to firm growth was the skillful manipulation of resources, as opposed to the mere possession of resources. Building on the work on Penrose, Richardson (1972) concentrated on the process-oriented vein of the budding resource-based view and adopted a focus on the distribution and coordination of activities in firms. However, since the work of Richardson (1972), a process orientation emerged within resource-based thinking in the literatures on organizational capabilities (e.g. Teece et al., 1997; Helfat et al., 2007) and the knowledge-based perspective (e.g. Kogut & Zander, 1996; Leonard-Barton, 1992; Loasby, 1999). The process orientation of this work supports the investigation of R&D effort as a potential contributor to firm outcomes.

Also embedded within resource-based thinking is the notion that not all resources are equally endowed in their ability to support a competitive advantage. One of the key underlying assumptions of resource-based thinking is the heterogeneity of resources across firms (Barney, 1991; Hoopes, Madsen & Walker, 2003; Peteraf, 1993), which implies that resources differ. By identifying the characteristics of resources that possess the potential to yield a sustained competitive advantage, Barney (1991) specifically highlighted the idea that all resources are not equally able to create an advantage. The various branches of resource-based thinking also reinforce the idea that all resources do not possess the same ability to yield competitive advantage since knowledge (Grant, 1996; Kogut & Zander, 1996), capabilities (Richardson, 1972), and dynamic capabilities (Teece et al., 1997) each represent a focal set of resources for a group of scholars. Hence, resource-based thinking provides a theoretical foundation for the mixed findings regarding the influence of R&D on firm performance given that not all R&D effort is equal, and supports further inquiry into understanding the factors that enable R&D effort to yield positive performance effects.

In an attempt to further refine our understanding of why or how R&D effort can represent a source of competitive advantage and contribute to enhanced firm performance, insights were also drawn from accumulation theory. The emphasis on organizational processes (or flows) over resources (or stocks) in accumulation theory resonates with the work of Penrose (1959) within the resource-based view. However, the insight of accumulation theory emanates from the idea that the accumulation process represents the isolating mechanism that enables the resources to yield an advantage as a result of asset mass efficiencies, time compression diseconomies, interconnectedness of asset stocks, asset erosion, and causal ambiguity (Dierickx & Cool, 1989). Parallels to this argument are also present in the dynamic capabilities perspective (Teece et al., 1997) in which path dependence and learning through repetition and experimentation play a salient role in the development of organizational capabilities that foster a competitive advantage (Teece et al., 1997). If these insights are correct, then it would be expected to see firms rewarded with strong performance

as a result of the competitive advantage accruing from the continued repetition of key activities. However, empirical results from both R&D research (Lin et al., 2006; Schoenecker & Swanson, 2002; Hsieh et al., 2003) and accumulation theory (Adams & Jaffe, 1996; Knott et al., 2003) suggest that there is more to the story.

Specifically, the empirical studies in accumulation theory show that stocks and flows are both important factors in a firm's production function and have comparable explanatory power (Adams & Jaffe, 1996; Knott, Bryce & Posen, 2003). While these findings are important to the stream of work in accumulation theory because they establish that the accumulation process alone may not convey sustainable advantage (Knott et al., 2003), insight from these findings informs the study of R&D effort by highlighting the potential gained from a consideration of the "stocks" that accrue from the "flow" of R&D effort. Hence, the empirical results from accumulation theory suggest that the effectiveness of R&D effort in creating recognized innovative output represents a relevant factor to consider in exploring the relationship between R&D effort and firm performance.

The insight taken from accumulation theory also resonated with ideas from the roots of resource-based thinking, which emphasized "skillful manipulation" (Penrose, 1959) and suggested that the effectiveness of R&D effort is a relevant factor to consider. Specifically, the focus was on effectiveness of R&D effort in yielding recognized innovative output as an intervening factor that influences the relationship between R&D effort and firm performance. R&D activities are expected to influence firm performance, especially in knowledge-based, research intensive settings, but these activities may not necessarily lead to higher profits if the firm is unable to leverage them into creating innovative output (Yeoh & Roth, 1999). Hence, the ability of R&D effort to produce "applied" innovative outputs is critical in knowledge or research intensive settings. The ability to develop applied innovations enabled these firms to generate revenues, to remain competitive and to exploit opportunities in the market.

A consideration of the effectiveness of R&D effort as an intervening factor in the relationship between R&D effort and firm performance also provides the opportunity to address a salient counterargument from institutional theory. The institutional perspective emphasized the importance of legitimacy; and the connection, approval, or support of the institutional environment (Meyer & Rowan, 1977; Scott & Meyer, 1983). This perspective argued that the relationship between R&D effort and firm performance results from R&D effort representing a signal of firm legitimacy to the institutional environment. For instance, the R&D effort indicated by research expenditures could serve as a signal of the relative likelihood of achieving future scientific breakthroughs to the investment and financial community (Zimmerman & Zeitz, 2002). If the institutional argument predominates, it would be expected that R&D effort and innovative output have separate and independent effects on firm performance, given their roles as signals to the external environment. Hence, the empirical investigation of the effectiveness of R&D effort as an intervening factor in the relationship between R&D effort and firm performance also has the potential to inform the ongoing institutional versus economic debate.

In sum, the effectiveness of R&D effort in generating useful innovative outputs is a salient and influential characteristic of interest for firms operating in research-intensive

settings (Yeoh & Roth, 1999), given the presence of a range in the effectiveness or functionality of R&D effort across firms (Helfat & Peteraf, 2003). For instance, lower effectiveness leads to fewer innovative outputs, which in turn compromises a firm's ability to neutralize threats from competitors or to exploit new product market opportunities (Barney, 1991). Hence, the effectiveness of R&D effort as a variable that refers to the ability of R&D to yield a desired set of innovative outputs is defined, and this variable as an intervening factor in the relationship between R&D effort and firm performance is explored. The investigation of the effectiveness of R&D efforts in producing recognized innovative output as an intervening factor provides the opportunity to extend the discussion of isolating mechanisms within resource-based thinking and accumulation theory, in addition to addressing a potential counterargument from institutional theory.

Hypothesis Development

The existence of multiple factors at work in research and innovation has been documented by other researchers. For instance, successful innovations that enhance firm performance are the result of two processes: research and commercialization decisions (Burgleman & Sayles, 1986). Hence, only examining the direct relationship between R&D effort and firm performance may mask important nuances in the distinct impact of R&D on performance (Ray, Barney & Muhanna, 2004).

First, the relationship between R&D effort and the generation of innovative output for thoroughness is revisted. Generally, there is agreement that increased R&D effort precipitates greater innovative outputs, but the details regarding the specific nature of this relationship are not clear. Prior work finds a positive relationship between R&D and innovative outputs (Graves & Langowitz, 1993; Henderson & Cockburn, 1996). These results echo and support the idea of the innovation funnel, in which increased effort fosters increased output since the ratio of new ideas to new products/processes is on the order of thousands to one (Schilling, 2005).

However, the point of contention is whether R&D efforts exhibit increasing (Henderson & Cockburn, 1996) or decreasing (Graves & Langowitz, 1993) returns. Both of these studies focus on innovative outputs, such as important patent grants and new chemical entities (NCEs) respectively, within the pharmaceutical industry. However, there are a few key differences that shed light on the conflict in these findings. First, there is a difference in the levels of analysis across these two studies. Henderson and Cockburn (1996) focused primarily on research programs, and concluded that larger firms are more productive based on results that revealed spillover effects at this level. Alternatively, Graves and Langowitz (1993) focused on the firm level of analysis. Second, Henderson and Cockburn (1996) did not include a squared term in their models to explicitly examine curvilinear trends, but Graves and Langowitz (1993) did test squared and cubic terms.

The methodological differences across these two studies lead to different, yet still important, conclusions regarding returns to R&D. The increasing returns of Henderson and Cockburn (1996) are increasing returns to size resulting from the spillover effects of multiple programs within a research portfolio. This result suggests

that there are advantages to being involved in multiple concurrent research programs, which is a benefit that accrues at firms with larger research expenditures. On the other hand, the decreasing returns of Graves and Langowitz (1993) relate to the finding that NCEs increase at a decreasing rate as R&D expenditures rise. This finding implies that returns to scale in R&D effort are limited.

However, the insight provided by these two studies does not resolve the question of whether greater R&D effort yields increasing or decreasing returns. In addressing this issue, it is acknowledged that the primary function of R&D is the generation of applied knowledge (Henderson & Cockburn, 1996; Kogut & Zander, 1992). Second, the dynamic capabilities perspective of resource-based thinking is drawn on since this perspective explicitly incorporates the role of learning. The dynamic capabilities perspective (Teece et al., 1997) emphasizes the role and potential of learning as a vehicle for the improvement of organizational processes and their performance. Specifically, organizational learning represents the development of knowledge, insights, and associations between past actions, the effectiveness of past actions, and future actions (Fiol & Lyles, 1985). Hence, an entity learns if any of its units acquire knowledge potentially useful to the organization (Huber, 1991). The increased productivity generated by prior R&D success (Henderson & Cockburn, 1996) represents the embodiment of learning or knowledge within R&D activities and suggests the importance of R&D effort to informing future efforts in a way that increases the likelihood of success. This benefit of learning gained through R&D effort supports the presence of increasing returns to R&D.

However, technological obsolescence, organizational forgetting, and organizational unlearning represent forces that counteract the benefits of learning in the repetition and experimentation within the research process. Particularly relevant in research-intensive, high-technology contexts, technological obsolescence lessens the value of knowledge generated through R&D (Dierickx & Cool, 1989). Furthermore, organizational knowledge is also lost or discarded both accidently and intentionally as a result of organizational forgetting and organizational unlearning. Organizational forgetting highlights the accidental loss of knowledge as a result of degradation, dissipation, or suspension (de Holan & Phillips, 2004) while organizational unlearning highlights the intentional discarding (Tsang & Zahra, 2008) or purging of routines (de Holan & Phillips, 2004).

Since continued research activities are processes that embody learning through repetition and experimentation (Teece et al., 1997), they build the foundation of firm's absorptive capacity (Cohen & Levinthal, 1990) in ways that are cumulative and path-dependent (Kale, 2010; Hoang & Rothaermel, 2010). Since absorptive capacity facilitates future knowledge acquisition as a result of past experience, the gains in absorptive capacity that accrue from ongoing R&D efforts yield benefits that persist even in the presence of forces that dissipate organizational knowledge. Therefore, we hypothesize that increased R&D efforts lead to increasing returns to scale in regards to the yield of recognized innovative output.

Hypothesis 1: Increased R&D effort yields increasing returns to scale in the creation of recognized innovative output.

Next, attention is turned to understanding the impact that both research efforts and research effectiveness have on firm performance. A number of previous studies examined the impact of research activities on firm performance and outcomes (e.g. Deeds, 2001; Deeds, DeCarolis & Coombs, 1997; Hill & Snell, 1989; Yeoh & Roth, 1999). Once again, the findings of these studies were mixed, which suggests that other factors may have influenced this relationship. For example, Hambrick and MacMillan (1985) found that external or contextual factors influenced the innovative efficiency of firms.

Yeoh and Roth (1999) emphasized the importance of innovative output as an intervening outcome in generating greater firm profitability. They argued that R&D efforts do not lead to higher firm performance directly, but rather must be leveraged into intermediate outcomes such as patents, trademarks, licenses and organizational knowledge. Building on Yeoh and Roth (1999), these recognized research outputs actually serve as mediators through which R&D activities act upon firm profits. Since these outputs also serve as indicators of research effectiveness, it is further hypothesized that the effectiveness of R&D efforts, which is indicated through innovative outputs, is a critical determinant of their impact on firm profitability.

The argument that these recognized research outputs are the pathway through which R&D efforts influence firm profits is also supported by accumulation theory (Adams & Jaffe, 1996; Dierickx & Cool, 1989; Knott et al., 2003). As articulated by Dierickx and Cool (1989), many intangible resources (stocks) important to a firm's competitive advantage accumulate as a result of the consistent repetition of certain activities over time (flows). In this context, stocks consist of innovative output while flows consist of R&D efforts. In addition, the stock (i.e. innovative output) reflects the productivity of flows (i.e. R&D efforts), which is also consistent with accumulation theory. While Dierickx and Cool (1989) claimed that the accumulation process represents a key isolating mechanism, later work found that outputs, such as intangible asset stocks (accumulated flows) and inputs, such as R&D efforts (current flows) are both important factors in a firm's production function and have comparable explanatory power with regard to firm performance (Adams & Jaffe, 1996; Knott et al., 2003).

The mixed empirical findings of R&D research and the empirical findings from accumulation theory suggest that intangible assets (a "stock" variable), which reflect the effectiveness of R&D efforts, serve as an intervening factor in the relationship between R&D efforts (a "flow" variable) and firm performance. Hence, drawing from both the resource-based perspective and accumulation theory, we purport that the effectiveness of R&D efforts in creating intangible asset stocks serves as the pathway through which R&D effort impacts firm performance.

Hypothesis 2: The effectiveness of R&D effort in creating stocks of intangible assets mediates the relationship between R&D effort and firm performance.

Methods

Given the focus on R&D effort, the pharmaceutical industry was selected as the setting to empirically test the role of effectiveness in R&D efforts because R&D represents a predominant endeavor for these firms. The pharmaceutical industry

includes a number of industry subsectors including biotechnology, pharmaceuticals, and medicinals/botanicals. However, the critical role of R&D activity represents a common thread across all of the included industries. An entire sector, Pharmaceutical Products (SIC 2833, 2834, 2835 and 2836), was examined instead of a single industry so that the findings could be more easily generalized, and so important differences between industry subgroupings could be identified. This sector includes firms engaged in manufacturing, fabricating or processing medicinal chemicals and pharmaceutical products as well as those involved in the grading, grinding and milling of botanicals (U.S. Census Bureau).

A desire to examine a large international sample of firms motivated the use of the Global Vantage database, which is provided by Standard & Poor's Research Insight (formerly Compustat). Financial statements (income statements, balance sheets, and statements of cash flow information) and product and industry information is available on over 12,000 international firms.

Selecting firms in SIC codes 2833-2836 yielded a total of 496 companies. A total of 193 companies from the sample were eliminated based on the requirement that firms have the following data: intangible assets, goodwill, R&D expenses, employees, sales, total assets, and pre-tax income. The final dataset included a total of 303 firms distributed across SIC codes as illustrated in Table 1. The Global Vantage database provided the firm SIC code classifications.

Table 1: *Distribution of Data Sample by SIC Code*

SIC Code	Description	Observations
2833	Medicinals and Botanicals	18
2834	Pharmaceutical Preparations	187
2835	Diagnostic Substances	34
2836	Biological Products, except Diagnostic	64

Measures

Table 2 summarizes the dependent, independent and control variables.

Dependent variable. Pre-tax Income (PI) represents operating and non-operating income, excluding interest expense and before extraordinary items. This figure was

chosen as the basis for measuring firm performance in order to capture firm profitability without the influence of one-time events such as asset sales. The elimination of non-recurring events provides a measure of performance more clearly linked to continuing firm operations, as opposed to measures that incorporate extraordinary items.

Independent Variables. *Research efforts* were operationalized by using R&D intensity which is *R&D expenditures/number of employees*. Given that patterned and established research activity requires funding for scientists, laboratories, equipment and plant personnel, the level of R&D expenses incurred by a firm represents a good indication of the magnitude of its research activity or effort. Furthermore, R&D expenditures represent a measure that more closely captures the presence and magnitude of the process, as opposed to the outcome of the process (Schoenecker & Swanson, 2002). Since this study is interested in decoupling the existence of firm efforts from their outcomes to investigate intervening factors that influence this relationship, we operationalize research efforts by using R&D expenditures to avoid measures that reflect outcomes of this process.

Research effectiveness was operationalized by using intangible asset intensity which is *intangible assets/number of employees*. Intangible assets reflect valued outcomes of research activities and processes for a number of reasons. First, intangible assets embody the two knowledge-based outputs of research efforts discussed in Pisano (2000): 1) project specific product or process technologies, and 2) broad based technical knowledge regarding general underlying cause and effect relationships. For example, patents, trademarks and licenses embody the results of specific technologies, as well as reflect the potential gain in technical knowledge from engaging in the process of these discoveries.

Second, intangible assets represent a measure that reflects the construct of R&D effort effectiveness. The trademarks, patents, licenses and organizational knowledge measured by intangible assets are relevant and recognized innovative output (Yeoh & Roth, 1999), and can be leveraged to enhance firm performance. In addition, intangible assets are defined as resources controlled by a firm from which future economic benefit is expected (e.g. cash inflows or other assets) (International Accounting Standards Board, 2004).

Third, intangible assets in the pharmaceutical sector are generated primarily by R&D expenditures as opposed to advertising and marketing. Knott et al. (2003) found not only that advertising expenditures are half or less of R&D spending for pharmaceutical firms, but that advertising and R&D intensities were only weakly correlated. Therefore, it is unlikely that these intangible asset measures will be biased by advertising.

Please reference Table 2 on the following page.

Table 2: *Dependent and Independent Variables*

Variable	Description
Dependent	
Pre-tax Income	Net operating and non-operating income, excluding interest expense; is a component of income before extraordinary items
Independent	
R&D Expense	All costs relating to development of new products and services, including amortization of software costs, company sponsored research and development, software expenses; excludes customer or government-sponsored research and development expense
R&D Intensity	R&D Expense / Employees
Intangible Assets	Including patents, trademarks and trade names, copyrights, licenses, organizational expense, design costs, contract rights, operating rights; excludes pending patents, firm development costs and unamortized research and development expense; also excludes goodwill.
Intangible Asset Intensity	Intangible Assets / Employees
Controls	
Employees	All employees of consolidated subsidiaries including part time and seasonal, excluding consultants, contract workers and employees of unconsolidated subsidiaries.
Total Acquisitions	Number of domestic and international firms acquired from 1962 to 2007
Biological Products, Except Diagnostic	Dummy Variable = 1 if SIC code = 2836
Diagnostic Substances	Dummy Variable = 1 if SIC code = 2835
Pharmaceutical Preparations	Dummy Variable = 1 if SIC code =2834
Medicinals and Botanicals	Dummy Variable = 1 if SIC code =2833

Control Variables. Following Helfat (1997), Graves and Langowitz (1993), Yeoh and Roth (1999), for organization size was controlled by using the number of employees in the denominator of our intensity measures (e.g. *R&D/employees* and *intangible assets/employees*). Since R&D expenditures tend to rise linearly with firm size, an R&D intensity variable can effectively control for organization size (Helfat, 1997).

The total *number of domestic* and *international acquisitions* was used from 1962 to 2007 to control for the impact of purchased innovative output on firm performance. Purchased innovative output does not result directly from the R&D efforts of the firm and could produce upwardly biased measures of R&D effectiveness.

Industry dummy variables were used to control for industry effects. The study examined each of the four-digit SIC codes in the sample, which included SIC 2833, 2834, 2835, and 2836. However, none of these industry subsectors were significant as indicated in the baseline models of Table 4 and 5.

Results

Table 3 presents the descriptive statistics and Pearson correlations for key dependent and independent variables. Only five of the fifteen correlations between continuous variables are greater than .50, which indicates that this analysis will not be affected by excessive multicollinearity. The correlations between the four industry dummy variables are technically Phi coefficients, which measure the association between two binary variables and are numerically identical to Pearson correlations (Yule, 1912). Significant negative Phi coefficients indicate that most of the data for these industry dummy pairs lies outside the diagonal cells (Yule, 1912).

Given that all of the measures are derived from financial statements, except for the number of acquisitions, the Harman's single factor test for common method variance (Harman, 1976) was conducted to determine the existence of a natural relationship between these measures beyond what is being explained. In this test, an exploratory factor analysis was performed, and if only one factor with an eigenvalue greater than one was extracted, then this finding supports the presence of such a natural relationship since this single underlying factor explains much of the variation in the data. A Harman's single factor test conducted on this data resulted in the extraction of two orthogonal factors with eigenvalues exceeding one, which does not support the presence of this type of relationship. To investigate the hypotheses, ordinary least squares multiple regression was used given the presence of continuous dependent variables.

Table 3: *Means, Standard Deviations, and Correlations* [a]

Variable	Mean	s.d.	1	2	3	4	5	6	7	8	9
1 Pre-tax Income	759.56	6683.70									
2 R&D Expense	277.39	1098.72	.53**								
3 R&D Intensity	135.87	415.53	.69**	.27**							
4 Intangible Assets	433.13	2747.55	.37**	.71**	.18**						
5 Intangible Asset Intensity	105.86	888.1	.91**	.24**	.68**	.31**					
6 Total Acquisitions	4.35	9.2	.12*	.46**	-.08	.34	-.01				
7 Medicinals & Botanicals	.06	.24	-.03	-.06	-.06	-.04	-.03	-.07			
8 Pharmaceutical Preparations	.62	.49	.09	.15*	-.03	.10	.05	-.15**	-.32**		
9 Diagnostic Substances	.11	.32	-.04	-.08	-.02	-.05	-.02	-.08	-.09	-.45*	
10 Biological Products	.21	.41	-.06	-.08	.08	-.05	-.02	-.08	-.13*	-.66**	-.18*

[a] n = 303.

** *Correlation is significant at the 0.01 level (2-tailed)*

* *Correlation is significant at the 0.05 level (2-tailed)*

Table 4 provides the results of regression analyses measuring the impact of research efforts on innovative output as set forth in Hypothesis 1. Models 1 and 2 of Table 4 illustrate the effect of research efforts on research effectiveness in comparison to a baseline model. The total number of acquisitions is not statistically significant in any of the models of Table 4. Model 1 reveals that research effort positively impacts research effectiveness (b=0.69, p<0.005) and Model 2 tests the curvilinear aspects of this relationship. The linear research effort term is negative and significant and the squared research effort term is positive and significant, indicating the presence of an inverted-U relationship. This finding is consistent with the presence of increasing returns, which lends support to Hypothesis 1.

Table 4: Regression Analyses: *The Impact of Research Efforts on Research Outputs* [a]

Variable	Baseline	Model 1	Model 2
R&D Intensity		.69***	-.58***
(R&D Intensity)^2			1.35***
Total Acquisitions	-.02	.04	.01
Pharmaceutical Preparations	.08	-.01	.04
Diagnostic Substances	.01	-.03	.04
Biological Products	.03	-.09	.09
Adjusted R^2	-.01	.47	.70

[a] n = 303. The dependent variable is intangible asset intensity.

* *p<0.05*

** *p<0.01*

*** *p<0.005*

Table 5 provides the results of the models used to investigate the impact of research effort and the results of research effectiveness on firm performance. The total number of acquisitions is significantly and positively associated with the pre-tax income in Models 1, 2 and 3, which indicates that greater numbers of acquisitions are associated with increases in size and profits. In the test of intangible assets as a mediator, the study followed Baron and Kenny (1986), and first estimated Model 1 to examine the relationship between the independent variable (research effort) and the dependent variable (firm performance). Then, Model 2 was estimated to examine the relationship

between the mediator (research effectiveness) and the dependent variable (firm performance). Lastly, Model 3 estimated to test the role of research effectiveness as a mediator between research effort and firm performance as set forth in Hypothesis 2.

The results provided strong support for Hypothesis 2. Both research effort (b=0.72, p<0.005) and effectiveness (b=0.91, p<0.005) had a significant positive relationship with firm performance as shown by Models 1 and 2, respectively. In Model 3, both research effort and effectiveness retained their significance at p<0.005. However, the impact of research effort diminished as indicated by the decrease in the coefficient for research effort from Model 1 (b=0.72) to Model 3 (b=0.16). These results suggest that effectiveness partially mediates the relationship between research efforts and firm performance. To confirm the mediating role of effectiveness, the Aroian version of the "Sobel test," was performed which Baron and Kenny (1986) popularized as the Sobel test. The Sobel test represents a formal test of the indirect effect of the independent variable (research capability) on the dependent variable (firm performance) that is carried via the mediator (effectiveness). The results of this test echo the initial regression results and provide further empirical support for the mediating role of effectiveness (z = 13.88, p <0.001).

Table 5: *Regression Analyses: Impact of Intensity of Research Efforts and Intensity of Research Outputs on Firm Performance* [a]

	Baseline	Model 1	Model 2	Model 3
Research Intensity		.72***		.16***
Intangible Asset Intensity			.91***	.80***
Total Acquisitions	.11	.17***	.13***	.14***
Pharmaceutical Preparations	.06	-.03	-.01	-.02
Diagnostic Substances	-.01	-.05	-.02	-.03
Biological Products	-.01	-.13	-.03	-.06
Adjusted R^2	.01	.52	.84	.86

[a] n = 303. The dependent variable is pre-tax income.

* *p<0.05*

** *p<0.01*

*** *p<0.005*

Discussion and Conclusion

The empirical results revealed an interesting set of relationships between research effort, research effectiveness, and firm performance. First, increases in R&D effort do lead to increases in research effectiveness and at an increasing rate. The coefficient of the squared term was positive and significant. The finding of increasing returns supported the findings of Henderson and Cockburn (1996) and indicated that R&D efforts have an increasingly positive impact on the absorptive capacity of the firm.

Secondly, it was found that effectiveness mediates the relationship between research efforts and firm performance. While the existence of research efforts alone has a small positive effect on firm performance – which suggests a possible signaling effect – the effectiveness of those efforts in yielding innovative output has a stronger impact. These results support the idea that recognized research outputs such as intangible assets are an important factor in the value creation of research activities (Pike, Roos & Marr, 2005) since effectiveness acts as a conduit that carries the positive influence of research efforts to firm performance.

A learning perspective also suggests that the difference between effective and ineffective research efforts lies in the relevance of the knowledge they embody. The presence of recognized research outcomes with future economic or commercial viability suggests that the knowledge embodied in the firm's research capabilities fosters the creation of innovative outputs that can potentially enhance performance. On the other hand, ineffective research efforts appear to be less likely to embody the knowledge necessary to produce useful innovative outputs (Yeoh & Roth, 1999).

Advancing understanding of the relationship between research efforts and firm performance represented the overall aim of this study. The discovery of effectiveness as an important intervening factor in the relationship between R&D activities and firm performance is a critical finding since managers in research-intensive industries base many strategic resource allocation decisions on the assumed influence of R&D on firm performance. Specifically, the findings suggested that the benefit of increased R&D may be lessened if these processes do not embody knowledge relevant to the creation of recognized research outcomes. This not only provides a more encouraging picture for the pharmaceutical industry than that painted by Graves and Langowitz (1993), but also establishes R&D effectiveness in creating the desired research outcomes as key to obtaining the benefits of scale from acquisition activity.

Overall, the empirical results implied that research effectiveness represents a neglected factor that contributes to the lack of consensus in previous work investigating the relationship between R&D and firm performance. Furthermore, the presence of any significant impact of effectiveness, such as in the results presented here, supports the importance of considering this factor in studies of research and development efforts.

In addition to attempting to integrate and resolve the mixed findings of previous work in this area and to evaluate the impact of expanding the study of research outputs beyond patents, this study provided a number of important implications. First, research effectiveness is a positive function of effort. The finding of increasing returns to research activity highlights the importance of learning in the exercise of research efforts. Research activities embody learning through the repetition and

experimentation involved in the research process (Teece et al., 1997), which enables continued research activity to enhance the absorptive capacity of the firm (Cohen & Levinthal, 1990) at an increasing rate.

Second, since the results revealed increasing returns, they demonstrated that effectiveness or functionality is not fixed in research efforts, but rather improves with the exercise of those efforts. This suggests that continued usage of and investment in research efforts enables firms to obtain the most value from their efforts by improving effectiveness. Since highly utilized activities generate more value than those that are not employed with the same intensity and consistency, firms have an avenue for enhancing the value of their efforts.

Thirdly, in a research context, the most valuable elements of research activities appear to be those that yield economically useful outcomes. While the economic impact on firm performance is quite powerful, we found that the presence of research activity also enhances firm performance to a lesser degree, which suggests that research expenditures may also have a signaling function that enhances firm legitimacy. This implied that the value of research efforts can be multi-dimensional, and that it is critical for managers to understand the relative importance of each dimension.

Limitations and Future Research

The authors' hope is that this work encourages conversation and additional research regarding the impact of research effectiveness. However, an important limitation of this study was its focus on a single sector of research or knowledge intensive firms. This raises the possibility that our findings apply only to the pharmaceutical sector and may not be as applicable to other research settings. Nevertheless, several potentially fruitful avenues of investigation to pursue can be seen.

First, additional research could explore the generalizability of these results by using alternative measures or samples. For example, the results of this study could be confirmed and augmented with investigations that employ alternative measures of research effectiveness, such as counts of patents, patent citations, or new product developments. Also, similar questions could be explored across different industry contexts.

Second, future work could investigate the impact of lagged effects on research efforts and effectiveness on firm performance. Convention in R&D productivity research compares R&D expenditure and accumulated R&D stocks from the same year (Griliches, 1984). Recent empirical findings also support the use of R&D expenditure and R&D outcomes from the same year since intangible asset stocks and flows have similar explanatory power even in industries such as pharmaceuticals, where extended periods of time exist between research activity and recognized research outcomes or commercial success (Knott et al., 2003). Despite the methodology of convention and recent empirical work, the use of lagged variables could explore the presence and role of learning over time and the impact of temporal dimensions of research flows and stocks on effectiveness and firm performance.

Another interesting avenue for further investigation would be to explore the relative importance of economic and signaling effects of research efforts across different industry contexts. In particular, the concurrent and explicit empirical investigation

of economic and institutional variables has the potential to provide more definitive conclusions regarding the relative influence of these two sets of factors. Investigations of this nature could provide an interesting test of the relative importance of economic and institutional factors on firm performance, as well as providing some insight regarding the contextual influences determining the salience of one perspective over the other.

Lastly, future research could further integrate the results of this study and other investigations by exploring additional factors influencing the relationship between research activities, innovation, and firm performance. A fruitful avenue of investigation that builds off of this study and its predecessors would examine a broader scope of intervening factors in the relationship between research activities and firm performance. Prior research has explored internal factors such as the availability of slack resources and performance aspirations (Greve, 2003), and has discussed the contingent impact of process management on innovation (Benner & Tushman, 2003). On the other hand, investigators have also examined external factors such as technological opportunity and market position (Hambrick & MacMillan, 1985). Studies encompassing factors from both the internal and external situation of the firm represent a logical next step in continuing to advance our understanding of the link between research activities and firm performance.

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