Business Management Dynamics
Vol.3, No.11, Nov 2014, pp.35-54

Age Matters: Disentangling the Effect of R&D Investment in the Global Chemical Products Industry

Annetta Fortune[1] and Lois M. Shelton[2]

Abstract

This study explores the role of intervening factors on the relationship between R&D investment and firm performance in the global chemical products industry. We found mediated moderation where innovative output partially mediates the relationship between R&D investment and firm performance and firm age represents the moderator. Older firms demonstrate larger positive effects of R&D investment on innovative output and firm performance relative to younger firms. Older firms also demonstrate a stronger indirect effect of R&D investment through innovative output than younger firms.

Key words: R&D; innovative output; firm age; firm performance

Available online
www.bmdynamics.com
ISSN: 2047-7031

INTRODUCTION

Many high technology, research-intensive firms throughout the world view R&D investment as an essential business function. Even during economic downturns, many global technology firms continue to invest heavily in R&D based on the assumption that the resulting innovative output represents an important factor that positively influences firm outcomes (Hunter 2003; Silverman 2002; Whiting and Ricadela, 2002). Given this strong sentiment and pattern of behavior among managers, academic research does not yield consistent findings regarding the effect of R&D investment on firm performance.

First, while the positive relationship between R&D investment and innovative output (i.e. new chemical entities and patents) is fairly consistent across research studies (Bierly and Chakrabarti, 1996; Graves and Langowitz, 1993; Griliches, 1990; Henderson and Cockburn, 1996; Fortune & Shelton, 2012), the support for a positive relationship between R&D investment and firm performance is more tenuous. With only two exceptions noted among studies testing multiple measures of firm performance (Hsieh et al., 2003; Chang and Hsieh, 2011), previous research generally finds mixed performance effects for R&D investment (Lin et al., 2006; Schoenecker and Swanson, 2002). The effect of R&D investment on firm profitability is the most tenuous; while, the effect of R&D investment on sales growth and market performance demonstrates the most consistency (Franko, 1989; Ito and Pucik, 1993; Morbey, 1989; Morbey and Reithner, 1990, Kim and Kwon, 2011, Falk, 2012; García-Manjón and Romero-Merino, 2012). Fortune and Shelton (2012) offer one explanation for this tenuous relationship by demonstrating that R&D effectiveness is a significant positive intervening factor in the link between R&D investment and firm performance.

Second, the existing body of research does not clearly resolve how or why R&D investment affects firm performance. Some research demonstrates the importance of institutional explanations that purport R&D investment as a signal to the external environment (Soh, Mahmood, and Mitchell, 2004; Zimmerman and Zeitz, 2002). However, research within the R&D productivity literature (Griliches, 1990; Griliches and Mairesse, 1984, Adams and Jaffe, 1996) emphasizes an economic, market-based explanation of R&D investment as a generator of innovative output that enables the firm to produce valuable goods and services, and subsequently to increase its profits. The presence of findings supporting both institutional and economic influences of R&D investment, as well as the mixed findings regarding the link between R&D investment and firm performance suggests that the relationship between R&D investment and firm performance may be more complex than previously conceptualized.

Drawing from an integration of ideas from the institutional and resource-based perspectives, we aim to advance our understanding of this relationship by exploring the influence of intervening factors that may

[1] *Widener University, School of Business Administration, One University Place, Chester, PA 19013*
E-mail: afortune@mail.widener.edu
[2] *California State University, Northridge, College of Business and Economics, 18111 Nordhoff Street, Northridge, CA 91330*
E-mail: lois.shelton@csun.edu

impact the relationship between R&D investment and firm performance. As opposed to embarking on another attempt to provide evidence of this relationship, we draw insight from the disaggregated approach (Ray et al., 2004) within resource-based thinking and the liability of newness (Stinchcombe, 1965) from institutional theory to explore innovative output and firm age as meaningful intervening factors impacting the relationship between R&D investment and firm performance.

The research intensive nature of the global chemical products industry (Medcof, 1999) makes it an ideal setting for this study. Investigators found that every dollar invested in R&D in this sector yields an average annual return of seventeen percent after taxes (Wolff, 2001). In addition, a high degree of uncertainty exists around the success of R&D investment endeavors, which creates pressures for conformity across firms (Dacin, 1997), and leads to the imitation of successful competitors, regardless of whether they are domestic or global (Oliver, 1997). The long, multi-year time frames associated with many R&D projects in this sector further contribute to this uncertainty. Thus, the global chemicals industry possesses the potential for both institutional and economic forces to be at work in determining the role of R&D investment.

The contributions of this work are both empirical and conceptual. Empirically, this study provides a deeper understanding of the mechanisms involved in the relationship between R&D investment and firm performance. In addition to addressing the inconsistency of previous findings, this enhanced understanding has the potential to yield valuable insight for both academics and managers about the conditions that foster stronger R&D performance effects. Conceptually, by addressing interplay of both institutional and resource-based ideas on the relationship between R&D investment and firm performance, this study contributes to the ongoing institutional versus economic debate by demonstrating the potential value of an integrated approach to advancing our understanding of relationships at the intra-firm level.

LITERATURE REVIEW

From a resource-based perspective, the importance of resource manipulation dates back to the work of Penrose (1959) and Richardson (1972). More contemporary resource-based thinking explicitly acknowledges the importance of firm activities and processes, such as R&D investment, as resources within the dynamic capabilities perspective (Helfat et al., 2007; Teece et al., 1997). As a firm activity, R&D investment contributes to firm performance and competitive advantage through the creation of valuable and unique output. Specifically, R&D investment is an organizational activity that yields specific product or process technology and knowledge (Pisano, 2000). These innovative outputs represent a factor of production that firms use to produce goods and services, and to generate a profit (Lee, 2002; Rouvinen, 2002). Consequently, R&D investment represents a key differentiator between successful and unsuccessful firms (Bettis and Hitt, 1995; Teece, 1982) from a resource-based perspective.

In addition to supporting the importance of R&D investment to firm performance, resource-based thinking also provides an avenue for further exploration given the mixed empirical findings in the R&D literature. The disaggregated approach (Ray et al., 2004) from within resource-based thinking highlights the exploration of intervening factors as a means of clarifying the relationship between a firm activity, such as R&D investment, and overall firm performance. Specifically, the disaggregated approach emphasizes the intermediate process outcomes of firm activities, such as innovative output, as an important consideration.

The institutional perspective often represents a salient counterargument to resource-based thinking; however, both perspectives arrive at a common conclusion regarding a positive relationship between R&D investment and firm performance. A closer consideration of institutional thinking provides insight regarding another key firm-level factor to consider in understanding the relationship between R&D and firm performance. While the institutional perspective does emphasize environmental level influences such as legitimacy and isomorphism (DiMaggio and Powell, 1983; Meyer and Rowan, 1977; Scott and Meyer, 1992), this perspective also acknowledges the influence of the firm level characteristics such as firm age and firm size. Motivated by the empirical support for the liability of newness (Stinchcombe, 1965), we also extend our investigation to include a considering of firm age as a relevant intervening factor. Hence, instead of conducting another study aimed at resolving this historical debate, we aim to

demonstrate how these competing perspectives can be integrated to reshape our thinking about the underlying mechanisms that yield the variations in the relationship between R&D investment and firm performance.

This aim is consistent with a growing body of work which concludes that institutional pressures may operate along with economic forces (Dacin, 1997; Dacin, Goodstein and Scott, 2002; Fernandez-Alles and Valle-Cabrera, 2006; Oliver 1991, 1997). Previous research analyzes the relative impact of these two perspectives in the context of organizational foundings (Dacin, 1997), strategy abandonment (Greve, 1995), and the adoption of innovative practices in the areas of human resource practices (Sherer and Lee, 2002), reengineering (Walston et al., 2000), total quality management programs (Westphal et al., 1997), matrix management programs (Burns and Wholey, 1993), and the multidivisional form by large U.S. corporations (Palmer et al., 1993). This body of work primarily addresses the relative importance of institutional and economic forces within contexts marked by either organization or population level change, such as the adoption/diffusion of new practices, or organizational foundings, respectively. Here, we extend the integration of institutional and resource-based ideas to understand firm level dynamics and focus on the interplay of institutional and resource-based influences impacting the relationship between an organizational resource (R&D investment) and firm performance.

HYPOTHESIS DEVELOPMENT

We ground our analysis of intervening factors on the relationship between R&D investment and firm performance in two perspectives: the resource-based view (Barney, 1991) and the liability of newness (Stinchcombe, 1965). The resource based view, coupled with the R&D productivity literature, supports an economically based argument for the role of innovative output as a mediator of the impact of R&D investment on firm performance. The liability of newness concept provides the basis for firm age, an institutional factor, to moderate the relationship between R&D investment and firm performance. Coupled with the findings of prior research, an integration of these two perspectives supports an argument for mediated moderation as illustrated in our conceptual model presented in Figure 1, and discussed below.

Insert Figure 1 here

Innovative Output as a Mediator

The disaggregated approach dissects the relationship between firm activities and firm performance by adopting intermediate process outcomes as the dependent variable to more accurately reflect the contribution of a given organizational activity given the multiple and varied influences on overall firm performance (Ray et al., 2004). The effectiveness of a business activity in yielding specific process outcomes represents an important intermediate outcome to consider as firm activities often possess a range of functionality or effectiveness (Helfat and Peteraf, 2003). The innovative output generated by R&D investment represents an important intermediate outcome since it represents a factor of production that enables a firm to generate profits (Fortune & Shelton, 2012; Lee, 2002; Rouvinen, 2002) by either raising the quality of output, and consequently, the price that the firm charges, as in product R&D; or by lowering the inputs required to produce a given amount of output, as in process R&D (Adams and Jaffe, 1996). Since the level of innovative output yielded by R&D investment represents a focal intermediate outcome of interest from the disaggregated approach, innovative output represents a theoretically motivated intervening factor to consider.

The findings of prior research also suggest the potential intervening influence of innovative output on the relationship between R&D investment and firm performance. First, the findings generally demonstrate a lack of consensus regarding the impact of R&D investment on firm performance (Lin et al., 2006; Schoenecker and Swanson, 2002), which broaches the discussion of intervening influences on this relationship. Second, existing research supports the positive relationship between R&D investment and innovative output with some consistency (Bierly and Chakrabarti, 1996; Graves and Langowitz, 1993; Griliches, 1990; Henderson and Cockburn, 1996), which suggests the relevance of innovative output as an important intervening factor. However, most previous empirical studies of R&D investment and firm performance have not explicitly incorporated innovative output or other intervening factors. To our knowledge the only exceptions are Fortune and Shelton (2012) who discovered a positive effect of

innovative output in the pharmaceutical industry, and Demirel and Mazzucato (2012) who found that the positive impact of R&D on firm growth depends on patenting ability. This finding is interesting since the link between patents and firm performance receives little support (Griliches, 1990), while more mature innovative output, such as new product development, has a positive effect on firm performance (Rothaermel, 2001).

To build on this body of work and advance our understanding of these results, an examination of a model that explicitly addresses the inferred relationship among R&D investment, innovative output, and firm performance represents an important step in understanding the role of R&D investment as a contributor to overall firm performance. Assimilating prior empirical findings and the conceptual insight of the disaggregated approach, we explicitly propose and examine innovative output as a mediating factor that carries the effect of R&D investment on overall firm performance. Specifically, we expect the indirect impact of R&D investment on firm performance through innovative output to be positive and statistically significant.

Firm Age as a Moderator

Stinchcombe (1965) receives credit for coining the term "liability of newness" to describe the disadvantages experienced by young firms, in particular, as a function of firm age. According to Stinchcombe (1965), newer organizations are at a disadvantage relative to older organizations due to a lack of legitimacy, weaker ties to external actors and a lack of experience (Aspelund et al., 2005; Hannan, 1998). A body of empirical work supports the liability of newness (Carroll, 1983; Freeman et al., 1983) including recent work that also controls for organization size. In addition to the results of Thornhill and Amit (2003), Hannan et al. (1998) identify a total of nine studies supporting the liability of newness.

The impact of aging on external ties and firm activities is an important part of Stinchcombe's argument for the liability of newness (Hannan, 1998), which bridges this ecological idea and institutional theory. Older firms possess more legitimacy and more connections to the external environment relative to younger firms, which provides older firms with more access to needed resources in the external environment (Meyer and Rowan, 1977; Scott and Meyer, 1992). For instance, suppliers, creditors, customers and other companies may be more reluctant to collaborate with newer companies due to their lack of legitimacy and experience, and this reluctance may hinder the efforts of newer companies in developing new products, goods or services (Zahra et al., 2005). However, over time as firms develop and maintain good relations with key external actors, the accumulation of favorable external ties enhances organizational performance (Hannan, 1998).

Similarly, as young organizations age, they acquire experience in their productive activities and can potentially learn. The importance of experimentation, repetition, and history involved in learning and organizational activity development (Teece et al, 1997) suggests that older firms may have more well-developed firm activities relative to younger firms. As younger firms learn from experience, they refine their productive activities, develop organization-specific human capital, and subsequently, improve their quality of performance (Hannan, 1998; Stinchcombe, 1965).

In the context of R&D investment, linkages to key external entities such as research institutes, scientific bodies, regulatory bodies and university departments can greatly enhance a firm's research efforts (Lynn et al., 1996). Older firms with stronger ties and longer histories are more likely to have an advantage, particularly during the commercialization stage (Lynn et al., 1996). The disadvantages of the liability of newness also extend to internal operations, where the employees and managers of younger firms may lack the experiences and skills required to develop and exploit complex technologies (Zahra et al., 2005). The consequences of the liability of newness are particularly acute for newer technology-based firms, which often lack considerable resources in terms of technology development (Aspelund et al., 2005).

Given the empirically supported disadvantages faced by younger firms in external connections and internal development which result in the liability of newness, we propose that firm age positively moderates the total effect of R&D investment on firm performance. Similar to the case of innovative output as a mediator, the influence of firm age on the relationship between R&D and firm performance represents an intervening factor which has generally not been considered in prior empirical work. An exception is Wöhrl, Hüsig, and Dowling (2009), who found that firm age moderates the impact of R&D intensity on sales growth and profitability. Specifically, the impact of R&D intensity on sales growth

(positive) and profitability (negative) were consistent with prior research; however, the relationships did differ across younger and older firms within a sample of technology-based growth companies in Germany (Wöhrl et al, 2012). The finding of this study motivates the empirical question about the generalizability of its findings in broader contexts, and supports the inclusion of firm age as a relevant moderator within an investigation of the relationship between R&D investment and firm performance.

Hypothesis 1: R&D investment has a more positive effect on firm performance for older firms relative to younger firms.

The Confluence of Intervening Factors: Mediated Moderation

At this point, we address the interplay among innovative output and firm age on the relationship between R&D investment and firm performance. The novelty of this study centers on examining how these two intervening factors operate together to impact the relationship between R&D investment and firm performance. Given the empirical and conceptual support for both the impact of firm age and innovative output as intervening influences, we expect that both factors will jointly influence the relationship between R&D investment and firm performance; however, our focal interest is to clarify how the moderating influence of firm age affects the indirect effect of R&D investment through innovative output.

In dissecting the indirect effect of R&D investment through innovative output, we first address how age affects the relationship between R&D investment and innovative output. Both resource-based and institutional arguments suggest that older firms would reap more innovative output for a given level of R&D investment relative to younger firms. From an institutional perspective (Meyer and Rowan, 1977; Scott and Meyer, 1992), liability of newness (Stinchcombe, 1965) suggests that younger firms are disadvantaged by a lack of quality and depth in their connections with key external parties that could enhance the productivity of R&D investment (Lynn et al., 1996; Zahra et al., 2005). From a resource-based perspective, younger firms are also disadvantaged by a shorter history which results in less developed resources or capabilities relative to older firms (Teece et al., 1997). Older firms have better developed R&D investment activities, and superior ties to key external entities than their younger counterparts, and consequently accrue larger benefits to their R&D activities. Thus, we expect firm age to positively moderate the relationship between R&D investment and innovative output.

Hypothesis 2: R&D investment has a more positive effect on innovative output for older firms relative to younger firms.

Similarly, both resource-based and institutional perspectives also suggest that older firms are also more likely than younger firms to be successful in leveraging this innovative output into better firm performance. For example, Lynn et al., (1996) and Zahra et al., (2005) note that the commercialization of research findings requires technological complementarities and the integration of diverse elements of skill, information and knowledge, all of which are more likely to be acquired and developed as firms age. Hence, we also expect firm age to positively moderate the relationship between innovative output and firm performance.

Hypothesis 3: Innovative output has a more positive effect on firm performance for older firms relative to younger firms.

We expect that the inclusion of firm age will not preclude the mediating role of innovative output based on a confluence of empirical evidence and conceptual reasoning as discussed above. A consideration of the influence of firm age on the relationships within a mediation model leads us to hypothesize a case of mediated moderation for the relationship between R&D investment and firm performance in which firm age represents the moderator and innovative outputs represents the mediator. However, given the overall impact of the liability of newness (Stinchcombe, 1965), we do expect that the indirect of effect of R&D investment on firm performance will be stronger for older firms relative to younger firms.

Hypothesis 4: The indirect effect of R&D investment on firm performance through innovative output is more positive for older firms relative to younger firms.

METHODS

Research Setting and Sample Selection

We selected the global chemical products industry as the setting to empirically examine how R&D investment impacts firm performance because research and development is a predominant endeavor for these firms. An entire industry group, Chemicals and Allied Products (SIC 28), was examined instead of solely pharmaceuticals and/or biotechnology so that these empirical findings can be more easily generalized and important differences between individual industries can be isolated. This industry group includes both firms producing basic chemicals as well as those manufacturing products primarily by chemical processes. These firms produce three general classes of products: basic chemicals, intermediate chemical products to be used for further manufacture (i.e. synthetic fibers, dry colors and pigments), and finished chemical products (i.e. drugs, cosmetics, paints and fertilizers) (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 & Poors Research Insight (formerly Compustat). Financial statements (income statement, balance sheet and statement of cash flow information) and product and industry information is available on over 12,000 international firms.

Our selection criteria of requiring that firms be included in SIC codes 2800-2899 yielded a total of 1162 companies. We eliminated a total of 525 companies from the sample based on the requirement that firms have the following data: employees, R&D expenditures, intangible assets, goodwill, and pre-tax income. The final dataset included a total of 637 firms distributed across SIC codes as illustrated in Table 1 and across thirty-five nations as shown in Table 1a. The Global Vantage database provided the firm SIC code classifications, and identified the nations of firm incorporation. In order to test firm age, we supplemented the Global Vantage database with firm age data collected from Lexis-Nexis Academic Universe.

Insert Table 1 and Table 1a here

Measures

Table 2 summarizes the dependent, independent and control variables, all of which were obtained from the Research Insight Global Vantage database and Lexis-Nexis Academic Universe.

***Dependent variable*:** We use pre-tax net income as our measure of firm performance. Pre-tax net income represents operating and non-operating revenue less operating and non-operating expense, excluding interest expense and before extraordinary items. We chose this measure because it captures 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 these extraordinary items.

***Independent variables*:** We operationalize R&D investment using R&D expenditures. Given that R&D investment 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 investment in organizational research. 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 and Swanson, 2002). By choosing a measure that decouples the presence of a firm activity from its results, we can more easily examine the intervening factors that influence the process-performance relationship.

We operationalize innovative output using intangible assets. We chose intangible assets over other types of innovative output because we wanted to employ a broader measure of innovative output that reflected the relevant and valued outcomes of both product and process R&D investment. The trademarks, patents, licenses and organizational knowledge measured by intangible assets are relevant and recognized innovative output (Yeoh and Roth, 1999), and therefore represent intermediate process outcomes of R&D investment as consistent with the disaggregated approach. Patents represent a readily available alternative to intangible assets that is also relevant within the chemicals industry; however, estimates suggest that at least 75% of R&D expenditures may not relate to patent activity (Rosegger, 1986). More specifically, Dosi (1988) estimated the composition of R&D expenditures to be $1/10^{th}$ for pure research, $1/4^{th}$ for applied research, and the balance to development. Since patents represent

innovative output for only a small portion of R&D expenditure, the relevance of patents as a measure of innovative output is limited given the purpose of this study.

We operationalized firm age using the actual age of the firm in years from the year of the firm's establishment through 2006.

Insert Table 2 here

***Control Variables*:** We used the number of employees to controls for firm size. Prior research indicates that firm size affects R&D expenditures, as well as the ability of this investment to produce innovative output (Helfat, 1997; Henderson and Cockburn, 1996; Knott, 2003). In light of this evidence, we follow Helfat (1997) by using R&D intensity and intangible asset intensity measures (i.e. R&D/ employees and intangible assets/ employees, respectively) to control for firm size.

Lastly, we included industry dummy variables to control for industry effects. We examined the following four-digit SIC codes, which each consisted of at least 32 firms (or 5% of the total sample) for statistical significance: SIC 2800, SIC 2810, SIC 2820, SIC 2821, SIC 2834, SIC 2835 and SIC 2836. Only three industry groups; SIC 2820 – Plastics, Materials and Synthetics, SIC 2835 – Diagnostic Substances, and SIC 2836 – Biological Products except Diagnostics, proved to be statistically significant. Hence, we used these three industry dummy variables in the model estimations to control for industry specific effects.

Statistical Analyses

We began by empirically confirming that innovative output mediated the relationship between R&D investment and firm performance. We employed the classic test for mediation (Baron and Kenny, 1986) including firm age as a control in these models. This test of mediation entailed estimating three regression equations to examine: 1) the overall direct effect of independent variable (R&D investment) on the outcome variable (firm performance), 2) the effect of the independent variable on the mediator (innovative output), and 3) the residual direct effect of independent variable on the outcome variable in the presence of the mediator.

The results support mediation if the mediator has a statistically significant effect on firm performance when controlling for independent variable, and if the residual direct effect of the independent variable on the outcome variable is less than the overall direct effect of the independent variable on the outcome variable. We confirmed the significance of the indirect effect through the mediator with the Sobel test popularized by Baron and Kenny (1986).

To examine the mediated moderation hypothesis in general, and the relationships of Hypotheses 1-4 in particular, we followed Muller et al. (2005) and incorporated interaction terms between the moderator (firm age, Mo) and the independent variable, and between the moderator and the mediator (innovative output, Me). We specifically hypothesized mediated moderation given the moderation of the overall direct effect of R&D on firm performance by age (Muller et al., 2005). The following set of equations illustrates the regression equations estimated to test for mediated moderation:

$$Y = \beta_{40} + \beta_{41}X + \beta_{42}Mo + \beta_{43}XMo + \varepsilon_4 \quad (1)$$

$$Me = \beta_{50} + \beta_{51}X + \beta_{52}Mo + \beta_{53}XMo + \varepsilon_5 \quad (2)$$

$$Y = \beta_{60} + \beta_{61}X + \beta_{62}Mo + \beta_{63}XMo + \beta_{64}Me + \beta_{65}MeMo + \varepsilon_6 \quad (3)$$

In the case of mediated moderation, firm age moderates the overall direct effect of the independent variable on the outcome variable; therefore, β_{43} is non-zero and statistically significant. Also, mediation must be present and at least one of the indirect paths (the effect of the independent variable on the outcome variable and/or the effect of the mediator on the outcome variable) must be moderated. As a result of these conditions, the moderation of the residual direct effect of the independent variable should be less than the moderation of the total direct effect of the independent variable ($\beta_{63} < \beta_{43}$) (Muller et al., 2005).

In addition to representing a key element of examining mediated moderation, the interaction terms of Equations 4-6 also enable us to specifically examine how firm age impacts the mediation of R&D investment through innovative output. Hence, we probed significant interactions by evaluating the

simple slopes at varying firm ages to get a clear understanding of the influence of firm age as a moderator, and to specifically address the relationships of Hypotheses 1-4.

RESULTS

Table 3 provides the descriptive statistics and correlations. As expected, notable correlations are present between the number of employees and R&D expenditures or intangible assets based on the precedence in the literature related to these relationships (Knott, 2003). Notable correlations are also present between R&D expenditures and intangible assets, as well as between R&D intensity and intangible asset intensity. These correlations are consistent with the empirically supported idea that R&D investment generates innovative output (Bierly and Chakrabarti, 1996; Graves and Langowitz, 1993; Griliches, 1990; Henderson and Cockburn, 1996).

While moderate levels of correlation are present between some independent variables, all correlations among independent variables are below the benchmark values of 0.75 (Tsui et al., 1995) and 0.80 (Kennedy, 1979). Furthermore, correlations are far from identities, and substantial variation is present in both R&D expenditures and intangible assets independent of firm size.

Insert Table 3 here

Based on the results of regression analyses in Table 4, we find support for partial mediation. As shown in Model 1 of Table 4, R&D investment has a positive and significant effect on firm performance ($\beta = 11.46$, $p<0.005$). In Model 2, R&D investment also has a significant positive effect on intangible asset intensity ($\beta = 1.46$, $p<0.005$). Lastly, the effect of R&D investment decreases in absolute value from Model 1 to Model 3, yet remains significant, which supports partial mediation ($\Delta = 8.72$). To confirm the statistical significance of this indirect effect, we performed the standard and Aroian versions of the Sobel test (Baron and Kenny, 1986), which both supported the presence of an indirect effect ($Z = 18.132$, $p<0.005$; $Z=18.125$, $p<0.005$, respectively). The increase in explanatory power from Model 1 to Model 3 also indicates the importance of the mediator, intangible asset intensity. Model 1 explains 46% of the variance in pre-tax income, but Model 3 explains 76% of the variance in pre-tax income.

Insert Table 4 here

The results of post-hoc analyses, which examine reverse causality and feedback effects, are presented in Tables 5, 5a and 6. In order to examine the specification of our model, we tested for the presence of reverse causality. According to Kenny (2012), the outcome variable may cause the mediator instead of vice versa; therefore, researchers should also perform the regression analysis for mediation analysis with the roles the mediator and outcome variables exchanged to evaluate the presence of reverse causality. In our case, testing for reverse causality involves estimating regression equations in which firm performance causes the intangible asset intensity. If the reverse results are similar to the original results, then the specification of the original model can be called into question. Specifically, reverse causality is a problem if the regression coefficients for the residual direct effect (c′ in Figure 1) and path from the mediator to dependent variable (b in Figure 1) are approximately the same in the two models.

The results of our reverse causality analysis are presented in Tables 5 and 5a. The coefficients representing the total direct effect (c), the residual direct effect (c′), and both indirect paths (a and b) of the reverse model are all positive and significant; however, their magnitudes are substantially lower than those in the original model. In Table 5a, the reverse model coefficients range in size from 7% to 1% of the original model coefficients. These results suggest that reverse causality effects are minimal and provide support for the original model specification.

Insert Tables 5 and 5a here

Given the results of previous work, we also examined feedback effects in which firm performance affects R&D investment. For instance, poor performance (Hundley et al., 1996; Greve, 2003a) and high organizational slack (Greve, 2003a) can lead to increased R&D investment. Given these findings, our goal is two-fold: 1) to determine if firm performance impacts R&D investment in the chemical products industry, and 2) if so, which effect is stronger – the impact of R&D investment on firm performance or vice versa. Table 6 contains the results of this investigation. In our sample, higher pre-tax net income leads to greater R&D investment as shown in the feedback effect model; however, the impact of R&D investment on firm performance in the total effect model is much larger. The regression equations in

Table 6 support the presence of: 1) a sizeable total effect of R&D investment on firm performance and, 2) a smaller secondary feedback effect of firm performance on R&D investment.

Insert Table 6 here

Table 7 provides the regression results for the test of mediated moderation. Model 1 demonstrates that firm age moderates the overall effect of R&D investment on firm performance which is consistent with mediated moderation, as opposed to moderated mediation. The coefficient of the interaction term for R&D intensity and firm age is positive and significant (β=0.44, $p<0.005$). Notably, this interaction maintains its direction and significance in Models 2 and 3 (β=0.05, $p<0.005$; β=0.29, $p<0.005$, respectively), and the interaction term for intangible asset intensity and firm age is also positive and significant (β=0.11, $p<0.005$) as shown in Model 3. Hence, firm age moderates both of the indirect paths associated with the mediator. Lastly, the coefficient of the interaction term between R&D intensity and firm age decreases in absolute value from Model 1 (β=0.44) to Model 3 (β=0.29). Taken together, these results support a case of mediated moderation in which firm age moderates the overall direct effect of R&D investment on firm performance, as well as the indirect effect that is carried through the innovative output. As a result, the moderation of the residual direct effect of R&D investment on firm performance is smaller in magnitude than the moderation of the overall direct effect.

Insert Table 7 here

We probed the significant interactions in Models 1 - 3 in Table 7 by evaluating the simple slopes at one standard deviation above mean firm age (older firms) and one standard deviation below the mean firm age (younger firms) to clarify the influence of firm age as a moderator. The simple slope of pre-tax net income on R&D intensity (Model 1) was 28.30X for older firms and 8.92X for younger firms. These simple slopes reveal that R&D investment has a larger positive effect on firm performance for older firms relative to younger firms, which supports Hypothesis 1.

The simple slope of intangible asset intensity on R&D investment (Model 2) was 3.18X for older firms and 0.33X for younger firms. These simple slopes reveal that R&D investment has a larger positive effect on innovative output for older firms relative to younger firms, which supports Hypothesis 2. The simple slope of firm performance on intangible assets (Model 3) was 5.50X for older firms and -1.22X for younger firms. These simple slopes reveal that innovative output has a positive effect on firm performance for older firms, and a negative effect on firm performance for younger firms, which supports Hypothesis 3.

To evaluate how the indirect effect of R&D investment on firm performance through innovative output differed across older and younger firms, we multiplied the simple effects of intangible asset intensity on R&D investment (a in Figure 1) and the simple effects of firm performance on intangible asset intensity (b in Figure 1). The total indirect effect older firms was 17.50 (3.18 * 5.50) and the total indirect effect for younger firms was -0.40 (0.33 * -1.22). Given that the total indirect effect for older firms is positive, yet the total indirect effect for younger firms is negative, these results provide support for Hypothesis 4.

DISCUSSION AND CONCLUSION

This study aimed to provide a more fine-grained understanding of how R&D investment affects firm performance by examining intervening influences on this relationship within the global chemical products industry. We drew on an integration of resource-based and institutional ideas to support an investigation of innovative output and firm age as important intervening influences on the relationship between R&D investment and firm performance. Our results support our hypotheses and reveal a case of mediated moderation where innovative output mediates the effect of R&D investment on firm performance and firm age acts as a moderator. These results highlight the value of looking beyond the existence of a relationship to gain a deeper understanding of the intervening factors that influence the relationship in question, in addition to providing insight into the relationship between R&D investment and firm performance.

First, the results demonstrate that the positive effects of R&D investment on either innovative output or firm performance are larger for older firms relative to younger firms. An enhanced performance effect for older firms relative to younger firms is consistent with an institutional perspective as a result of the increased legitimacy and connections of older firms (Scott and Meyer, 1992; Meyer and Rowan, 1977). However, this result is also consistent with a resource-based rationale that credits the enhanced performance effect to more developed organizational capabilities of older firms. Within the dynamic

capabilities perspective, experimentation and repetition play a salient role in learning and capability development (Teece et al., 1997). An absorptive capacity perspective echoes this sentiment by emphasizing the importance of history and prior experience in the ability of firms to recognize and assimilate knowledge which fosters the development of innovative capabilities (Cohen and Levinthal, 1990). Since the passage of time enables learning and capability development, these results suggests that older firms may benefit from an increased opportunity to learn and develop their organizational capabilities relative to younger firms.

Similarly, the enhanced performance effect of older firms also extends to engage evolutionary economics by supporting the notion that the passage of time is important in the generation and storage of firm knowledge within firm routines (Nelson and Winter, 1982). Directed R&D investment and the activities supported by R&D investment constitute a class of organizational routine (Winter, 1990) that embodies the knowledge accumulated through engaging in these activities over time. Similar to the rationale of the dynamic capabilities perspective (Teece et al., 1997), the passage of time is important to the "learning by doing" process within evolutionary economics in which benefits accrue to older firms in the form of more firm knowledge. Hence, older firms may benefit from the wisdom and relationships that come with age, which represents an integration of both resource-based and institutional explanations.

Second, the results demonstrate that the performance effects of innovative output, as well as the indirect effect of R&D investment via innovative output, were positive for older firms, but negative for younger firms. The learning perspective discussed above supports a less positive effect for younger firms since undeveloped R&D routines and capabilities hinder innovative output, but the negative effect is somewhat unexpected. However, just as the consideration of upstream versus downstream relationships informs the performance effects of alliances (e.g. Rothaermel, 2001; Rothaermel and Deeds, 2004), the learning argument gains traction if we consider the development of organizational capabilities downstream from R&D investment in a firm's value chain. Just as time favors the maturation and development of R&D routines and capabilities, time also favors the development of downstream capabilities such as commercialization capabilities that incorporate innovative output into products and services, and marketing capabilities that position these products and services for success in the marketplace. Hence, the lack of downstream capabilities can represent an obstacle that prevents young firms from transforming their innovativeness into returns.

In addition to providing insight into the relationship between R&D investment and firm performance from an academic perspective, these results provide valuable insight for firm managers charged with making R&D investment decisions. Specifically, the results of this study suggest that firm managers should be sensitive to the long-term ramifications of R&D investment when making decisions about shifts in R&D investment levels. Work from a behavioral perspective finds that R&D investment fluctuates with the degree to which performance falls below expectations, the availability of slack resources, Greve (2003a) and proximity to bankruptcy (Chen and Miller, 2007). These findings reveal that near term organizational cues influence R&D investment decisions, even though sustained R&D investment contributes the long-term learning capacity (i.e. absorptive capacity) and capability endowment of firms operating in research or knowledge intensive settings (Cohen and Levinthal, 1990). The ability of older firms to realize more performance related benefits to R&D investment supports the case for sustained R&D investment, and casts a positive light on institutionalized search (Greve, 2003b) where R&D investment assumes a standard routine (Dosi, 1988).

LIMITATIONS AND FUTURE RESEARCH

Like much previous work, this study is not without its limitations. First, future research could continue to pursue a deeper understanding of the role of R&D investment. Research using different methodological approaches, such as case studies or field experiments, may provide more fine grained and detailed information regarding how R&D impacts firm performance through the use of measures that move even closer to capturing the essence of research processes and the various forms of innovative output, such as knowledge. Research investigating the interplay of additional institutional and resource-based intervening factors other than firm age and innovative output, respectively, may extend our understanding and explore the robustness of the interplay of institutional and resource-based ideas.

Second, research exploring a diversity of contexts could explore the generalizability of our findings. Focusing on other organizational activities, future research could examine whether or not the relationship between other organizational activities and firm performance also represents a case of mediated moderation. Focusing on other industries, future research could re-examine the relationship between R&D investment, firm performance, and firm age. Lastly, additional work exploring the nuances present between process and product R&D represents a fruitful line of inquiry given that the relevant outputs, institutional influences, and performance implications may shift depending type of R&D that receives the primary emphasis.

CONCLUSION

The performance impact of R&D investment and the ongoing debate between the institutional and the economic represent ongoing areas of discussion within organizational literature. In this study, our aim was to engage both of these lines of discussion by employing a disaggregated approach to examine how R&D investment impacts firm performance. The results of this study demonstrate the value in looking beyond the mere existence of a relationship to unpacking the intervening influences in an effort to understand why we see variance in given relationship. We find that resource-based and institutional ideas together highlight influential intervening factors that work in concert to impact firm performance. Given that the intervening influences of innovative output and firm age have not been addressed previously within a single study, the findings of this work offer a potential explanation for the existing lack of consensus. Overall, we hope that this investigation motivates us to reshape our thinking about organizational processes such as R&D by providing insight and generating inquiry regarding the mechanisms that drive some of the patterns that we see in the business landscape.

REFERENCES

Adams, J.D, Jaffe, A.B. (1996). "Bounding the effects of R&D: An investigation using matched establishment-firm data," *Rand Journal of Economics*, Vol. 27, No. 4, pp. 700-621.

Aspelund A., Berg-Utby, T., Skjevdal, R. (2005). "Initial resources' influence on new venture survival: a longitudinal study of new technology-based firms," *Technovation*, 25, pp. 1337-1347.

Barney, J. (1991). "Firm resources and sustained competitive advantage," *Journal of Management*, 17, pp. 99-120.

Baron R.M., Kenny, D.A. (1986). "The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations," *Journal of Personality and Social Psychology*, 51, pp. 1173-1182.

Bierly, P., Chakrabarti, A. (1996). "Technological learning, strategic flexibility, and new product development in the pharmaceutical industry," *IEEE Transactions Engineering Management,* 43, pp. 368-380.

Bettis, R.J., Hitt, M.A. (1995). "The new competitive landscape," *Strategic Management Journal*, 16, pp. **7-**20.

Burns, L.R., Wholey, D.R. (1993). "Adoption and abandonment of matrix management programs: Effects of organizational characteristics and interorganizational networks," *Academy of Management Journal*, 36, pp. 106-138.

Caroll, G.R. (1983). "A stochastic model of organizational mortality," *Social Sciences Research*, 12, pp. 303-329.

Chang, W.S., Hsieh, J. (2011). "Intellectual capital and value creation – Is innovation capital a missing link?" *International Journal of Business and Management*, Vol. 6, No. 2, pp. 3-12.

Chen, W., Miller, K.D. (2007). "Situational and institutional determinants of firms' R&D search intensity," *Strategic Management Journal,* 28, pp. 369-381.

Cohen, W.M., Levinthal D.A. (1990). "Absorptive capacity: A new perspective on learning and innovation," *Administrative Science Quarterly*, 35, pp. 128-152.

Dacin, T. (1997). "Isomorphism in context: the power and prescription of institutional norms," *Academy of Management Journal*, 40, pp. 46-81.

Dacin, T., Goodstein, J., Scott, R. (2002). "Institutional theory and institutional change: introduction to the special research forum," *Academy of Management Journal*, 45, pp. 45-57.

Demirel, P., Mazzucato, M. (2012). "Innovation and firm growth: Is R&D worth it?" *Industry and Innovation,* Vol. 19, No. 1, pp. 45.

DiMaggio, P.J., Powell. W.W. (1983). "The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields," *American Sociological Review*, 48, pp. 147-160.

Dosi, G. (1988). "Sources, procedures, and microeconomic effects of innovation," *Journal of Economic Literature*, Vol. 26, No. 9, pp. 1120-1171.

Falk, M. (2012). "Quantile estimates of the impact of R&D intensity on firm performance," *Small Business Economics,* Vol. 39, No. 1, pp. 19-37.

Fernandez-Alles, M., Valle-Cabrera, R. (2006). "Reconciling institutional theory with organizational theories: How neoinstitutionalism resolves five paradoxes," *Journal of Organizational Change*, Vol. 19, No. 4, pp. 503-517.

Fortune, A., Shelton, L. (2012). "R&D effort, effectiveness, and firm performance in the pharmaceutical sector," *Journal of Business and Management,* Vol. 18, No. 1, pp. 97-115.

Franko, L.G. (1989). "Global corporate competition: Who's winning, who's losing," *Strategic Management Journal*, Vol. 10**,** No. 5, pp. 449-474.

Freeman, J., Carroll, G.R., Hannan, M.T. (1983). "The liability of newness: Age dependence in organizational death rates," *American Sociological Review*, 48, pp. 692-710.

García-Manjón, J.,V., & Romero-Merino, M. (2012). "Research, development, and firm growth. empirical evidence from European top R&D spending firms," *Research Policy,* Vol. 41, No. 6, pp. 1084 - 1092.

Graves, S.B., Langowitz, N.S. (1993). "Innovative productivity and returns to scale in the pharmaceutical industry," *Strategic Management Journal*, 14, pp. 593-605.

Greve, H.R. (1995). "Jumping ship: The diffusion of strategy abandonment," *Administrative Science Quarterly*, 40, pp. 444-473.

Greve, H.R. (2003a). "A behavioral theory of R&D expenditures: Evidence from shipbuilding," *Academy of Management Journal*, 46, pp. 685-703.

Greve, H.R. (2003b). *Organizational Learning from Performance Feedback: A Behavioral Perspective on Innovation and Change*. Cambridge University Press: Cambridge, U.K.

Griliches, Z. (1990). "Patent statistics as economic indicators: A survey," *Journal of Economic Literature*, 28**,** pp. 1661-1707.

Griliches, Z., Mairesse, J. (1984). "Productivity and R&D at the firm level," In *R&D, Patents, and Productivity*, Griliches, Z (ed); NBER Conference Report. University of Chicago Press: Chicago: pp. 339-374.

Hannan, M.T. (1998). "Rethinking age dependence in organizational mortality: Logical formalizations," *The American Journal of Sociology*, Vol. 104, No. 1, pp. 126-64.

Hannan, M.T, Carroll, G.R, Dobrev, S., Han, J. (1998). "Organizational mortality in European and American automobile industries Part I: Revisiting the effects of age and size," *European Sociological Review*, Vol. 14, No. 3, pp. 279-302.

Helfat, C.E. (1997). "Know-how and asset complementarity and dynamic capability accumulation: the case of R&D," *Strategic Management Journal,* 18, pp. 339-360.

Helfat C.E, Finkelstein, S., Mitchell, W., Peteraf, M.A., Singh, H., Teece, D.J., Winter, S.G. (2007). *Dynamic Capabilities: Understanding Strategic Change in Organizations*. Blackwell Publishing: Malden, MA.

Helfat, C.E., Peteraf, M.A. (2003). "The dynamic resource-based view: Capability lifecycles," *Strategic Management Journal*, 24, pp. 997-1010.

Henderson, R., Cockburn, I. (1996). "Scale, scope, and spillovers: The determinants of research productivity in drug discovery," *The Rand Journal of Economics*, 27, pp. 32-59.

Hsieh, P., Mishra, C.S., Gobeli, D.H. (2003). "The return on R&D versus capital expenditures in pharmaceutical and chemical industries," *IEEE Transactions on Engineering Management***,** 50, pp. 141-150.

Hundley, G., Jacobson, C.K, Park, S.H. (1996). "Effects of profitability and liquidity on R&D intensity: Japanese and U.S. companies compared," *Academy of Management Journal*, 39, pp. 1659-1675.

Hunter, D. (2003). "Preserving R&D spending," *Chemical Week*, Vol. 165, No. 14, p. 5.

Ito, K., Pucik, V. (1993). "R&D spending, domestic competition, and export performance of Japanese manufacturing firms," *Strategic Management Journal,* 14, pp. 61-75.

Kennedy, P. (1979). *A Guide to Econometrics*. Cambridge, MA: MIT Press.

Kenny, D.A. (2012). Mediation. http://davidakenny.net/cm/mediate.htm, Accessed January 23, 2013.

Kim, J., Kwon, G. (2011). "The persistence and market reaction of R&D investment," *International Journal of Business and Management*, Vol. 6, No. 4, pp.100-110.

Knott, A.M. (2003). "Persistent heterogeneity and sustainable innovation," *Strategic Management Journal*, 24, pp. 687-705.

Lee, C. (2002). "A simple model of R&D: An extension of the Dorfman-Steiner theorem," *Applied Economics Letters*, Vol. 9, No. 7, pp. 449-453.

Lin, B., Chen, C., Wu, H. (2006). "Patent portfolio diversity, technology strategy, and firm value," *IEEE Transactions on Engineering Management*, 53, pp. 17-26.

Lynn, L.H., Reddy, N.M., Aram, J.D. (1996). "Linking technology and institutions: the innovation community framework," *Research Policy*, 25, pp. 91-106.

Medcof, J. (1999). "Identifying 'super-technology' industries," *Research Technology Management*, July-August, pp. 31-36.

Meyer, J.W., Rowan, B. (1977). "Institutionalized organizations: Formal structure as myth and ceremony," *American Journal of Sociology*, 83, pp. 340-363.

Morbey, G.K. (1989). "R&D expenditures and profit growth," *Research Technology Management*, Vol. 32, No .3, pp. 20-23.

Morbey, G.K., Reithner, R.M. (1990). "How R&D affects sales growth, productivity and profitability," *Research Technology Management*, Vol. 33, No. 3, pp. 11-14.

Muller, D., Yzerbyt, V.Y., Judd, C.M. (2005). "When moderation is mediated and mediation is moderated," *Journal of Personality and Social Psychology*, Vol. 89, No. 6, pp. 852-863.

Nelson, R.R, Winter, SG. (1982). *An evolutionary theory of economic change*. Belknap Press of Harvard University Press: Cambridge, MA.

Oliver, C. (1991). "Strategic responses to institutional processes," *Academy of Management Review*, 16, pp. 145-79.

Oliver, C. (1997). "Sustainable competitive advantage: combining institutional and resource-based views," *Strategic Management Journal*, 18, pp. 697-713.

Palmer, D.A., Jennings, P.D., Zhou, X. (1993). "Late adoption of the multidivisional form by large U.S. corporations: Institutional, political, and economic accounts," *Administrative Science Quarterly*, 38, pp. 100-131.

Penrose E.T. (1959). *The Theory of the Growth of the Firm*. Wiley: New York.

Pisano, G.P. (2000). "In search of dynamic capabilities: The origins of R&D competence in biopharmaceuticals," In *The Nature and Dynamics of Organizational Capabilities,* Dosi, G, Nelson, R, Winter, S (eds.). Oxford University Press/Books: Oxford, pp. 129-153.

Ray, G., Barney, J., Muhanna, W.A. (2004). "Capabilities, business processes, and competitive advantage: Choosing the dependent variable in empirical tests of the resource-based view," *Strategic Management Journal*, 25, pp. 23-37.

Richardson, G.B. (1972). "The organisation of industry," The Economic Journal, 82, pp. 883-896.

Rosegger, G. (1986). *The Economics of Production & Innovation*, 2ed. Pergamon Press: Oxford, pp. 190-197.

Rothaermel, F.T. (2001). "Incumbant's advantage through exploiting complementary assets via interfirm cooperation," *Strategic Management Journal*, 22, pp. 687-699.

Rothaermel, F.T, Deeds, D.L. (2004). "Exploration and exploitation alliances in biotechnology: A system of new product development," *Strategic Management Journal*, 25, 2 pp. 201-221

Rouvinen, P. (2002). "R&D-Productivity dynamics: Causality, lags and 'dry holes," Journal of Applied Economics. Vol. 5, No. 1, pp. 123-156.

Schoenecker, T., Swanson, L. (2002). "Indicators of firm technological capability: Validity and performance implications," *IEEE Transactions on Engineering Management*, Vol. 49, No.1, pp. 36-44.

Scott, W.R, Meyer, J.W. (1992). "The organization of societal sectors," In *Organizational Environments: Ritual and Rationality*, Meyer, JW, Scott, WR (eds.). Sage: Beverly Hills, CA.

Sherer, P., Lee, K. (2002). "Institutional change in large law firms: a resource dependency and institutional perspective," *Academy of Management Journal*, 45, pp. 102-19.

Silverman, R.E. (2002). "GE goes back to the future: R&D grows in importance as innovation becomes key to industrial titan's growth," *Wall Street Journal*, May 7, 2002.

Soh, P., Mahmood, I.P., Mitchell, W. (2004). "Dynamic inducements in R&D investment: Market signals and network locations," *Academy of Management Journal*, 47, pp. 907-917.

Stinchcombe, A.L. (1965). "Social structure and organizations," In *Handbook of Organizations,* March, JG (ed). Rand McNally: Chicago, pp. 142-193.

Teece, D.J. (1982). "A behavioural analysis of OPEC: An economic and political synthesis," *Journal of Business Administration*, 13, pp. 127-160.

Teece, D.J, Pisano, G., Shuen, A. (1997). "Dynamic capabilities and strategic management," *Strategic Management Journal*, 18, pp. 509-533.

Thornhill, S., Amit, R. (2003). "Learning about failure: Bankruptcy, firm age and the resource-based view," *Organization Science*, 14, pp. 497-509.

Tsui, A.S., Ashford, .S.J, St. Clair, L., Xin, K.R. (1995). "Dealing with discrepant expectations: Response strategies and managerial effectiveness," *Academy of Management Journal*, 38, pp. 1515-1543.

U.S. Census Bureau. (2013). "Chemicals and allied products," http://www.census.gov/epcd/ec97sic/def/D28.TXT, Accessed January 23, 2013.

Walston, S.L., Burns, L.R., Kimberly, J.R. (2000). "Does reengineering really work? An examination of the context and outcomes of hospital reengineering initiatives," *Health Services Research*, 34, pp. 1363–1388.

Westphal, J.D., Gulati, R., Shortell, S.M. (1997). "Customization or conformity? An institutional and network perspective on the content and consequences of TQM adoption," *Administrative Science Quarterly*, 42, pp. 366-394.

Whiting, R, Ricadela, A. (2002). "Future funding," *InformationWeek*, October 28, 2002.

Winter, S. (1990). "Survival, selection and inheritance in evolutionary theories of organization," In *Organization Evolution: New Directions,* Singh, J (ed.)**.** Sage Press: Thousand Oaks, CA.

Wöhrl, R., Hüsig, S., Dowling, M. (2009). "The interaction of R&D intensity and firm age: Empirical evidence from technology-based growth companies in the German Neuer Markt," *The Journal of High Technology Management Research*, Vol. 20, No. 1, pp. 19-30.

Wolff, J. (2001). "Making the case for R&D investment," *Research Technology Management,* Vol. 44, No. 5, p, 5.

Yeoh, P., Roth, K. (1999). "An empirical analysis of sustained advantage in the U.S. pharmaceutical industry: Impact if firm resources and capabilities," *Strategic Management Journal*, 20, pp. 637-653.

Zahra, S.A., Keil, T., Maula, M. (2005). "New ventures' inward licensing: examining the effects of industry and strategy characteristics," *European Management Review*, 2, pp. 154-166.

Zimmerman, M.A., Zeitz, G.J. (2002). "Beyond survival: Achieving new venture growth by building legitimacy," *Academy of Management Review*, 27, pp. 414-431.

TABLE 1: Distribution of Data Sample by SIC Code

SIC Code	Description	Observations	SIC Code	Description	Observations
2800	Chemicals and Allied Products	53	2840	Soaps, Cleaners and Toilet Goods	14
2810	Industrial Inorganic Chemicals	54	2842	Polishes and Sanitation Goods	9
2820	Plastics, Materials and Synthetics	32	2844	Toilet Preparations	31
2821	Plastics, Materials and Resins	35	2851	Paints and Allied Products	19
2833	Medicinals and Botanicals	18	2860	Industrial Organic Chemicals	28
2834	Pharmaceutical Preparations	187	2870	Agricultural Chemicals	25
2835	Diagnostic Substances	34	2890	Miscellaneous Chemical Products	28
2836	Biological Products, except Diagnostic	64	2891	Adhesives and Sealants	6

TABLE 1a: Distribution of Data Sample by Country of Incorporation

Country of Incorporation	Number of Firms	Country of Incorporation	Number of Firms	Country of Incorporation	Number of Firms	Country of Incorporation	Number of Firms
Japan	218	Canada	11	Finland	3	Hong Kong	1
United States	183	Taiwan	10	Bermuda	3	Croatia	1
United Kingdom	36	Austria	9	South Africa	3	Hungary	1
S. Korea	28	Sweden	6	Pakistan	2	Indonesia	1
India	26	Netherlands	6	Turkey	2	Ireland	1
Germany	25	Malaysia	5	Italy	2	Israel	1

France	16	Denmark	4	Austria	1	Philippines	1
Cayman Islands	13	Norway	3	Czech Republic	1	Singapore	1
Switzerland	11	Belgium	3	Finland	3		

TABLE 2: Dependent and Independent Variables

Variable	Description
Dependent	
Pre-tax Income	The sum of net operating and non-operating income, which equals operating and non-operating revenues less operating and non-operating expenses, excluding interest expense; is a component of income before extraordinary items
Independent	
R&D expenditures	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 Expenditures / Employees
Intangible Assets	Patents, trademarks and trade names, copyrights, goodwill, 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
Age	Firm age in years
Controls	
Employees	All employees of consolidated subsidiaries including part time and seasonal. Excluding consultants, contract workers and employees of unconsolidated subsidiaries.
Biological Products, Except Diagnostic	Dummy Variable = 1 if SIC code =2836
Diagnostic Substances	Dummy Variable = 1 if SIC code =2835
Plastics, Materials and Synthetics	Dummy Variable = 1 if SIC code =2820

TABLE 3: Means, Standard Deviations, and Correlations[a]

Variable	Mean	SD	1	2	3	4	5	6	7	8
Pre-tax Income	571.54	4898.80								
1. R&D Expenditures	166.56	781.61								
2. R&D intensity	70.29	294.20	.29**							
3. Intangible Assets	278.53	1955.91	.71**	.19**						
4. Intangible intensity	56.17	614.25	.25**	.68**	.30**					
5. Employees	5.95	15.09	.61**	-.06	.55**	-.01				
6. Plastics, Materials, and Synthetics	.05	.22	-.01	-.03	-.01	-.01	.02			
7. Diagnostic Substances	.05	.23	-.04	.04	-.03	.00	-.08	-.06		
8. Biological Products	.10	.30	-.02	.15**	-.02	-.01	-.11**	-.08	-.08*	
9. Age	44	32	.11**	-.12**	.05	-.01	.25**	.03	-.15*	-.29**

[a] n = 637.

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

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

TABLE 4: Regression Analysis: Mediation and Firm Age[1,2]

Dependent Variable	**Baseline** Pre-tax inc.	**Model 1** Pre-tax inc.	**Model 2** Intangible Intensity	**Model 3** Pre-tax inc
Constant	253.21	-783.41	-62.45	-410.50
	(384.50)	(285.65)	(35.51)	(192.02)
Firm age	**7.403**	**16.01*** **	**0.854**	**11.00*** **
	(6.51)	**(4.79)**	**(0.60)**	**(3.22)**
R&D intensity		**11.46*** **	**1.46*** **	**2.74*** **
		(0.50)	**(0.06)**	**(0.46)**
Intangible intensity				**5.97*** **
				(0.22)
Plastics etc.	961.56	1236.86	6.00	1201.04**
	(893.04)	(655.45)	(81.47)	(439.54)
Diagnostic	-451.96	-964.08	-83.87	-463.25
Substances	(881.99)	(647.60)	(80.50)	(434.66)
Biological Products	-324.26	-1710.42***	-174.70	-667.13
	(682.54)	(504.39)	(62.70)	(340.32)
Adjusted R^2	.00	.46	.47	.76

Unstandardized coefficients and standard errors in parentheses

[2] Sobel test statistic of the indirect effect is significant (Z=18.132, p<0.005)

* p<0.05

** p<0.01

*** p<0.005

TABLE 5: Regression Analyses: Testing for Reverse Causality[1]
(n=637)

Dependent variable	**Baseline** Intangible Intensity	**Model 1a** Intangible Intensity	**Model 2a** R&D Intensity	**Model 3a** Intangible Intensity
Constant	69.64	42.16	80.24***	9.84
	(48.35)	(24.46)	(16.75)	(23.95)
Firm Age	-.254	-1.06*	-1.06***	-.631
	(.819)	(.414)	(.284)	(.403)
Pre-tax Income		**.11*** **	**.04*** **	**.09*** **
		(.003)	**(.002)**	**(.003)**
R&D intensity				**.40*** **
				(.06)
Plastics etc.	-29.08	-133.43*	-62.81	-108.13*
	(112.30)	(56.84)	(38.92)	(54.79)
Diagnostic	-18.61	30.43	62.92	5.09
Substances	(110.91)	(56.10)	(38.40)	(54.08)
Biological Products	1.914	37.10	134.03***	-16.89
	(85.83)	(43.41)	(29.72)	(42.43)
Adjusted R^2	-.01	.74	.47	.76

Unstandardized coefficients and standard errors in parentheses
* p<0.05
** p<0.01
*** p<0.005

TABLE 5a: Testing for Reverse Causality – Comparing Key Coefficients[1]

	Base Model - Table 4 Intangible intensity → Net income	**Reverse Model - Table 5** Net income → Intangible intensity
Total Effect **c**	11.46	.11
Residual Direct Effect **c′**	2.74	.09
Indirect Path **a**	1.46	.04
Indirect Path **b**	5.97	.40

[1] A large difference in coefficients between the base and reverse models does not support the presence of significant reverse causality.

TABLE 6:Regression Analyses: Testing for Feedback Effects[1] (n=637)

	Total Effect	**Feedback Effect**
Dependent variable	Pre-tax inc.	R&D intensity
Constant	-783.41**	80.24***
	(285.65)	(16.75)
Firm Age	16.10***	-1.06***
	(4.792)	(.284)
Pre-tax Income		**.04*** **
		(.002)
R&D intensity	**11.46*** **	
	(.492)	
Plastics etc.	1236.86	-62.81
	(655.45)	(38.92)
Diagnostic Substances	- 945.08	62.92
	(642.84)	(38.41)
Biological Products	-.1710.42***	134.03***
	(504.39)	(29.72)
Adjusted R^2	.46	.47

[1] Unstandardized coefficients and standard errors in parentheses
* p<0.05
** p<0.01
*** p<0.005

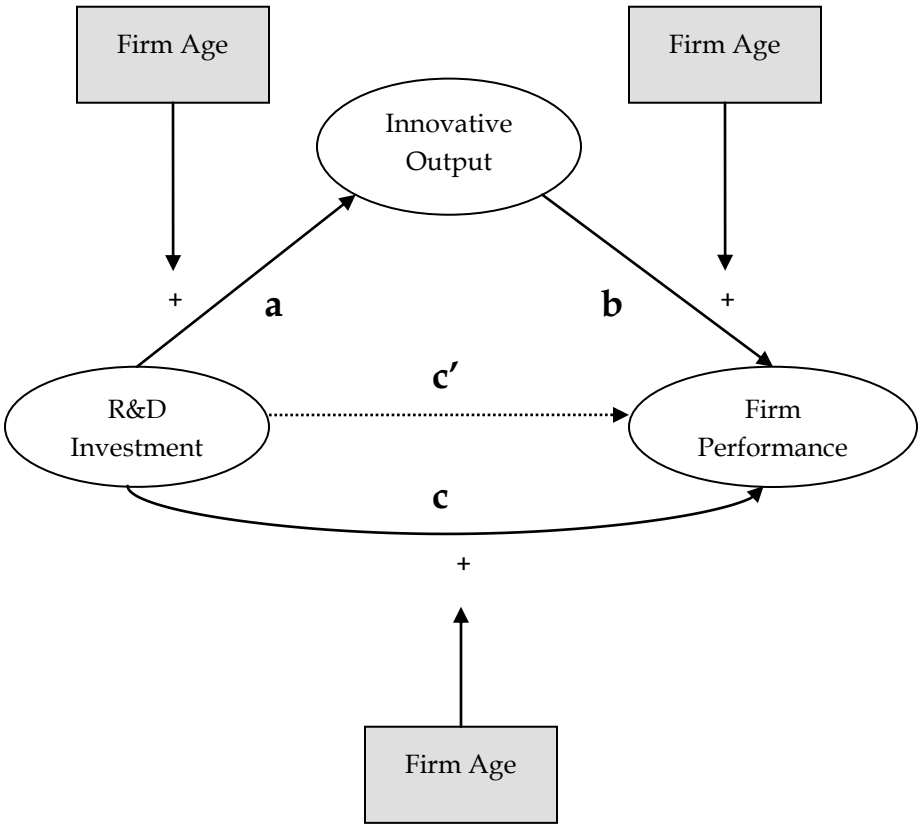
TABLE 7: Regression Analysis: Mediated Moderation[1]

Dependent Variable	**Baseline** Pre-tax inc.	**Model 1** Pre-tax inc.	**Model 2** Intangible Intensity	**Model 3** Pre-tax inc
Constant	613.70	155.45	34.04	247.06
	(217.64)	(166.84)	(26.53)	(152.87)
Firm age		**-1.34**	**-0.94****	**-1.25**
		(2.81)	**(0.45)**	**(2.55)**
R&D intensity		**-4.99*** **	**-0.23****	**3.94*** **
		(0.54)	**(0.09)**	**(0.49)**
R&D x Firm age		**0.44*** **	**0.05*** **	**0.29*** **
		(0.01)	**(0.00)**	**(0.02)**
Intangible intensity				**-2.54****
				(1.20)
Intangibles x Firm age				**0.11*** **
				(0.02)
Plastics etc.	952.93	1088.26**	-9.27	1114.94***
	(893.21)	(378.04)	(60.11)	(333.16)
Diagnostic Substances	-630.21	-678.06*	-54.47	-543.77*
	(868.15)	(373.58)	(59.41)	(329.47)

Biological Products	-561.33 (650.07)	-510.48* (292.85)	-51.39 (46.57)	-285.33 (258.93)
Adjusted R^2	.00	.82	.71	.86

[1] Unstandardized coefficients and standard errors in parentheses
* p<0.05
** p<0.01
*** p<0.005

FIGURE 1: The R&D Investment - Firm Performance Link: a Mediated Moderation Model[1]



c = total direct effect; c′ = residual direct effect; a and b = indirect effects through the mediator