The Knowledge-Incentive Trade-off: Understanding the Relationship between Organizational Design and Innovation

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Abstract

Managers face a fundamental trade-off when designing their organizations for innovation. On the one hand, a differentiated design with more independent sub-units is associated with high observability of effort and the ability to use higher powered incentives, increasing efforts to innovate. On the other hand, greater differentiation reduces intra-organizational knowledge flows which can hinder innovation. I offer a framework to understand the implications of this trade-off for firms’ innovation outcomes. To do so, I unpack the innovation process into upstream tasks around invention, and downstream tasks around product development and commercialization. I argue that knowledge flows play a more important role towards upstream tasks and incentives play a more important role towards downstream tasks. I explore this premise using fine-grained data on firms’ organizational designs and their innovation outcomes in terms of upstream inventions and downstream product development in the global pharmaceutical industry from 1995 to 2015. I find that greater differentiation while yielding higher numbers of inventions is associated with less original inventions that draw on a narrower array of knowledge, and fewer inventions progressing through the earlier stages of development. In contrast, greater differentiation is associated with more inventions progressing through the later stages of development. These findings highlight how the knowledge- and incentives-based perspectives are intertwined with respect to firms’ organizational design, and that viewing innovation as a process can help uncover the trade-offs associated with firms’ design choices.
Introduction

Strategy and innovation scholars have drawn on two distinct theoretical perspectives of the firm. The knowledge-based perspective focuses on what firms are able to do through examining firms’ coordination and integration of their employees’ knowledge to create superior capabilities (e.g., Grant, 1996; Kogut & Zander, 1992). In contrast, the incentive-based perspective, grounded in a more organizational economics tradition, focuses on what managers within firms choose to do through examining the alignment of incentives with desired organizational outcomes (e.g., Kaplan & Henderson, 2005; Zenger, 1992). An evolving debate within the strategic management literature has highlighted that rather than providing opposing views of the firm, these theories can be integrated to provide a deeper understanding of organizational issues such as the boundaries of the firm (e.g., Argyres, Felin, Foss, & Zenger, 2012). Integration of these theories can also provide richer insights into internal organizational design choices such as the extent to which firms differentiate into a greater number of units or integrate into fewer units (e.g., Puranam, Alexy, & Reitzig, 2014). However, these two perspectives suggest an inherent trade-off managers face when making their design choices. Greater differentiation facilitates the more effective use and alignment of incentives (Zenger & Hesterly, 1997) but comes at the cost of reduced intra-organizational knowledge flows (e.g., Karim & Kaul, 2015). Managing this trade-off is especially important with respect to firms’ innovation tasks which rely heavily on knowledge recombination (e.g., Argyres & Silverman, 2004; Kapoor & Lim, 2007).

Yet despite multiple calls (e.g., Dosi, Levinthal, & Marengo, 2003; Foss, 1996) to study
such phenomena using both knowledge- and incentive-based lenses, scholars have tended to examine how design choices impact firms’ innovation outcomes using one theory or the other. Further, Argyres and Zenger (2012) highlight that integrating both perspectives could help to provide keener insight into how internal design choices can impact the development of new knowledge within firms. This lack of theoretical integration could explain why the extant literature provides mixed findings as to how organizational differentiation and innovation outcomes are related. Some studies highlight the benefits of increased differentiation and reduced integration in the development of new innovations (e.g., Tushman, Smith, Wood, Westerman, & O’Reilly, 2010) whereas others highlight the benefits of reduced differentiation (e.g., Argyres & Silverman, 2004; Arora, Belenzon, & Rios, 2014). Further, there is no clear evaluation of the boundary conditions in which greater differentiation facilitates or hinders firms’ innovation outcomes.

In this study I integrate the knowledge- and incentive-based perspectives to examine how various facets of organizational differentiation are associated with firms’ innovation outcomes. I do this through disassembling the innovation process into the upstream stage of invention, and downstream stages of product development and commercialization (Garud, Tuertscher, & Van de Ven, 2013). The composition of knowledge and nature of incentives will vary through the process influencing their relative impact on innovation outcomes. This enables the trade-off between knowledge flows and incentives managers face when making their design choices to be examined more directly. Further, this approach enables a more specific articulation of how design choices (i.e. which part of the organization is more or less differentiated) pertinent to each stage might differentially influence innovation outcomes. Using this approach, I argue that greater differentiation and its associated reduction in intra-organizational knowledge flows
decreases the breadth of knowledge firms draw upon in creating their inventions and in addressing issues during the technically-rich early stages of development. In contrast, I argue that greater differentiation and its associated enhancement of incentives impacts managerial effort which influences the quantity of inventions created and the progression of inventions through the later, less technically complex, stages of development.

I test these arguments in the context of the pharmaceutical industry using a unique dataset hand-collected from both multiple archival sources and over 50 interviews with senior executives of leading firms. Specifically, I find that differentiation of research and development (R&D) into multiple units across different technical domains (e.g. therapeutic or scientific areas), as compared to integration of R&D into a single unit, is associated with the creation of less original inventions and the progression of fewer inventions through early development. I also find that the benefits of R&D integration are greater for firms with a more diverse stock of technical knowledge as well as for the development of more novel inventions. However, I find technical differentiation of R&D is associated with the creation of more inventions and accelerated granting of patents. Functional differentiation of R&D into separate research and development units is associated with the progression of more inventions through development. Further, greater overall organizational differentiation, in which a firm is more divisionally than functionally aligned (e.g., Burton, Obel, & DeSanctis, 2011), is associated with the progression of more inventions through the later parts of development.

This study contributes to both the organizational design and innovation management literatures. First, this study highlights it is important to understand both where (in the organization) and when (in the innovation process) design choices are made to fully appreciate the role of such choices on innovation performance. Further, this study shows that although a
firm may have superior capabilities, they may not always translate into enhanced performance because design choices can limit access to these capabilities. Finally, this study contributes to the recent debate concerning integration of knowledge-based and organizational economics theories by highlighting that the interplay of knowledge flows and incentives varies through the innovation process. Richer knowledge flows associated with reduced differentiation appear to be more critical during the technically-rich invention and early development stages, whereas greater incentives associated with greater differentiation facilitate innovation in the later, less technically intensive stages of development. Thus these insights can help to reconcile some of the disparate findings in the extant literature pertaining to the relationship between organizational differentiation and firms’ innovation outcomes.

Theory and Hypotheses

A key design choice that firms make is the degree to which they differentiate their structure into more or fewer units (e.g., Lawrence & Lorsch, 1967). The classic organization design literature suggests that greater differentiation is associated with increased adoption of innovations (e.g., Damanpour, 1991). Similarly, the ambidexterity literature suggests the benefits of having autonomous units differentiated from the broader organization for the development of more explorative (Tushman et al., 2010) or disruptive (Christensen & Bower, 1996) innovations. Consistent with these streams, literature focused on the post-merger integration of technology-based firms indicates that maintaining greater autonomy of acquired entities is associated with an increased likelihood of the launch of new products (Puranam, Singh, & Zollo, 2006). However, recent studies focused primarily on firms’ R&D units suggest that reduced differentiation associated with the centralization of R&D results in higher inventive productivity and more
novel inventions (e.g., Argyres & Silverman, 2004; Arora et al., 2014).

These studies have tended to focus on understanding the relationship between firms’ design choices and their innovation outcomes through either a knowledge-based (e.g., Puranam et al., 2006) or an incentives-based (e.g., Argyres & Silverman, 2004) lens. A knowledge-based perspective suggests that firms can gain competitive advantage through developing superior capabilities which enhance what they can do through knowledge embedded in their employees and associated routines (e.g., Grant, 1996). However, greater differentiation can result in reduced knowledge flows across an organization hindering innovation outcomes (e.g., Karim & Kaul, 2015).

The incentive-based perspective grounded in the tradition of organizational economics focuses on the appropriate use of incentives to ensure managerial choices are in alignment with firms’ objectives (e.g., Holmstrom, 1989). Greater differentiation is associated with an increased ability to observe managerial effort, a stronger linkage between action and outcomes and the more effective provision of high-powered incentives which can all enhance firms’ innovation outcomes (e.g., Zenger & Hesterly, 1997). Thus these theories provide contrasting predictions suggesting a fundamental trade-off. On the one hand, greater differentiation hinders rich knowledge flows. On the other, differentiation facilitates more effective usage of incentives.

As innovation consists of an array of activities throughout an organization (e.g., Dougherty, 1992), this trade-off is likely to manifest itself differently when knowledge flows or incentives are more critical. For example, greater incentives may be of limited value if a firm is unable to leverage its broader knowledge to undertake a specific innovation activity. Through uncovering the boundary conditions for when knowledge flows and incentives are more pertinent, a richer understanding of how firms’ design choices can impact their innovation
outcomes can be developed thereby helping to reconcile existing differences within the literature.

**Deconstructing the Innovation Process**

Taking a process-based perspective of innovation (Garud et al., 2013) can provide a route to understand the trade-off between firms’ design choices and their innovation outcomes. This is because there is likely to be a different relative emphasis on knowledge and incentives as a firm progresses an initial idea through the various stages of the innovation process. The nature of knowledge will also change through the innovation process from, for example, a greater scientific focus to a more commercial focus. Further, more precise facets of differentiation can be aligned to the various stages of the innovation process. Thus, unlike prior studies, this approach can help to determine when (in the innovation process) and where (in the organization) greater differentiation can facilitate firms’ innovation outcomes.

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The innovation process can be divided into three stages as illustrated in Figure 1. First, there is the act of invention (e.g., Schumpeter, 1939). Outcomes associated with invention relate to both the quantity of inventions and their associated attributes (e.g., Hall, Jaffe, & Trajtenberg, 2001).

Second, the act of innovation as defined by Schumpeter (1939) is divided into distinct stages – development and market launch. Development pertains to multiple activities such as refining and supplementing inventions with complementary knowledge (e.g., Zahra & Nielsen, 2002). Development outcomes pertain primarily to the progression of inventions through the development process (e.g., Kapoor & Kluteer, 2015).

Finally, there is market launch that pertains to firms’ commercialization and value
appropriation from their developed offerings. Outcomes from this stage relate to measures such as revenues or profits from new offerings. It should be noted that this innovation process is often iterative. To simplify the theoretical argumentation and empirical analyses, the focus in this paper is on the invention and development stages in isolation with an emphasis on forward progression of inventions.

Organizational Differentiation and Invention

Invention is primarily the domain of firms’ research organizations (e.g., Fleming & Sorenson, 2004). A fundamental design choice that managers have is whether to integrate R&D into a single unit or differentiate it into multiple specialized units (e.g., Kay, 1988) – technical differentiation. Differentiation in this case relates to dividing R&D into separate units focusing on, for example, different scientific areas or product domains. It is akin to horizontal dis-integration of R&D. These more differentiated units may be located within business units or be separate corporate research units reporting to different leads (e.g., Argyres & Silverman, 2004). I distinguish between a single integrated R&D unit and multiple units across different technical domains through allocation of decision rights (e.g., Jensen & Meckling, 1992). Managers leading an integrated unit have decision rights across the complete portfolio of firms’ inventions and hierarchical authority over the parts of the organization working on these inventions. In contrast, managers associated with an R&D unit pertaining to a specific technical domain only have decision rights for the relevant sub-portfolio of inventions and hierarchical authority over those associated parts of the organization creating and developing those inventions.

Taking a knowledge-based perspective, the creation and subsequent refinement of inventions can be considered to be a knowledge recombination activity (e.g., Fleming, 2001;
Fleming & Sorenson, 2004). Organizational differentiation can impact the recombination of a firm’s knowledge through influencing intra-organizational knowledge flows (e.g., Zhang, Baden-Fuller, & Mangematin, 2007).

Knowledge may be present in both documented information or more tacit knowledge within employees’ minds (e.g., Haas & Hansen, 2005). Sharing this knowledge across organizational units can be problematic for two key reasons. First, leveraging the concept of stickiness of knowledge transfer, it becomes apparent that both the source and recipient of the knowledge may lack the motivation to transfer or utilize this knowledge or the organizational context may not be suitable (Szulanski, 1996). For example, increased differentiation of R&D is likely to be associated with competition between units pertaining to different technical domains (Haas & Hansen, 2007). As a result, sources of knowledge may be less motivated to share their knowledge with other units to provide both a competitive advantage and also to help focus on their own inventive efforts rather than being distracted with sharing knowledge. In contrast, integration of R&D into a single unit is likely to be associated with reduced competition thereby facilitating the sharing of knowledge (e.g., Karim & Kaul, 2015).

Second, Szulanski (1996) and Grant (1996) highlight that the highly tacit knowledge associated with the creation and refinement of inventions may require rich and frequent communications between the provider and recipient of the information. This necessitates a degree of “intimacy” between the recipient and source. If the recipient and source of the relevant knowledge are in separate organizational units, the more distant relationship between these units is likely to result in greater difficulties in the transfer of more tacit knowledge (Szulanski, 1996). However, within an integrated unit the sole hierarchical authority helps to ensure that both the source and unit share and utilize relevant knowledge (e.g., Tsai, 2002).
These arguments suggest that differentiation of R&D into multiple units across technical domains hinders the flow of knowledge between these units as compared to within a single integrated R&D unit. Thus, with respect to the invention stage, technical differentiation of R&D into multiple units is likely to hinder access to a firm’s broader knowledge base as compared to the case of R&D being integrated into a single unit. As a result:

*H1: Firms with multiple differentiated R&D units across technical domains are associated with inventions that draw on a narrower array of knowledge than firms with single, integrated R&D units across technical domains*

Unlike the knowledge-based perspective which can provide insight into the type of inventions created, the incentive-based perspective can provide more insight into the quantity of inventions created as this provides a more immediate and readily available measure of invention performance. Greater differentiation is associated with division of the relevant part of an organization into smaller, more autonomous units. Using an incentive-based argumentation suggests that this greater division will provide three primary benefits. First, Holmstrom (1989) indicates that moral hazard is likely to be of greater concern in larger, integrated organizational units. This is because of the greater difficulty in monitoring shirking in more integrated units.

Second, managers may fall prey to the inertial pressures that may impede the creation of inventions and their subsequent refinement (e.g., Kaplan & Henderson, 2005). These inertial pressures may slow decision making or access to vital resources associated with the innovation process. This inertia is likely to be greater in more integrated units as opposed to otherwise equivalent multiple, differentiated units due to their larger size (Hannan & Freeman, 1984).

Third, smaller differentiated units enable managers to leverage higher powered incentives (Zenger & Hesterly, 1997). This is because such disaggregation enables the unique contributions of managers within each unit to be more readily observed and rewarded. With the provision of
suitable higher powered incentives associated with greater differentiation, managers are more likely to exert greater effort in undertaking innovation activities (Zenger, 1994).

Beyond these benefits associated with increased managerial effort, an incentive-based reasoning also suggests that increased differentiation may be associated with managers taking steps to mitigate the greater risk associated with their smaller portfolios (e.g., Klingebiel & Rammer, 2014). For example, a firm may have a single integrated unit managing 10 innovation projects, or two units undertaking 5 innovation projects each with managers incentivized to create final innovations for market launch. For the integrated unit, the pooling effect of having multiple projects can help mitigate the risk of failure. In contrast, for the two separate units the risk of failure is greater due to the smaller number of available projects. In order to increase their likelihood of success, managers in the two decentralized units have two available strategies. First, managers can increase the pool of innovation projects to try and replicate the broader pool of an integrated unit. Second, managers can leverage the fact that they can pay more attention to each project (e.g., Sull, 2003) to ensure more projects make it through the development process.

Ultimately these arguments suggest that managers will exert greater effort and will have more of an incentive to mitigate risk when in multiple, differentiated units as compared to a single, integrated unit. This is likely to result in the creation of more inventions for firms with multiple differentiated R&D units. Thus:

\[ H2: \text{Firms with multiple, differentiated R&D units across technical domains are associated with the generation of more inventions than firms with single, integrated R&D units across technical domains} \]

Organizational Differentiation and Development

In the early stages of the development process R&D will continue to be the focal unit refining inventions (Hansen & Birkinshaw, 2007) and technical differentiation continues to be a
pertinent dimension. During these early stages of the development process, greater knowledge flows can provide significant benefits that are pertinent to the refinement of firms’ inventions. For example, managers responsible for such activities are more able to solve technical problems through accessing a firms’ broader capabilities as well as develop more creative solutions to problems (e.g., Haas & Hansen, 2005). In addition, such enhanced knowledge flows can provide access to a firm’s set of best practices (Szulanski, 1996) and help to limit fruitless work such as “reinventing the wheel” (Hansen, Nohria, & Tierney, 1999). Thus, having more ready access to a firm’s knowledge base and capabilities in a single, technically integrated R&D unit can enable managers to more effectively and efficiently address technical challenges that arise thereby increasing the number of inventions progressing through the development process. This leads to:

\[ H3: \text{ Firms with multiple, differentiated R&D units across technical domains are associated with the progression of fewer inventions through the development process than firms with single, integrated R&D units across technical domains} \]

It is likely that these benefits of greater integration will diminish as inventions progress through the development stage, as there will be less incremental technical development of inventions as they get closer to market launch. As a result, the knowledge-based perspective becomes less pertinent as the requirement for rich tacit cross-organizational knowledge flows diminishes as the nature of the knowledge required to undertake development tasks becomes more routinized and explicit (e.g., Eisenhardt & Martin, 2000). Further access to explicit information on inventions (e.g., Spencer, 2003) and process tools such as the stage gate process help to provide more structure and reduce the associated uncertainty of the development stage compared to the invention stage (e.g., Grönlund, Sjödin, & Frishammar, 2010)

As an invention moves towards the more applied sub-stages of development, functional differentiation of R&D becomes an important dimension. Functional differentiation is associated
with the separation of R&D into individual research and development units. It is akin to vertical dis-integration of R&D as compared to the horizontal dis-integration associated with technical differentiation. Decision rights are split between research and development activities and there are separate hierarchical reporting lines pertaining to each function. In contrast, a functionally integrated R&D unit is associated with decision rights over the complete R&D process and has a single associated hierarchical authority covering all parts of the R&D organization.

A key stage early in the development process involves the handover of inventions from the research to the development function (e.g., Kapoor & Klueter, 2015). In line with the incentive-based argumentation, functional differentiation of R&D is likely to be associated with the progression of more inventions through the earlier stages of the development process. This is because in functionally separate units, research managers will exert greater effort to ensure more inventions progress from research to development as their outputs of their actions are more observable. Further, research managers will ensure more inventions progress to development either because they are directly incentivized or, for incentives based on final market offerings, because moving more inventions into development helps to increase the likelihood of creating a final offer. Thus:

**H4: Firms with functionally differentiated R&D units are associated with the progression of more inventions through the earlier stages of the development process than firms with a functionally integrated R&D unit**

With respect to finalizing a refined invention for ultimate launch, this decision is likely to be made at a cross-organizational level. This is because of the greater investment associated with later stage development activities and the resultant need for broader commercial input (e.g., Dougherty, 1992). Differentiation (Corporate Differentiation) in this context refers to whether the organization is more functionally orientated and focused on its overall portfolio of innovation candidates or more differentiated into individual business units that are focused on their own
sub-set of innovations (e.g., Burton et al., 2011). During the later stages of the development process, there is much less of a focus on technical development of innovation candidates with more attention to scaling up for launch and developing supporting commercial plans that are less dependent on rich cross-organizational knowledge flows. As a result, the incentive-based perspective is more pertinent and managers are likely to exert more effort in more differentiated firms than in more integrated firms. Also due to the fragmentation of a firms’ portfolio of innovation candidates, each individual unit will be incentivized to progress more of their sub-set of innovations to mitigate the risk of not being able to launch any innovations, resulting in more progressing for the entire firm. Thus:

*H5: Firms that are more decentralized and sub-divided into multiple business units are associated with the progression of more inventions through the later stages of the development process than firms that are more centralized and functionally orientated*

**Methods**

**Research Context**

The context for this study is the global pharmaceutical industry. This provides a suitable context for the investigation of how various facets of organizational differentiation are associated with firms’ innovation outcomes for two primary reasons. First, the industry has a well-defined innovation process (e.g., Kapoor & Klueter, 2015). This enables the determination of clear measures of invention and development outcomes.

Second, invention and development form a core focus of large global pharmaceutical companies ensuring that senior managers pay close attention to how their firms should be structured to enhance these outcomes. During the 20-year period of this study, pharmaceutical firms have undergone significant structural change driven by factors such as the emergence of new technologies (e.g. biotechnology) and multiple mergers and acquisitions.
Data and Sample

The study sample consists of 49 leading pharmaceutical firms over the period 1995 to 2015. Focusing on larger pharmaceutical firms that are responsible for the majority of innovation within the industry\(^1\) is common within the strategic management literature (e.g., Anand, Oriani, & Vassolo, 2010). The sample is based on 2004-6 annual prescription drug sales as defined by the Pharmaceutical Executive magazine’s Top 50 Pharmaceutical companies (e.g., Klueter, Monteiro, & Dunlap, 2017). In this period 64 separate firms appeared in the Top 50 in one or more years. The 15 firms over that period that are excluded are either private firms or did not provide sufficient information on their organizational structures in their public filings.

Invention performance is based on patent data which is obtained from the European Patent Office (EPO) Worldwide Patent Statistical (PatStat) database (e.g., Conti, Gambardella, & Mariani, 2013). Development data is based on the progression of drug candidates through clinical trials using the Pharmaprojects database (e.g., Kapoor & Klueter, 2015). Organizational structural data is hand-collected from company 10-K, 20-F, DEF14A SEC filings and annual reports.

This analysis is supplemented with 58 interviews with mid- and senior-level executives in strategy and R&D roles from 27 of the sample firms and industry experts. The focus of these interviews was to evaluate the validity of the differentiation measures, to determine how different clinical phase transitions map to the hypotheses and to discuss how organizational differentiation can impact knowledge flows and incentives.

\(^1\) The top 20 pharmaceutical firms by R&D spend represented 60 % of industry R&D spend (EvaluatePharma, 2016).
Measures

**Dependent Variables.** *Invention Measures:* All the invention measures (Hypotheses 1 and 2) are based on patent-related variables. Using patent data to measure firms’ inventive output suffers from multiple limitations such as not all inventions may get patented (e.g., Levin et al., 1987), patents may not always correspond to products (e.g., Hall et al., 2001) and patents may be filed for strategic rather than knowledge capture purposes. However, some of these limitations are mitigated within the pharmaceutical industry as firms patent a large proportion of their inventions and these patents closely relate to final products (e.g., Gunther McGrath & Nerkar, 2004).

A key challenge in using patent-based measures is ensuring accurate assignment of the assignee. A two-fold process is pursued in order to obtain accurate patent assignee names. First, manual matching of assignees to sample firms is conducted using text strings with correction for merger and acquisition activity. Second, the assignee-matching process utilized by Arora et al. (2014) is also pursued. Both approaches used to develop standardized names provide similar results with 99.7% of assignees being the same for each sample patent.

To measure quantity of inventions (*Quantity*), the number of patent families filed by firms on a firm-year basis is estimated. Patent family counts are used rather than patent counts to avoid double counting of patents that are filed in multiple jurisdictions. Patents assigned in the European Community statistical classification of economic activities category (NACE2) 21 (manufacture of basic pharmaceutical products) are focused upon. The year in which a patent family is developed is defined as the earliest filing date of a patent in that family.

To measure the breadth of knowledge from which patents draw (Argyres & Silverman, 2004) or patent originality (Hall et al., 2001), the International Patent Classification (IPC) 4-digit
technical classifications of the citations made by a focal patent are examined. Measures of
originality from data produced by the OECD are utilized (Squicciarini, Dernis, & Criscuolo,
2013). This Originality measure is developed using the approach recommended by Hall et al.
(2001). For a specific patent family, the maximum originality patent in the family is evaluated
and this originality value is assigned to the patent family. These values are then used to estimate
an average originality per patent family with at least one granted patent for each firm-year
(Originality).

Development Measures: This measure is built using the number of drug candidates
progressing through the various phases of clinical development per firm-year. Using data from
the Pharmaprojects clinical trials database, a panel dataset by drug candidate -year is developed
in which parent firms are assigned to each drug candidate and the clinical phase which a drug has
reached at the end of the relevant year is captured. Assigning drug candidates in the
Pharmaprojects database to parent firms requires a careful assessment of individual deals
between firms in which a specific drug candidate may be sold to another firm, a firm may
acquire or merge with another firm or drug candidates may be developed through alliances with
other firms. Using data from both Pharmaprojects “Overview” section and the Recap database,
firms can be assigned to each specific drug candidate. Drug candidates that are inactive for a
period of greater than three years are assumed to have been dropped by the focal firm unless
evidence of later progression of the drug-candidate to a more advanced clinical phase is
observed.

The number of drug candidates in a firm’s portfolio moving from pre-clinical trials
(phase 0) to phase 1 \((prog1)\), phase 1 to phase 2 \((prog2)\), phase 2 to phase 3 clinical trials
\((prog3)\) and phase 3 clinical trials to pre-registration (PR) \((prog4)\) per year are measured. This
enables a more granular perspective of how various facets of organizational differentiation are associated with the progression of inventions through the various sub-stages of the development process. Early stage development (Hypotheses 3 and 4) is defined as the progression from phase 0 to 2 and later stage development (Hypothesis 5) as the progression from phase 2 to pre-registration. This distinction is made as the level of investment moves up dramatically from phase 2 to 3 (Sertkaya, Wong, Jessup, & Beleche, 2016).

**Independent Variables.** The independent variables relate to various forms of organizational differentiation. In this study the differentiation measures are developed using top management team data available from companies’ filings. A database of 15,129 executive and extended executive team roles for the sample of 49 firms over the period 1995-2015 is developed using these sources. This results in a total of 898 firm-years of data and an average of 16.8 executive and extended executive roles per firm-year (standard deviation = 11.1). Two research assistants (RAs) collected the data from the relevant reports and the other two RAs checked and corrected their work. Coding of roles and various facets of organizational differentiation are undertaken by the author through careful review of the management roles in each organization and further validated through review of organizational descriptions from companies’ various filings undertaken by another RA. For 27 of the 49 firms, interviews with strategy and R&D managers were conducted to validate measures.

Using these data sources three separate measures of organizational differentiation are developed. Due to the limitations of access to detailed structural data, the focus is on higher level measures of differentiation based on whether there is a single or multiple direct reports to the CEO for the relevant domain. The managers within the sample firms interviewed confirmed that the structure of the top management team provides an accurate reflection of their firms’ high
level structures, specifically the key business units and how R&D is structured.

Specific examples of the three measures are illustrated in Figure 2. First, to evaluate
differentiation of R&D across technical domains (e.g. therapeutic or scientific areas), it was
determined whether firms’ R&D or Research (in the case of functionally separate R&D) is
organized into a single or multiple units across different technical domains. For diversified firms
which operate beyond pharmaceuticals, R&D units that pertain to pharmaceuticals were focused
upon and R&D units dedicated to areas such as consumer products were excluded in order to
control for the level of diversification of firms’ activities. Using this approach, the variable
*Technical Differentiation* is defined as a binary variable set to 1 if there are multiple R&D or
research groups reporting to separate heads within the TMT covering different technical domains
or to leads of business units within the pharmaceutical domain and 0 if the firm has a single
integrated R&D or research group reporting to a single TMT lead. 12% of the sample firm-years
have *Technical Differentiation* = 1.

------------ Figure 2 --------------

The variable *Functional Differentiation* measures whether firms’ R&D is integrated into
one unit or has separate research and development units. The variable is coded as a binary
variable set to 1 if there are separate, identifiable research and development heads in the
management team reporting to the CEO and 0 if research and development are integrated into a
single unit. Firms’ descriptions of R&D in their financial filings are also examined to clarify
whether R&D is integrated. 22% of the sample firm-years have *Functional Differentiation* = 1.

In order to develop a measure of corporate differentiation, TMT members are categorized
as general managers, functional administrative managers or product administrative managers
using the approach developed by Guadalupe, Li, and Wulf (2014). The independent variable
Corporate Differentiation is therefore determined as a proportion, namely it is the number of general manager (or business unit) roles in a top management team divided by the total size of the team (excluding CEO). Again to account for firms operating in non-pharmaceutical domains such as bulk chemicals and consumer products business unit leads in these areas are excluded.

Control Variables. A sequence of firm-year level time-varying variables are used as control variables (Table 1).

Descriptive statistics are presented in Table 2 and Table 3.

Analysis Approach

The independent variable Originality (H1) is bounded between 0 and 1. The main analyses use the fractional logit approach (Papke & Wooldridge, 1996) but linear probability models are also used as a robustness check. To avoid issues with over-dispersion using count dependent variables (Long & Freese, 2006), for the dependent variables quantity (Hypothesis 2), and prog1-4 (Hypotheses 3-5) negative binomial regression analyses are conducted. Where relevant, unconditional firm-fixed effects models are conducted by including firm dummy variables (Allison & Waterman, 2002).

Results

Main Analysis – Invention (Hypotheses 1-2)

First, fractional logit (H1) and negative binomial regression analyses (H2) with year and category fixed effects are conducted. Second, propensity score matching of firm-year
observations with *Technical Differentiation* as the treatment variable is undertaken. In the first stage, a logit regression is used to estimate the likelihood that a firm has multiple differentiated R&D units across technical domains using the full set of variables outlined in Table 4. In the second stage, the same regressions as the first analysis are conducted using only observations that are successfully matched using the logit regression.

Across both models (2-3), H1 is supported as illustrated by the statistically significant negative coefficient for *Technical Differentiation*. Thus firms with multiple R&D units differentiated across technical domains are associated with less original inventions.\(^2\) On average, R&D technical differentiation is associated with patents that have 0.04 lower originality (7 % of mean value or 0.22 standard deviation higher value of *originality*). Similar results are obtained using a variety of alternative specifications such as linear probability models and using firm-fixed effects\(^3\). The reduced knowledge flows between separate R&D units was a common theme raised in managerial interviews. For example:

> “One issue with our previous [decentralized] structure was that there was not enough communication between different units”. – R&D Manager

H2 is supported in models 5 and 6. On average, differentiation of R&D across technical domains is associated with the generation of 60 more patent families per year (26 % of mean or a 0.24 standard deviation higher value of *Quantity*). Similar results are obtained using alternative specifications such as OLS regressions were the dependent variable is log (*quantity*).\(^3\) The issue of greater differentiation being associated with increased incentives was a less common theme raised in the R&D managerial interviews, however some managers did mention the issue:

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\(^2\) Note in model 3, that the coefficients are significant for functional and corporate integration, however these were not robust to alternative specifications unlike technical differentiation which was always strongly statistically significant.

\(^3\) Firm-fixed effect models were limited as 31/49 of the firms in the sample do not change their degree of R&D differentiation across technical domains over the 20-year time period thus reducing the statistical power of this analysis. This limited variation in organizational design features over time is consistent with previous studies (Arora et al., 2014). For H1, the hypothesis continues to be supported with firm-fixed effects, however for H2, the sign of the coefficient for *Technical Differentiation* is still positive but not statistically significant.
“A more corporate [integrated] structure lacks the provision of good incentives as you tend to under-reward good performance”, Strategy Manager

Main Analysis – Development (Hypotheses 3-5)

-----------Table 5-------------

At each stage of the clinical and product development process negative binomial regression models are used. In addition, propensity score matching analyses are undertaken using the same two-step approach as H1 and H2 matching across different “treatment” variables using all the all key co-variates in Table 3.

I find support for H3 for drug candidates progressing from clinical phase 0 to 1 in models 2 and 3 (Table 5) as exhibited by the statistically significant negative coefficient for technical differentiation. Differentiation of R&D across technical domains is associated with the progression of 0.74 fewer drug candidates from phase 0 to 1 (0.13 standard deviation lower number of drug candidates). I see some further support for H3 in models 8 and 9 but not in models 5 and 12. This is broadly consistent with the theoretical argumentation outlined above in that the benefits of access to a firms’ broader technical R&D knowledge will diminish as a drug progresses through the development process. The nature of knowledge associated with these later development phases is less closely related to the technical R&D knowledge associated with the earlier development stages. Here the focus is on ensuring that the product can be manufactured at scale, knowledge of customers and healthcare systems and testing product efficacy.

It appears that for the transition from phase 0 (pre-clinical) to phase 1 clinical trials (Table 5, Models 2 and 3) functional differentiation of R&D is associated with the progression of fewer inventions as exhibited by the negative coefficients for functional differentiation counter to H4. However, the expected result of a statistically significant positive coefficient for functional differentiation (Table 5, Models 5 and 6) is observed for the transition from phase 1 to 2. For
multiple firms, interviews with R&D managers suggest that research managers’ key exit point is around drug candidates moving from phase 1 to 2:

“Research managers are incentivized by the number of drugs that they can get into Phase 2 (Proof of Concept), which means a lot of questionable candidates may get thrown over the fence into Phase 2” –R&D Manager

Further, interviews and review of companies’ filings provide some evidence to suggest that for functionally separate research and development units, research undertakes early stage (Phase 1) clinical trials. However, this data is only available for a small proportion of firms and there may be heterogeneity in how firms with functionally separate research and development units split their responsibilities. Further, consistent with the incentive-based argumentation, the interviews highlighted that functional integration of R&D was associated with a single R&D budget as opposed to separate research and development budgets. Managers suggested that this resulted in a shift of resources to later stage development incentivized by being able to capture value sooner. This in turn leads to fewer drug candidates progressing from Phase 1 to 2.

Based on this tentative evidence, it appears that for the phase 0 to 1 transition, integration of R&D may facilitate greater knowledge flows which may enable more technical issues to be addressed thereby facilitating the progression of more inventions. Managers from firms with functionally integrated R&D units do highlight the creation of cross-functional R&D teams starting as early as the pre-clinical phase (phase 0) suggesting that this may be the case. However, incentives appear to play a bigger role for the Phase 1 to 2 transition. Functional differentiation of R&D is associated with 0.42 more inventions progressing from Phase 1 to 2 in a year on average (0.15 standard deviation higher number of drug candidates).

Consistent with the H5, interviews with R&D managers indicate that commercial functions tend to only be significantly involved in the latter stages of clinical development:
“Marketing and other commercial functions don’t tend to be significantly involved in the drug development process till it comes to the Phase 2 to 3 transition, prior to that it is mainly R&D driven” - R&D Manager

No significant relationship between corporate differentiation and any development outcomes are observed prior to the phase 2 to 3 transition as suggested by these qualitative findings. For the critical Phase 2 to 3 transition in which firms are making a key decision as to which drug candidates to progress into Phase 3 clinical trials (Sertkaya et al., 2016), models 8 and 9 illustrate that greater organizational differentiation is associated with the progression of more inventions. This is exhibited by the statistically significant positive coefficients for corporate differentiation in models 8 and 9 (where Corporate Differentiation is dichotomized around the median to enable propensity score matching). A one standard deviation increase in corporate differentiation (0.25) is associated with 0.12 more drug candidates progressing from Phase 2 to 3 in a year on average (0.07 standard deviation higher number of drug candidates progressing).4,5

Analysis of Knowledge Flow and Incentive Mechanisms

In order to provide a richer perspective into the mechanisms through which various facets of organizational differentiation can impact innovation outcomes two supplementary sets of analyses are conducted. First, how firms’ pre-existing breadth of knowledge (tech diversity) moderates the association between technical differentiation and the progression of inventions

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4 Using a similar analysis (not reported) examining the number of drug candidates dropping out of phase 2 and not progressing to Phase 3 (using the dependent variable drop), corporate differentiation now has a significant, negative coefficient. This suggests that greater corporate differentiation is associated with fewer drug-candidates dropping out from phase to 2 also consistent with an incentives-based argumentation.

5 It may be the case that greater differentiation and its associated higher powered incentives may result in more inventions progressing that are of lower quality rather than, for example, managers exerting greater effort. This alternative explanation is examined through evaluating the likelihood of inventions that enter phase 2 progressing to phase 3 and the likelihood of inventions entering phase 3 progressing to PR using both cox proportional hazards and logit models with a time-varying co-variable (Allison, 1982). No evidence is observed to suggest that functionally differentiated R&D units and firms with higher values of corporate differentiation progress lower quality inventions as the inventions progressed in these firms are as likely to progress through the later stages as those in firms that are functionally integrated across R&D and with lower values of corporate differentiation.
through the early stages of the development process (phase 0 to 1) is examined. If the knowledge flow mechanism is pertinent, firms with a broader array of knowledge across technical domains will benefit more from integration of R&D across technical domains as these enhanced knowledge flows will provide an even greater array of knowledge for managers to further develop inventions and tackle technical issues. I find support for this analysis using an extended version of model 2 which includes an interaction term $technical\ diversity \times technical\ differentiation$ which is negative and statistically significant at the 99% confidence level.

In addition, firms with a greater proportion of more novel inventions in their early development portfolio (as estimated through the variable $NCE$) are likely to benefit more from a greater degree of R&D integration across technical domains. This is because such inventions are likely to require a greater proportion of organizational knowledge to address the more challenging technical issues associated with the early development of such novel inventions. I find support for this argumentation using an extended version of model 2 which includes an interaction term $NCE \times technical\ differentiation$ which is negative and statistically significant at the 99% confidence level. Both interactions are graphically illustrated in Figure 3.6

--------Figure 3------------------

Second, the incentives mechanism through which organizational differentiation can impact firms’ innovation outcomes is examined. An indirect route to examine the incentive-based mechanism is to evaluate the time lag between the date of filing of firms’ patents and their eventual grant date. Régibeau and Rockett (2010) indicate that this lag is dependent on the efforts made by the filing organization. Thus a lower grant lag can indicate that firms exert more

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6 Further, consistent with the theoretical argumentation provided above, both interaction terms $technical\ diversity \times technical\ differentiation$ and $NCE \times technical\ integration$ are only statistically significant for the phase 0 to 1 transition where the benefits of rich technical knowledge flows are likely to be the greatest in the development process.
effort to create inventions controlling for an array of factors such as the originality of the patent and the number of claims being made (Harhoff & Wagner, 2009). The grant lag is regressed against the variables in Table 2 with two additional controls pertaining to the average number of claims and non-patent citations per patent within a patent family. The coefficient for technical differentiation is negative and significant at the 95% confidence level. This analysis indicates that firms with R&D differentiated across technical domains are associated with grant lags that are 50 days shorter (Sample mean is 1212 days with standard deviation of 364 days) than firms with single, integrated R&D units. This result is consistent with the argument that managers in more differentiated units expand more effort

Discussion and Conclusion

This study examines the relationship between firms’ organizational design choices and their innovation outcomes through both knowledge- and incentive-based perspectives. Consistent with the knowledge-based view, integration of R&D into a single unit, as opposed to being differentiated into multiple units across technical domains, is associated with the creation of more original inventions and the progression of more inventions through the early stages of development. These benefits of integration are greater for firms with a broader array of technical knowledge and for the development of more novel inventions. However, consistent with the incentive-based view, differentiation of R&D across technical domains is associated with the creation of more inventions. Further, functional differentiation of R&D into separate research and development units and greater overall organizational differentiation, in which a firm is more decentralized into separate business units as opposed to being more functionally aligned, are both associated with the progression of more inventions through the later stages of development.
Together these results contribute to the strategic management literature in four important ways. First, this study contributes to the broader innovation management literature. This rich literature stream has highlighted the importance of recombining knowledge to create innovations (e.g., Karim & Kaul, 2015) as well as the role incentives can play in the generation (e.g., Argyres & Silverman, 2004; Lerner & Wulf, 2007) and ultimate commercialization of inventions (e.g., Christensen & Bower, 1996). Yet, despite the calls of multiple scholars (e.g., Dosi et al., 2003; Foss, 1996; Kapoor & Lim, 2007), few studies in this domain have taken both a knowledge- and incentive-based perspective of firms’ innovation activities. This study combines both perspectives to suggest that rich intra-organizational knowledge flows are more critical during invention and early development whereas more powerful incentives are more pertinent later in development.

Second, this study contributes to the literature on organizational design by highlighting that different facets of organizational differentiation play a greater or lesser role throughout the innovation process. This is because different problems need to be solved requiring diverse design solutions throughout this process (e.g., Puranam et al., 2014). In the invention and early development stages, technical differentiation of R&D into multiple units spanning varying technical domains is most significant. As an invention moves further into development, functional differentiation of R&D into separate research and development units plays a more important role. Finally, closer to the market overall organizational design and the degree of differentiation into multiple business units is more pertinent. This has broader implications for future studies relating to organizational design choices in that the relevant design choice must be very closely mapped to the specific activities being undertaken. Broad measures of design may not be able to capture how such choices can impact a targeted set of organizational outcomes.
leading to misleading or null inferences. Thus it is important to understand where (in organization) and when (in the relevant process) design choices are made in order to fully appreciate the role of such choices on organizational performance.

Third, by breaking down the innovation process this study helps to integrate the organizational design and innovation literatures. Much prior work in the innovation domain has tended to conflate the various stages of the innovation process and focused on a narrow set of innovation outcomes (e.g., Garud et al., 2013). This study illustrates that the same organizational design choice may have very different associated outcomes depending on whether it pertains to firms’ invention or development activities. This study therefore highlights an important additional contingency beyond, for example, the type of innovation when investigating the relationship between firms’ design choices and their innovation outcomes, namely the innovation process stage. This may go some way to explaining the varied findings within the strategic management literature pertaining to how firms’ design choices can impact their innovation outcomes.

Finally, this study also contributes to the literature on the resource-based view of the firm (e.g., Barney, 1991). Similar to external markets, firms’ knowledge and associated capabilities may be unevenly distributed within their own boundaries. Being able to access these capabilities when required can help firms to deliver superior performance. This study highlights that firms’ design choices can strongly influence firms’ access to their broader capabilities. For example, this study illustrates in the early stages of development integration of R&D across technical domains is associated with the progression of more inventions, with the benefits of integration being enhanced when a firm has a broader knowledge-base. Thus, by being able to access their broader knowledge base and array of capabilities managers within technically integrated R&D
units can more effectively address the technical challenges that they are likely to face during the early stages of the development process. This study therefore highlights that although a firm may have superior capabilities, they may not always translate into superior performance simply because they are not accessible.

The approach used in this paper provides a framework for addressing other important research questions. First, this study did not examine the relationship between firms’ design choices and the later stages of the innovation process. Limited prior work has examined how such choices can influence value capture from firms’ innovations subsequent to their market launch. The results from this study imply that an incentives-based perspective is most pertinent and differentiation into multiple units may facilitate greater value capture. However, consistent with the knowledge-based view, greater integration may facilitate more effective reallocation of resources and capabilities to ensure greater value capture from innovations. Second, although the analysis in this study controls for the proportion of external inventions in firms’ portfolios, the impact of the source of an invention on its subsequent development is not investigated. External sourcing of innovation-related activities could be seen as an extreme form of differentiation. West and Bogers (2014) highlight that there has been “a relative dearth of research related to integrating and commercializing” externally sourced knowledge suggesting this may be fecund area of future research.

In conclusion, this paper helps to shine light on an inherent trade-off firms face in that greater differentiation is associated with more effective usage of incentives, yet limits knowledge flows. Through unpacking the innovation process into its constituent stages, this study highlights the boundary conditions of when (in the innovation process) and where (in the organization) greater differentiation may facilitate or hinder firms’ innovation outcomes.
References


Figure 1: Hypotheses

Figure 2: Differentiation measures

1. Technical Differentiation of R&D
   - Roche
     - CEO
     - Head Small Molecule R&D
     - Head Biotech R&D (Genentech)
     - Chugai R&D
     - Elsäsi
   - Amgen
     - CEO
     - EVP R&D

2. Functional Differentiation of R&D
   - AstraZeneca
     - CEO
     - EVP Discovery Research
     - EVP Development
     - Biogen
   - Pfizer
     - CEO
     - President Research
     - President Development

3. Corporate Differentiation
   - CSL - 2008
     - CEO
     - Ch. Sci. Off.
     - Corp. Dev.
     - CSL Biother.
     - CSL Biopharma
     - Finance
     - Gen Counsel
     - GM HR
     - CEO

- Corporate Differentiation = 0.00
- Corporate Differentiation = 0.38

Role Key: Admin Func. - BU/WR - Prod Func.

Figure 3: Interaction between technical differentiation and (a) tech. diversity and (b) NCE

Technical Differentiation = 0
Technical Differentiation = 1
# Table 1: Summary of control variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Diversification controls</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category Dummies</td>
<td>Series of dummy variables representing whether a firm has operating segments in categories beyond pharmaceuticals. Specifically: consumer goods, medical devices, animal medication, bulk chemicals, nutrition. Also have dummy if firm has a generics business. These can vary by firm-year as firm acquires or divests specific businesses.</td>
<td>Control for diversification of firms’ businesses beyond pharmaceuticals</td>
</tr>
<tr>
<td>SBU</td>
<td>Reflects the total number of business units within a firm – namely the number of operating segments that report separate financials statements in their annual reporting documents</td>
<td>Controls for general firm diversification.</td>
</tr>
<tr>
<td>tech. diversity</td>
<td>Measure of technological diversity of firms’ R&amp;D efforts. For invention this is measured using a Herfindahl measure. The sum of the squared proportions of patent families filed in a focal year that pertain to each therapeutic class is subtracted from 1. Similarly for development, the sum of the squared proportions of drug candidates in each therapeutic class in a firm’s portfolio within a specific phase in a focal year is subtracted from 1. Controls for the level of technological diversity of a firm’s R&amp;D activities. Firms undertaking a broader array of technological activities are more likely to differentiate their R&amp;D efforts.</td>
<td></td>
</tr>
<tr>
<td><strong>2. Firm-level controls</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm-fixed effects</td>
<td>Series of dummy variables for each firm</td>
<td>Control for a range of sources of unobserved heterogeneity</td>
</tr>
<tr>
<td>R&amp;D Intensity</td>
<td>The annual spend on R&amp;D by a firm as a proportion of annual revenues (lagged one year)</td>
<td>Firms that spend a higher proportion of their sales on R&amp;D may potentially see higher inventive and innovative output (e.g., Mairesse &amp; Mohnen, 2005).</td>
</tr>
<tr>
<td>size</td>
<td>Natural log of the annual sales of each firm in the study sample (lagged one year)</td>
<td>Larger firms may potentially generate more innovation outputs as they have access to more resources such as a broader knowledge base. They are also likely to be more differentiated.</td>
</tr>
<tr>
<td>performance</td>
<td>The annual return on assets of the firm (Richard et al., 2009) (lagged one year)</td>
<td>Higher performing firms may potentially develop a higher volume of higher quality innovations</td>
</tr>
<tr>
<td>slack</td>
<td>Current Ratio (lagged one year)</td>
<td>Prior studies have indicated greater slack may help to drive the development of new technologies (Greve, 2003).</td>
</tr>
<tr>
<td>patent stock</td>
<td>Discounted total quantity of patent families filed by focal firm (Arora et al., 2014). Measured in 000s.</td>
<td>Controls for firms’ existing knowledge collected over a period of time which will impact innovation outcomes</td>
</tr>
<tr>
<td>sga</td>
<td>Natural log of a firm’s selling, general and administrative (sga) expenses (lagged one year)</td>
<td>Potentially those firms with higher values of sga are more innovation focused</td>
</tr>
<tr>
<td>CEO</td>
<td>A dummy variable set to 1 if a new CEO was appointed in a specific firm-year (lagged one year)</td>
<td>May be the catalyst for a reorganization or uptick in performance.</td>
</tr>
<tr>
<td><strong>3. Competition controls</strong></td>
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<td></td>
</tr>
<tr>
<td>competition</td>
<td>Measure of competition firms face across their development portfolio. Sum of squared “market shares” (by drug-candidate count) of drug-candidates within all development phases per therapeutic class subtracted from 1. Higher value signifies firms operate in more competitive therapeutic classes</td>
<td>Firms in more competitive markets may be incentivized to innovate and organize differently.</td>
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<tr>
<td><strong>4. Portfolio level controls</strong></td>
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<td></td>
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<tr>
<td>portfolio</td>
<td>Number of drug candidates in drug pipeline at particular stage in clinical development (e.g. Phase 0)</td>
<td>A larger portfolio is likely to be strongly correlated with the number of inventions that progress through the commercialization process.</td>
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<tr>
<td>external</td>
<td>Proportion of externally-sourced drugs in portfolio at specific stage of clinical development</td>
<td>Externally-sourced drug-candidates may be more difficult to commercialize due to issues such as not invented here syndrome (Katz &amp; Allen, 1982).</td>
</tr>
<tr>
<td>bio</td>
<td>Proportion of portfolio at specific stage of clinical development that are biologics</td>
<td>High level control for firms that tend to focus on biotechnology as opposed to small molecules.</td>
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<tr>
<td>NCE</td>
<td>Proportion of portfolio at specific stage of clinical development that are new chemical entities (NCE)</td>
<td>Indication of degree of novelty of portfolio. NCEs include no component that has been previously approved by the FDA. NCE designation from the US Food and Drug Administration (FDA) provides firms with five years of marketing exclusivity.</td>
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<td><strong>Other Controls</strong></td>
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<td>Series of dummies for each year</td>
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Table 2: Descriptive statistics invention analyses. N=803

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Table 3: Descriptive statistics development analyses (H3-5: firm-year-clinical phase analysis level)
Table 4: Regression analyses (H1/2)

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<td>1.596*</td>
<td>1.749**</td>
<td>1.798**</td>
<td>2.381*</td>
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<td>0.469**</td>
<td>0.462**</td>
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<td>(1.190)</td>
<td>-2.503*</td>
<td>-5.263**</td>
<td>-2.965*</td>
<td>-3.132*</td>
<td>-3.926*</td>
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<td>-4479.3</td>
<td>-1046.6</td>
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Standard errors in parentheses: * p < 0.1, ** p < 0.05, *** p < 0.01
### Table 5: Negative binomial regression analyses (H3-5)

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<tr>
<th>Dependent Variable</th>
<th>Number of inventions progressing to next phase (prog)</th>
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<td><strong>Clinical Phase</strong></td>
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<tr>
<td><strong>Model</strong></td>
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<tr>
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<td>R&amp;D Intensity</td>
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<td>sga</td>
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<tr>
<td>slack</td>
<td>0.0239 (0.025)</td>
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<td>CEO</td>
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<td>portfolio</td>
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<td>external</td>
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<td>bio</td>
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<td>tech. diversity</td>
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</table>

Standard errors in parentheses: **p < 0.1, *p < 0.05, **p < 0.01