Understanding the Relationship between Divestitures and Innovation

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ABSTRACT

This paper investigates how divestitures influence firms' innovation outcomes. On the one hand, divesting firms would be expected to produce fewer inventions after undertaking divestitures due to the reduction in corporate scope that these transactions entail. On the other hand, divesting firms would be expected to produce more novel inventions and to progress a greater number of those inventions into development after undertaking divestitures due to the resource reallocation benefits of these transactions. Further, the gains in invention novelty would be expected to be amplified in firms that have higher Research and Development (R&D) intensity and in firms that have centralized (rather than decentralized) R&D units. We find support for these arguments in the context of the global pharmaceutical industry.

Keywords: innovation, invention, development, divestitures, corporate strategy

The authors contributed equally and are listed alphabetically. We thank JP Eggers, Claudine Gartenberg, Rahul Kapoor, Paul Nary, Violina Rindova, Lori Yue, and seminar participants at the 2020 AOM Annual Meeting, the 2019 SMS Annual Meeting, Purdue University (Krannert), Western University (Ivey), and the University of Southern California (Marshall) for helpful comments on earlier drafts of this paper. We gratefully acknowledge the generous financial support of the Mack Institute for Innovation Management. Any errors are our own.

INTRODUCTION

> *"In 2008, we took decisive steps to ensure the robust future of our biologic medicines and specialty drugs. To focus on these assets more completely, we've captained a massive and cleanly executed reallocation of resources… By August, we had completed the sales of both our Medical Imaging business and our ConvaTec wound care business, for gross proceeds of more than $4.6 billion."* Bristol Myers Squibb Annual Report 2008

The above quote highlights a common pattern when it comes to divestitures: firms divest peripheral businesses and reallocate the resources that these transactions free up to their remaining core businesses (Capron, Mitchell, & Swaminathan, 2001; Helfat & Eisenhardt, 2004; Kaul, 2012). Although scholars have inferred this pattern of activity from the positive relationship between divestitures and firm performance in the aggregate (Comment & Jarrell, 1995; John & Ofek, 1995; Markides, 1992, 1995; Vidal & Mitchell, 2015), with few exceptions, existing research has yet to observe and measure resource redeployment following divestitures and the implications that this carries for more granular performance outcomes. Innovation is one critical domain where resource redeployment following divestitures and the performance implications thereof are likely to be both salient and observable. Innovation is a highly resource-intensive process (Ahuja & Katila, 2001) in which the availability of additional resources is likely to offer significant performance benefits (Rothaermel & Deeds, 2004), and it is possible to measure these gains at a fine-grained level using data on patent quality and progress through the innovation pipeline (Kapoor & Klueter, 2015).

To contextualize these ideas, we observe that much of the literature at the intersection of innovation and corporate strategy has focused on the innovation benefits of *expansionary* corporate strategies such as acquisitions (Ahuja & Katila, 2001; Puranam, Singh, & Chaudhuri, 2009) and alliances (Rothaermel & Deeds, 2004). Much of this literature suggests that expansionary corporate strategies can help firms innovate by giving them direct access to new technologies (Puranam et al., 2009; Puranam, Singh, & Zollo, 2006), enabling them to develop

new capabilities (Rothaermel & Deeds, 2004; Sears & Hoetker, 2014), eliminating competitors' inventions (Cunningham, Ederer, & Ma, 2019), or allowing them to recombine different pieces of knowledge in novel ways (Argyres, 1996; Karim & Kaul, 2015). By comparison, an apparent omission from the literature at the intersection of innovation and corporate strategy is an understanding of how *contractionary* corporate strategies—in particular, divestitures—might affect innovation outcomes. This may be partially due to the prevailing assumption that divestitures, by removing one or more businesses from a divesting firm's portfolio, will mechanically result in a loss of important knowledge and capabilities that are relevant to the innovation efforts of the firm's remaining businesses (Hitt, Hoskisson, Johnson, & Moesel, 1996). However, as the introductory quote and the above discussion illustrate, divestitures may in fact generate important innovation benefits, which have yet to be considered by research in this area.

In this study, we analyze how divestitures influence three key innovation outcomes: the quantity and novelty of inventions that firms produce, and the quantity of inventions that they progress through development. Because divestitures reduce the overall scope of divesting firms, we argue that these companies are likely to produce fewer inventions post-divestiture than they did pre-divestiture. At the same time, we also explain that divestitures are likely to promote the allocation of the resources that these transactions free up to novel rather than incremental inventions, especially in divesting firms that have higher R&D intensity and that have centralized R&D units. We also argue that the availability of additional resources is likely to enable divesting firms to progress a greater number of their inventions through development, a key stage in the innovation process. Using proprietary data on the divestitures and innovation outcomes of 49 leading companies in the global pharmaceutical industry from 1995 to 2015, we find empirical support for all of these predictions.

The key contribution of this paper is to articulate the major tradeoff that is faced by firms undertaking divestitures: while divestitures do remove capabilities and knowledge from divesting firms by reducing their overall scope, these transactions can also promote greater focus and more effective resource allocation processes within those firms. This insight contributes to the corporate strategy literature by highlighting the benefits of contractionary (rather than expansionary) corporate strategies for firms' innovation outcomes, and to the innovation literature by illustrating how divestitures may be able to help firms overcome inertia in their innovation processes.

THEORY AND HYPOTHESES

The innovation process

To analyze the relationship between divestitures and innovation, we must first describe the innovation process, which consists of three key sets of activities (Garud, Tuertscher, & Van de Ven, 2013). First, the act of invention involves the search to solve complex technical problems (Arora, Cohen, & Walsh, 2016; Kapoor & Klueter, 2015). The creation of inventions is a knowledge recombination activity focused on finding solutions to these complex problems (Fleming, 2001; Fleming & Sorenson, 2004). These solutions are of limited economic value in and of themselves (Schumpeter, 1939). Second, the act of development focuses on converting an invention into a final product that is of economic value. Development itself typically consists of several activities, such as addressing any remaining technical issues associated with an invention, refining and supplementing inventions with complementary knowledge, and scaling up for manufacturing (Barge-Gil & López, 2015). Development activities are more routinized than invention activities, with a greater focus on issues such as resource allocation (Eisenhardt & Martin, 2000). Furthermore, the nature of the final product and its market potential are much clearer at this stage (Aghion & Tirole, 1994). The organizational unit responsible for a firm's

invention and development activities is generally the R&D unit (DeSanctis, Glass, & Ensing, 2002). The third and final stage of innovation is commercialization, where a firm brings new products to market and captures value from them (Garud et al., 2013).

In this study, we focus on the two "upstream" stages of innovation, invention and development. We theorize that divestitures are likely to have a significant impact on two invention outcomes and one development outcome: respectively, the quantity and novelty of inventions produced (Hall, Jaffe, & Trajtenberg, 2001), and the quantity of inventions that progress through development (Chandy, Hopstaken, Narasimhan, & Prabhu, 2006; Kapoor & Klueter, 2015). The quantity of inventions produced determines the initial breadth of a firm's innovation funnel. Firms that produce more inventions have a greater likelihood of successfully creating more new products (Griffin, 1997). Additionally, firms that produce more novel inventions may be able to create more differentiated products that can potentially attract a higher price premium (Valentini, 2012). Empirically, we represent invention novelty using the originality of a firm's inventions, which is a measure of the breadth of knowledge utilized in an invention (Hall et al., 2001; Squicciarini, Dernis, & Criscuolo, 2013; Valentini, 2012). Finally, the quantity of inventions that progress through development is the primary driver of a firm's overall output of new products (Barge-Gil & López, 2015; Kapoor & Klueter, 2015). Now, having described the innovation process and articulated the main innovation outcomes that are specifically of interest in this study, we will develop hypotheses predicting how divestitures may affect them.

Divestitures and invention

Divestitures can impact firms' invention outcomes in two main ways. First, by removing the divested business and thereby reducing the overall scope of the divesting firm, divestitures may result in a decrease in the quantity of inventions produced. Second, divestitures may alter the types

of inventions that managers choose to pursue, tipping the balance from incremental inventions to novel inventions. In turn, because a firm's R&D unit significantly influences the novelty of the inventions it is able to produce, this effect is likely to be magnified in divesting firms that have a higher R&D intensity and in those that have centralized R&D units (Argyres & Silverman, 2004; Cohen & Levinthal, 1990; DeSanctis et al., 2002; Tsai & Luan, 2016).

Firm scope and the quantity of inventions produced. At the most fundamental level, divestitures reduce the overall scope of the divesting firm by removing one or more divested businesses from its portfolio (Chang & Singh, 1999). There are two reasons why this is likely to result in a reduction in the quantity of inventions produced by the divesting firm.

First, some invention projects may simply be removed from the divesting firm altogether, especially when they follow the divested business, because they are more relevant to it than to the divesting firm's remaining operations. Other invention projects may be shut down altogether after divestitures are complete, particularly when they do not align with a firm's revised strategic direction (Helfat & Eisenhardt, 2004). Still other invention projects may have exhibited synergies or interdependences with those in the divested business (Feldman, 2014), such that it may not be possible to continue these invention projects once that business is removed from the divesting firm. Lastly, certain invention projects may simply fall by the wayside when managers shift their attention to other projects (Eggers & Kaplan, 2009). These points indicate that divestitures can result in the termination or removal of some of the divesting firm's invention projects, leading to a lower quantity of inventions produced after these transactions.

Second, divestitures involve the movement of some employees away from the divesting firm, to other entities where their knowledge will no longer be accessible to that firm (Grant, 1996). This movement of employees may be to an acquiring firm in the case of selloffs, or to an

independent company in the case of spinoffs. The knowledge that is removed from the divesting firm may have been important to the success of its remaining invention projects. For example, in our empirical context of pharmaceutical companies, employees in a divested oncology unit may have unique expertise in protein chemistry that other employees in the divesting firm's cardiovascular unit drew upon in their invention projects. To execute its remaining invention projects, the divesting firm may need to either internally rebuild its knowledge base or else find suitable external partners with relevant knowledge (Macher & Boerner, 2012). Given that knowledge is highly tacit, however, neither of these two strategies is likely to be completely effective at replacing the knowledge that the divesting firm has lost (Hoetker & Agarwal, 2007). Furthermore, due to time compression diseconomies (Dierickx & Cool, 1989), simply allocating new resources to invention projects may not accelerate the time it takes to regain lost knowledge. As a result, progress in the divesting firm's invention projects may slow as it rebuilds the knowledge that the divestiture removed. This is another reason why divesting firms may produce fewer inventions following divestitures.

Hypothesis 1: Divesting firms produce a smaller quantity of inventions post-divestiture.

Managerial choice and invention novelty. Divestitures are also likely to alter the types of inventions that managers choose to pursue. Managers can focus either on creating incremental inventions that recombine a narrower base of knowledge, or on developing novel inventions that involve the combination of a broader array of knowledge (Fleming, 2001; Valentini, 2012). The creation of novel inventions entails a greater degree of risk, as there is increased variability in the possible outcomes associated with such projects (Park & Tzabbar, 2016). In contrast, the pursuit of incremental inventions is less risky and can provide managers with more definitive outcomes (Fernhaber & Patel, 2012).

Divestitures may make divesting firm managers less likely to pursue incremental inventions. Because larger firms often incur significant sunk costs in prior investments (Nelson & Winter, 1982), managers of these companies are more likely to select projects that leverage internal economies of scale, which tend to be associated with more incremental inventions (Valentini, 2012). Thus, by reducing the overall size of the divesting firm, divestitures may steer managers away from creating incremental inventions.

Instead, divestitures may prompt divesting firm managers to pursue novel inventions by freeing up slack resources that can be reallocated to the divesting firm's remaining businesses. For example, divestitures may free up tacit knowledge, in that the employees in which such knowledge generally resides can be reallocated from the divested business to other units within the divesting firm. Alternately, employees in centralized units such as R&D may shift from working on invention projects pertaining to the divested business to the projects of other business units within the divesting firm. Divestitures can also free up capital assets that were previously shared with the divested business, enabling the divesting firm to reallocate them to invention projects in its remaining businesses (Teodoridis, Bikard, & Vakili, 2019). Divestitures can even free up cash, often from the proceeds of the sale of the divested business, which can readily be used in other areas of the divesting firm's operations due to its fungibility (Levinthal & Wu, 2010).

In turn, the availability of these resources can lead divesting firm managers to pursue novel invention projects. One reason is that the downside of pursuing novel invention projects is lower when the divesting firm has slack resources available to absorb losses from failures (Vanacker, Collewaert, & Zahra, 2017). For example, a firm that has additional cash reserves from a divestiture can afford to reinvest in new invention projects quickly if existing projects fail (Bromiley, 1991; Chan, Nickerson, & Owan, 2007). Additionally, there may be less internal

resistance to the divesting firm pursuing novel invention projects if it still has the slack resources available to continue pursuing less risky, incremental options at the same time (Bromiley, 1991). Lastly, because the divesting firm has fewer businesses on which to focus following the completion of a divestiture, it may be able to dedicate slack resources to supporting those remaining businesses (Hoskisson & Hitt, 1988). In this case, the resources that divestitures free up can be applied to existing projects in those businesses, increasing the likelihood that they will succeed, and hence, their potential returns. This may enhance divesting firm managers' willingness to pursue novel invention projects in the future (Park & Tzabbar, 2016).

Hypothesis 2: Divesting firms produce more novel inventions post-divestiture.

Two characteristics of divesting firms' R&D units—their R&D intensity and the structure of their R&D units—are likely to influence the extent to which these firms will produce novel inventions after undertaking divestitures (Argyres & Silverman, 2004; DeSanctis et al., 2002).

First, the relationship between divestitures and invention novelty will be amplified in divesting firms that have a higher R&D intensity. R&D managers will be particularly likely to apply the slack resources that divestitures free up to novel invention projects (Cohen & Levinthal, 1990) if they are able to address two key issues. One is that R&D managers must have access to a sufficient number of high-quality ideas that can be translated into novel invention projects (Keum & See, 2017). The other is that R&D managers must have the appropriate capabilities required to execute these novel invention projects effectively (Leonard-Barton, 1992).

Both of these conditions are likely to be met in divesting firms that have a higher R&D intensity. A divesting firm's investments in R&D allow it to develop a robust set of internal resources, especially human capital that encapsulates critical scientific knowledge (Cohen & Levinthal, 1990; Fabrizio, 2009). This can help the divesting firm develop an extensive knowledge

base from which to draw when creating inventions (Grant, 1996). As a result, managers in divesting firms that have a higher R&D intensity may be able to explore more of the possible knowledge combinations that promote idea generation (Cohen & Levinthal, 1990; Fleming, 2001). Additionally, in divesting firms that have a higher R&D intensity, inventors may have greater insight into which knowledge-rich resources are available in external markets (Fabrizio, 2009), whether those resources are undervalued (Denrell, Fang, & Winter, 2003), and how those resources can complement knowledge within the firm (Cohen & Levinthal, 1990). Thus, the combination of better internal capabilities and a superior ability to identify suitable external resources may enhance the ability of managers in divesting firms with a higher R&D intensity to execute the novel invention projects they generate (Macher & Boerner, 2012; Rothaermel & Deeds, 2004).

Hypothesis 3a: The post-divestiture increase in the novelty of inventions is greater for divesting firms that have a higher R&D intensity.

Second, the relationship between divestitures and invention novelty will also be amplified in divesting firms that have centralized rather than decentralized R&D units. A key design feature of a firm's R&D unit is its degree of centralization (Argyres & Silverman, 2004; DeSanctis et al., 2002). Some firms may decentralize R&D into multiple stand-alone units or into business units, such that each R&D unit has its own separate reporting line (Eggers, 2016). Other firms may have highly centralized R&D units reporting to a single Head of R&D, which focuses on a single portfolio of inventions and can relatively easily shift resources across R&D activities. Multiple hybrid forms exist in between these two extremes, in which some aspects of R&D are more decentralized and others are more centralized (DeSanctis et al., 2002).

Managers of firms that have centralized R&D units tend to have a longer-term perspective and to pursue invention projects that focus on technologies that are not specific to any particular business unit (Argyres & Silverman, 2004). While these kinds of invention projects are generally

more novel, they may or may not pay off in the short-term (DeSanctis et al., 2002).[1] By contrast, managers in firms that have decentralized R&D units face greater pressure from their associated business units to create lower risk, business-specific inventions (Christensen & Bower, 1996) that can help ensure ongoing, consistent revenue flows (DeSanctis et al., 2002). In firms that have decentralized R&D units, there is a closer connection between R&D and the commercial functions of business units, such as marketing, production and customer service. For example, Ogbuehi and Bellas (1992) argue that firms that have separate R&D units that are linked to particular geographical markets tend to be more closely connected to their end customers. In turn, this can increase the pressure on managers of decentralized R&D units to meet shorter term commercial needs, generally by producing incremental inventions.

Given these differences, managers in divesting firms with centralized R&D units are likely to choose to utilize the slack resources that divestitures free up in a different way than managers in divesting firms with decentralized R&D units (Tsai & Luan, 2016). Free to pursue more speculative and general invention projects (Argyres & Silverman, 2004), and perhaps attracted by the higher potential long-term payoffs of such projects (Park & Tzabbar, 2016), managers in divesting firms with centralized R&D units may be more likely to apply the slack resources that divestitures free up to novel invention projects (DeSanctis et al., 2002). By contrast, often reporting to business unit leads that have a short term profitability focus (Hoskisson & Hitt, 1988), managers in divesting firms with decentralized R&D units may instead choose to apply the resources that divestitures free up to incremental invention projects that carry a greater likelihood of success (Argyres & Silverman, 2004; DeSanctis et al., 2002).

[1] For example, Microsoft Research is a centralized unit that reports up to the company's Chief Technology Officer. This unit is focused on undertaking fundamental scientific research that could potentially be applied in the longer term in such areas as environmental science, which are not directly aligned with Microsoft's current product range (https://www.microsoft.com/en-us/research/).

Hypothesis 3b: The post-divestiture increase in the novelty of inventions is greater for divesting firms that have centralized (rather than decentralized) R&D units.

Divestitures and development

In addition to their influence on divesting firms' invention activities, divestitures can also affect the development activities of these companies. To move an invention project through development, firms must resolve a host of technical and commercial issues to enhance the invention's viability (Barge-Gil & López, 2014). To do this, firms must allocate sufficient resources to various tasks, such as fully understanding how the invention solves the problems it was designed to address, examining the feasibility of scaling up production of the invention, and modifying the invention so that it can become a prototype product (Barge-Gil & López, 2014; Eisenhardt & Martin, 2000). For example, a pharmaceutical company would need to develop a full understanding of the mechanism of action of the drug candidate in the human body, evaluate the feasibility of producing large volumes of the drug (which may be especially challenging for biological molecules such as vaccines), and select the appropriate method of delivering the drug's active ingredient within the human body (such as a pill, an injection, or a patch).

The resources that divestitures free up are likely to facilitate and promote all of these endeavors. For example, human and physical capital that were previously deployed to development projects in the divested unit can instead be reallocated to development projects in the divesting firm's remaining businesses (Shepherd, Patzelt, Williams, & Warnecke, 2014). This can help divesting firms develop a deeper understanding of how their inventions work, and also facilitate appropriate modifications to create and scale up prototype products (Barge-Gil & López, 2015; Chiesa, 1996, 2001). Relatedly, divestitures can free up capacity in resources, such as technical equipment, that were previously shared between the divested business and the remaining units within the divesting firm (Chang & Singh, 1999), potentially eliminating bottlenecks that

may have slowed the progress of inventions through development. As a result, more inventions can be screened in a given time period, allowing managers to more quickly identify the inventions that have the greatest prototype and scaling potential (Chiesa, 1996, 2001). Cash, which can be used to access additional human and physical capital to be used in the development activities described above, can equally be plowed back into divesting firms' remaining development projects. Lastly, following the removal of a divested business, managers might reallocate attention to the remaining businesses within the divesting firm (Ocasio, 1997), helping them surmount organizational bottlenecks in development by ensuring that they have access to sufficient and appropriate shared resources (Eggers & Kaplan, 2009).

Hypothesis 4: Divesting firms progress a greater quantity of inventions through development post-divestiture.

METHODS

Research context

This study is set in the global pharmaceutical industry, where invention involves the creation of new patents that can lead to new drugs, and development involves clinical trials to convert these patents into new drug products (Fleming, 2001; Kapoor & Klueter, 2015). There are three reasons why the pharmaceutical industry provides a rich context in which to test our hypotheses.

First, pharmaceutical companies patent many of their inventions and these patents relate closely to final products (Gunther McGrath & Nerkar, 2004). This mitigates some of the limitations that affect studies that use patent data, such as the fact that not all inventions get patented (Levin et al., 1987), patents do not always correspond to products (Hall et al., 2001), and patents are filed for strategic rather than knowledge capture purposes (Spender & Grant, 1996).

Second, the creation of patents and their conversion into final marketed drugs form the lifeblood of pharmaceutical companies (Petrova, 2014). This ensures that senior managers pay

close attention to invention and associated patent creation, as well as clinical development. With only a limited period of exclusivity afforded by patent protection, pharmaceutical firms continuously seek to create and develop new inventions that can lead to new products.

Third, pharmaceutical companies continually re-evaluate the composition of their businesses and frequently engage in major transactions like acquisitions, alliances, and divestitures. The total value of divestitures in this sector increased from $3.9 B in 2010 to $10.9 B in 2017.[2] A key driver of this increase has been the desire for firms to simplify their drug portfolios:

> *"Ten years ago, most pharmaceutical companies saw value in having a complex and diversified portfolio that included small-molecule drugs, biologics, and even medical devices. We've been seeing that strategy change over the past couple of years, and many of our clients are simplifying and realigning their portfolios. This trend is helping drive a new wave of mergers, acquisitions, divestitures, and spin-offs."*[3]

A 2019 industry study found that 83% of life science companies were considering a divestiture and 64% of firms planned to use the funds from divestitures to re-invest in their remaining businesses:

> *"Life sciences businesses are tightening their portfolio review processes and divesting, driven by a need to invest in new assets or areas, especially capabilities that allow the delivery of personalized, high touch care."*[4]

Prior studies have found that 83% of divestitures in this industry are motivated by a desire to free up resources, such as cash, and to increase strategic focus (Ström, 2018). In a similar vein, we coded the reasons for the 42 divestitures in our dataset based on an analysis of company annual reports and financial filings in which CEOs discuss the rationales for their firms' divestitures (Table 1). We found that 85% of the divestitures in our sample resulted from a desire to increase organizational focus and free up resources.

[2] https://www.mckinsey.com/industries/pharmaceuticals-and-medical-products/our-insights/divestiture-in-medtech-are-you-the-natural-owner-of-your-businesses
[3] https://www2.deloitte.com/us/en/blog/health-care-blog/2020/ma-activities-diversities-continue.html
[4] https://www.ey.com/en_us/divestment-study/2019/life-sciences

-----Table 1 here-----

Sample and data

The sample consists of 49 leading pharmaceutical firms that we identified using the *Pharmaceutical Executive* magazine's Top 50 Pharmaceutical companies (Klueter, Monteiro, & Dunlap, 2017). 64 unique firms appeared in the Top 50 in one or more years in the period 2004 to 2006. We dropped 15 firms that were either privately-held or did not provide sufficient information on their organizational structures in their public filings. We then collected data on this set of 49 firms over the period 1995 to 2015. Our focus on leading companies is consistent with prior studies within the strategic management literature, which have concentrated on the larger pharmaceutical firms that are responsible for the majority of innovation in the industry (Gunther McGrath & Nerkar, 2004; Kapoor & Klueter, 2015).

We use SDC Platinum to identify the divestitures that the firms in our sample undertook. Divestitures include both sales of businesses to other firms and spinoffs of businesses into new companies. We only consider deals of $500m or more in value to ensure that these divestitures had a significant impact on the invention and development activities of the sample firms. 19 out of the 49 firms in our sample undertook a total of 42 divestitures over the 1999-2012 period.[5]

We gather invention data from the European Patent Office Patstat database (Conti, Gambardella, & Mariani, 2013). This database provides good coverage across multiple patent-granting jurisdictions (Kang & Tarasconi, 2016). We utilize data from the Pharmaprojects database to develop variables pertaining to firms' clinical development portfolios (Chandy et al., 2006; Kapoor & Klueter, 2015) and EvaluatePharma database for drug sales data. As we will describe in

[5] Although the sample period runs from 1995 to 2015, we only consider divestitures that were undertaken between 1999 and 2012, in order to have a sufficient number of pre-divestiture observations for firms that divested in 1999 and a sufficient number of post-divestiture observations for firms that divested in 2012.

more detail, we hand-collected organization structure data from company 10-K, 20-F, DEF14A SEC filings, and annual reports. We obtain financial data from Compustat.

Empirical strategy

The empirical strategy we follow in this study is to compare the pre- versus post-divestiture changes in the invention and development outcomes of firms that undertook divestitures (the "treated" firms), relative to those of comparable firms that did not undertake divestitures (the "control" firms). To do this, we use differences-in-differences regressions on propensity score matched sets of treated and control firms.

The treated firms in our sample are the 19 firms that undertook 42 divestitures during the 1999-2012 period. We used a propensity score matching model to generate a matched set of firms that did not undertake divestitures—the control firms. In this model, a probit regression first predicts the likelihood that a given firm in our sample undertook a divestiture in *year n*, using the control variables described below as covariates to predict that probability. Results of this first-stage probit regression appear in Appendix Table A-1. From there, we identified the nearest neighbor to each treated firm in *year n*, as predicted by the propensity scores. We were able to match 17 of the 19 treated firms that undertook 35 out of the 42 divestitures in *year n* to comparable control firms that did not undertake divestitures in that same year. Observations dropped out for either not being in the area of common support or because matching variables were not available.

Balance tests comparing the characteristics of the matched treated and control firms in *year n* appear in Appendix Table A-2. This table shows that the values of the covariates for the treated and control observations are quite similar in the matched sample, but not in the unmatched sample.

Having identified the matched set of treated and control firms, we built seven-year panels of firm-year observations around the year of the divestiture (*year n*). For the treated (divesting)

firms, each panel consists of seven years: the three years prior to, the year of (*year n*), and the three years after each divestiture. Analogously, for the control (non-divesting) firms, each panel consists of seven years: the year in which it was matched to a firm that undertook a divestiture (*year n*), the three years before, and the three years after.[6] Any control observations that fell within three years of a divestiture by a control firm were dropped to ensure the control observations only included firms that had not divested during the relevant window. This led to a final sample of 365 observations, of which 237 were treated (i.e., firm-year observations in the seven-year period in which a given company undertook a divestiture) and 128 control observations (i.e., firm-year observations in the seven-year period in which a given company that did not undertake a divestiture was matched to a firm that did).

Variables

Dependent variables. To test our hypotheses, we use three dependent variables that represent the quantity and novelty of a firm's inventions and the progression of inventions through development. For Hypothesis 1, we measure the quantity of inventions (*Invention Quantity)* using the number of patent families filed annually by the firms in our sample. Patent family counts are used to avoid double counting patents filed in multiple jurisdictions. We used patents assigned in the European Community statistical classification of economic activities category (NACE2) 21 (manufacture of basic pharmaceutical products and pharmaceutical preparations). We define the year in which a patent family was created as the earliest filing date of a patent in that family. Because *Invention Quantity* is a count variable, we use negative binomial regressions in our analyses.

[6] This approach allows a firm to appear as treated within the seven-year window in which it undertook a divestiture, but as a control in the seven-year windows in which it did not undertake divestitures. For example, Abbott Laboratories sold TAP Pharmaceuticals to Takeda in 2008, and then sold its non-U.S. businesses to Mylan in 2014. Thus, Abbott could appear as a control firm in our analysis between 1995 and 2004, as it undertook no divestitures during that time period, but Abbott could then appear as a treated firm starting in 2005 because it undertook divestitures after that time.

For Hypotheses 2, 3a, and 3b, we measure invention novelty (*Invention Novelty*) using the breadth of knowledge from which patents draw (Argyres & Silverman, 2004; Hall et al., 2001). To do so, we used the International Patent Classification (IPC) 4-digit technical classifications of the citations made by a focal patent to create an originality measure of novelty (Squicciarini et al., 2013). To convert the citation data into an originality measure at the patent level, we used the approach recommended by Hall et al. (2001). We assign the maximum originality of a patent in a given family as the originality for that family. We used these values to estimate an average originality per patent family filed in each firm-year (*Invention Novelty*). The larger the value of *Invention Novelty,* the greater the breadth of knowledge from which a firm's patents draw in the relevant year. As *Invention Novelty* is continuous and bounded between zero and one, we use fractional logit regressions in our analyses.

To test Hypothesis 4, we measure the progression of inventions through development (*Development Progress*). We create this variable by counting the number of drug candidates in a firm's portfolio moving forward at least one stage in the clinical development process (Pre-clinical to Phase1, Phase 1 to 2, Phase 2 to 3 or Phase 3 to New Drug Application (NDA)) per year. Because *Development Progress* is a count variable, we use negative binomial regressions.

Independent variables. To implement the differences-in-differences model described above, we develop four key independent variables. Consistent with the earlier discussion, we define *Treat* as a binary variable taking the value one in each of the firm-year observations pertaining to the treated firms (i.e., those that undertook divestitures), and zero in each of the firm-year observations pertaining to the control firms in our sample (i.e., the matched companies that did not undertake divestitures). We also define *After* as a binary variable taking the value one in the "post-divestiture" years pertaining to both the treated and control firms, and zero in the "pre-

divestiture" years for those companies.[7]

For Hypothesis 3a, we estimate *R&D Intensity* by dividing a firm's annual R&D expenditures by its annual sales, using data provided by Compustat (Cohen & Levinthal, 1990). This results in a continuous variable bounded between zero and one. For Hypothesis 3b, we define *R&D Centralization* using top management team (TMT) data available from company 10-K/20-F/DEF 14A SEC filings (Albert, 2018; Guadalupe, Li, & Wulf, 2014).[8] We developed a database of 15,129 executive and extended executive team roles for the sample of 49 firms over the 1995-2015 period, resulting 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).[9] To represent the centralization of R&D, we determined whether firms' R&D or Research (in the case of functionally separate R&D) was organized into a single or multiple units. For diversified firms that operate beyond pharmaceuticals, we focused on R&D units that pertain to pharmaceuticals, while R&D units dedicated to areas such as consumer products were excluded in order to control for the level of diversification. Using this approach, the variable *R&D Centralization* takes the value zero if there are multiple R&D or research groups reporting to separate heads within the TMT or to leads of business units, and one if the firm has a single integrated pharmaceutical R&D or research group reporting to a single TMT lead.

To test Hypotheses 1, 2 and 4, we undertake differences-in-differences models in which

[7] For the treated firms, the pre-divestiture years are the three years before those companies undertook divestitures and the year of each divestiture, while the post-divestiture years include the three years subsequent to the year of the divestiture. For the control firms, the comparable, "pre-divestiture" years are the year in which the relevant matched treated firm undertook a divestiture and the three years prior to that (years n, n-1, n-2, and n-3), and the "post-divestiture" years are the three years subsequent to that (years n+1, n+2, and n+3).

[8] In interviews with R&D managers, they confirmed that the structure of the TMT provides an accurate reflection of their firms' high level structures, specifically in regard to how R&D is organized.

[9] The coding of roles and various facets of organizational decentralization were undertaken in the dissertation research of one of the authors through careful review of the management roles in each organization. This coding was validated through review of organizational descriptions from companies' filings (e.g., CEOs' letters to shareholders).

we include three key independent variables: *Treat*, *After* and the interaction term, *Treat* x *After*. To test Hypotheses 3a and 3b, we implement triple differences-in-differences models incorporating seven key independent variables: *Treat*, *After*, the moderating variables (*R&D Intensity* and *R&D Centralization)* the three two-way interaction terms between these variables (*Treat* x *After*, *Moderator* x *Treat*, and *Moderator* x *After)*, and the triple interaction term among all three variables (*Moderator* x *Treat* x *After*). We expect to observe a negative coefficient on *Treat* x *After* in regressions taking *Invention Quantity* as the dependent variable (Hypothesis 1), positive coefficients on *Treat* x *After* in regressions taking *Invention Novelty* and *Development Progress* as the dependent variables (Hypotheses 2 and 4), and positive coefficients on the triple interaction terms (*R&D Intensity* x *Treat* x *After* and *R&D Centralization* x *Treat* x *After*) in regressions taking *Invention Novelty* as the dependent variable (Hypotheses 3a and 3b).

Control variables. We include numerous control variables in our regression analyses. We include two structural variables to account for heterogeneity in the organization designs of the sample firms. *R&D Functional Differentiation* measures whether firms' R&D units are integrated into one unit or have separate research and separate development units. This binary variable takes the value one if there are separate research and development heads reporting to the CEO, and zero if R&D is integrated.[10] *Corporate Decentralization* is measured as the proportion of business unit roles in the TMT relative to the overall size of the TMT (excluding the CEO) (Albert, 2018; Guadalupe et al., 2014). Business unit roles relate to roles that are responsible for the performance of a defined sub-section of the business. To account for firms operating in non-pharmaceutical domains, business unit leads in these areas are excluded.

[10] By way of interpretation, *R&D Functional Differentiation* takes the value one when decision rights are split between research and development and there are separate hierarchical reporting lines pertaining to each function. By contrast, *R&D Functional Differentiation* takes the value zero when a functionally-integrated R&D unit has decision rights over the complete R&D process and has a single associated hierarchical authority covering all R&D.

We also include multiple firm-specific control variables in our regressions. We control for firm size (*Size)* using the natural log of annual sales (Macher & Boerner, 2012; Rothaermel & Deeds, 2004). We include each firm's discounted patent stock (*Patent Stock*) (Henderson & Cockburn, 1994). We control for CEO turnover using a binary variable (*New CEO*) that takes the value one if a firm's CEO changes in any given year. We also control for a firm's operating performance using their return on assets (*Performance)*, and for the log of its selling, general and administration expenses (*SG&A*) (Kapoor & Klueter, 2015; Rothaermel, 2001). We control for the lagged 3-year rolling average of the number of major mergers and acquisitions (> US$500 M): *M&A Quantity* (Bennett & Feldman, 2017).

We control for the type of divestitures firms undertake. We code divestitures as either related or unrelated. If the divestiture involved the sale or spin-off of a pharmaceutical business we coded *Unrelated* as zero. Sale of non-pharmaceutical businesses such as consumer goods or medical devices were coded as *Unrelated* being equal to one.[11]

We also control for the degree of diversification of each firm. The variable *SBU Count* reflects the total number of operating segments (Albert, 2018). The variable *Technical Diversity* is a measure of the technological diversity of firms' R&D efforts, as calculated using a Herfindahl measure, whereby the sum of the squared proportions of patent families filed in a focal year that pertain to each therapeutic class is subtracted from one (Macher, 2006).

Finally, we control for characteristics of firms' clinical development portfolios. The variable *Portfolio size* represents the number of drug-candidates under development in a firm's pipeline in a focal year (Kapoor & Klueter, 2015). *External Portfolio Proportion* represents the

[11] Anecdotally, divesting firms tend to sell businesses that are unrelated to their pharmaceutical operations to acquirers that are not pharmaceutical companies (e.g., Bristol Myers Squibb sold its Clairol haircare business to Procter & Gamble), but divesting firms tend to sell businesses that are related to their pharmaceutical operations to other pharmaceutical companies (e.g., Sanofi sold its insulin business to Pfizer).

proportion of externally sourced drug candidates (Higgins & Rodriguez, 2006). *NCE Portfolio Proportion* represents the proportion of drug candidates that are New Chemical Entities (Petrova, 2014).[12] *Bio Portfolio Proportion* represents the proportion of drug-candidates that are biologics (Kapoor & Klueter, 2015). *Development Portfolio Novelty* takes a value between zero and two (Klueter, 2013). If the mechanism of action and origin of material in the relevant broad therapeutic domain are new to the firm, the value is set at two; if one is new, the value is one; and if neither are new, the value is zero. These values are averaged across a firm's portfolio in each firm-year.

Descriptive statistics appear in Appendix Table A-3. In addition to the above-described control variables, our specifications also include year, firm and business category fixed effects[13], and standard errors are clustered at the firm-level to account for intra-group correlation.

RESULTS

Main analyses

Regression results testing Hypothesis 1 appear in Model 1 of Table 2. The negative coefficient on *Treat* x *After* (p=0.025) indicates that divesting firms produce fewer patents (i.e., a lower quantity of inventions) post-divestiture than non-divesting firms. Consistent with Hypothesis 1, the coefficient estimate indicates that on average, divesting firms produce 58 fewer patents (12.7% of the mean value) post-divestiture than comparable non-divesting firms.

Regression results testing Hypothesis 2 appear in Model 2 of Table 2. The positive coefficient on *Treat* x *After* (p=0.021) indicates that divesting firms produce more novel inventions post-divestiture than firms that do not divest. Supporting Hypothesis 2, the coefficient estimate

[12] NCEs include no component that has been previously approved by the US Food and Drug Administration (FDA). NCE designation from the FDA provides firms with five years of marketing exclusivity.

[13] The business category fixed effects consist of a set of dummies measuring whether firms have operating segments in categories other than pharmaceuticals in each sample year (consumer goods, medical devices, animal medication, bulk chemicals, nutrition, and generic pharmaceuticals).

indicates that the average novelty of inventions produced by divesting firms is 1.2 percentage points higher post-divestiture than it is for equivalent non-divesting firms.

Regression results testing Hypothesis 4 appear in Model 3 of Table 2. The positive coefficient on *Treat* x *After* (p=0.013) indicates that post-divestiture, divesting firms progress more inventions through development than non-divesting firms. Consistent with Hypothesis 4, the coefficient estimate indicates that divesting firms progress 2.2 (11.4% of mean value) more inventions through development post-divestiture than comparable non-divesting firms.

-----Table 2 here-----

Regression results testing Hypothesis 3a appear in Model 1 of Table 3. The positive coefficient on *R&D Intensity* x *Treat* x *After* (p=0.012) provides evidence in support of Hypothesis 3a. Post-divestiture, divesting firms in the top decile of *R&D Intensity* produce inventions that have a 3.6%-point *higher* novelty, on average, than non-divesting firms. By contrast, post-divestiture, divesting firms in the bottom decile of *R&D Intensity* produce inventions that have a 2.3%-point *lower* novelty than non-divesting firms. Thus, the post-divestiture change in invention novelty is more positive for divesting firms that have higher R&D intensity.

Regression results testing Hypothesis 3b appear in Model 2 of Table 3. The positive coefficient on *R&D Centralization* x *Treat* x *After* (p=0.054) provides evidence in support of Hypothesis 3b. Post-divestiture, divesting firms with centralized R&D units produce inventions that have a 1.4%-point *higher* novelty than non-divesting firms. By comparison, post-divestiture, firms with decentralized R&D units produce inventions that have a 0.6%-point *lower* novelty, on average, than non-divesting firms. Thus, the post-divestiture change in invention novelty is more positive for firms with centralized rather than decentralized R&D units.

-----Table 3 here-----

We undertook six additional analyses to test the robustness of our main results. First, in Models 1-5 of Appendix Table A-4, we use caliper (rather than nearest neighbor) matching (caliper = 0.005) in the propensity score matching model. Second, in Models 6-10, we set the variable *After* to one (rather than zero) in the year of the divestiture. Third, a limitation of non-linear models is that interaction terms may be difficult to interpret (Hoetker, 2007). Accordingly, in Models 11-15, we use ordinary least squares or linear probability regressions (rather than fractional logit models). Fourth, in Model 16, we use the number of granted (rather than filed) patent families per firm-year as our dependent variable to test Hypothesis 1. Fifth, in Models 17-19, we use *Radicalness* as an alternative measure for *Invention Novelty* to test Hypotheses 2 and 3. *Radicalness* not only measures the variety of the technology classes of the patents cited by a focal patent but also the variety of technology classes cited in these cited patents (Squicciarini et al., 2013). Sixth, in Model 20, we use the proportion of drug candidates in a firm's portfolio that progresses forward at least one stage in the clinical development process per year as an alternative dependent variable to *Progress.* The results of all of these tests are broadly consistent with those of our main analyses.

Post-hoc analyses

We also conducted six post-hoc analyses to explore the mechanisms behind our hypotheses, and to rule out alternate explanations for our results.

First, Hypotheses 2-4 are predicated on the argument that divestitures free up resources that facilitate an increase in invention novelty and a greater progression of inventions through development. One route through which firms could use the resources freed up by divestitures is to undertake acquisitions. The positive coefficient on *Treat* x *After* (p=0.029) in Model 1 in Table 4 supports this point, showing that divesting companies undertake a greater number of acquisitions after undertaking divestitures. 100% of the unrelated (i.e., non-pharmaceutical) divestitures are followed by a major acquisition (> $500 M) of related (i.e., pharmaceutical) businesses in the next

three years, whereas 53% of unrelated divestitures are followed by major acquisitions of related businesses in the next three years. For example, following the divestiture of its consumer healthcare business to J&J in 2006 for $16.6 B, Pfizer CEO Hank McKinnell commented:

> *"We will now be in an even stronger position to capitalize on the many opportunities we see in our core pharmaceuticals business*[14]*"*

Indeed, after this divestiture, Pfizer acquired Wyeth Pharmaceuticals and Sanofi's insulin business, both of which were aligned with Pfizer's pharmaceutical business.

Second, if our argument is correct that divestitures free up resources that can be used in other areas of the divesting firm, the benefits of divestitures for invention novelty should be more pronounced for unrelated divestitures. Unrelated (i.e., non-pharmaceutical) businesses primarily share corporate resources with other business units in their companies such as information technology, financial capital, managerial talent, and real estate. Because these resources are highly fungible (Levinthal and Wu, 2010), they can easily be monetized or redeployed to the remaining businesses within that company when they are freed up by a divestiture. For example, financial capital from the divested business can freely be redeployed internally to access other invention-related resources, such as human or physical capital (Teodoridis et al., 2019). This should enhance the novelty of the inventions that divesting firms can produce after undertaking a divestiture. By comparison, when a firm divests a related (i.e., pharmaceutical) business, key resources that may have been shared across businesses (such as research laboratories, scientists, research databases and other intellectual property) may depart with the divested business (Chang & Singh, 1999). The loss of these resources can disrupt key activities within the remaining firm that are dependent on them (Feldman, 2014), constraining the novelty of the divesting firm's inventions. For example,

[14] https://www.businesswire.com/news/home/20070301006082/en/Pfizer-Reaches-Agreement-to-Sell-Its-Consumer-Healthcare-Business-to-Johnson-Johnson-for-16.6-Billion

in the pharmaceutical context, scientists familiar with complex DNA sequencing techniques may depart with the divested business, which can limit the ability of the divesting firm's remaining businesses to create novel inventions. Together, these arguments suggest that unrelated divestitures will be associated with a greater increase in the novelty of a divesting firm's inventions post-divestiture than related divestitures. The positive coefficient on *Unrelated* x *Treat* x *After* in Model 2 of Table 4 (p=0.006) supports this point.

Third, if our argument is correct that divestitures free up resources for use in the divesting firm's remaining businesses, larger divestitures, which free up more resources, should be associated with a greater increase in invention novelty and a greater progression of inventions through development. The positive coefficients on *Divestiture Value* x *Treat* x *After* in Models 3 and 4 of Table 4 support the logic that larger divestitures free up more resources and are therefore associated with greater increases in *Invention Novelty* (p=0.044), and, to a lesser extent, *Development Progress* (p=0.136).

Fourth, to further test the argument that divestitures free up resources for use in the divesting firm's remaining businesses, we examine the variance in the progression of inventions through the different stages of development, leveraging the fact that different stages of clinical development require different resource levels. Specifically, Phase 3 clinical trials (and, in turn, the transition from Phase 3 to NDA) are the most resource intensive part of development within the pharmaceutical industry (Sertkaya, Wong, Jessup, & Beleche, 2016). Phase 3 of clinical development generally requires multiple large-scale trials to be undertaken with thousands of patients, often in multiple countries. Thus, we expect the resources that divestitures free up to have the greatest impact on the transition of drug candidates from Phase 3 to NDA. To test whether the impact of divestitures on the progression of inventions through development is greater for the more

resource-intensive Phase 3 to NDA transition, we develop four separate dependent variables: *Progress01, Progress12, Progress23* and *Progress3N*. These variables respectively represent the number of drug candidates that progress between Pre-clinical and Phase 1 trials, Phase 1 and Phase 2 trials, Phase 2 and Phase 3 trials, and Phase 3 and NDA for each firm-year. If the impact of additional resources following divestitures is greatest for the Phase 3 to NDA transition, we would expect that the coefficient on *Treat* x *After* would be greater when the dependent variable is *Progress3N* as compared to *Progress01, Progress12* and *Progress23.* Consistent with this logic, Models 5-8 in Table 4 illustrate that the coefficient for *Treat* x *After* is largest for the Phase 3 to NDA transition (Model 8).[15]

Fifth, in our tests of Hypothesis 4, we show that firms progress more inventions through development after they undertake divestitures, again illustrating the benefits of the resources that divestitures free up for innovation outcomes. However, an important alternative explanation for these results is that they have little to do with resources, and that firms are simply progressing less novel (and hence, easier to progress) inventions through development after they undertake divestitures. To rule out this alternative explanation, we examine whether firms that have less novel invention portfolios (measured using the variable *Development Portfolio Novelty* as defined above) progress a greater number of inventions through development post-divestiture. Contrary to this prediction, we observe a null coefficient on *Development Portfolio Novelty* x *Treat* x *After* in Model 9 of Table 4, whose dependent variable is *Development Progress*. This result indicates that there are no differences in the number of inventions that divesting firms progress through development post-divestiture, regardless of the degree of novelty of their development portfolios.

[15] Although this coefficient is approximately double that of the next highest value of *Treat x After* (Model 5, Pre-clinical to Phase 1 transition), Wald tests indicate that the coefficient on *Treat x After* in Model 8 is only statistically greater than that of Model 7 (Phase 2 to 3 transition).

Finally, to the extent that firms utilize the resources that are freed up by divestitures on the "wrong" ideas, firms may not benefit commercially from the improvements in invention novelty and development progress that divestitures impel. To investigate this matter, we examine how the sales of firms' leading products change after they undertake divestitures. Divesting firms appear to enjoy higher sales from their top one, two and three products after they divest (positive coefficients on *Treat* x *After* in Models 10-12 in Table 4), suggesting that improvements in invention novelty and development progress are translating into longer-term commercial success.

-----Table 4 here-----

DISCUSSION AND CONCLUSION

The key contribution of this paper is to articulate the significant tradeoff in terms of innovation that is faced by firms that undertake divestitures. On the one hand, when firms divest units, corporate scope is reduced, which can come at the cost of lost capabilities and knowledge. On the other hand, when firms divest units, resources that were tied up in the divested unit are freed up, which can come with the benefit of greater focus and more effective resource allocation processes within those firms. Accordingly, in firms that undertake divestitures, while the overall quantity of inventions produced declines post-divestiture, the inventions that are produced are, in fact, more novel and a greater number of them progress through development, a critical stage along the way to the commercialization of new products and ultimately, to greater profitability for the firm as a whole. Overall, these points imply that divestitures make firms "lean and mean" when it comes to innovation, promoting the efficiency and effectiveness of their invention and development processes over the simple count of inventions produced—in other words, quality over quantity.

This contribution is an important one from the perspective of the corporate strategy literature, which has largely focused on how expansionary corporate strategies, especially

acquisitions, influence firms' innovation outcomes. In particular, prior studies have shown that firms produce a greater quantity of inventions after undertaking acquisitions (Ahuja & Katila, 2001; Jo, Park, & Kang, 2016; Valentini, 2012). In terms of invention quality, Zhou and Li (2012) find that firms with a deeper (as opposed to a broader) knowledge base tend to produce more radical inventions after undertaking acquisitions, whereas Valentini (2012) shows that invention quality declines following acquisitions. In a similar vein, other scholars have found that the impact of acquisitions on a firm's innovation outcomes is highly dependent on its post-merger integration strategy, especially whether the acquired business is fully integrated into the acquiring firm or left as a stand-alone entity (Gulati & Puranam, 2009; Puranam et al., 2006). Thus, a comparison of these findings to our results in this paper yields two key insights. First, while acquisitions appear to promote the production of a greater number of inventions that may or may not be of higher quality, divestitures reduce the quantity of inventions produced but improve their quality. Second, the impact of acquisitions on innovation depends on how the acquired business is integrated into the acquiring firm, which is clearly not an issue for divestitures. Thus, our paper highlights that within a firm's corporate strategy toolkit, divestitures fulfill a very different function than acquisitions. Namely, divestitures are a valuable approach for firms seeking to unlock the full potential of their existing knowledge to create more novel inventions, whereas acquisitions may be preferable for firms looking to incorporate new knowledge into their organizations to increase invention output.

The idea that divestitures make firms "lean and mean" when it comes to innovation also contributes to the innovation literature. Existing research suggests that large organizations are often hamstrung by inertia stemming from codified routines and processes (Nelson & Winter, 1982), social and financial pressures that constrain decision-making (Cyert & March, 1963;

Eisenhardt & Bourgeois, 1988), and implicit and explicit resistance from both internal and external stakeholders (Christensen & Bower, 1996). As a result, it may be difficult for organizations to change the novelty associated with their inventions or accelerate the progression of inventions through development using regular business processes. Divestitures can spur exactly these kinds of changes by helping firms to focus their resources and take greater risks with respect to their selection of projects. This insight is important because it illustrates that divestitures can help firms overcome inertia in their innovation processes.

Beyond these ideas, our analyses of the two moderators we have explored in our work also offer some unique insights to both the innovation and corporate strategy literatures.

First, our findings that R&D intensity and R&D centralization each amplify the relationship between divestitures and invention novelty speak to a key debate that exists within the innovation literature (Argyres, Rios, & Silverman, 2020; DeSanctis et al., 2002; Kapoor & Lim, 2007; Lerner & Wulf, 2007). While the knowledge-based view of the firm holds that firms should seek to optimize the recombination of their knowledge to enhance their innovation outcomes (Argyres et al., 2020; Fleming, 2001; Fleming & Sorenson, 2004; Grant, 1996), the incentives-based view of the firm holds that firms should seek to optimize managerial incentives in order to do so (Lerner & Wulf, 2007). On the one hand, our finding that higher R&D intensity promotes the application of the resources that are freed up by divestitures to the creation of more novel inventions is consistent with the knowledge-based perspective: when firms have a higher R&D intensity, they have greater absorptive capacity, which enables them to explore the broader knowledge combinations that yield more novel inventions (Cohen & Levinthal, 1990; Fabrizio, 2009). But, on the other hand, our arguments that higher R&D intensity and R&D centralization prompt divesting firm managers to pursue novel rather than incremental inventions equally lend support

to the incentives-based view by showing that the manner in which managers allocate their efforts shapes firms' innovation outcomes (Lerner & Wulf, 2007). These two points illustrate that firms must consider *both* perspectives if they are to create novel inventions (Argyres, Felin, Foss, & Zenger, 2012; Argyres & Zenger, 2012; Eggers & Kaul, 2018).

Second, our finding that R&D centralization enhances the benefits of divestitures for invention novelty highlights the intricate relationship between the internal and external boundaries of the firm. The literatures on organization design and corporate strategy have largely remained separate from one another, with the former exploring internal boundary decisions such as the structure of R&D units (Argyres & Silverman, 2004), the relationship between the corporate center and international subsidiaries (Rugman & Verbeke, 2001) and the degree of divisionalization within firms (Argyres, 1996), and the latter considering the antecedents and consequences of external boundary decisions such as M&A, alliances, and divestitures (Feldman, 2014; Kale & Singh, 2009; Puranam et al., 2006). A few prior studies have examined the relationship between internal organization design and external firm boundaries, finding that firms that are more decentralized tend to undertake more acquisitions (DeSanctis et al., 2002) and to have richer communications with alliance partners (Badir, Büchel, & Tucci, 2009), while firms with centralized R&D are more likely to form strategic alliances (Badir et al., 2009; Zhang, Baden-Fuller, & Mangematin, 2007). While these studies have focused on how internal design choices can shape the *propensity* of firms to undertake corporate strategies, our work instead illustrates how internal design elements *interact with* corporate strategies to influence firm outcomes. This distinction is important because it underscores the point that organization design choices are not only an antecedent of corporate strategy decisions, but rather that these two forms of decision-making are closely intertwined.

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Table 1: Summary of divestiture rationales

Primary Rationale	Unrelated	Related	Total
Focus	21 (50%)	9 (21%)	30 (71%)
Funding	3 (7%)	3 (7%)	6 (14%)
Legal	0 (0%)	4 (10%)	4 (10%)
Underperforming	1 (2%)	1 (2%)	2 (4%)
Total	**25 (60%)**	**17 (40%)**	**42 (100%)**

Table 2: Regression analyses (Hypotheses 1, 2, and 4)

	Model 1	Model 2	Model 3
Dependent Variable	**Invention Quantity (H1)**	**Invention Novelty (H2)**	**Development Progress (H4)**
Model	**Negative Binomial**	**Fractional Logit**	**Negative Binomial**
Treat	**0.098**	**0.015**	**-0.053**
	(0.024)	**(0.576)**	**(0.146)**
After	**0.126**	**-0.075**	**-0.081**
	(0.028)	**(0.095)**	**(0.068)**
Treat x After	**-0.128**	**0.091**	**0.115**
	(0.025)	**(0.021)**	**(0.013)**
R&D Intensity	-0.393	0.313	1.010
	(0.181)	(0.266)	(0.046)
R&D Centralization	0.025	0.043	0.122
	(0.270)	(0.480)	(0.004)
R&D Functional Differentiation	0.022	0.053	0.080
	(0.584)	(0.229)	(0.210)
Corporate Decentralization	-0.019	-0.041	0.255
	(0.805)	(0.557)	(0.228)
Size	-0.155	-0.025	-0.064
	(0.082)	(0.792)	(0.635)
Patent Stock	0.000	-0.000	0.000
	(0.000)	(0.174)	(0.070)
New CEO	-0.023	-0.039	0.029
	(0.475)	(0.206)	(0.483)
Performance	-0.563	1.005	-0.087
	(0.105)	(0.084)	(0.900)
SG&A	0.073	0.014	0.223
	(0.345)	(0.903)	(0.155)
M&A Quantity	-0.041	0.025	0.030
	(0.002)	(0.285)	(0.047)
SBU Count	0.161	0.039	-0.238
	(0.024)	(0.558)	(0.065)
Technical Diversity	-0.718	0.262	2.181
	(0.127)	(0.399)	(0.062)
Unrelated	-0.033	0.023	-0.005
	(0.041)	(0.232)	(0.859)
Portfolio size	-0.000	-0.000	0.003
	(0.403)	(0.845)	(0.002)
External Portfolio Proportion	0.075	-0.134	-0.287
	(0.742)	(0.547)	(0.444)
NCE Portfolio Proportion	-0.485	0.668	-0.292
	(0.217)	(0.177)	(0.675)
Bio Portfolio Proportion	-0.570	1.005	0.425
	(0.096)	(0.072)	(0.631)
Development Portfolio Novelty	0.236	0.761	-0.113
	(0.432)	(0.131)	(0.855)
Year Fixed effects	Y	Y	Y
Firm Fixed-effects	Y	Y	Y
Business Portfolio Fixed effects	Y	Y	Y
N	368	366	368
Log Likelihood	-1967.129	-156.674	-998.957

p-values in parentheses. Errors clustered at firm-level. N is above 365 due to some control observations having higher weightings when they match to more than one treated observation.

Table 3: Regression analyses (Hypotheses 3a and 3b)

DV=Invention Novelty	**Model 1**	**Model 2**
Hypothesis	**3a**	**3b**
Moderator	**R&D Intensity**	**R&D Centralization**
Treat	0.410 (0.025)	-0.017 (0.872)
After	0.467 (0.015)	-0.055 (0.092)
Treat x After	-0.392 (0.027)	-0.046 (0.380)
Moderator	3.725 (0.024)	-0.027 (0.811)
Moderator x Treat	-2.911 (0.030)	0.030 (0.779)
Moderator x After	-3.827 (0.010)	-0.022 (0.602)
Moderator x Treat x After	**3.415** **(0.012)**	**0.156** **(0.054)**
Structural controls	Y	Y
Firm-level controls	Y	Y
Diversification controls	Y	Y
Divestiture type controls	Y	Y
Development Portfolio controls	Y	Y
Year Fixed effects	Y	Y
Firm Fixed-effects	Y	Y
Business Portfolio Fixed effects	Y	Y
N	366	366
Log Likelihood	-156.591	-156.667

p-values in parentheses. Errors clustered at firm-level. All regressions are Fractional Logit regressions.
N is above 365 due to some control observations having higher weightings when they match to more than one treated observation.

Table 4: Post-hoc analyses

Model	**Model 1 NB**	**Model 2 FL**	**Model 3 FL**	**Model 4 NB**	**Model 5 NB**	**Model 6 NB**
Dependent Variable	**M&A Quantity**	**Invention Novelty**	**Invention Novelty**	**Dev. Progress**	**Progress01**	**Progress12**
Moderator		**Unrelated**	**Divestiture Value**	**Divestiture Value**		
Treat	-0.038 (0.769)	0.062 (0.147)	0.008 (0.877)	0.113 (0.344)	-0.058 (0.379)	-0.056 (0.315)
After	-0.199 (0.086)	0.076 (0.111)	0.141 (0.070)	0.104 (0.258)	-0.068 (0.310)	-0.152 (0.030)
Treat x After	0.354 (0.029)	-0.100 (0.069)	-0.139 (0.081)	-0.056 (0.593)	0.126 (0.075)	0.117 (0.208)
Moderator x Treat		-0.099 (0.025)	0.037 (0.085)	-0.076 (0.217)		
Moderator x After		-0.263 (0.011)	-0.039 (0.082)	-0.060 (0.086)		
Moderator x Treat x After		0.325 (0.006)	0.047 (0.044)	0.055 (0.136)		
Other independent variables	Y	Y	Y	Y	Y	Y
Structural controls	Y	Y	Y	Y	Y	Y
Firm-level controls	Y	Y	Y	Y	Y	Y
Diversification controls	Y	Y	Y	Y	Y	Y
Development Portfolio controls	Y	Y	Y	Y	Y	Y
Year Fixed effects	Y	Y	Y	Y	Y	Y
Firm Fixed-effects	Y	Y	Y	Y	Y	Y
Business Portfolio Fixed effects	Y	Y	Y	Y	Y	Y
N Log Likelihood	368 -350.9	366 -156.645	277 -118.082	278 -742.379	368 -890.1	368 -691.8

p-values in parentheses
FL- Fractional Logit Model; NB – Negative Binomial Models
Errors clustered at firm-level

Table 4: Post-hoc analyses (Continued)

Model	**Model 7 NB**	**Model 8 NB**	**Model 9 NB**	**Model 10 NB**	**Model 11 NB**	**Model 12 NB**
Dependent Variable	**Progress23**	**Progress3N**	**Dev. Progress**	**Sales from Top Product**	**Sales from Top 2 Products**	**Sales from Top 3 Products**
Moderator			**Dev. Portfolio Novelty**			
Treat	-0.068 (0.366)	-0.086 (0.174)	-0.271 (0.338)	-0.072 (0.023)	-0.079 (0.011)	-0.065 (0.047)
After	0.061 (0.514)	-0.193 (0.082)	-0.103 (0.786)	-0.056 (0.004)	-0.058 (0.017)	-0.051 (0.099)
Treat x After	-0.040 (0.687)	0.248 (0.023)	0.242 (0.604)	0.082 (0.033)	0.093 (0.028)	0.087 (0.064)
Moderator x Treat			0.253 (0.486)			
Moderator x After			0.019 (0.972)			
Moderator x Treat x After			-0.160 (0.797)			
Other independent variables	Y	Y	Y	Y	Y	Y
Structural controls	Y	Y	Y	Y	Y	Y
Firm-level controls	Y	Y	Y	Y	Y	Y
Diversification controls	Y	Y	Y	Y	Y	Y
Development Portfolio controls	Y	Y	Y	Y	Y	Y
Year Fixed effects	Y	Y	Y	Y	Y	Y
Firm Fixed-effects	Y	Y	Y	Y	Y	Y
Business Portfolio Fixed effects	Y	Y	Y	Y	Y	Y
N	368	368	368	368	368	368
Log Likelihood	-557.0	-575.3	-1004.0	-2911.8	-2974.7	-3050.7

p-values in parentheses
FL- Fractional Logit Model; NB – Negative Binomial Models
Errors clustered at firm-level