REGIONALIZATION OF R&D ACTIVITIES: (DIS)ECONOMIES OF INTERDEPENDENCE AND INVENTIVE PERFORMANCE

ABSTRACT

This paper examines the impact of the extent of the regionalization of MNEs' R&D activities on their inventive performance. By joining the regionalization theory with the recombinant view of invention, we challenge the implicit assumption that all foreign knowledge-seeking activities will necessarily offer new knowledge to the firm. We introduce the (dis)economies of interdependence, defined as the (dis)advantages that the firm derives due to the interdependence among countries within a region, as a new theoretical mechanism explaining the benefits and costs of regionalization. Our analysis of global pharmaceutical firms shows an inverted U-shaped relationship exists between the number of regions in which a firm has R&D activities and its inventive performance. Our results also indicate that a firm's recombinant capability moderates the inverted U-shaped relationship in such a way that when a firm's recombinant capability is high, it reaches its turning point at a larger number of regions and the inverted U-shaped relationship is flatter. These results underscore that recombinant capability significantly influences the firm's ability to derive benefits and reduce costs from the regionalization of R&D activities. Our findings suggest that it is through the consideration of the (dis)economies of interdependence that offers the essential reasoning needed to unwind the inferred assumption that all foreign knowledge-seeking activities will offer access to new knowledge.

Keywords: regionalization, R&D activities, (dis)economies of interdependence, inventive performance

INTRODUCTION

In their watershed study, Rugman and Verbeke (2004) challenged the notion of firm globalization and empirically showed that most of the world's 500 largest firms operate regionally, not globally. More specifically, the authors identified that over 80% of those 500 firms had concentrated their sales within their home region of the triad. A subsequent stream of research examining the regional nature of firm internationalization flourished following their 2004 study. Now, over a decade later, Rugman and Verbeke's once controversial conclusion is well received, as the emerging consensus among scholars is that most multinational enterprises (MNEs) are *regional* in their extent of internationalization[1] (Banalieva & Dhanaraj, 2013).

The Rugman and Verbeke (2004) hypothesis of regionalization has continued to open up new areas of research.[2] These include the examination of regionalization's implication on firm financial performance. For example, Qian, Li, Li, and Qian (2008) investigated and found that different degrees of regional diversification affect firm financial performance. Further exploring the relationship between regionalization and firm financial performance, Qian, Khoury, Peng, and Qian (2010) extend the examination to include both *intra*- and *inter*-regional diversification. More recently, in their studies on the relationship between home region orientation and firm financial performance, Banalieva and colleagues drew on firm sales to identify firm financial performance implications from regionalization (Banalieva & Dhanaraj, 2013; Banalieva & Eddleston, 2011).

Clearly, existing studies on the regionalization of firms' sales and its implications on firm financial performance have considerably advanced our understanding of this significant phenomenon. We offer key observations across the extant work on regionalization. First, there is still an important link missing between regionalization and firm financial performance. Recent research highlights that as technological life cycles grow progressively shorter and more industries demand that firms invent on the global frontier, a firm's ability to generate inventions plays an ever-increasing key role in its competitiveness and financial performance (Banbury & Mitchell, 1995; Geroski, Machin, & Van Reenen, 1993; Roberts,

1999; Roberts & Amit, 2003; Sharma & Lacey, 2004; Sood & Tellis, 2009, *inter alia*). Yet, we have limited understanding of the relationship between regionalization and firm *inventive* performance, which would, in turn, have important implications on firm financial performance. Indeed, the increased significance of a firm's inventiveness identified by recent research elevates its already vast stature in the literature, as a firm's ability to generate inventions has long been identified as one of the most important determinants of firms' supra-normal profitability (Schumpeter, 1942). It is therefore imperative to examine the impact of the extent of firm regionalization on inventive performance.

This foregoing discussion prompts our second observation. Previous research has primarily focused on the regionalization of *downstream* activities (sales) and its implications on firm *financial* performance, leaving the regionalization of *upstream* activities and its implications on *inventive* performance less illuminated. As the firm's upstream activities, especially the research and development (R&D) activities, drive its ability to generate inventions, this shift of focus in the firm's value chain from the downstream to the upstream offers new insights into addressing the unexamined link. By nature, these are different areas of the value chain (downstream sales versus upstream R&D) and require separate consideration. In summary, investigating the relationship between the regionalization of R&D activities and a firm's inventive performance may contribute new insights to understanding the missing link. Such an investigation, in turn, opens a new area of research to further extend Rugman and Verbeke's (2004) seminal line of inquiry on regionalization to the domain of technological innovation.

Toward this end, drawing on the regionalization theory and the recombinant view of invention, we introduce a new concept of (dis)economies of interdependence, and build our theoretical framework focusing on the benefits and costs of crossing *regional boundaries* for R&D activities and their implications on inventive performance. We define the (dis)economies of interdependence as the (dis)advantages that the firm derives due to the interdependence among countries within a region.

We empirically test our theoretical predictions through an analysis of the R&D activities of 154 global pharmaceutical firms operating in 18 regions over a 9-year time period. In order to thoroughly examine firms' R&D activities, we use a unique dataset covering every R&D activity in the drug

discovery and development process conducted by global pharmaceutical firms. We also utilize 18 regions classified in the United Nations Statistics Division's (UNSD) region classification system (Arregle, Beamish, & Hébert, 2009; Arregle, Miller, Hitt, & Beamish, 2013).

We find that an inverted U-shaped relationship exists between the number of regions in which a firm has R&D activities and its inventive performance. Our results also indicate that a firm's recombinant capability moderates the inverted U-shaped relationship in such a way that when a firm's recombinant capability is high, it reaches its turning point at a larger number of regions and the shape of the inverted U-shaped relationship is flatter. These results underscore that recombinant capability significantly influences the firm's ability to derive benefits and to reduce costs from regionalization of R&D activities.

This paper contributes to the regionalization literature by further extending Rugman and Verbeke's (2004) seminal line of inquiry. To begin with, we extend the regionalization hypothesis to the domain of technological innovation. Whereas previous studies primarily focused on downstream activities and firm financial performance, we investigate regionalization of firms' upstream R&D activities and their implications on inventive performance.

Second, in doing so, we combine theories of regionalization and technological innovation, whose synergistic outcome provides more insightful understanding of the phenomenon than any one singular theory can provide. By joining the regionalization theory with the recombinant view of invention, we challenge the implicit assumption that all foreign knowledge-seeking activities will necessarily offer new knowledge to the firm. We introduce (dis)economies of interdependence as a new theoretical mechanism and reveal why this inferred assumption of offering new knowledge in the literature might not necessarily be the case. By the fusion of these two theories, we derive the unique insight that regional commonalities may include common knowledge and suggest that there will be greater knowledge heterogeneity *across* regions than *within* a region. Moreover, our drawing together of regionalization theory with the recombinant view of invention offers a way to resolve the inconsistent findings across the handful of studies examining how the internationalization of R&D activities affects firms' *overall* inventive performance.

Third, we contribute toward an understanding of how the regionalization of firms' R&D activities affects their inventive performance. In doing so, we offer an important first step in uncovering the link that is missing between regionalization and firm financial performance. As a firm's inventiveness continues to play an increasingly essential role in its competitiveness and financial performance, our study on the relationship between regionalization and firm inventive performance offers new insights into the value-creating process leading to firm financial performance.

It is our hope that these contributions position our study as one of the first of further studies to continue to expand the scope of Rugman and Verbeke's (2004) pivotal line of inquiry on regionalization to the domain of technological innovation. Our theoretical framework and empirical results highlight the need for an integrative approach to theory development, emphasizing the need for stronger linkages between regionalization, inventive performance, and the international R&D literatures. We suggest that a deeper consideration of the firm's inventive processes where regionalization is included in the analyses can greatly enhance our understanding of the underlying mechanisms governing multiple research domains.

The paper continues as follows. In the next section, we develop our theory and hypotheses. The section thereafter describes our data, sample, measures, and empirical specification. We then detail our statistical results. The final section concludes by discussing this study's theoretical contributions, managerial implications, limitations, and future directions.

THEORY AND HYPOTHESES

The theoretical focus of our paper is firms' regionalization of their R&D activities and its implications on inventive performance. As such, we build our theoretical framework on the important distinction in the literature between *invention* and *innovation* (Ahuja & Lampert, 2001; Fleming, 2001; Hitt, Hoskisson, & Nixon, 1993; Kim & Pennings, 2009; Roberts, 2007; Schumpeter, 1939). Scholars have aptly explicated the difference, where invention refers to the development of a new idea (the R&D processes), while innovation includes not only the R&D processes but also the commercialization processes in the launch of new products (Kim & Pennings, 2009). To put it another way, Roberts (2007)

elucidates that "*innovation is composed of two parts: (1) the generation of an idea or invention, and (2) the conversion of that invention into a business or other useful application…innovation [includes] all of the stages from the technical invention to final commercialization*" (Roberts, 2007: 36, italics in original). In our work here, we focus on the relationship between the regionalization of firms' R&D activities and inventive performance. Therefore, we direct our attention to theorize on the regionalization of firms' R&D processes, rather than their commercialization processes.

Seeking New Knowledge to Address Technological Exhaustion

The recombinant view of invention posits that invention occurs through recombining knowledge in novel ways (Fleming, 2001; Henderson & Clark, 1990; Kogut & Zander, 1992; Leiponen & Helfat, 2010; Nelson & Winter, 1982; Schumpeter, 1939). Namely, invention often results as firms experiment to find valuable recombinations by varying the configuration of their existing components and by introducing new components. Schumpeter details that the innovative process through recombination "combines components in a new way, or that it consists in carrying out New Combinations" (1939: 88). However, as firms continue to experiment with a given set of components, invention subsequently declines because firms overly repeat and deplete recombinant opportunities. Fleming (2001) terms this phenomenon as *technological exhaustion*, brought about by the continued reuse of a set of components after the identification of most recombination possibilities. Similarly, Kim and Kogut (1996: 285) describe how "[t]he repeated application of a particular set of technologies or organizing principles eventually exhausts the set of potential combinations" thereby leading to decreasing returns. Thus, to avoid such exhaustion, firms will need to seek new knowledge to fuel the opportunity set of components available for recombination in their inventive process (Ahuja & Lampert, 2001).

Indeed, access to new knowledge is a major factor in motivating firm internationalization of innovative activities (Almeida & Phene, 2004; Cantwell, 1989; Chung & Alcacer, 2002; Contractor, 2012; Doz & Wilson, 2012; Dunning, 1996; Florida, 1997; Kogut & Chang, 1991; Kuemmerle, 1997, *inter alia*). Inquiry into this area is fundamental to the theory of the MNE as extant research describes MNEs' unique role of gaining new knowledge and capabilities in foreign locations and transferring this

knowledge across borders to be shared throughout the organization as a basis of value creation and competitive advantage for the MNE (Archibugi & Michie, 1995; Bartlett & Ghoshal, 1989; Cantwell, 1989; Kogut & Zander, 1993; Teece, 2014).

While theoretical development of the knowledge-seeking motivation has greatly expanded, empirical confirmation has been sparse.[3] In addition, although few studies confirm the success of MNEs' foreign *subsidiaries* in seeking knowledge in a foreign location, we have limited understanding of how the internationalization of R&D activities affects firms' *overall* inventive performance. Namely, despite the literature underlining the theoretical importance of external knowledge, the verification of whether and how the extent of firm internationalization of R&D activities may influence inventive outcomes is scarce. Moreover, the limited number of studies examining firms' *overall* inventive outcomes have yielded conflicting findings. Specifically, studies have found that firm internationalization of R&D activities leads to a decrease in the quality of the inventive output (Singh, 2008), to an increase followed by a decrease in the quality of inventive output (Lahiri, 2010), and to an increase in inventive output (Penner-Hahn & Shaver, 2005).

(Dis)economies of Interdependence

One possible reason for the inconsistent findings in the papers discussed above may be that, while it is the assumption that the internationalization of inventive activities offers new knowledge to the firm, this might not necessarily be the case. More specifically, not all foreign knowledge-seeking investment will provide equal opportunity for accessing new knowledge. This is because regions, defined as groupings of countries in geographic proximity, share commonalities (Ghemawat, 2005). As such, firm internationalization of R&D activities all within one region will have probabilities of accessing new knowledge different from firm internationalization of R&D activities across multiple regions.

Specifically, regionalization theory, with underpinnings from semi-globalization,[4] argues that firms face opportunities and limitations at the regional level as global evaluation exposes an intermediate state where colligations of countries are regionally well-integrated (Flores & Aguilera, 2007; Ghemawat, 2003, 2005, 2007; Kim & Aguilera, 2015; Rugman & Verbeke, 2004, 2007, *inter alia*). Regionalization theory posits

that because countries within a region are well-integrated, firms can enact regional strategies that take advantage of the *interdependence* between countries within a region. To that point, firms can take advantage of cultural, administrative, geographic, and economic proximity within regions (Ghemawat, 2005). Moreover, "these four factors are interrelated: Countries that are relatively close to one another are also likely to share commonalities along other dimensions…those similarities have intensified in the past few decades through free trade agreements, regional trade preferences and tax treaties, and even currency unification" (Ghemawat, 2005: 100). Thus, the benefits offered by regions are not just the sum of the countries within a region as the shared commonalities create synergies thereby elevating regional benefits further (Flores & Aguilera, 2007; Ghemawat, 2003; 2005; Kim & Aguilera, 2015; Rugman & Verbeke, 2004; 2007, *inter alia*).

We offer the observation that previous studies on the regionalization of downstream activities have largely focused on the economies of interdependence. Firms can leverage their resources across a collection of well-integrated countries within a region to gain significant synergistic benefits from the interdependence. As such, we submit that previous studies emphasize the benefits of staying in one's home region to enjoy the economies of interdependence (Banalieva & Dhanaraj, 2013; Banalieva & Eddleston, 2011; Qian, et al., 2010).

However, we advance that the *dis*economies of interdependence can matter in regionalization, in addition to the economies of interdependence, especially in the context of the regionalization of R&D activities. The interdependence, although a great source of commonality, can perpetuate knowledge homogeneity. For instance, regional science consortiums, regional industry technology associations, regional technology initiatives supported by a regions' universities, regional research institutes, and the movement of scientists, engineers, and professors within the region offer knowledge-sharing opportunities and stimuli that may increase the likelihood that some knowledge is common across a region (Almeida & Kogut, 1999; Kuemmerle, 1997, 1999). Consequently, there will be greater knowledge homogeneity *within* a region than *across* regions. For that reason, firms may enjoy economies of interdependence when operating within a region, because they incur fewer costs to coordinate and

integrate the homogeneous knowledge. However, firms may experience *dis*economies of interdependence when operating within a region, because they are not likely to access less redundant and more heterogeneous knowledge, a necessary component for invention (Schumpeter, 1939). As such, the greater a firm's internationalization of R&D activities *across* regions, the greater the likelihood the firm will be accessing new knowledge to stock its opportunity set of components available for recombination in its inventive process; however, at the same time, the costs are greater to coordinate and integrate the newly gained heterogeneous knowledge. Accordingly, both economies and diseconomies of interdependence *matter,* especially in the relationship between regionalization and inventive performance.

Despite the importance of both the economies and diseconomies of interdependence, previous studies on the regionalization of downstream activities focus primarily on economies of interdependence and emphasize the importance of firm internationalization *within* a region, or *intra-regionalization*. However, explicit consideration of the (dis)economies of interdependence offers the critical insights necessary to relax the implicit assumption that all foreign knowledge-seeking activities offer access to new knowledge, especially in the context of the intra-regionalization of R&D activities.[5] We posit that one of the key factors that determine whether the internationalization of R&D activities offers new knowledge to the firm will depend on the extent of the firm's internationalization *across* regions, or *inter-regionalization*.

Benefits and Costs of Regionalization of R&D Activities

The foregoing discussion highlights the benefits and costs of conducting R&D activities *across* regions. First, it is more likely for firms to access less redundant knowledge when operating *across* regions than *within* a region. However, in addition to the benefits of accessing less redundant knowledge, firm internationalization of R&D activities *across* an increasing number of regions can also incur substantial costs. More specifically, each additional R&D activity across regions entails capital expenditures, coordination costs, and integration costs due to the lack of interdependence among countries in the existing and new regions. We refer to these three factors collectively as recombinatory costs. First, a firm might be incurring significant costs and sacrificing economies of scale in its internationalization of R&D activities across multiple regions. R&D activities require a significant amount of capital. Moreover, many

of these expenditures have a significant fixed-cost component. The presence of such fixed costs increases the attractiveness of pursuing additional projects in the same research location, as the already incurred fixed costs can amortize over the larger activity base. In contrast, largely due to regional differences and, thus, lack of interdependence among countries across regions, entering multiple regions requires new, significant investments in additional equipment and personnel. Furthermore, such investments may entail a certain lumpiness due to indivisibility (Penrose, 1959). The setting up of a new research laboratory or project may not be subdividable beyond a point (Lampert & Kim, 2019). For example, a full-functioning, new laboratory may be required even for a small project. For these reasons, firm internationalization of R&D activities beyond a certain number of regions may bring excessive costs and forsake scale benefits.

Second, coordination across multiple regions might be extremely challenging. To this point specifically, the absolute number of regions to orchestrate across could be large, intensifying the task further. In addition, some regions may fall into the "hassle" category, making it more difficult to coordinate across because of significant differences in language, time zones, and geographic barriers (Schotter & Beamish, 2013).

Third, the technological knowledge gained in the host region might hold tremendous value for the organization, but integrating and transferring such tacit knowledge for use throughout the organization is an extremely difficult task that the literature well documents (Kogut & Zander, 1993; Leonard–Barton, 1995; Nonaka & Takeuchi, 1995; Szulanski, 1996; Teece, 2014; Teece, Pisano, & Shuen, 1997). Furthermore, research has detailed complications arising from foreign subsidiaries hoarding knowledge for greater power in the organization to challenges arising from multiple embeddedness (Meyer, Mudambi, & Narula, 2011; Mudambi & Navarra, 2004; Mudambi, Pedersen, & Andersson, 2014; Narula, 2014).

In summary, new knowledge is a necessity in the recombinant view of invention to address technological exhaustion. Regionalization theory offers a view into the *knowledge structure of the world*. Due to the interdependence among the countries within a region, increasing firm internationalization of R&D activities across regions can improve the likelihood that the firm indeed accesses less-redundant

and, thus, new knowledge. However, firm internationalization of R&D activities across an increasing number of regions can also incur substantial recombinatory costs, due to the *lack* of interdependence among countries across regions. We maintain that the benefits of new knowledge for recombination will increase with the number of regions, but at a decreasing rate as the marginal benefit of each additional region drops. On the other hand, recombinatory costs grow at an increasing rate as the number of regions increase because the coordination and integration costs increase exponentially (Ahuja & Katila, 2001; 2004; Lee & Kim, 2016). Accordingly, we hypothesize:

Hypothesis 1: There is an inverted U-shaped relationship between the number of regions in which a firm has R&D activities and its inventive performance.

The Moderating Role of Recombinant Capability

The foregoing discussion details our recombinant view of inventive performance hypothesis where we develop a theoretical framework detailing the (dis)economies of interdependence and the subsequent benefits and costs of operating in multiple regions to firm inventive performance. In our framework, we posit that firm internationalization of R&D activities across multiple regions can increase the likelihood that the firm will tap into heterogeneous and, thus, new knowledge, thereby providing recombinant benefits. However, each additional R&D activity across regions entails recombinatory costs.

Drawing on both regionalization theory and the recombinant view of invention, we further theorize that the extent of the benefits and costs of operating across multiple regions depends on a firm's recombinant capability. We combine these two complementary streams to better theorize on the role of recombinant capability in shaping the geographic scope of firms' R&D activities to address the technological exhaustion in recombinant invention. First, in the recombinant view of invention, recombinant capability is defined as the firm's ability to recombine knowledge components to generate inventions. Indeed, prior work suggests that a firm's recombinant capability is one of the key determinants of its inventive performance (Carnabuci & Operti, 2013; Fleming, 2001; Henderson & Clark, 1990; Kogut & Zander, 1992; Schumpeter, 1934; Yayavaram & Ahuja, 2008; Yayavaram & Chen, 2015, *inter alia*).[6]

Second, regionalization theory articulates that the MNEs' capability to link their firm-specific advantages (FSAs) with location-specific advantages (LSAs), or *recombinant capability*, determines their geographic scope (Rugman & Verbeke, 2005; Verbeke & Forootan, 2012). The literature on regionalization theory offers that, "most MNEs are simply not capable of deploying and exploiting their firm-specific advantages (FSAs) around the world in an indiscriminate fashion" (Rugman and Verbeke, 2007; 201), due to the fact that MNEs face "difficulties in transferring, deploying and recombining FSAs across regional borders" (Verbeke & Kano, 2012: 136). In this light, "*the liability of intra-regional expansion appears to be much lower than the liability of inter-regional expansion*: the additional costs of doing business abroad are often much higher when venturing into other regions of the world than when expanding intra-regionally" (Rugman & Verbeke, 2007: 201, italics in original). This observation is central to the explanation of the phenomenon of regionalization, in which MNEs' recombinant capability plays a critical role in determining their geographic scope.

We maintain that firms with greater recombinant capabilities are likely to derive greater benefits yet incur fewer costs from a given number of regions in which the firm has R&D activities. First, we theorize that the firm's recombinant capability and the firm's attainment of the advantages that come from the new knowledge by operating across multiple regions are closely related. This helps the firm to better utilize the new, foreign knowledge accessed at a given number of regions for recombination in its R&D process. Other things being equal, firms with greater recombinant capabilities will have had greater exposure to the recombinant activity, thereby improving their productivity with the recombinant process of invention at a given number of regions. Second, in addition to the greater benefits, these firms are likely to incur fewer costs from a given number of regions in which the firm has inventive activities. Greater recombinant capabilities indicate that the firm is more efficient in the coordination and integration of new knowledge, which can serve as the basis for minimizing two of the three costs that constitute recombinatory costs. In other words, greater recombinant capabilities can lessen both coordination costs and integration costs so that both are limited.

On the basis of the foregoing discussion, we submit that a firm's recombinant capability moderates the inverted U-shaped relationship in such a way that firms with a higher level of recombinant capability can enjoy higher benefits and lower costs; thus, they are able to conduct their R&D activities across a larger number of regions, which would, in turn, change the turning points of the inverted U-shaped relationship to be at a larger number of regions. Accordingly, we hypothesize:

Hypothesis 2a: With increasing levels of recombinant capability, the turning points of the inverted U-shaped relationship will be at a larger number of regions.

Once passing the turning point, increases in the number of regions would be detrimental for inventive performance. The detrimental effect will be larger for firms with a lower level of recombinant capability, as they face a higher level of costs to process the additional new knowledge from the region. As such, when recombinant capability is *low*, increases in the number of regions beyond the turning point would decrease the firm's inventive performance *more* steeply as it increases the processing costs more drastically, thus steepening the inverted U-shaped relationship. When recombinant capability is *high*, increases in the number of regions beyond the turning point will decrease the firm's inventive performance *less* steeply, thus flattening the inverted U-shaped relationship.

Hypothesis 2b: With increasing levels of recombinant capability, the shape of the inverted U-shaped relationship will be flatter.

DATA AND METHODS

Sample

The empirical setting of our research is the global pharmaceutical industry. This research setting is appropriate to test the hypotheses for several reasons. First, it is decidedly a global industry with innovative activities widely internationalized. Accordingly, this industry offers, arguably, an ideal empirical context to test the theory on the impact of the extent of the regionalization of R&D activities on inventive performance. Second, the global pharmaceutical industry is technology intensive. According to the National Science Foundation (NSF), in 2003 the U.S. pharmaceutical industry invested over $17

billion in R&D, almost more than any other industry in the United States (CBO Report, 2006). The pharmaceutical industry's key trade organization, *Pharmaceutical Research and Manufacturers of America* (PhRMA), reported that in 2004 its members invested over $39 billion in R&D (CBO Report, 2006; PhRMA, 2015). The differences between NSF and PhRMA estimates of R&D spending are due to the fact that NSF's totals only cover domestic R&D spending, whereas PhRMA's totals include expenditures in the United States and abroad (CBO Report, 2006). Third, the global pharmaceutical industry maintains a highly structured innovative process with clearly defined steps regulated by governmental authorities. Such highly detailed information on the innovative process enables us to distinguish and analyze the discrete R&D steps of the industry's value chain. Fourth, we need to be able to measure firms' overall inventive performance across multiple regions instead of being limited to local subsidiaries or individual units of the firm. The global pharmaceutical industry, by its very nature, has a presence in multiple regions for its R&D activities. Thus, this allows us to investigate the relationship between the extent of the regionalization of R&D activities and inventive performance. In sum, the global pharmaceutical industry comprises an attractive empirical setting for our research and is an industry in which we can empirically observe relevant aspects of our theory.

We tested the hypotheses of the study with longitudinal data on the R&D activities of the leading global pharmaceutical firms during the time period of 1997 to 2005. We identified the leading players in the global pharmaceutical industry using lists published annually by private research companies such as *IMS Health*, the industry's key trade organization *PhRMA*, popular press outlets such as *Forbes*, and the industry's trade journals such as *Pharmaceutical Executive*. After compiling and consolidating the lists, we merged the result with financial data. We were able to obtain information on 154 of the leading, public global pharmaceutical firms for our final analysis. We employed *Compustat*, annual reports, and trade publications to obtain financial data. We researched each firm's history, including all of the divisions and subsidiaries of the parent firms using *Who Owns Whom* (published by GAP Books in association with Dun & Bradstreet), *The Directory of Corporate Affiliations,* LexisNexis, and each firm's website, to ensure that we accounted for all of the firm's entities. Table A1 in the Appendix lists details regarding our

sample firms. Specifically, Panel (a) shows the home countries of our sample firms and Panel (b) lists the regions in which our sample firms conduct R&D activities. To the best of our knowledge, this is one of the largest and most geographically rich samples studied in the global pharmaceutical industry to date.

For information on firms' R&D activities, we utilized the *AdisInsight* database (Danzon, Nicholson, & Pereira, 2005; Girotra, Terwiesch, & Ulrich, 2007).[7] The *AdisInsight* database is a proprietary dataset created as a competitor analysis tool for pharmaceutical firms that compete in the global pharmaceutical industry. The *AdisInsight* database tracks all of the R&D activities involved in drug discovery and the development of firms as they pursue Food and Drug Administration (FDA) approval for their compounds *worldwide*. To clarify this further, geographically speaking, even though firms are pursuing FDA approval for their compounds, and where approval thereby allows them to commercialize their newly approved drug in the United States, firms may conduct R&D activity in the drug discovery and development process abroad pursuant to FDA approval. In addition, for approval to sell drugs in other countries, firms often need to comply with requisite drug discovery and development activities in the foreign country itself. The *AdisInsight* database tracks compounds through the drug discovery and development process pursuant to FDA approval by monitoring over 1,700 medical, pharmacological, and scientific publications, scientific meetings, direct company communications, annual reports, press releases, and Internet sources. It is from this detailed audit trail that we are able to determine the geographic location of the firms' R&D activities.

Figure 1 illustrates the value chain activities in the global pharmaceutical industry. As illustrated in the R&D process (inventive process), the *preclinical* stage is composed of various drug discovery activities while the *clinical* stage comprises three phases of drug development. We refer the reader to Girotra, Terwiesch, and Ulrich (2004) for a detailed description of the drug discovery and development process in the global pharmaceutical industry.

[Insert Figure 1 here]

Variables

Dependent variable

We employ *the number of successes in preclinical trials* to operationalize inventive performance. Specifically, in each year we count the number of compounds of a focal firm that have successfully advanced from the preclinical stage (animal trials) to the clinical stage (human trials). A compound[8] that reaches the clinical stage signals a major milestone in the inventive process and thus provides a good proxy to capture inventive performance (CBO Report, 2006; DiMasi, Hansen, & Grabowski, 2003; Giovannetti & Morrison, 2000; PhRMA, 2009). We base the calculation of the number of successful preclinical trials on pharmaceutical firms' global activities.

In the global pharmaceutical industry, a firm's success in drug discovery and development is paramount. Though long lead times, high costs, and low odds of success characterize product development in many industries, the global pharmaceutical industry takes it to an extreme.[9] In particular, as shown in Figure 1, advancement from the preclinical stage to the clinical stage maintains high levels of uncertainty and low odds of success.[10] A compound reaching the clinical stage is one of the most important milestones in the R&D process since only 10 of 10,000 compounds (0.1%) pass the preclinical stage and enter the clinical stage according to the FDA (2002).[11] We therefore measure inventive performance as the number of compounds of a focal firm that have successfully advanced from the preclinical stage to the clinical stage and, more specifically, reached Phase I of the clinical stage. We specify a one-year time lag between the dependent variable and independent variables.

Independent variable

We employ *the number of regions* in which a firm has R&D activities to operationalize the regionalization of the focal firm's R&D activities. In terms of regions, we follow the definition provided by Arregle and colleagues (2009: 88) of a "geographical conceptualization of a region, in which the physical continuity and proximity among countries of the grouping is emphasized" and is consistent with prior research (Arregle et al., 2009; Arregle et al., 2013; Buckley & Ghauri, 2004; Ghemawat, 2001, 2007; Khanna, Kogan, & Palepu, 2006; McNamara & Vaaler, 2000; Rugman & Verbeke, 2004, 2007). For the classification of the regions, we employ the United Nations Statistics Division's (UNSD) 'Standard country or area codes for statistical use (M49)' or the M49 standard (UNSD, 2017). Namely,

we used 18 of the regions classified in the M49 standard in which our sample firms have R&D activities with varying degrees. Table A1 Panel (b) in the Appendix lists the 18 regions used in the current study. Our employment of this classification is consistent with empirical research on firm internationalization (Arregle et al., 2009; Arregle et al., 2013).

Moderating variable

We operationalize the construct of *recombinant capability* with the diversity of the firm's knowledge base (Carnabuci & Operti, 2013) and measure it with the firm's diversity of compound-indication combinations. In the field of medicine, the definition of an indication is "a reason to prescribe a medication or perform a treatment. A bacterial infection may be an indication for the prescription of a specific antibiotic; appendicitis is an indication for appendectomy" (*Mosby's Medical Dictionary*, 9th edition. © 2009 Elsevier). A firm may seek the approval of a compound for multiple indications. As such, every compound-indication must submit to a separate clinical review. Each indication (health problem or disease), identified as likely to be benefited by a candidate medicine is studied in clinical trials. Once determined that such benefit is appropriate through approval by regulatory authorities, the medicine receives approval for a specified indication (*Segen's Medical Dictionary* © 2012 Farlex, Inc).

In general, measuring a firm's recombinant capability is difficult, as recombinant capabilities arise from the interaction of internal learning, external learning, and experience (Fleming, 2001; Henderson & Clark, 1990; Kogut & Zander, 1992, *inter alia*). A firm with greater recombinant capability is more likely to have accumulated greater learning, experience, and knowledge assets for recombination in its inventive process. Prior work on recombinant capability has used measures constructed through patent data, identifying the technology classes associated with patents to proxy for recombinant capability (Carnabuci & Operti, 2013). However, in the pharmaceutical industry, patents are, at best, an indirect measure of a firm's recombinant capability as pharmaceutical firms file patents to protect active ingredients, yet 1 in 5,000-10,000 active ingredients actually result in a successful drug (Abud, Hall, & Helmers, 2015). Thus, reflective of the incredible odds and great uncertainty, "many of these [patent] filings will either not be pursued, or if granted, will never be related to a marketed drug" (Abud et al., 2015: 3). Moreover, given

the tremendous distance that can exist in both the temporal and the technological space between a patent and a compound or an approved drug, we believe focusing on a firm's compound-indication combinations pursing FDA approval represents a more direct measure for recombinant capability.

In light of this, we believe there are two reasons that the diversity of compound-indication measure can effectively capture the recombinant capabilities. First, the diversity of the compound and indication suggests that the firm has a diverse knowledge base in the compound and indication spaces. Second, the various combinations between the compound and indications suggest that the firm has capabilities that enable it to recombine the compounds and indications in previously unused ways. Toward this end, we employ Blau's (1977) index of diversity and calculate the recombinant capabilities of a focal firm operating in the global pharmaceutical industry as follows:

$$Recombinant\ Capabilities_{it} = 1 - \sum_{j=1}^{N} S_{jit}^2$$

where S_{jit} is the share of j^{th} compound-indication combination of firm i in year t. A high index of recombinant capabilities would suggest that drug discovery and development of the firm disperses across segments in the compound-indication combination space.

Control variables

We control for variables that can influence inventive performance. We control for firm size measured as the natural log of firm assets. We also control for firm's R&D intensity measured as a firm's R&D expenditure as a proportion of its assets. In addition, we control for firm age and the number of preclinical activities, and specify the number of the previous year's successes in preclinical trials of a focal firm as an offset term. Finally, we specify home country and year dummies to control for potential home country and year-effects. The home country and year dummies are jointly significant ($p < 0.001$ and $p \leq 0.023$, respectively).

Methodology

We consider a family of count data models since the dependent variable, *the number of successes in preclinical trials*, is a count variable. We first conduct two tests to determine an appropriate count data

model for the analysis of our data. First, we test the extent of overdispersion in the sample. Results of the likelihood-ratio test show that the alpha parameter is statistically different from zero (p <0.001), providing strong evidence for overdispersion. Second, due largely to the intrinsic difficulty in the preclinical R&D and firms' strategic choices, *the number of successes in preclinical trials* comes with a high proportion of zero counts. Since the Poisson and negative binomial distributions expect a certain number of zero counts for a given value of the mean, existence of excessive zero counts violates the distributional assumptions (Hilbe, 2011). We employ the Vuong (1989) test to examine the existence of excess zero counts in our sample. The z statistic of the test is positive and statistically significant (p < 0.020), favoring zero-inflated models over non-zero-inflated models. On the basis of these test results, we employ the zero-inflated negative binomial (ZINB) regression analysis when testing the hypotheses. As robustness checks, we test hypotheses employing the Poisson and the negative binomial specifications and find consistent results.

The ZINB model consists of two parts: *count equation* and *binary equation*. The count equation estimates the full range of counts, while the binary equation estimates the likelihood of the structural zeros (Hilbe, 2011; Lambert, 1992). For the binary estimation of the ZINB regression analysis, we specify two more variables in addition to the control variables specified in the count estimation of the ZINB regression analysis. First, we control for the ratio of the new preclinical R&D activities to the total preclinical R&D activities. Second, we specify the number of the previous year's successes in preclinical trials of a focal firm. In addition, we specify the cluster-correlated robust variance estimates to address potential nonindependence among observations of a firm (Froot, 1989; Wooldridge, 2010).

RESULTS

Table 1 lists descriptive statistics and correlations. Table 2 shows the results of ZINB regressions. Model 1 lists only control variables. In Model 2, we add linear and quadratic terms for the number of regions to test Hypothesis 1. Model 2 shows that the coefficient of the linear term is positive ($\beta = 0.243$, $p = 0.010$), while the coefficient of the quadratic term is negative ($\beta = -0.016$, $p = 0.013$). Figure 2 illustrates the inverted U-shaped relationship between the number of regions and inventive performance

estimated in Model 2. To formally test the inverted U-shaped relationship, we follow the three-step procedure Lind and Mehlum (2010) and Haans, Pieters, and He (2016) suggest. The first step is to check whether the coefficient of the quadratic term is negative and statistically significant; as reported above this is the case ($\beta = -0.016$, $p = 0.013$). The second step is to test whether the slopes at both ends of the independent variable range are sufficiently different from zero. When the number of regions is two, the slope is 0.020 ($p = 0.017$), while it is −0.020 ($p = 0.018$) when the number of regions is 13. The last step is to examine whether the turning point is located within the range of the independent variable. The turning point is located at 7.537 regions, with its 95% confidential interval ranges from 5.486 to 9.588 regions, which is well within the range of the number of regions in our sample. The results, therefore, support Hypothesis 1 that the number of regions in which a firm has R&D activities will have an inverted U-shaped relationship to its inventive performance.

[Insert Tables 1 and 2 here]

[Insert Figure 2 here]

In order to test Hypotheses 2a and 2b, we specify interaction terms between the recombinant capability and both of the linear and quadratic terms of the number of regions. The linear interaction term is negative ($\beta = -2.459$, $p = 0.052$), while the quadratic interaction term is positive ($\beta = 0.309$, $p = 0.065$). Figure 3 illustrates the moderating effect of the recombinant capability on the relationship between the number of regions and the inventive performance. As illustrated in the figure, firms with a high level of recombinant capabilities (one standard deviation above the mean) reach the highest inventive performance (i.e., the turning point) at a larger number of regions than those with a low level of recombinant capabilities (one standard deviation below the mean). In addition, the shape of the curve is flatter when firms have a higher level of recombinant capabilities.

To formally test Hypotheses 2a and 2b on the changes in the turning point and the shape, respectively, we conduct the following analyses. First, for Hypothesis 2a on the turning points, we calculate the turning points of each curve and test whether they are statistically different from each other. The turning point of the curve for *high* recombinant capability is located at 8.262 regions, with its 95% confidence interval

ranges from 4.884 to 11.640 regions. The turning point of the *low* recombinant capability curve is located at 4.418 regions, with its 95% confidence interval ranges from 2.989 to 5.847 regions. These two turning points are statistically different from each other at $p = 0.063$.

Second, for Hypothesis 2b on the shapes, we follow the guideline suggested by Haans, Pieters, and He (2016). In case of nonlinear specifications such as ours, "testing for flattening or steepening is less straightforward: in these models, a significant β_4 [the coefficient of the quadratic term × the moderating variable] is neither necessary nor sufficient for flattening and steepening" (Haans, Pieters, & He, 2016: 1187). As such, following Haans et al.'s (2016) recommendation, we compare slopes at equidistance from the turning points in each curve. Specifically, we compute the slopes at ± 2 and ± 3 regions from the turning points. At ± 2 regions from the turning points, the slopes of the curve for *low* recombinant capability are ± 0.051, while those for *high* recombinant capability are ± 0.011, suggesting that the shape of the curve becomes flatter as the level of recombinant capability increases. Similarly, at ± 3 regions from the turning points, the slopes of the curve for *low* recombinant capability are ± 0.042, while those for *high* recombinant capability are ± 0.016.

In sum, the additional analyses presented above and the graphical illustration in Figure 3 corroborate Hypotheses 2a and 2b that with increasing levels of recombinant capability the turning points of the inverted U-shaped relationship will be at a larger number of regions, and the shape of the inverted U-shaped relationship will be flatter.

[Insert Figure 3 here]

We conduct several robustness checks. First, we operationalize our dependent variable, *the number of successes in preclinical trials*, using Phase II in the clinical stages in addition to Phase I, and find consistent results. In some observations in the sample, preclinical activities directly advance to the Phase II stage, skipping Phase I. These observations largely represent the cases where advancement to Phase I and Phase II occur in the same year or simply the information for Phase I is missing.

Second, we complement our findings by creating a new measure of regions, utilizing the proportion of a firm's R&D activities conducted in each region to its total number of R&D activities so as to capture the

relative importance of each region. Specifically, we calculate the sum of the squared proportion of a firm's R&D activities in each region, which measures the extent to which the firm's R&D activities are concentrated. We then subtract this measure from 1 so that the new measure can capture the extent to which a firm's R&D activities disperse across regions (i.e., Blau's [1977] index). Results are consistent.

Third, we also measure the recombinant capability with the indication only (Danzon et al., 2005) and find consistent results. We also use the diversity of phenotypes across the firms' compounds, drawn from phenome-wide association studies (PheWASs) for disease-gene associations. PheWAS are used to develop reverse genetics approaches to determine which phenotypes are associated with disease-genetic variants, analyze pharmacogenetic traits, and identify disease indications and possible adverse drug effects for a target gene (Bush, Oetjens, & Crawford, 2016; Chen, Lorenzi, Sandberg, Wolgast, & Malin, 2017; Denny, et al. 2010; Pessig et al., 2014). The diversity of phenotypes across the firm's compounds is a complementary measure for the diversity of compound-indication combinations, as they highlight two different aspects of the same phenomenon. Operationalization of the recombinant capability with the diversity of phenotypes also yields consistent results.

Last, we conduct additional analysis as a robustness check for potential endogeneity issues. Specifically, we consider that our independent variable, *the number of regions,* could be endogenous. To address this potential endogeneity, we consider the instrumental variable estimator approach. However, given that our empirical analysis employs the ZINB regressions, traditional instrument approaches may not be directly applicable (Jensen, Quinn, & Weymouth, 2015). However, we still proceeded in an attempt to approximate the traditional instrument variable approach by specifying a two-stage model and employing the exponential conditional mean model with endogenous regressors.

As instruments, we utilize information of the Pharmaceutical Intellectual Property Protection (PIPP) index (Liu & La Croix, 2015) and the patent activities in the region. We use total and standard deviations of the patent activities by residents in the region and the regional PIPP index. These instruments capture the regional-level inventiveness and institutional protection for intellectual property rights, respectively, over which a focal firm does not have much control. Therefore, we expect that these variables are not

correlated with the error term in the second stage. Also, they are associated with the extent of firms' regionalization for their R&D activities. The first-stage *F*-statistic is 18.46, indicating that the instruments are not weak (Stock, Wright, & Yogo, 2002). In addition, we conduct a test for the overidentifying restrictions to check the validity of the instruments and are not able to reject the null hypothesis that the instruments are valid (the *p*-value for Hansen's *J*-statistic is 0.133). The results of the exponential conditional mean model with endogenous regressors are consistent with those of the ZINB models.

DISCUSSION

In this study, we examine the impact of the extent of the regionalization of R&D activities on inventive performance. Our paper makes a novel theoretical contribution on the relationship between the regionalization of upstream activities and inventive performance, which are distinct and unique from the previous studies on the relationship between the regionalization of downstream activities and firm financial performance. We offer the (dis)economies of interdependence as a new theoretical mechanism leading to benefits and costs of regionalization. We find that there is an inverted U-shaped relationship between the number of regions in which firms' have their R&D activities and inventive performance. We also find that with increasing levels of recombinant capability the turning points of the inverted U-shaped relationship will be at a larger number of regions and the shape of the inverted U-shaped relationship will be flatter. We now turn to the theoretical and practical implications of these findings.

Our findings speak to one of the most essential and timely discussions of the day regarding how firms can navigate a world characterized by growing regionalization. How to meet the challenges that the increasing emergence of regionalization poses on firms is a question that lies at the forefront of a collective conversation shared by both academia and the business press. Indeed, *The Economist*'s Jan. 24, 2019 cover story entitled, "Slowbalisation[12]: The Future of Global Commerce," discusses such changing dynamics for firms, where "as globalization fades, the emerging pattern of cross-border commerce is more *regional*. This matches the trend of shorter supply chains and fits the direction of geopolitics" (*The Economist,* 2019; italics added). The article suggests, "the new world will work differently. Slowbalisation will lead to deeper links within the regional blocs."

Similarly, academia is also abuzz on the subject of the changing landscape, which has been the focus at key international conferences. For example, the Strategic Management Society's 38th Annual Conference in September 2018 examined the theme "Strategies in the era of de-globalization." Likewise, the scholarly event at Adam Smith's historic home, the Panmure House, in July 2019 explored the topic "The new enlightenment: Reshaping capitalism and the global order in a neo-mercantilist world." Additionally, the upcoming Annual Meeting of the Academy of International Business in July 2020 includes an eye-catching and well-timed track on "De-globalization, slowbalization, and regionalization." The academic enthusiasm is well warranted, for as Witt (2019) aptly explains, the field of international business was "built on an implicit assumption of ongoing globalization", making de-globalization a "significant turn of events" (Witt, 2019: 1053-1054). Thus, the world state of growing regionalization requires novel theory. It remains unclear how the era of de-globalization will create new opportunities and challenges for firms to manage the internationalization of their activities, but work on this important topic has begun (Lampert, Kim, Hubbard, Roy, & Leckie, 2019; Petricevic & Teece, 2019; Verbeke, Coeurderoy, & Matt, 2018; Witt, 2019). Our timely findings on the regionalization of firms' R&D activities and their implications on inventive performance contribute a new area of investigation into regionalization scholarship in the international business domain to help stay ahead of the curve of a growing phenomenon.

To that point specifically, we extend Rugman and Verbeke's (2004) seminal line of inquiry on regionalization to the domain of technological innovation and our findings validate such an approach. While great advances in understanding how regionalization can impact firm financial performance continue to occur, as we noted at the start of this paper, an important link remains missing in this relationship. Specifically, in the increasingly technology-driven economy, with ever-changing technological advances shortening technological life cycles, a firm's inventiveness plays an essential role in its competitiveness and performance (Banbury & Mitchell, 1995; Geroski et al., 1993; Roberts, 1999; Roberts & Amit, 2003, *inter alia*). However, the relationship between regionalization and the firm's inventive performance remains an unaddressed issue in the literature that would, in turn, shed additional

light on firm financial performance. We find this void all the more surprising, given that a firm's ability to generate inventions is a long-established determinant of supra-normal profitability (Schumpeter, 1942). In this paper, we take the first step toward identifying the link between regionalization and firm financial performance by studying the relationship between the regionalization of firms' R&D activities on inventive performance. Our study's results draw attention to a possible linkage and open a new area for additional investigation and future research connecting regionalization of R&D activities, firm inventive performance, and firm financial performance.

Complementing previous studies, our paper extends the regionalization literature and sheds new light on the understudied aspects of regionalization by illuminating a new area of a firm's value chain, the *upstream component*, and its implications on firm *inventive* performance. Previous studies on regionalization have mostly focused on firms' downstream activities such as sales and their implications on firm financial performance. Although the findings that scholars have contributed on the downstream activities has deeply enhanced our view of regionalization, any attempt to address the missing link must move the discussion from the confines of the downstream to the upstream component of the value chain, as this is where firms generate their inventions. In the current study, we shift our focus from downstream activities to upstream activities and investigate the relationship between the regionalization of R&D activities and a firm's inventive performance. In doing so, our study joins the regionalization and technology innovation literatures, two domains rarely united, thereby extending the scope of our theory's explanatory power. Thus, our theory enjoys synergies from cross-fertilization and we offer a new exchange in a now shared conversation between a larger swath of researchers across the international business and technology management literatures.

In this paper, we also contribute to the regionalization literature by introducing the (dis)economies of interdependence as a new theoretical mechanism leading to benefits and costs of regionalization. Since the R&D activities are in a different area of the value chain, we posit that the theoretical mechanism between regionalization and inventive performance is distinct from that between regionalization and financial performance. We detail how the (dis)economies of interdependence delineate a unique

theoretical mechanism leading to the benefits and costs in the process of regionalization of firms' R&D activities. In this study, we complement the heterogeneous-knowledge-seeking motivation of the extant studies by drawing attention to the implicit assumption that the internationalization of R&D activities will necessarily offer new knowledge to the firm. We maintain that it is through the consideration of the (dis)economies of interdependence that offers the essential reasoning needed to unwind the inferred assumption that all foreign knowledge-seeking activities will offer access to new knowledge. We hope that our study's novel theoretical mechanism will foster more research further theorizing on the (dis)economies of interdependence and discover additional insights.

The paper also makes a contribution toward managerial practice. Firm's global investments continue to grow both in size and significance. Specifically, over the last 20 years, global foreign direct investment (FDI) flows have grown from $325 billion in 1996 to $1.75 trillion in 2016 (UNCTAD, 1997; 2017). The growing FDI flows also include tremendous increases in the practice of foreign R&D activities (Gilman, 2010). In particular, within the global pharmaceutical industry, firms spend billions of dollars developing new compounds (CBO Report, 2006; PhRMA, 2015). From a managerial standpoint, explaining the determinants of inventive performance is tremendously important given the significant financial expenditures connected with them and the hard-to-redeploy nature of the investments. As managers must plan the firm's R&D activities with limited resources, our findings offer an important lesson. Our research shows that a regionalization view enables managers to rethink and strategize in locations, especially in order to maximize the access to the non-redundant knowledge. Our study clearly highlights that firms that do not take into account that the regionalization view may be significantly handicapped in their efforts to seek *new knowledge* through the internationalization of their R&D activities.

Limitations and Future Studies

Despite its contributions, the study has several limitations that provide promising avenues for future studies. First, our focus is on examining the impact of the extent of the regionalization of R&D activities on inventive performance. However, it would also be valuable for future research to extend investigation to *innovation* performance. Invention refers to the development of a new idea (the R&D processes);

innovation includes not only the R&D processes but also the commercialization processes in the launch of new products[13] (Kim & Pennings, 2009; Roberts, 2007). In our paper, we focus on firms' R&D efforts, but a fuller analysis covering the entire R&D process and the commercialization process within the firm calls for further research.

Second, for our construct of recombinant capability, we use the firm's diversity of compound-indication combinations. Empirically, this study offers a more direct measure for recombinant capability over previous studies using patent data given the tremendous distance that can exist in both the temporal and the technological space between a patent and a compound or an approved drug. However, although our study does show that heterogeneity in recombinant capability significantly moderates the impact of the extent of the regionalization of R&D activities on inventive performance, we do not distinguish between the different dimensions of recombinant capabilities. Future studies can greatly enhance our understanding of the underlying mechanisms and relationships between the different dimensions of recombinant capabilities with differentiating measures. Despite this limitation, we make a significant step toward better understanding the recombinant mechanisms of recombinant creation, recombinant reuse, and coupling patterns and how such capabilities can be especially helpful when a firm's operations span several geographic areas (Bartlett & Ghoshal, 1989; Kogut & Zander, 1993).

Finally, the current study is conducted in the context of a single industry (i.e., the global pharmaceutical industry) when testing the hypotheses. Although studying a single industry provides the benefits of controlling for potential industry effects (Ahuja, Lampert, & Tandon, 2008), replication in other contexts would extend its generalizability. Future studies can apply the theoretical framework advanced in the current study to other industries, thus, validating and further generalizing its findings.

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Table 1: Descriptive Statistics and Correlations

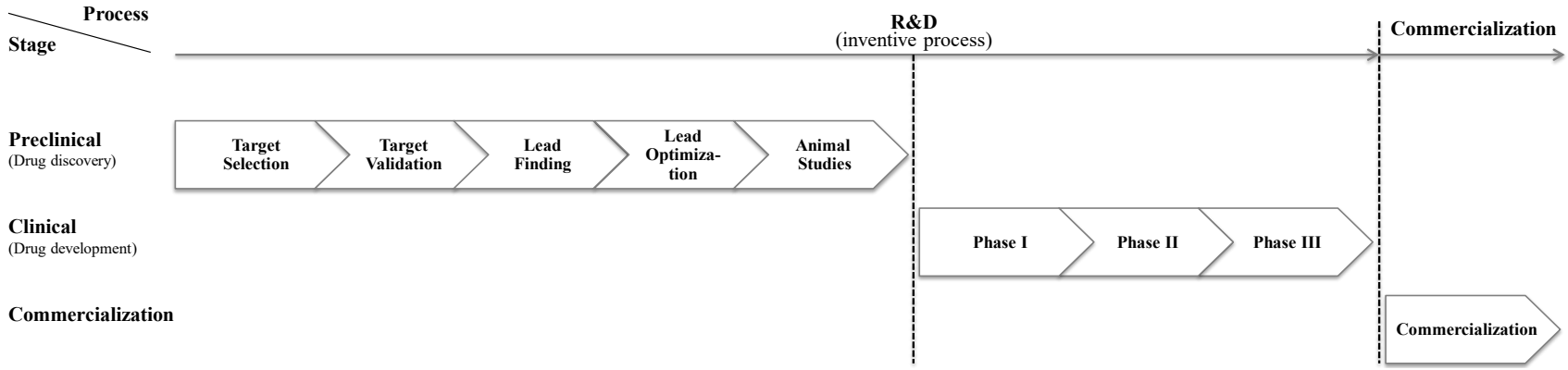
	Variables	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1)	No. of successes in preclinical trials	0.32	0.78	1						
(2)	No. of regions	3.68	2.62	0.31	1					
(3)	Recombinant capability	0.86	0.20	0.20	0.42	1				
(4)	Firm size	7.05	2.39	0.25	0.59	0.44	1			
(5)	R&D intensity	0.20	0.45	-0.05	-0.16	-0.23	-0.45	1		
(6)	Firm age	65.44	63.95	0.15	0.35	0.20	0.60	-0.22	1	
(7)	No. of preclinical activities	18.67	30.39	0.38	0.68	0.35	0.51	-0.11	0.30	1

Table 2: Results of Zero-Inflated Negative Binomial Regression Analysis on the Number of Successes in Preclinical Trials

Variables	Model 1	Model 2	Model 3
Number of Successes in Preclinical Trials			
No. of regions		0.243	2.660
		(0.010)	(0.032)
No. of regions^2		-0.016	-0.322
		(0.013)	(0.054)
No. of regions × Recombinant capability			-2.459
			(0.052)
No. of regions^2 × Recombinant capability			0.309
			(0.065)
Recombinant capability	2.411	1.801	5.263
	(0.025)	(0.067)	(0.025)
Firm size	0.027	-0.018	-0.009
	(0.598)	(0.752)	(0.882)
R&D intensity	0.377	0.300	0.430
	(0.069)	(0.140)	(0.082)
Firm age	-0.001	-0.000	-0.000
	(0.599)	(0.633)	(0.756)
No. of preclinical activities	0.008	0.008	0.008
	(0.000)	(0.000)	(0.000)
Home country dummies (joint significance)	(0.000)	(0.000)	(0.000)
Year dummies (joint significance)	(0.023)	(0.012)	(0.013)
No. of the previous year's successes in preclinical trials	Offset	Offset	Offset
Constant	-17.735	-17.297	-20.683
	(0.000)	(0.000)	(0.000)
Inflate			
Ratio of new preclinical R&D activities	-11.280	-10.213	-10.567
	(0.000)	(0.001)	(0.001)
No. of the previous year's successes in preclinical trials	0.356	0.344	0.354
	(0.064)	(0.063)	(0.056)
Recombinant capability	-0.093	-0.111	0.223
	(0.967)	(0.959)	(0.914)
Firm size	-0.127	-0.144	-0.123
	(0.487)	(0.417)	(0.501)
R&D intensity	0.199	0.159	0.269
	(0.469)	(0.584)	(0.379)
Constant	1.142	1.206	0.692
	(0.549)	(0.515)	(0.711)
Observations	1046	1046	1046
AIC	1326.578	1327.017	1328.787
Log-likelihood	-632.289	-629.509	-628.394

p-values in parentheses

Figure 1: Value Chain in Global Pharmaceutical Industry



Adapted from Hill and Rang (2012) and Sosa (2009)

Figure 2: Inverted U-Shaped Relationship between Number of Regions and Inventive Performance

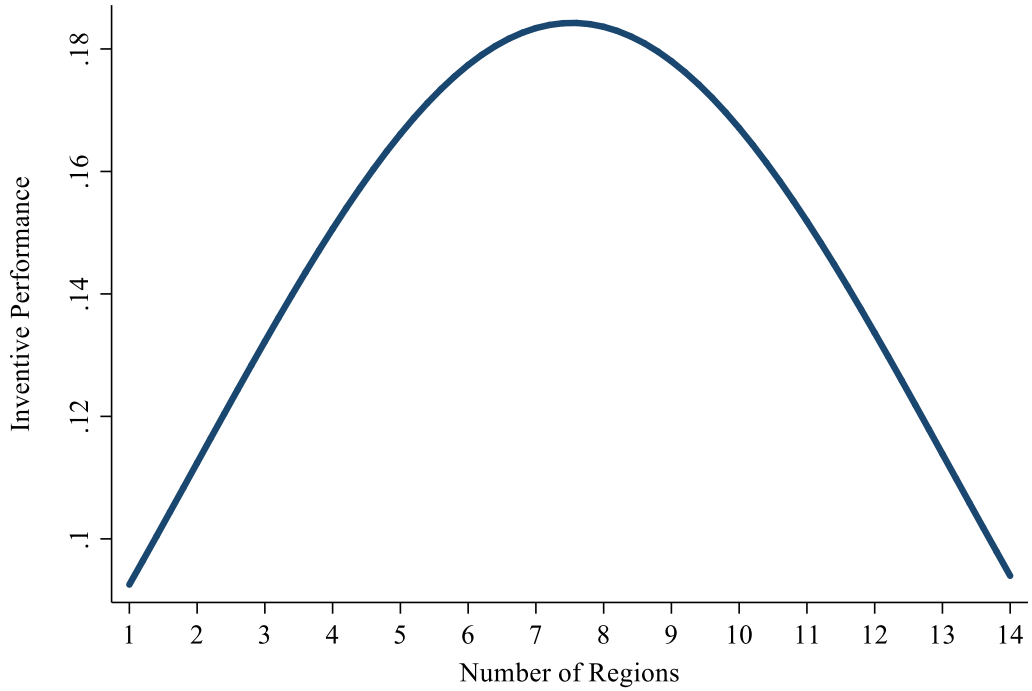


Figure 3: Moderating Effect of Recombinant Capability

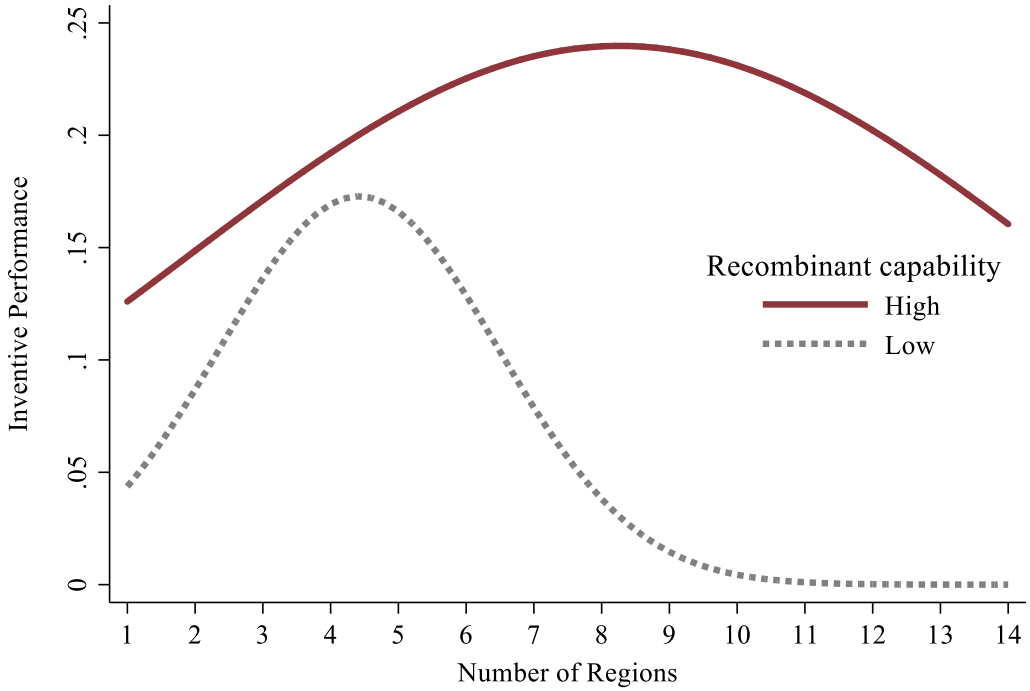


Table A1: Geographic Details of our Sample Firms

(a) List of the home countries of our sample firms

No	Home Countries	No of Firms
1	Australia	1
2	Belgium	3
3	Canada	4
4	Denmark	2
5	Finland	1
6	France	3
7	Germany	7
8	Hungary	2
9	India	3
10	Ireland	5
11	Israel	1
12	Italy	1
13	Japan	27
14	Netherlands	3
15	Norway	1
16	Switzerland	7
17	United Kingdom	4
18	United States	79

(b) List of the regions where our sample firms conduct their R&D activities

No	Regions of Innovative Activities
1	Eastern Africa
2	Middle Africa
3	Northern Africa
4	Southern Africa
5	Western Africa
6	Caribbean
7	Central America
8	Northern America
9	South America
10	Eastern Asia
11	South-Central Asia
12	South-Eastern Asia
13	Western Asia
14	Eastern Europe
15	Northern Europe
16	Southern Europe
17	Western Europe
18	Australia and New Zealand

Note: We employ the M49 standard or the United Nations Statistics Division's (UNSD) "Standard country or area codes for statistical use" when classifying the 18 regions.

ENDNOTES

[1] The focus of our paper is on the impact of the extent of firm internationalization. However, the literature refers to the construct of internationalization using such terms as geographic expansion, geographic scope, international expansion, and multinationality (Hitt, Bierman, Uhlenbruck, & Shimizu, 2006). We can classify the extent of firm internationalization into three levels; a high status of firm internationalization is *global*, a medium status of firm internationalization is *semi-global* or *regional*, and a low status of firm internationalization is *domestic*.

[2] The Rugman and Verbeke (2004) hypothesis has spurred an impressive body of work, including Almódovar & Rugman (2014); Bausch, Fritz, & Boeseke (2007); Delios & Beamish (2005); Elango (2004); Gilbert & Heinecke (2014); Heinecke (2011); Li (2005); Mohr, Fastoso, Wang, & Shirodkar (2014); Oh & Contractor (2014); Oh, Kim, & Shin (2019); Rugman & Oh (2007); and Rugman & Sukpanich (2006). The literature on regionalization also includes several special issues dedicated to the subject—for example, the *Management International Review* (2005), the *European Management Journal* (2009), the *British Journal of Management* (2014), and the *Multinational Business Review* (2015).

[3] Among the few demonstrating empirical support, Almeida (1996), for example, showed that MNEs' foreign subsidiaries successfully acquired technological knowledge in their foreign host environment and, in fact, used the knowledge more so than domestic firms. Frost (2001) linked the inventions of MNEs' foreign subsidiaries to the knowledge in their foreign host environment and also identified factors affecting the extent to which it happens.

[4] Rugman and Verbeke (2004: 6) posit, "[r]egionalization should be viewed as an expression of semi-globalization (Ghemawat, 2003). Semi-globalization implies that we observe neither extreme geographical fragmentation of the world in national markets nor complete integration."

[5] In 2004, Rugman and Verbeke presented the first empirical evidence that firms operate regionally. Their discovery prompted a seminal moment of reflection in the international business literature, for prior to Rugman and Verbeke's (2004) pivotal paper, the international business discipline had always "assumed" that firms operated globally. Bolstered by the authors' empirical observations of the regional phenomenon, scholars began to develop the theoretical structure and arguments supporting regionalization theory. Little more than a decade later, regionalization theory and the region construct—defined as a grouping of countries in geographic proximity—has quickly gained distinction in both the international business and strategy literatures (Arregle, Beamish, & Hérbert,

2009; Arregle, Miller, Hitt, & Beamish, 2013; Buckley & Ghauri, 2004; Cantwell, 2009; Dunning, 1998; Flores & Aguilera, 2007; Ghemawat, 2001, 2003, 2005; Kim & Aguilera, 2015; Rugman & Verberke, 2004, 2007, *inter alia*).

[6] We can classify recombinant capabilities into three dimensions. The first dimension concerns recombinant creation, which focuses on a capability in creating technological combinations that are new to the firm and thereby widen the firm's repertoire of technological combinations (Carnabuci & Operti, 2013). The second dimension—which we refer to as recombinant reuse—focuses on the creation of reconfigured combinations. Recombinant reuse encompasses a capability in the refinement of known technological combinations to solve new problems and thereby deepen the firm's existing repertoire of technological combinations (Carnabuci & Operti, 2013). The last dimension concerns the grouping of knowledge components together for recombination, which we refer to as coupling patterns. Scholars have also determined variations in coupling patterns, a capability concerning which knowledge components should be recombined and that results in recombinant inventions that are more useful and valuable (Yayavaram & Ahuja, 2008; Yayavaram & Chen, 2015). These studies on the recombinant mechanisms of recombinant creation, recombinant reuse, and coupling patterns confirm that firms differ in their recombinant capabilities and that this has important consequences on firms' inventiveness and inventive performance outcomes.

[7] The *AdisInsight* database is a proprietary dataset that only a handful of academic researchers have been fortunate enough to obtain (please see studies using the *AdisInsight* database including Danzon, Nicholson & Pereira [2005] with the time frame of 1988 to 2000 and Girotra, Terwiesch & Ulrich [2007] with the time frame of 1994 to 2004), and we were able to secure a similar time period. It is more difficult to obtain more recent data from the *AdisInsight* database, as it is utilized as a cross-sectional tool and not a longitudinal tool.

[8] In the discovery and development process, the term "compound" refers to a candidate medicine. When a compound receives official FDA approval for commercialization, it receives the new label of a drug.

[9] The entire process of moving a compound from the preclinical stage to final approval for commercialization can extend 10-15 years and can cost over $802 million (CBO Report, 2006; DiMasi et al., 2003; PhRMA, 2009). The probability of a compound succeeding and becoming an approved drug for commercialization is extremely low. For every 10,000 compounds generated in drug discovery, only one receives FDA approval for commercialization (0.01%) (Giovannetti & Morrison, 2000; PhRMA, 2009).

[10] In the preclinical stage, testing takes place in laboratories on animals, whereas in the clinical stage, testing is on humans.

[11] There is greater uncertainty in the earlier stages of the R&D process rather than in the more advanced stages of the R&D process (more advanced stages of the R&D process signal the end of the inventive process) (Giovannetti & Morrison, 2000; PhRMA, 2009). For example, in the most advanced stage of the inventive process, Phase III trials, 80% of compounds advance from Phase III clinical trials to FDA approval for commercialization (Giovannetti & Morrison, 2000; PhRMA, 2009).

[12] The term "slowbalisation" was coined by Adjiedj Bakas in 2015 to characterize the shifting forces where global investment and trade have been sluggish relative to world GDP (*The Economist*, Jan. 24, 2019).

[13] To put it another way, "*innovation is composed of two parts: (1) the generation of an idea or invention, and (2) the conversion of that invention into a business or other useful application…innovation [includes] all of the stages from the technical invention to final commercialization*" (Roberts, 2007: 36; italics in original).