'Absorptive link': an absorptive capacity and alliance approach to biotechnological product success

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Abstract

As biotechnologies are increasingly specialized and interrelated, the research question posed by this study is: what determines a biotechnology firm's product performance, if the development and commercialization of drug products require multiple technologies that are not possessed by any one firm? In drawing on concepts from strategic alliance and absorptive capacity research, this study develops and empirically examines a concept of 'absorptive link' in the biotechnology industry. A firm's absorptive link underscores that a firm's ability to develop new products stems from its prior knowledge in commercializing new applications of resources held by not only the firm, but also that of its alliance partners. Such a concept generated 6 testable hypotheses to which were mostly supported in this study's Poisson regression analysis of the biotechnology industry. This study concludes by offering three key contributions to product performance research.

Keywords: Penrose resource based view, product innovation, prior knowledge

1. Introduction

A firm's competitive survival depends on its ability to successfully develop and bring products to the market (Deeds and Hill, 1996; Penrose, 1959; Schoonhoven *et al.*, 1990). However, as technologies are increasingly specialized and interrelated (Bettis and Hitt, 1995), the creation of products often involves sourcing multiple technologies that are not held by any one firm (Pennings and Harianto, 1992; Powell *et al.*, 1996; Rothaermel, 2001; Rothaermel and Deeds, 2004, 2006). For instance, in the biotechnology industry, the development of therapeutic drugs is the result of combining the research expertise of various biotechnology start-ups and the commercializing assets of large pharmaceutical companies (Baum *et al.*, 2000; Pennings and Harianto, 1992; Pisano, 1990; Powell *et al.*, 1996; Rothaermel and Deeds, 2004; Teece, 2000). Hence, given the interdependent nature of the biotechnology industry, the research question posed by this study is: what determines a biotechnology firm's product performance, if the development and commercialization of drug products require multiple technologies that are not possessed by any one firm?

As the development of products is inherently a process of novel resource recombinations (Danneels, 2002; Ng, 2007; Pennings and Harianto, 1992; Penrose, 1959; Schumpeter, 1934), a firm's ability to absorb and integrate the resources or technologies of alliance partners is instrumental to a firm's product performance (e.g. Hess and Rothaermel, 2011; Rothaermel and Deeds, 2004, 2006; Rothaermel and Hess,

2007). Such an argument rests on the concept of 'absorptive capacity' (Cohen and Levinthal, 1990) which refers to a firm's 'ability to recognize the value of new information, assimilate it, and *apply it to commercial ends*' (128) [*italics emphasized by this study*]. In particular, since the development of a biotechnology firm's products requires transforming basic research technologies into commercialized products (Deeds and Hill, 1996; Nerkar and Roberts, 2004), such transformations often require assimilating the resources of its alliances partners. Thus, various studies have suggested that a biotechnology firm's absorptive capacity is a necessary requirement to reaping the benefits of alliances (Hoang and Rothaermel, 2005; Lane and Lubatkin, 1998; Mowery *et al.* 1996; Pennings and Harianto, 1992; Rothaermel and Hess, 2007).

Yet, although strategic alliance (Deeds and Hill, 1996; Rothaermel 2001; Rothaermel and Deeds, 2004) and absorptive capacity (Danneels, 2002; Helfat and Peteraf, 2003; Helfat and Raubitschek, 2001; Peteraf and Bergen, 2003) arguments have been used to explain a firm's product performance, most studies, however, fail to sufficiently integrate both perspectives (Rothaermel and Alexandre, 2009; Rothaermel and Hess, 2007). Prior research tends to identify firm or alliance level factors as primary explanations of product success, while mutually excluding the causal determinants of the other (Rothaermel and Hess, 2007). For instance, strategic alliance research (Chan *et al.* 1997; Deeds and Hill, 1996; Dyer and Singh, 1998; Powell *et al.*, 1996; Rothaermel 2001; Rothaermel and Deeds, 2004) tends to understate a firm's ability to '*apply and commercialize*' the

resources of alliance members. While, absorptive capacity research tends to focus on organizational mechanisms that promote the application and commercialization of externally relevant information (see Lane *et al.*, 2006; Jansen *et al.*, 2005; Todorova and Durisin, 2007; Zahra and George, 2002), while providing limited consideration of the complementary and commercializing role of alliance partnerships.

As a result, there has been a growing but limited body of research that integrates these various levels of analysis (Lane *et al.*, 2006; Lichtenthaler, 2009; Lichtenthaler and Lichtenthaler, 2010; Rothaermel and Hess, 2007; Zhao and Anand, 2009). For instance, in Rothaermel and Hess' (2007) study of the biotechnology industry, they argue and find that a firm's absorptive capacity is not only influenced by factors residing at the employee, firm and network levels of analysis, but can also be influenced by substitute and complementary relationships amongst these various levels. Yet, in spite of such contributions, such multi-level approaches (see also Rothaermel and Hess, 2007; Zhao and Anand, 2009) offer a limited attention to the nature of a firm's 'prior knowledge'. The nature of a firm's 'prior knowledge' is important to the concept of absorptive capacity because a firm's product performance not only depends on the firm's ability to assimilate externally relevant knowledge, but it also depends on a firm's 'prior knowledge' in 'applying' and 'commercializing' such external experiences (Cohen and Levinthal, 1990). Although there have been some efforts to examine such prior knowledge, the firm-alliance level studies of Zhao and Anand (2009), Rothaermel and Hess (2007) and Hess and Rothaermel (2011) and even that of absorptive capacity research (Jansen *et al.*, 2005; Todorova and Durisin, 2007; Zahra and George, 2002) have focused their attention on the role of a firm's tacit knowledge (e.g. Rothaermel and Hess, 2007; Rothaermel and Deeds, 2006) or organizational mechanisms (Jansen *et al.*, 2005; Todorova and Durisin, 2007; Zahra and George, 2002) in promoting the transfer of external knowledge, but not on the types of 'prior knowledge' that promote the 'application' and 'commercialization' of firm-alliance level experiences.

Hence, in order to address this research gap, a concept of 'absorptive link' is introduced to deal with this study's research question. Namely, to underscore the 'prior knowledge' (Cohen and Levinthal, 1990) aspects of the absorptive capacity concept, this study develops a concept of absorptive link. Such a concept is comprised of two categories of 'prior knowledge': a firm's functional and commercial knowledge of the various applications of resource use. Specifically, in explaining a firm's functional knowledge of resources uses, Penrose (1959) as well as more modern resource based approaches (Denrell *et al.*, 2003; Ng, 2007) contend that the development of a firm's products stems from a firm's heterogeneous knowledge of the ways

in which its resources can be applied to different product-markets. Furthermore, a firm's prior knowledge not only entails a functional knowledge of a resource's varied uses, but also a commercial knowledge of their market viability. Such prior knowledge constitutes a firm's absorptive link to which serves to innovate new product-market opportunities by seeking new ways to apply and commercialize firm-alliance level resources. Specifically, as the development of new products involves drawing on technologies or resources that are not held by any one firm, this study argues that a firm's product performance stems from its absorptive link to not only discover and commercialize its firm's resources' varied uses, but also that of its alliance partners.

To organize the development of this study, definitions used in this study are first stated. This is followed by a review of strategic alliance and absorptive capacity research. These areas are then integrated in which absorptive link arguments and hypotheses are developed and empirically tested in the biotechnology industry. Specifically, in drawing on a sample of 372 biotechnology firms in 2004, Poisson estimations examined the relationship between a biotechnology firm's absorptive link and alliances on its product performance. This study then concludes with its contributions and implications to product performance research.

2. Conceptual model

Definitions

As the biotechnology firm is the primary unit of analysis, the biotechnology firm is defined by a for profit firm that is involved in the research, development, and commercialization of human therapeutics (e.g. Hess and Rothaermel, 2011; Rothaermel and Deeds, 2004). This includes those biotechnology firms involved in the development of human therapeutic products, such as drug treatments for diabetes, cholesterol, cardiovascular diseases and other drugs for the prevention and improvement of human health. Human therapeutic products can also include diagnostic services and products. Hence, given this unit of analysis, a biotechnology firm's product performance is defined by the transformation of a firm's basic technological research into human therapeutic products and services of commercial value. Although there are various measures of product performance (Montoya-Weiss and Calantone, 1994), this definition is adopted because it is consistent with the 'applied' and 'commercializing' aspects of Cohen and Levinthal's (1990) concept of 'absorptive capacity' (see also Deeds and Hill, 1996; Nerkar and Roberts, 2004; Rothaermel 2001; Rothaermel and Deeds, 2004). Based on these definitions, strategic alliance explanations of product performance are discussed as follows:

Strategic alliances

As the locus of product innovation increasingly depends on a network of technology and commercializing partnerships (e.g. Powell *et al.*, 1996), the cooperation and pooling of alliance resources can complement a firm's competitive position (Baum *et al.*, 2000; Chan *et al.*, 1997; Deeds and Hill, 1996; Dyer and Singh, 1998; Harrison *et al.*, 2001; Lichtenthaler, 2009; Lichtenthaler and Lichtenthaler, 2010; Powell *et al.*, 1996; Rothaermel 2001; Rothaermel and Deeds, 2004; Rothaermel and Hess, 2007). As Chan *et al.* (1997) describe:

strategic alliances bring together otherwise independent firms to share resources in product design, production, marketing or distribution. Forging an alliance enable a firm to focus resources on its core skills and competencies while acquiring other components or capabilities it lacks from the market place (199)

Strategic alliances are important to the biotechnology industry because they provide access to external experiences that can transform a biotechnology firm's basic research inventions into commercialized innovations (Deeds and Hill, 1996; Nerkar and Roberts, 2004; Rothaermel and Deeds, 2004; Rothaermel and Hess, 2007; Schumpeter, 1934). For instance, strategic alliances amongst research start-ups serve to pool complementary research experience and thus promoting the creation of 'basic' research inventions (i.e. genome mapping and sequencing) that can exhibit various applications in the treatment of diseases (Baum *et al.*, 2000; Liebeskind *et al.*, 1996; McFadyen and Cannella, 2004; Powell *et al.*, 1996). Yet, in order to bring such research inventions to the market, research start-ups tend to also form commercialization alliances to established pharmaceutical firms (Danzon *et al.*, 2003; Graves and Langowitz, 1993; Rothaermel, 2001; Teece, 2000). Such commercializing alliances provide access to marketing, distribution and manufacturing assets that advance the development of basis research prototypes, such as drug candidates, into commercially viable innovations (Danzon *et al.*, 2003; Graves and Langowitz, 1993; Rothaermel and Deeds, 2004; Teece, 2000). As these alliances complement a firm's competitive position, biotechnology studies (Deed and Hill, 1996, Rothaermel, 2001; Rothaermel and Deeds, 2004, 2006) have found that a biotechnology firm's alliances positively influence its product performance.

Some alliance researchers however suggested that increasing strategic alliances could eventually yield diminishing returns to a biotechnology firm's product performance (Deeds and Hill, 1996; Rothaermel and Deeds, 2004, 2006). For instance, Deeds and Hill (1996) find that a biotechnology

firm's product performance has a non-monotonic inverted U shape relationship to its strategic alliances. This diminishing effect arises because of basic cognitive limits in a firm's ability to manage multiple alliances (e.g. Deeds and Hill, 1996; Rothaermel and Deeds, 2004). To capture this positive yet diminishing effect of alliances, Hypothesis 1 constitutes our base hypothesis.

Hypothesis 1: a firm's product performance – number of products on the market – has an inverted U-shaped relationship to the total number of strategic alliances.

As alliances provide access to different types of resources (Shan *et al.*, 1994), different types of alliances can yield different effects on a firm's innovation (Hoang and Rothaermel, 2005; Rothaermel and Deeds, 2006). For instance, strategic alliances can take a variety of exchange relationships involving licensing, manufacturing, research, marketing and development agreements (Chan *et al.*, 1997; Harrison *et al.*, 2001; Jones *et al.*, 1997; Lane and Lubatkin, 1998; Osborn and Hagedoorn, 1997; Pennings and Harianto, 1992; Rothaermel and Deeds, 2004). Since research and marketing related resources are key requirements to a firm's product success (Dutta *et al.*, 1999; Danneels, 2003), this suggests Research & Development (R&D) and Marketing alliances should yield a greater influence on a firm's product performance than other types of alliances. The following is thus hypothesized:

Hypothesis 2: A firm's R&D and marketing alliances have the greatest positive effect on a firm's product performance.

Moreover, in firm level studies of product performance, Dutta *et al.* (1999) and Danneels (2002, 2003) find research and marketing activities tend to mutually complement a firm's product performance. This is because research often requires efforts in marketing such that basic research technologies can be developed to meet the needs of a firm's customers (Dutta *et al.*, 1999). Hence, in extending these arguments to R&D and Marketing alliances, their mutual influences are also hypothesized:

Hypothesis 2a: A firm's product performance is positively related to the joint influence of a firm's R&D and marketing alliances.

Absorptive link an integration of absorptive capacity and strategic alliances

Yet, since innovation spans across multiple levels of analysis (Rothaermel and Hess, 2007; Lichtenthaler and

Lichtenthaler, 2010), product innovation not only depends on a firm's ability to gain access to its partners' experiences, but it also depends on a firm's 'absorptive capacity' to assimilate such experiences. As a firm's absorptive capacity is directly a function of its 'prior knowledge' (Cohen and Levinthal, 1990; Danneels, 2002; Lane and Lubatkin, 1998; Mowery *et al.*, 1996; Nerkar and Roberts, 2004; Pennings and Harianto, 1992), Cohen and Levinthal (1990) argue that increasing a firm's prior experiences increases a firm's memory to which increase a firm's ability to recall from its prior experience in assimilating and commercializing external information in the next period (e.g. Lane *et al.*, 2006; Van den Bosch *et al.*, 1999; Zahra and George, 2002;). Although a firm's memory – as a form of prior experience – is central to this absorptive capacity concept (Cohen and Levinthal, 1990), behavioural and network explanations have argued excessive reliance on a firm's past memory or experiences can reduce a firm's ability to innovate. A reliance on past experiences can lead to routine behaviours that inhibit a firm's creativity and thus innovation (e.g. Jansen *et al.*, 2005; Levinthal and March, 1993; Nelson and Winter, 1982). Furthermore, network studies find that a firm's reliance on past experiences will favour partners with similar experiences and thus the selection of redundant alliance partners will inhibit a firm's efforts to innovate (e.g. Coleman, 1988; Ng, 2004; Ng *et al.*, 2006).

Concept of absorptive link

As the concept of absorptive capacity exhibits multi-dimensional properties (e.g. Jansen *et al.*, 2005; Lichtenthaler, 2009; Lichtenthaler and Lichtenthaler, 2010; Todorova and Durisin, 2007; Zahra and George, 2002), this study however argues that a firm's absorptive capacity can be driven by other types of 'prior knowledge'. As the development of products stems from a firm's resources (e.g. Denrell *et al.*, 2003; Penrose, 1959; Ng, 2007), this study argues that a firm's prior knowledge entails more than a firm's memory but can also entail a knowledge about the functional and commercial uses of firm-alliance level resources. Such knowledge serves to not only discover new ways to apply firm and inter-firm level resources to new product-markets, but also to realizing their commercial potential. This study argues that this prior knowledge constitutes a firm's absorptive link. Specifically, a firm's absorptive link is defined by a firm's ability to draw on its prior knowledge of the functional uses of its resources for the discovery and commercialization of new product-market opportunities found inside and outside of its organizational boundaries.

Absorptive link: knowledge of the functional use of resources

To elaborate on the functional aspects of this absorptive link concept, a firm's knowledge of its resources' functional uses originates from Penrose's (1959) and later Wernerfelt's (1984) notion of 'resource duality'. 'Resource duality' refers to the idea that a firm's resources and products are 'two sides of the same coin' (Wernerfelt, 1984). Resources duality underscores that the same set of resources can be applied to different market settings (Penrose, 1959). Hence, unlike Barney's (1986) resource based view, resources are heterogeneous not because they have unique physical attributes, but rather resources are heterogeneous in their functional uses (Penrose, 1959). As Penrose (1959) describes:

the fact that most resources can provide a variety of different services is of great importance for the productive opportunity of a firm. It is the heterogeneity, and not the homogeneity of the product services available or potentially available from its resources that give its unique character (75).

This resource duality is also expressed by Teece (1982) in which he notes,

... the final products produced by a firm at any given time merely represent one of several ways in which the organization could be using its internal resources (Penrose, 1959) ... a firm's capabilities lie upstream from the end product – it lies in a generalizable capability which might well find a variety of final product applications (p. 45).

In particular, as product innovation is inherently a process of novel resource combinations (Danneels, 2002; Pennings and Harianto, 1992; Schumpeter, 1934), the dual nature of resources is central to a firm's product innovation process. This is because a firm's prior knowledge of resource uses provides 'cues' in the selection of other resources. This yields the discovery of other resources that can reveal an 'eventual combination' of resources whose functional uses can propel the development of new product innovations (Denrell *et al.*, 2003; Ng, 2007). As Denrell *et al.*, (2003) describe,

... when many of the necessary components were available to the firm, it is possible that the value of the eventual combination could be foreseen. The process is analogous to an individual facing a jigsaw puzzle with only a few lacking piece (987).

Functional knowledge of resources uses: cumulative knowledge

This ability to see this 'eventual combination' stems from a firm's cumulative knowledge of functional resource uses. A firm's 'cumulative' knowledge of resource uses is argued to positively influence a firm's absorptive link in discovering new product opportunities. This is because a firm with greater cumulative experiences develops a greater understanding of the functional uses of the 'component parts' of a firm's resource bundle. By understanding the functional uses of each component part, this cumulative knowledge enables the firm to see how these resources fit with others resources. This facilitates the discovery of new resource combinations and uses. Hence, since the concept of absorptive link is driven by a firm's prior knowledge of the functional uses of its resources, a firm's absorptive link in discovering new products is influenced by those firms who possess greater cumulative experiences because such experiences enable the firm to see an 'eventual combination' of resources and uses that is required in the product innovation process. The following is hypothesized:

Hypothesis 3: A firm's accumulated experiences are positively related to its product performance.

Moderating effects of alliances on a firm's cumulative knowledge

However, unlike Penrose (1959) who focuses on firm level explanations of the product discovery process (e.g. Denrell *et al.*, 2003; Ng, 2007), the concept of absorptive link extends a firm's discovery of resources uses beyond its organizational boundaries. By drawing on a firm's cumulative knowledge, a firm's absorptive link reflects an ability to not only see an 'eventual combination' of resources that are held within the firm, but also to see how such a combination fits within a greater 'puzzle' of resources held by its alliance partners. That is, by leveraging a firm's cumulative knowledge of resource uses, it enables the firm to infer the resource combinations and uses of its alliance partners. This is consistent with empirical studies that find as firms accumulate experiences in the development of new technologies, a firm increases its ability to determine the compatibility of externally relevant technologies (Hoang and Rothaermel, 2005; Pennings and Harianto, 1992).

Although this concept of absorptive link leverages the resource uses of a firm's alliance partners, a firm's absorptive link is nevertheless subject to diminishing effects in its alliances. Namely, as a firm leverages its cumulative knowledge to discovering new ways to combine its resource uses with that of its alliance partners, a firm's cumulative

knowledge can be subject to 'network myopic' (Coleman, 1988) effects. This is because as a firm continues to leverage its cumulative knowledge of resource uses, this prior knowledge constrains the firm to exchange with only those alliance members that share similar prior experiences. This is supported by network closure arguments whereby firms tend to develop relationships with those who share similar beliefs and experiences (Coleman, 1988; Gargiulo and Benassi, 2000; Hoang and Rothaermel, 2005; Ng, 2004). Such a closed network generates a 'network myopia' that stifles a firm's absorptive link to discovering new resource combinations and uses and thus reducing the product performance benefits of a firm's alliances. This positive yet diminishing effect on a firm's absorptive link is thus captured by the following:

Hypothesis 3a: The effect of a firm's accumulated experiences on product performance is positively moderated by the diminishing effects of a firm's alliances.

Functional knowledge of resources uses: Diverse knowledge

In addition to a firm's cumulative knowledge, a firm's diverse knowledge of resource uses constitute another functional aspect of a firm's absorptive link. According to absorptive capacity research, diversity in a firm's prior knowledge strengthens a firm's ability to assimilate external information and promotes the development of new innovations (Cohen and Levinthal, 1990; Nerkar and Roberts, 2004; Pennings and Harianto, 1992; Zahra and George, 2002). As Cohen and Levinthal (1990) describe:

a diverse background [knowledge] provides a more robust basis for learning because it increases the prospect that incoming information will relate to what is known (131).

Yet, since resources have heterogeneous uses (Penrose, 1959), a Penrosian explanation, argues that diversity in a firm's knowledge extends beyond the relational arguments of Cohen and Levinthal (1990). Specifically, a firm's diverse knowledge of resource uses capitalizes on the 'heterogeneous in use' (Penrose, 1959) aspects of resources in which such diversity not only enables the firm to see a greater variety of applications or uses from any given set of resources, but as a result enables the firm to see a 'larger' puzzle of resource combinations and uses than that of a firm's cumulative experiences. Hence, a firm's ability to develop new products arises not just because a firm's diversity of experiences promotes an ability to relate to a broader set of external experiences (Cohen and Levinthal, 1990), but it

can also arise because a firm's diversity in their knowledge of resource uses enables the firm to see a 'larger' combination of resources and uses (e.g. Ng, 2007; Penrose, 1959). Such a diverse knowledge of resource uses is thereby argued to positively impact a firm's absorptive link in introducing new products to the market. The following is thus hypothesized:

Hypothesis 4: A firm's prior knowledge diversity is positively related to its product performance.

Moderating effects of research alliances on a firm's diverse knowledge

With a firm's diverse knowledge of resources uses, a firm's absorptive link enables the firm to develop products by assimilating the resource uses of its research alliances. This diverse knowledge of resources uses can be manifested by a biotechnology firm's diversity of research programs (see also Rothaermel and Deeds, 2006). Biotechnology firms involved in a diversity of research programs, such as cancer therapies, protein engineering, medical diagnostics, screening for molecular compounds are more likely to understand the medical applications of such basic research and thus are better able to relate and recombine the basic research of its alliance partners. Namely, the ability to relate a firm's prior experiences to the experiences of alliance members requires that the firm has some overlapping knowledge experiences with its alliance partners (Lane and Lubatkin, 1998; Mowery *et al.*, 1996). For instance, according to Lane and Lubatkin (1998), they show that the transfer of inter-firm knowledge is dependent on a firm having some prior knowledge that is basic or fundamental to the new and external knowledge. Basic knowledge consists of the 'general understanding of the traditions and techniques upon which a discipline is based' (Lane and Lubatkin, 1998: 464). Hence, in building on Lane and Lubatkins' (1998) arguments, the greater the diversity of research programs, the greater is the likelihood that the firm possesses knowledge that is basic or fundamental to its aligning partners. This diversity of research programs not only promotes a greater understanding of the basic 'disciplinary knowledge' of its alliances, but it also enables the firm to better understand their combined uses in the development of drug candidates.

Although a firm's diversity of research experiences positively influences a firm's absorptive link in leveraging the research uses of its alliance partners, this firm's absorptive link is, however, subject to diminishing return in its research alliances. This is because even though a firm's diversity increases a firm's absorptive link to recognize a broader combination of resource uses from its research partners, this diversity renders the firm increasingly vulnerable to

assimilating incompatible research that erodes a firm's core area of research expertise. Excessive dependence on research alliances will eventually reduce the product performance benefits of a firm's absorptive link and is as hypothesized as follows:

Hypothesis 4a: The effect of a firm's prior knowledge diversity on product performance is positively moderated by the diminishing effects of its research alliances.

Absorptive link: commercial knowledge of resource use. products in development

Since the development of products also requires that a firm be able to commercialize the varied functional uses of resources, the concept of absorptive link thereby not only includes a firm's cumulative and diverse knowledge of resource uses, but also includes knowledge surrounding their commercial potential. A firm's products in development (Nichols-Nixon and Woo, 2003) constitutes one such aspect of this commercial knowledge. Namely, in order to commercialize basic research, a firm's knowledge of resource uses needs to be imbued into a prototype product, such as a drug candidate. Such a prototype drug candidate is involved in a product development and regulatory phase involving clinical trials and is subjected to FDA regulation (e.g. Rothaermel and Deeds, 2004). Yet, since only 5% of all drug candidates make it to the clinical trials of the product development phase (Graves and Langowitz, 1993), a firm's products in development thereby signify knowledge surrounding its commercial viability and potential prospects for market acceptance (e.g. Rothaermel and Deeds, 2004). As a result and consistent with Nicholls-Nixon and Woo (2003), a firm's commercial knowledge is characterized by a firm's products in development in which such knowledge underscores that the innovation of new products not only arises from an understanding of the varied uses of a firm's resources (i.e. basic research involved in developing a drug candidate), but also knowledge of their commercial potential (i.e. commercializing experiences in moving the drug candidate through market approval). To capture this commercializing aspect of the absorptive link concept, the following is hypothesized:

Hypothesis 5: A firm's products in development are positively related to its product performance.

Moderating effects of commercial alliances on a firm's product in development

A firm's products in development also enable the firm's absorptive link to commercialize the resources uses of its alliance partners. As a firm's products in development signify a commercial readiness or a 'proof of concept', it generates opportunities to collaborate with firms that possess the requisite commercializing skills and resources (Rothaermel and Deeds, 2004). This, as a result, generates alliance opportunities in manufacturing, marketing, distribution and other commercializing related alliances (Rothaermel and Deeds, 2004). However, a firm's absorptive link is subject to the diminishing effects of commercializing alliances. This is because since a firm's products in development demonstrate significant potential for commercial success, this invites opportunistic rent seeking behaviours amongst its commercial alliance partners. Such rent seeking behaviour exposes the firm to opportunistic threats of adverse selection, moral hazard and hold up (Jones *et al.*, 1997; Osborn and Hagedoorn, 1997; Pisano, 1990). Hence, even though a firm's products in development serve to attract commercial partnerships, the greater the number of such commercial alliances, the greater is the potential for the firm to be subject to these various forms of opportunism. This reduces a firm's absorptive link in commercializing the resource uses of its commercial alliance partners. This is captured by the following absorptive link hypothesis:

Hypothesis 5a: The effect of a firm's product in development on product performance is positively moderated by the diminishing effects of a firm's commercializing alliances.

Commercial knowledge of resource use: mergers and acquisitions (M&A)

The commercializing aspects of a firm's absorptive link are also influenced by a firm's knowledge or history of M&A experiences. As the biotechnology has experienced a long history of M&A activity, such M&A are commonly motivated by scale efficiencies and revenue based synergies (Capron, 1999; Graves and Langowitz, 1993; Walter and Barney, 1990). A firm's knowledge or history of M&A thereby reflects a firm's competency in exploiting scale efficient practices and in exploiting product synergies. As these competencies are experientially based and are mutually related to the commercialization of products, a firm's M&A experiences should thereby positively impact a firm's ability to 'see' the commercial applications or uses from its resources. Hence, in addition to a firm's products in development, a firm's knowledge or history of M&A reflects another

'commercialization' aspect of the absorptive link concept and is hypothesized as follows:

Hypothesis 6: A firm's history of mergers and acquisitions has positive effect on a firm's product performance.

Moderating effects of research alliances on a firm's M&A

A firm's history of M&A also enables the firm's absorptive link to exploit the benefits of its research alliances. In the biotechnology industry, M&A are motivated by excess capacity arguments (Danzon *et al.*, 2003). Excess capacity occurs when a firm faces gaps or shortages in their pipeline of drugs to which render a firm's current level of specialized manufacturing, sales and marketing capital excessive (Danzon *et al.*, 2003). Such problems of excess capacity arise because there is often competition among established pharmaceutical firms for research projects (Danzon *et al.*, 2003; Pisano, 1990; Rothaermel and Deeds, 2004; Teece, 2000). Such competition can dry up a firm's drug pipeline and thus renders a firm from fully utilizing its M&A experiences. With this threat of excess capacity, a biotechnology firm is induced to seek research alliances to fill up their drug pipeline so as to more fully utilize this commercializing experience. This is consistent with Penrose's (1959) who argues that a firm's growth is motivated by inducements to improve the utilization of slack or unused capital (e.g. Ng, 2007). As a result, with a firm's history of M&A, this suggests that a firm's absorptive link seeks to form research alliances because by gaining access to research, it more fully utilizes a firm's commercial experiences in bringing basic research to the market.

However, unlike the diminishing effects of prior hypotheses, the moderating influence of a firm's research alliance on its absorptive link is not subject to a diminishing return effect. Due to the scarcity and thus competition of research projects (Danzon *et al.*, 2003; Graves and Langowitz, 1993; Pisano, 1990), the selection of research projects is subject to a 'pecking order' effect (see also Rothaermel and Deeds, 2006). Due to the threat of excess capacity, a firm is induced to seek the most promising and commercializable research projects first. Subsequent research alliance partnerships then lead to eventual reductions in firm performance because competition for the most promising research projects leaves fewer remaining projects with commercial potential. Hence, this pecking order effect suggests that there is a first mover advantage in seeking research alliances. Yet, since biotechnology research continues in a rapid and at a times at a revolutionary technological pace (Liebeskind *et al.*, 1996; Pisano, 1990), new and promising research discoveries are continually being injected with in the biotechnology

technology landscape. This suggests that further increases in research alliances can provide a firm access to the most current and potentially promising research. To capture this non-monotonic U shape effect, the moderating effects to a firm's absorptive link is hypothesized as follows:

Hypothesis 6a: The effect of a firm's history of M&A on product performance is moderated by a U shape relationship to a firm's research alliances

3. Method

Data and sample

In using one of the most commonly used databases in the biotechnology industry (Deeds and Hill, 1996; Lane and Lubatkin, 1998; Powell *et al.*, 1996; Rothaermel, 2001; Rothaermel and Deeds, 2004, 2006; Hess and Rothaermel, 2011), this study draws from the 'BioScan' database to empirically examine the six absorptive link hypotheses. This study's empirical analysis is based on the 2004 edition of BioScan in which a sample of 372 public biotechnology and pharmaceutical companies is used. Consistent with samples used in prior studies (see Deeds and Hill, 1996; Hoang and Rothaermel, 2005; Rothaermel, 2001; Rothaermel and Deeds, 2004, 2006), this sample contains firms that produce human therapeutic products and related diagnostic services and products. However, unlike prior studies, this study's sample is based on a more recent sampling period of 2004. For instance, Rothaermel and Deeds' (2006) study period was based in 1997 and more recently, Hess and Rothaermel's (2011) study was based on a 1997-2003 sampling period. To our knowledge, this study's sample reflects one of the most up to date samples in studies of product performance in the biotechnology industry.

Measures

Dependent variable

As the dependent variable is a firm's product performance, the aggregate number of commercialized firm products is measured by a count variable (see also Rothaermel and Deed, 2006), *Products*. Commercialized products are products that have completed all phases of product development – preclinical, phase I, phase II and phase III, received FDA approval – and are currently on the market. This definition is consistent with one of the absorptive capacity (output) measures (i.e. new product announcements) proposed by Zahra and George (2002). Similar definitions of firm performance have also been used in prior product studies (Deeds and Hill, 1996; Nerkar and

Roberts, 2004; Rothaermel 2001; Rothaermel and Deeds, 2004, 2006;).

Independent variables

Strategic alliances: A biotechnology firm's strategic alliances, *Alliance*, is a count variable of the cumulative alliances formed by the firm, since founding¹. This strategic alliance variable, *Alliance*, consists of the aggregation of *Licensing*, *Research and Development (R&D)*, *Marketing*, *Manufacturing*, and *Distribution* agreements (see also Chan *et al.*, 1997; Deeds and Hill, 1996; Lane and Lubatkin, 1998; Powell *et al.*, 1996; Rothaermel and Deeds, 2004, 2006). To examine Hypotheses 2a and 4a, R&D and Marketing agreements were used to construct the respective R&D and Marketing alliances. Furthermore, to examine Hypothesis 5a, a commercial alliance (*C.Alliance*) variable was also created by aggregating *Licensing*, *Marketing*, *Manufacturing* and *Distribution* agreements. To test for the non-monotonic influences of strategic alliances, the quadratic form of these variables were constructed.

A firm's absorptive link as prior knowledge: Since a firm's absorptive link is driven by its prior knowledge, a firm's absorptive link is proxied by four knowledge measures. First, a firm's age, *Age*, is used as a broad proxy to capture a firm's prior cumulative knowledge of resource uses. Although this is a coarse grained measure, other types of cumulative knowledge, such as learning curve effects, were controlled for by a firm's size with the variable, *Employees* (see also Rothaermel and Deeds, 2006). To capture a firm's diverse knowledge of resource uses, a firm's research diversity, *Diversity*, is used (see also Rothaermel and Deeds, 2006). *Diversity* is a count of the distinct number of technological and/or research areas of specialization. This diversity measure reflects the number of subfields in which the firm has participated in. This diversity measure has also been used by Rothaermel and Deeds (2006) and Shan *et al.* (1994). To capture the commercializing aspects of the absorptive link concept, a firm's commercial knowledge is measured by its cumulative number of products in development (see also Nicholls-Nixon and Woo, 2003; Rothaermel and Deeds, 2004). A firm's products in development, *P.Dev.*, is a count variable of all products that have entered clinical trials but have not yet reached the market. The other commercializing aspect of the absorptive link concept is captured by a firm's history of mergers and acquisitions. *M&A* are used to capture a firm's experiences from the acquisition or loss of knowledge through M&A activities. It is computed as

¹ For some of the firms in this sample, they have alliances that trace back to 1980 (see also Rothaermel and Deeds, 2004).

the difference in the cumulative number of firm mergers less divestitures, *M&A*, since the firm's founding (see also Rothaermel and Deeds, 2006). The moderating impacts of alliances on a firm's absorptive link are measured by the interactions between each of these four measures of prior knowledge with each of their respective alliances.

Control variables: In knowledge intensive industries, firm size is measured by the number of employees, *Size* (Graves and Langowitz, 1993; Pennings and Harianto, 1992; Rothaermel and Deeds, 2004; Shan *et al.*, 1994). Moreover, to account for institutional differences, the location of the firm, *Location*, is coded as a dummy variable (0 US based, 1 non-US based) (Rothaermel and Deeds, 2004, 2006). The number of subsidiaries, *Subsidiaries*, held by a firm is included because they provide access to foreign markets and/or provide entrance into new product-markets (Rothaermel and Deeds, 2006). Lastly, the number of institutional investors, *Investors*, (i.e. investors from major banks, fund agencies) is also included because investors provide sources of funding necessary to bring products to markets (Rothaermel and Deeds, 2004).

Estimation procedure

Poisson and Negative binomial estimations are often used (Wooldridge, 2003) when the dependent variable of interest involves count data (see also Rothaermel and Deeds, 2006; Rothaermel and Hess, 2007; Hess and Rothaermel, 2011; Wooldridge, 2003). This is because as count data does not have a normal distribution other estimation procedures, such as OLS, would result in biased and inefficient estimates (Wooldridge, 2003). In this study, Poisson regression using Maximum Likelihood Estimation (MLE) methods was chosen not only because the dependent variable, *Products*, is a count variable, but also because 34.5% of this sample exhibits zero observations. According to Greene (2000) and Wooldridge (2003), the Poisson estimation procedure is generally appropriate when a significant population of the sample contains zero values. However, one of the assumptions of a Poisson regression is it requires that the mean is equivalent to its variance. Negative binomial regressions have thereby been proposed to relax such a restriction (see Rothaermel and Deeds, 2004). Yet, a uni-variate parametric estimation of the dependent variable does not support this probability distribution (Simetar Software) and therefore the Poisson regression is used in favour of the Negative binomial model (see also Rothaermel and Deeds, 2006). Wooldridge (2003) also argues the Poisson regression is robust to the restriction of mean-variance equivalence. Hence to test hypotheses 1-6, MLE estimations of a Poisson regression was applied to

eight models. Models corresponding to each of the tested hypotheses were estimated with the Shazam econometrics software (version 9.0).

When estimating these models, a number of distinctions should, however, be noted. First, as a firm's absorptive link is moderated by its alliances, such moderating effects are tested through interactions between a firm's prior knowledge and that of its alliances. These interactions are standardized (Aiken and West, 1991). This is because since the concept of absorptive link is mutually related to a firm's alliances, these variables are likely to be strongly correlated. Hence, the standardization of these interacting variables was done to overcome problems of multi-collinearity (Aiken and West, 1991; see also Rothaermel and Deeds, 2006). To standardize these variables, the absorptive link and alliance variables are 'mean centered' the estimation (Aiken and West, 1991; see also Rothaermel and Deeds, 2006). Lastly, as there was considerable variability in the size variable, *Employees*, has been log transformed to minimize heteroscedastic influences (Wooldridge, 2003).

4. Results

The descriptive statistics for the theoretical variables of interests and their correlations are shown in Table 1 and the Poisson regression estimates are shown in Table 2. Given the interrelationships between the concept of absorptive link and alliances – as well as other variables –, the models in Table 2 were assessed for multi-collinearity. To measure multi-collinearity, the condition index or variance inflation factor for each of the models was calculated. Multi-collinearity is moderate to strong when the condition index falls within a range of 10 to 30 (Gujarati, 1988). Because the variables of theoretical variables of interest were standardized, most of the models – with the exception of models Hypothesis 2a and 4a – were below the 10 point cut off. For instance, all models with the exception of models Hypothesis 2a (condition index = 14.45) and 4a (condition index = 13.08)² did not exceed 9.98. For these remaining models, problems of multi-collinearity should be taken into account when interpreting their estimated coefficients.

² For these remaining models, a common procedure for the correction of multi-collinearity is to combine correlated variables into a single variable. However, as one can see in Hypothesis 4a., the aggregation of *R&D*, *Licensing*, *Marketing*, *Distribution* and *Manufacturing* into a single *Alliance* variable, the Variation Inflation factor for model 5 dropped from 14.45 (model 3) to 13.08. Hence, in spite of such corrective procedures – in addition to that of standardization, these model estimates need to take problems of multi-collinearity into account when interpreting these model estimates.

Table 1. Descriptive statistics and correlations.

Variables	Mean	St. Dev	P.Dev	Products	Age	Location	Investors	Subsidiaries	Size	R&D	Licensing	Marketing	Distribution	Manufacturing	Alliances	M&A	Diversity
P.Dev	5.772	6.882	1.000														
Products	4.325	7.841	0.444	1.000													
Age	21.226	23.647	0.117	0.341	1.000												
Location	0.651	0.477	-0.028	-0.101	-0.157	1.000											
Investors	1.893	3.445	0.076	-0.113	-0.139	0.143	1.000										
Subsidiaries	3.164	13.649	0.228	0.344	0.259	-0.032	-0.083	1.000									
Size	5.233	2.202	0.324	0.549	0.471	-0.235	-0.043	0.342	1.000								
R&D	4.479	6.397	0.499	0.474	0.095	0.076	0.061	0.212	0.430	1.000							
Licensing	2.403	4.107	0.404	0.447	0.152	0.057	0.047	0.110	0.332	0.539	1.000						
Marketing	1.288	2.330	0.381	0.465	0.221	0.042	-0.004	0.322	0.453	0.563	0.473	1.000					
Distribution	0.683	1.523	0.154	0.321	0.060	0.107	0.010	0.906	0.185	0.128	0.299	0.444	1.000				
Manufacturing	0.395	1.183	0.093	0.247	0.094	-0.041	-0.039	0.130	0.198	0.213	0.199	0.341	0.152	1.000			
Alliances	9.164	11.705	0.526	0.577	0.171	0.089	0.050	0.245	0.489	0.885	0.801	0.751	0.407	0.268	1.000		
M&A	0.984	2.767	0.347	0.260	0.052	0.077	-0.013	0.183	0.259	0.289	0.229	0.277	0.161	0.046	0.322	1.000	
Diversity	3.513	3.293	0.304	0.335	0.173	-0.071	-0.062	0.073	0.384	0.283	0.258	0.275	0.185	0.095	0.341	0.258	1.000

Table 2. Poisson regression estimates for dependent variable products.

Variables	Baseline	Hyp. 1	Hyp. 2	Hyp. 2a	Hyp. 3	Hyp. 3a	Hyp. 4	Hyp. 4a	Hyp.4a(opt)	Hyp. 5	Hyp. 6
Pseudo R ²	0.3366	0.4780	0.5353	0.5507	0.4881	0.5203	0.4997	0.5055	0.5039	0.5619	0.55367
Log likelihood	-1347.32	-1242.11	-1186.72	-1172.86	-1233.36	-1204.59	-1225.05	-1223.5	-1223.11	-1202.06	-1206.9
LikeLikelihood Ratio Test	210.42	210.42	321.20	27.72	17.50	57.54	16.62	3.10	3.88	45.98	36.30
Relative to Model X	1.0*	1.0*	1.0*	3*	2*	4*	4*	6	6	6*	6*
Estimated coefficients											
Location	-1.232856	-0.2359*	-0.2668*	-0.2145*	-0.2515*	-0.128**	-0.238*	-0.21774*	-0.2464*	-0.1651*	-0.164*
Investors	-0.0273*	-0.0366*	-0.0412*	-0.0420*	-0.0335*	-0.0287*	-0.0301*	-0.0315*	-0.0283*	-0.0289*	-0.0329*
Subsidiaries	0.0016**	0.0014***	0.0045*	0.0049*	0.0015***	0.000996	0.00224*	0.00204*	0.0025*	0.0018***	0.00183***
Size	0.3301*	0.2160*	0.2382*	0.2318*	0.1907*	0.2569*	0.181*	0.181*	0.1807*	0.1759*	0.169*
Alliance	0.0428*	0.0428*	0.0752	0.1135*	0.0433*	0.0357*	0.0389*	0.0407*	0.0362*	0.0456*	0.0385*
Alliance ²	-0.0003	-0.0003	0.0194*	-0.0297*	-0.0003	-0.000181*	-0.000232*	-0.000262*	-0.0002*	-0.0005*	-0.000281*
R&D			0.0117***								
Licensing			0.0344*	0.0338*							
Marketing			-0.0533*	-0.0317**							
Distribution			0.1646*	0.1561*							
Manufacturing			0.0752	0.0767*							
R&D*Marketing				0.1135*							
R&D*Marketing ²				-0.0297*							
Age					0.00321*	0.0285*		0.00301*	0.0031*	0.0045*	0.00373*
Age*Alliance						0.0773*					
Age*Alliance ²						-0.0190*					
Age*Size						-0.00261*					
Diversity							0.0236*	0.0289*	0.0154***	0.0284*	0.0213*
Diversity*R&D								-0.0402***			
Diversity*R&D ²								0.00806			
Diversity*Alliance											
Diversity*Alliance ²									0.0532***		
Diversity*Alliance ²									-0.0100**		
Pdev										-0.0058	0.0121*
Pdev*C.Alliances										0.0961*	
Pdev*C.Alliances ²										-0.0079	
M&A											0.0326*
M&A*R&D											-0.0906*
M&A*R&D ²											0.0127*

* = $P < 1\%$; ** = $P < 5\%$; *** = $P < 10\%$.

According to Table 2, the base line model indicates that all control variables with the exception of *Location* were significant. The subsidiary (Rothaermel and Deeds, 2004) and size (Rothaermel and Deeds, 2006) coefficients are significant at their respective 5% and 1% levels and are consistent with prior expectations. The investor coefficient was significant at the 1% level but was negative. This negative estimate may be due to the fact that the count nature of the investor variable does not account for the magnitude of investments. With regards to the main variables of interest, model Hypothesis 1 – as well as in all remaining models – show that the *Alliance* and *Alliance2* estimates are significant and exhibit an inverted U shape relationship to a firm's product performance. Hypothesis 1 is supported. In model Hypothesis 2 and with the exception of *Marketing* alliances, all alliances – *R&D*, *Licensing*, *Distribution* and *Manufacturing* alliances – were significant ($P < 1\%$) and positive. Increasing a firm's *R&D*, *Licensing*, *Distribution* and *Manufacturing* alliances by 0.1 or 10% yield a respective increase of 0.194%, 0.344%, 1.64%, and 0.752% to a firm's number of products. As *R&D* has the lowest impact to a firm's product performance and given that the *Marketing* alliance coefficient was negative and significant ($P < 1\%$), Hypothesis 2 is not supported. However, as shown in model Hypothesis 2a, the interaction coefficient between the *R&D* and *Marketing* alliances is positive and significant ($P < 1\%$) and thus providing support for Hypothesis 2a. Although this result confirms Hypothesis 2a, the product-marketing literature also indicates that an excessive focus on customer marketing can crowd out a firm's efforts to innovate (e.g. Christensen and Bower, 1996; Danneels, 2003; Hamel and Prahalad, 1991). Hence, to examine this effect, we also included a squared *Marketing* alliance term to this model. As the interaction between *R&D* and *Marketing*² alliance is negative and significant ($P < 1\%$), the complementary effect described in Hypothesis 2a appears to diminish with increasing *Marketing* alliances. This lends support to the 'tyranny of the served market' argument made by product-marketing researchers (e.g. Christensen and Bower, 1996; Danneels, 2003; Hamel and Prahalad, 1991).

To examine the absorptive link arguments, model Hypothesis 3 – as well as in models 4a-6³ – shows a firm's age is positive and significant ($P < 1\%$) and thus supporting Hypothesis 3. Model Hypothesis 3a introduces the interaction between a firm's age and its alliances. Yet, since both a firm's age and size can be potentially

correlated, these firm level interactions were controlled for when assessing this absorptive link hypothesis. This is because since size is measured by the number of a firm's employees, each employee possesses understanding of the functional uses of its firm's resources. Therefore, a firm with a large number of employees may also possess great knowledge of resource uses and thus can interact with a firm's cumulative experiences, age. Therefore to control for such influences, their interactions are also included in the model Hypothesis 3a. When controlling for this firm level interaction, the absorptive link between a firm's age and alliances shows that their interaction coefficient is positive and significant ($P < 1\%$). The diminishing effect of alliances on a firm's age is negative and significant ($P < 1\%$). These results support Hypothesis 3a.

In model Hypothesis 4 as well as in all remaining models, a firm's diversity estimate is positive and significant ($P < 1\%$). Hypothesis 4 is supported. However, with respect to the moderating effects of *R&D* on a firm's absorptive link, the *Diversity***R&D* interaction has a negative estimate that is significant ($P < 1\%$). While, the *Diversity***R&D*² interaction has a positive estimate that is significant ($P < 10\%$). As Hypothesis 4a predicts a respective positive and negative estimate, these findings do not support Hypothesis 4a. Moreover, in model Hypothesis 5, the products in development, *P.Dev.*, estimate was not significant and thus Hypothesis 5 was not supported. With respect to the moderating influences on a firm's absorptive link, the *P.Dev.***C.Alliances* interaction is positive and significant ($P < 1\%$). However, this absorptive link did not exhibit any significant diminishing effects and therefore only the positive moderating effects of Hypothesis 5a was supported. In examining model Hypothesis 6, a firm's history of M&A is positive and significant ($P < 1\%$). Hypothesis 6 is supported. With respect to the moderating effects to a firm's absorptive link, the interaction estimates of a firm's M&A and Research Alliances are all significant ($P < 1\%$) and have the predicted signs described in Hypothesis 6a.

5. Discussion

In relating our empirical findings to broader research on product innovation, the support for Hypothesis 1 in model Hypothesis 1 confirms earlier findings that indicate a biotechnology firm's product performance is a non-monotonic function of its alliances (Rothaermel and Deeds, 2004, 2006; Hess and Rothaermel, 2011). However, unlike these earlier studies, this study's findings are based on a later sampling period to which suggests that this non-monotonic relationship may be robust to different periods of industry development. Furthermore, as alliances have been previously reported (Rothaermel and Deeds, 2006)

³ To be consistent with model Hypothesis 3 that only examined the cumulative aspects of the absorptive link variable, model Hypothesis 4 was used to examine the exclusive effects of a firm's diversity of knowledge resource on its product performance. Both variables are however then included in the subsequent model.

and/or argued (Hess and Rothaermel, 2011; McEvily and Chakravarty, 2002) to have differential effects on a firm's product performance, model Hypothesis 2 adds to this discussion. Model Hypothesis 2 shows that different alliances yield different effects on a biotechnology firm's product performance. Although we did not find support for Hypothesis 2, one possible explanation for this lack of support is that given the long lagged times in the drug development process (e.g. Powell *et al.*, 1996), R&D alliances may have a latent effect on a firm's product performance that is not captured by the cross sectional nature of this model. Moreover, with respect to a firm's marketing alliance, an increase of 0.1 or 10% in the number of marketing alliances yielded a decrease of 0.533% in the firm's product performance. Although unexpected, this finding appears to be consistent with the withdrawal of marketing activities among major pharmaceutical firms. For instance, Bristol Meyers had announced its withdrawing of conventional TV advertising and Weyer has announced significant reductions in its sales forces. Such reductions in marketing activities have been attributed to the increasing consumer distrust of drug advertisements (Forbes, 2005). Our negative coefficient findings may be attributed to some of these considerations. Although Hypothesis 2 was not supported, model Hypothesis 3a nevertheless did find support for the complementary effect between R&D and marketing alliances on a firm's product performance. This finding builds on Rothaermel and Hess (2007) study in which they found a biotechnology's R&D capability exhibited a complementary effect to its biotechnology alliance. Model Hypothesis 3a shows that complementarities can exist not only between firm and alliance level interactions (Rothaermel and Hess, 2007), but also between alliances themselves. With respect to this study's absorptive link hypotheses, models Hypothesis 3 – Hypothesis 4 indicate a firm's cumulative and diverse knowledge experiences positively influence a firm's product performance. This suggests that a Penrosian (1959) explanation of the product discovery process can be used to further supplement absorptive capacity explanations of innovation. In particular, as the concept of absorptive capacity rests on a firm's 'prior knowledge' (Cohen and Levinthal, 1990), a firm's prior knowledge may entail more than its memory but may also entail a firm's cumulative and diverse knowledge of resources uses. Furthermore and as indicated in model Hypothesis 3a, a firm's cumulative knowledge in discovering new resources uses from its alliances partners is subject to diminishing return effects and thus, unlike a firm's memory, this prior knowledge implies a need to manage alliances more effectively. However, with regards to the moderating effects on a firm's diverse knowledge, model Hypothesis 4a did not support our absorptive link

arguments. Yet, since diverse knowledge increases a firm's ability to relate to a broader set of external experiences (Cohen and Levinthal, 1990), we examined this relationship by introducing a model Hypothesis 4a (optional) that included the interaction between a firm's diversity and the aggregation of 'all' alliance types. In this model, the positive yet diminishing effects described in Hypothesis 4a was observed. This is also consistent with McFadyen and Cannellas' (2004) findings. This finding thereby suggests the behaviour of a firm's absorptive link is sensitive to the level of aggregation used in the construction of alliances. With regards to the commercial aspects of the absorptive link concept, model Hypothesis 5 indicated that a firm's product in development did not influence product performance (Hypothesis 5) and that the diminishing effects of a firm's commercializing alliances on a firm's product development was not observed (Hypothesis 5a). This suggests that although prior studies indicated that strategic alliances can be subject to opportunistic threats of adverse selection, moral hazard and hold up (Jones *et al.*, 1997; Osborn and Hagedoorn, 1997; Pisano, 1990), this lack of a diminishing effect suggests that such threats of opportunism among commercializing alliances are not a significant deterrent to a firm's absorptive link. Model Hypothesis 6. provides support for Hypotheses 6 and 6a which suggest that a firm's product performance is not only driven by its commercial knowledge (i.e. M&A experience), but that such commercial knowledge is instrumental to exploiting the 'pecking order' dynamics of R&D alliances. This is consistent with Liebeskind *et al.* (1996) who argue that there tends to be a winner takes all or technology race dynamic in the biotechnology industry. Lastly, since a firm's product performance depends on both a firm's functional as well as commercial knowledge of resource uses, the joint impact of these two distinct sources of 'prior' knowledge appears to be supported in model Hypothesis 6. In this model, all four proxies of prior knowledge – Cumulative, Diverse, Products in Development, and M&A – were positive and significant ($P < 1\%$ level). This suggests that future research on the absorptive capacity concept may want to consider these different forms of 'prior knowledge'.

6. Conclusions

This study posed the question: what determines a biotechnology firm's product success, if the product requires multiple technologies that are not held by any one firm? To address this question, this study introduced and empirically examined an 'absorptive link' concept to the biotechnology product market. A central argument of this study is that: driven by a firm's functional and commercialized knowledge, a firm's absorptive link serves

to not only discover and commercialize a firm's varied resources uses, but also that of its alliance partners. Such a concept generated 6 testable hypotheses and was empirically examined in a sample of 372 biotechnology firms. Based on this concept of absorptive link and its analyses, this study offers three key contributions and implications to product performance research.

First, as cross level analyses are increasingly called for in management research (Rynes, 2005), the concept of absorptive link explains a firm's product performance by bridging firm level factors with that of alliance level considerations. Such a concept builds upon recent studies that advocate a more multi-levelled approach to innovation research (Rothaermel and Deeds, 2006; Rothaermel and Hess, 2007; Hess and Rothaermel, 2011). A contribution of this absorptive link concept is that a firm's memory is but one of many experiences that promote the assimilation of external experiences (Cohen and Levinthal, 1990). In addition to a firm's memory, a firm's functional and commercial knowledge of resources uses is argued to also impact this assimilation of alliance experiences by seeking to discover and commercialize new resources uses that extend beyond a firm's organizational boundaries. Such knowledge experiences, as a consequence, are distinct from other types of alliance experiences. For instance, alliance management capability research (Ireland *et al.* 2002; Rothaermel and Deeds, 2006) contends that repeated alliance exchanges or alliance experiences promote the transfer of complex, tacit, and causally ambiguous knowledge. This transfer of knowledge can overcome various transaction cost problems relating to hold up moral hazard in learning races, and an underinvestment in assets by alliance partnerships etc (Ireland *et al.*, 2002). Thus, alliance management capability has been argued to improve a firm's performance – including that of its product performance – because a firm's experiences in managing such alliances can curtail such governance problems (see also Dyer and Singh, 1998; Ireland *et al.*, 2002; Rothaermel and Deeds, 2006). Although such governance provides a more equitable distribution of rents amongst alliance partners (see Dyer and Singh, 1998; Ireland *et al.*, 2002; Osborn and Hagedoorn, 1997), such an approach, however, does not explain the types of knowledge responsible for the discovery of these rents. A firm's absorptive link, driven by its functional and commercial knowledge of resource uses, addresses this gap in which product innovation not only depends on a firm's alliance experiences in governing 'effective' partnerships, but it also depends on a firm's ability to discover and commercialize new uses of resources that are not known by their alliance partners.

Second, the functional and commercialized aspects of the absorptive link concept also extend Penrosian explanations

of the product discovery process. With regards to a firm's functional knowledge of resource uses, the concept of absorptive link extends Penrose's (1959) firm level analysis to a network level of examination. This study argues that a firm's cumulative and diverse knowledge of the functional uses of resources enable the firm to 'see an eventual combination of resources' that extend beyond a firm's organizational boundaries to include those resource combinations and uses of its alliance partners. This enables the firm to solve a 'larger jigsaw problems' that was not previously envisioned by Penrose's treatment on the theory of the growth of firm (see also Denrell *et al.*, 2003; Ng, 2007). Furthermore, the 'commercial' aspects of the absorptive link concept also extend Transaction Costs explanations of product diversification (Denrell *et al.*, 2003; Williamson, 1975). Williamson (1975) and Denrell *et al.* (2003) argue that a firm diversifies into new and unrelated product markets because it has an internal capital market that is better suited to discovering the commercial value of a new product initiative than that of the market price system. The distinction with this study is that the commercial value of a new product does not depend on an internal competitive valuation process (e.g. Williamson, 1975), but rather can depend on a firm's commercialized knowledge. Specifically, unlike Williamson (1975), a firm introduces new products to the market not because of an internal competitive market process, but because the firm has commercial knowledge about the functional uses of resources that cannot be readily known by the external market.

Third, this concept of absorptive link also introduces two implications to the practicing manager. First, and especially in accordance to absorptive capacity research, a firm's investment in R&D is often viewed as an important means to developing new products because it enables a firm to assimilate external technologies (Rothaermel and Hess, 2007). However, when dealing with the biotechnology industry, managers may at times face many research projects that compete for internal corporate resources and thus investments in R&D offers limited guidance on those projects a manager should invest in. This study argues that along with standard capital budgeting techniques, the selection of internal research projects by managers should consider projects that the manager has the most functional and commercial knowledge about. That is to say, managers should not just focus their investments in basic research, as basic research inherently has many functional uses, but rather the selection of these internal projects needs to also consider those projects in which a firm has commercial experiences in bring them to market. Such an attention to a firm's functional and commercial experiences are not typically addressed in capital budgeting techniques, such as Net Present Value analysis, and that of Real option

valuations. The attention to these knowledge considerations in conjunction with these valuation techniques can thus assist in a manager's selection of internal investment projects. Second and subsequently, as such functional and commercial knowledge can be leveraged to the resources of alliance partners, the implication to managers of new products is that investments in R&D is not a panacea to the success of its firm's product, but success requires considering that the functional and commercialized aspects of its investment operates within a greater firm-inter-firm context. More generally speaking, the broader implication to managers of the absorptive link concept is it serves to broaden a firm's product discovery process to outside experiences and thus mitigates 'myopic' behaviours that can inhibit a firm's product innovation process. That is, as managers tend to resist the adoption of external ideas, the concept of absorptive link serves to mitigate problems relating to 'not invented here syndrome'.

In light of these distinctions, this study's absorptive link arguments and findings should however be tempered by its limitations. First, the development of new products involves a temporal component and thus future research should consider using panel regression methods (e.g. Hess and Rothaermel, 2011; Rothaermel and Hess, 2007). Second, our measures of a firm's prior knowledge are relatively coarse grained, especially with that of a firm's age. Therefore, other measures should be examined to determine the robustness of our absorptive link arguments. Nevertheless, this study's findings do provide some initial promise with the proposed absorptive link construct and thus future empirical research is called for to further validate the robustness of this concept.

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