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Partner Type Diversity in Alliance Portfolios: Multiple Dimensions, Boundary Conditions and Firm Innovation Performance

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ABSTRACT Our research extends the current knowledge based view on the configuration of alliance portfolios and their deployment in different external knowledge environments. We study these alliance portfolios in a longitudinal sample (1996–2010) for over three thousand firms that operate in a large number of industries in the Netherlands. Our findings indicate that partner type variety and partner type relevance, as different dimensions of partner diversity in alliance portfolios, both have an inverted U-shaped association with firm innovation performance. However, alliance portfolios characterized by both high partner type variety and high relevance cause inferior innovation performance. Different external knowledge environments, characterized by different levels of industry modularity and scope of knowledge distribution, moderate the inverted U-shaped associations of partner type variety and relevance in alliance portfolios with firm innovation performance in opposing directions. While for partner type variety, a high level is found to be optimal in environments with greater modularity or broader scope of knowledge distribution, for partner type relevance it turns out that a low level is optimal under more modular industry conditions.

Keywords: alliance portfolios, industry contingencies, innovation performance, knowledge-based view, portfolio diversity

INTRODUCTION

Scholars studying firm alliances increasingly argue that corporate objectives such as the spurring of innovation are not achieved through the success of one particular alliance but through the joint effect of the overall portfolio of collaborations (e.g., Lavie, 2007;

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Wassmer, 2010). Alliance portfolios enable the development of new capabilities and new products through various knowledge inputs (Rothaermel and Alexandre, 2009) and thereby, have a potential influence on firm innovation performance. Accordingly, recent research suggests that the configuration of an alliance portfolio, in particular with respect to its diversity, is a critical strategic issue (Faems et al., 2005; Hoffmann, 2007; Jiang et al., 2010; Lee et al., 2017).

Previous studies have explored various types of alliance portfolio diversity, such as technological, governance, national, or partner type diversity (see Lee et al., 2017, for an overview). Empirical work reveals mixed findings regarding the implication of these types of diversity for firm innovation performance, ranging from positive (e.g., Nieto and Santamaria, 2007; Srivastava and Gnyawali, 2011), to negative associations (Cui and O'Connor, 2012), as well as inverted U-shaped (De Leeuw et al., 2014; Oerlemans et al., 2013) or even U-shaped relationships (Wuyts and Dutta, 2014). Relying on the knowledge-based view (KBV), we contribute to this literature by shedding light on the intricacies of the alliance portfolio diversity – innovation performance relationship. Given the increasing number of actors that are participating in a more distributed innovation process (e.g. Faems et al., 2010; Laursen and Salter, 2006), we focus on partner type diversity as an important type of alliance portfolio diversity. Our investigation of partner type diversity addresses two important gaps in this line of research on alliance portfolios.

First, so far extant studies have investigated specific types of diversity (for instance, partner type diversity) in terms of single dimensions or measures (Caner and Tyler, 2013; Jiang et al., 2010; Van de Vrande, 2013). We argue that it is imperative to adopt a multi-dimensional perspective of partner type diversity. Prior studies already indicated that diversity does not only refer to the number of partner categories with which a firm forms alliances (i.e., partner types), but also includes the extent to which resources are distributed across these categories (see for instance Bruyaka and Durand, 2011). While previous research collapses these two dimensions within one construct, we tease them apart as we understand variety and relevance to refer to different aspects of alliance portfolio diversity. On the one hand, we define partner type variety as the number of different partner types (i.e., customers, suppliers, competitors, universities, research institutes) with whom a focal firm collaborates. On the other hand, we define partner type relevance as the importance of different partner types as sources of knowledge used in collaborative innovation activities.

Drawing from the KBV, we theorize that partner type variety and relevance trigger different knowledge sharing mechanisms that explain their associations with firm innovation performance. Prior literature differentiates between two knowledge sharing mechanisms in the context of alliances – knowledge access and knowledge integration (Grant and Baden-Fuller, 2004; Inkpen, 1998). First, knowledge access refers to a form of knowledge sharing in which each firm accesses its partner's knowledge base in order to exploit complementarities, but with the intention of maintaining its distinctive base of specialized knowledge (Grant and Baden-Fuller, 2004; Lavie, 2007). Second, knowledge integration suggests that firms use their alliances to actually absorb and internalize their partner's knowledge base (Grant and Baden-Fuller, 2004; Lorenzoni and Lipparini, 1999; Vasudeva and Anand, 2011). We follow this perspective and suggest that these two knowledge sharing mechanisms help explain how partner type variety and relevance contribute to firm innovation performance. We further argue that the multi-dimensional perspective of partner type diversity becomes particularly crucial when investigating the joint implications of partner type variety and relevance for firm innovation performance. As explained in detail in the next section, based on our KBV perspective we examine potential negative consequences for the innovation performance of firms when they pursue alliance portfolios with both high partner type variety and high relevance simultaneously.

A second gap that this study addresses refers to the boundary conditions that influence the effectiveness of alliance portfolio diversity. Prior studies have seldom examined the environmental conditions under which alliance portfolio diversity it is most effective for innovation performance. Yet, our KBV perspective suggests that it is not only relevant to investigate knowledge deployment (i.e., knowledge sharing) but that it is crucial to pay equal attention to the underlying characteristics of the knowledge that is being deployed (Grant 1996b). When firms interact with multiple partners through alliance portfolios, their focus shifts from a predominant consideration of the characteristics of knowledge embedded within organizations (Henderson and Clark, 1990) to a greater attention for the characteristics of knowledge residing in the external environment Garriga et al., 2013). Following suggestions by the literature that extends the KBV to external knowledge inputs, we study two types of external knowledge characteristics – modularity and the scope of knowledge distribution – and argue that these characteristics influence the effectiveness of knowledge sharing in the context of alliance portfolios.

A first characteristic that is fundamental to the KBV is the modularity of knowledge resources (Grant, 1996b). Modularity refers to the degree of which knowledge can be organized in relatively independent sub-systems (Rosenkopf and Schilling, 2007) and is particularly important in organizing complex capabilities, which are typically found in an innovation context. While the KBV has focused on modularity of internal organizational resources and their effects on knowledge integration, we extend this perspective and examine empirically how the modularity of external knowledge influences the relationships between partner type diversity of alliance portfolios and innovation performance. A second relevant characteristic of external knowledge resources refers to the scope of knowledge distribution. Products, sectors, and industries differ in terms of the breadth of knowledge requirements and to the extent that knowledge tends to be narrow or broad (Grant and Baden-Fuller, 2004). In the case of broad knowledge requirements, knowledge inputs are not solely based on intra-firm innovative activities but are likely to be derived from other organizations. Hence, knowledge is more broadly distributed across external actors. Conversely, when knowledge requirements are narrower and product specific, external knowledge is likely to be less widely distributed. These knowledge requirements and associated distributions may have important implications for the effectiveness of alliance portfolio diversity.

We study the impact of both knowledge characteristics – modularity and the scope of knowledge distribution – at the level of the industry. Seminal contributions by Scherer (1982), Pavitt (1984) and Rosenkopf and Schilling (2007) already indicated that industries differ widely in terms of modularity and knowledge distribution. These findings suggest that firms face continuing long-term differences in the scope of knowledge distribution and the degree of modularity among the industries in which they operate.

In sum, adopting a KBV lens of alliance portfolio diversity this study addresses the following research questions: What is the influence of multiple dimensions of alliance portfolio partner type diversity (i.e., partner type variety and relevance) on firm innovation performance? How do these effects vary across characteristics of the external knowledge environment (i.e., modularity and scope of knowledge distribution)? A set of related hypotheses is tested on a longitudinal sample of over three thousand firms that operated in the Netherlands in a large number of industries during the period 1996–2010.

Our research indicates that in alliance portfolios both partner type diversity and relevance have an inverted U-shaped association with firm innovation performance. Pursuing an alliance portfolio with both high partner type variety and high relevance simultaneously, however, generates inferior innovation performance compared to when firms concentrate on either dimension of partner type diversity. In terms of the boundary conditions that impact the effectiveness of alliance portfolio diversity, our research indicates that the inverted U-shaped associations of partner type variety and relevance with firm innovation performance are moderated by the degree of industry modularity and the scope of knowledge distribution. Interestingly, these moderators influence the effectiveness of partner type variety and relevance in opposing directions: while in environments with greater modularity (broader scope of knowledge distribution) greater variety is optimal, these modular conditions favour lower partner type relevance. These findings extend existing research on a KBV understanding of the configuration of effective alliance portfolios and their deployment in different external knowledge environments.

THEORY AND HYPOTHESES

The overarching logic of our theoretical framework is based on the KBV and considers how two dimensions of alliance portfolio diversity (i.e., partner type variety and relevance) influence firm innovation performance via two separate knowledge-sharing mechanisms (i.e., knowledge access and knowledge integration). More specifically, knowledge access is primarily related to partner type diversity whereas knowledge integration is primarily related to partner type relevance. While knowledge access and integration have positive implications for innovation performance, we argue that increasing partner type variety and relevance are also associated with escalating costs that eventually exceed the benefits of the two knowledge-sharing mechanisms. Furthermore, we investigate how the effects of partner type variety and relevance on innovation performance are shaped by two characteristics of the external knowledge environment, i.e., modularity and scope of knowledge distribution. In the following, we develop hypotheses (see Figure 1) regarding the precise relationships between alliance portfolio diversity, innovation performance, and contingencies in the external knowledge environment.

Partner Type Variety, Relevance and Firm Innovation Performance

First, increasing variety of partner types in a firm's alliance portfolio generates benefits for innovation performance as it provides broader knowledge access. Different types of partners often possess unique resources as well as distinctive skills and experiences (Faems et al., 2010; Koka and Prescott, 2002). With increasing variety in alliance portfolios, firms develop relational breadth that enables passive access to these distinct

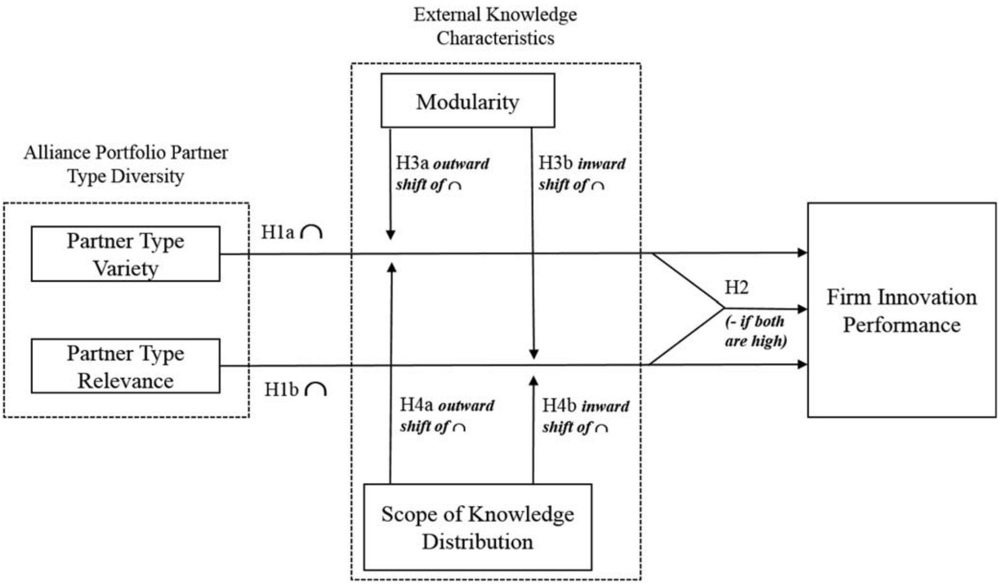

Figure 1. Theoretical model depicting relationships between alliance portfolio partner type diversity, firm innovation performance, and contingencies in the external knowledge environment

knowledge resources (Wassmer et al., 2017). Hence, the pool of knowledge resources that the firms can access is broadened through their collaboration with a variety of partner types. Following the KBV, the breadth of specialized knowledge that an organization can draw upon is a key mechanism for obtaining a competitive advantage, as it increases the causal ambiguity of knowledge combinations that are hidden from competitors (Grant, 1996a). Moreover, the more types of specialized knowledge firms can access, the greater the potential for creative recombination, complementary alignment, and spillover between these knowledge types, which contributes to innovation performance (Grant, 1996a; Lorenzoni and Lipparini, 1999; van den Bergh, 2008).

At the same time, alliance portfolios characterized by increasing partner type variety generate some costs. As the variety of partner types increases, the degree of complexity of the portfolio escalates and surges coordination and managerial costs (Bruyaka and Durand, 2011; Sarkar et al., 2009). Following transaction costs logic (Williamson, 1981), partner type variety will accelerate search costs for heterogeneous and less familiar partner types as well as increase the costs for monitoring and coordinating collaborations with very different partner categories (see also Goerzen and Beamish, 2005; Lee et al., 2017). As a firm is subject to a limited pool of attention that it can allocate across activities (Ocasio, 1997), these costs will likely reduce its focus on innovation (see also Laursen and Salter, 2006). Searching, monitoring and coordinating activities will limit the resources that a firm could otherwise allocate to those activities that generate innovation performance.

Following the above, we suggest that firms initially benefit from increased partner type variety in their alliance portfolios as it enables them to access and recombine a broader pool of knowledge to positively impact innovation performance. However, with increasing partner type variety, the transactional costs that a firm faces accelerate, resulting in an exponential cost curve. Subtracting these costs from the linearly increasing benefits gives rise to an inverted U-shaped relationship between partner type variety and firm innovation performance (see Haans et al., 2016). Initially, firms benefit from enhanced variety in partner types, but as this variety increases further, the costs of search, monitoring and coordination exceed the initial benefits of partner type variety that are associated with innovation performance. Hence:

Hypothesis 1a: Partner type variety in a firm's alliance portfolio has an inverted U-shaped association with firm innovation performance.

Second, increasing relevance of different partner types, by focusing on partners with important knowledge inputs, generates benefits for innovation performance, as it enables knowledge integration. As specific partner categories become more important to a focal firm and the more resources it commits to specific categories, the more it will develop relational depth with these partner types (Krishnan et al., 2006; Wassmer et al., 2017). With increasing relational depth, firms become more experienced and familiar with a specific partner type (Grant and Baden-Fuller, 2004). This facilitates the transfer of knowledge resources across partners and thus enables the actual internalization of external knowledge resources (Grant and Baden-Fuller, 2004; Kogut and Zander, 1992). Furthermore, familiarity and experience with a specific partner type enables the development of common norms and language (Kogut and Zander, 1992) and helps to build up partner type specific absorptive capacity (Sampson, 2007). Common language and absorptive capacity will not only facilitate knowledge sharing, but also allow for the actual absorption and internalization of external knowledge resources, which has positive implications for innovation performance.

However, increasing partner type relevance also comes with costs. Relational depth might develop into relational inertia, whereby a firm becomes rigid in its partner type preferences (Gargiulo and Benassi, 2000; Katila and Ahuja, 2002). Because of such inertia and path-dependency, firms may become locked-in into a sub-optimal partner type portfolio (van den Bergh, 2008). Over-dependence on particular partner types restricts the strategic flexibility of firms (Hagedoorn and Frankort, 2008) and hinders the re-allocation of resources to alternative partner types that may deliver more relevant knowledge resources. In line with the KBV, restrictions in knowledge reconfiguration possibilities are detrimental for innovation performance (Grant, 1996a). Moreover, as the relevance and relational depth of particular partner types increase so does the risk of unintended knowledge leakage (Hagedoorn and Frankort, 2008; Oxley and Sampson, 2004). This unintended knowledge leakage may reduce the uniqueness of firms' internal knowledge resources, which will eventually have a negative effect on innovation performance. The costs of relational inertia and knowledge leakage are likely to escalate quickly with increased relevance of partner type categories, resulting in an exponential cost curve that has a negative impact on innovation performance. Given these arguments, we expect the exponentially increasing costs of higher levels of partner type relevance to eventually exceed the linearly increasing benefits of this relevance. At lower levels of partner type relevance the benefits of experience, common language and shared knowledge base dominate, while at higher levels of relevance, costs of inertia and knowledge leakage prevail. Therefore:

Hypothesis 1b: Partner type relevance in a firm's alliance portfolio has an inverted U-shaped association with firm innovation performance.

Joint Effects of Partner Type Variety and Relevance on Firm Innovation Performance

We argue that pursuing both high variety and high relevance within partner type diversity (i.e., in larger number of partner categories) undermines innovation performance due to three reasons. First, the previous hypotheses suggest that partner type variety and relevance rely on two separate knowledge-sharing mechanisms – knowledge access and knowledge integration – that in turn contribute to innovation performance. These knowledge-sharing mechanisms are based on distinct organizing principles and routines (Kogut and Zander, 1992). Knowledge access routines refer to patterns of interaction that permit knowledge sharing while at the same time maintaining a distinctive base of specialized knowledge (Grant, 1996a; Grant and Baden-Fuller, 2004). Knowledge integration routines include the transfer and absorption of partner knowledge and aim at stimulating organizational learning (Grant and Baden-Fuller, 2004). The simultaneous pursuit of both types of distinctive routines is likely to result in increased complexity, tensions and coordination challenges that undermine innovation performance (Stettner and Lavie, 2014).

Second, and relatedly, the KBV emphasizes that efficiency in knowledge production and utilization requires specialization in the acquisition of knowledge (Grant, 1996a). This would suggest a lack of additivity between the two knowledge transfer mechanisms. On the one hand, partner type diversity is associated with a more passive approach to knowledge access that leaves the focal firm's knowledge base relatively unchanged. On the other hand, partner type relevance aims at a more active approach of knowledge internalization, where partners' knowledge is integrated and absorbed. Pursuing both passive knowledge access and active knowledge internalization, simultaneously and to a similar degree reduces the efficiency of knowledge aggregation and will ultimately have a negative impact on innovation performance (see e.g., Milgrom and Roberts, 1995 and Stettner and Lavie, 2014 for a broader discussion of conflicting routines).

Third, combining increased levels of partner type variety and relevance further reduces the strategic flexibility of a firm's alliance portfolio. As firms develop relational breadth with a larger number of partner types, they may develop an overall understanding about the nature and combination potential of external knowledge resources. These insights may lead focal firms to re-allocate resources from less promising partners to partners that deliver more valuable knowledge resource. However, the rigidity and inertia that is associated with high partner type relevance may hinder the focal firm to re-allocate resources across partner types. Hence, variety would be better combined with some focus or selectiveness in the relevance dimension. High variety combined with lower partner type relevance (i.e., fewer partner type categories that are relevant) would enable firms to react to information gained during collaborations and reallocate resources from less to more promising partner types. The extent to which firms can re-allocate and reconfigure existing knowledge sources is pertinent to competitive advantage (Grant, 1996a).

In sum, given conflicting routines, reduced efficiency and flexibility as firms pursue knowledge access and knowledge integration simultaneously, we expect that:

Hypothesis 2: Pursuing both high variety and high relevance within partner type diversity will undermine a firm's innovation performance relative to concentrating on either variety or relevance.

External Knowledge Characteristics

Modularity. Modularity refers to the degree to which production systems and product designs, used in particular industries, can be decomposed into separate components that are connected and matched to various configurations, albeit within a standardized interface (Baldwin and Clark, 2000; Rosenkopf and Schilling, 2007; Sanchez and Mahoney, 1996). In modular knowledge environments, design changes do not have to be fully system integrated but can be established as more or less independent component adaptations. As such, all production systems are to some degree modular as very few components of any product system are fully inseparable (Schilling, 2000). Therefore, modularity refers to a continuum that describes the degree to which components can be separated and recombined (Rosenkopf and Schilling, 2007). In the following, we discuss how these characteristics of modularity are associated with an increase of benefits that firms can derive from higher partner type variety in their alliance portfolio (see Hypothesis 1a). At the same time, these characteristics of modularity are associated with a decrease of the benefits associated with higher partner type relevance in their alliance portfolio (see Hypothesis 1b).

First, as more modular industrial settings enable division of labour and specialization, the capabilities and skills of different partner types become more differentiated and technical options offered by different partners become more diverse (Schilling, 2000). As a focal firm collaborates with a higher variety of partner types in such modular settings, it can derive greater benefits from broad knowledge access. Broader knowledge access enables the firm to consider multiple distinct capabilities and technical options when developing innovative components. This multitude of options increases the expected value of the combination that the firm selects (Ethiraj and Levinthal, 2004; Hoetker et al., 2007) and thereby enhances innovation performance.

In addition to increasing the value of knowledge combination, more modular environments enhance the potential and benefits derived from knowledge recombination. As firms access knowledge from a variety of partner types in a more modular setting, the potential for recombining different modular inputs increases. Loose coupling of components and sub-systems permits both adaptability and evolutionary development (Grant and Baden-Fuller, 2004; Sanchez and Mahoney, 1996) and thereby increases recombination benefits associated with broader knowledge access from a variety of partner types.

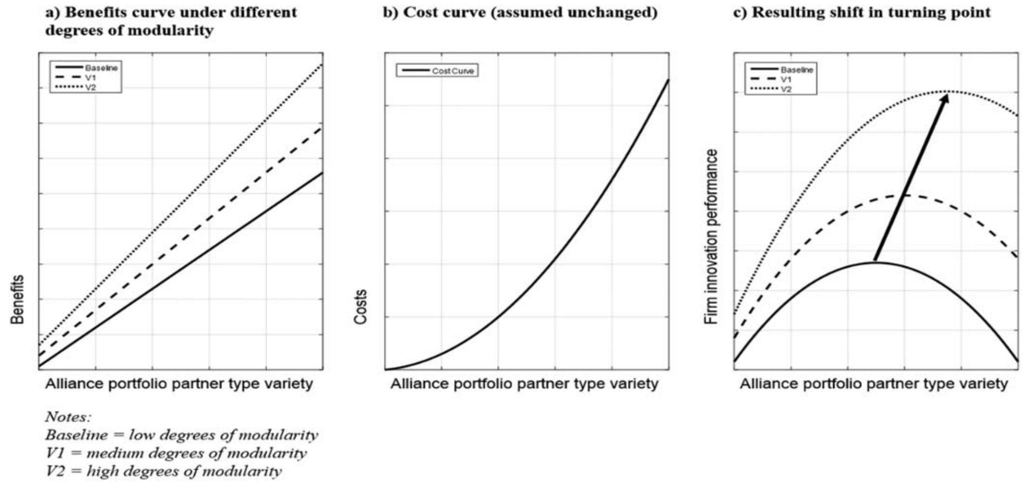

Figure 2. Alternative settings for different degrees of modularity, alliance portfolio partner type variety, and firm innovation performance

The above arguments suggest that in more modular environments the benefits associated with partner type variety and, thus, broader knowledge access, increase. The impact of increasing modularity on the costs of variety are, however, less clear. On the one hand, modularity may decrease the monitoring and coordination costs associated with higher partner type variety, due to more standardized interfaces. On the other hand, an increased availability of technical options through a variety of partners may accelerate the costs of searching for diverse partner types. In line with the KBV, we focus on how modularity influences benefits (i.e., knowledge access) associated with partner type diversity and assume that costs remain unchanged.

Due to higher value derived from broader knowledge access and recombination, we assume that in more modular environments the benefits associated with partner type variety are higher for all levels of variety. Furthermore, we assume that in more modular environments the benefits derived from partner type variety rise with an increasing rate, resulting in a steeper benefits curve (see picture A in Figure 2). Given these effects on the benefits curve, while the (convex) costs remain the same (see picture B in Figure 2), we expect an outward shift in the turning point of the inverted U-shaped association between partner type variety and firm innovation performance. More specifically, higher degrees of partner type variety will be optimal and the resulting innovation performance will be higher compared to environments characterized by lower degrees of modularity (see picture C Figure 2). Therefore:

Hypothesis 3a: The degree of modularity in the external knowledge environment positively moderates the inverted U-shaped association between partner type variety in a firm's alliance portfolio and firm innovation performance.

Second, we suggest that the identified benefits of partner type relevance are reduced in external knowledge environments that are characterized by higher degrees of modularity. More specifically, knowledge integration and internalization enabled by higher partner type relevance become less valuable, or even detrimental in more modular settings. In particular, relational depth in the form of experience, familiarity, and common knowledge is less important in a context that emphasizes division of labour, specialization and standardization. Quite the opposite, the actual internalization of external knowledge that is facilitated by experience, familiarity and common knowledge may even be inefficient when knowledge resources are highly modular. Similarly, common language, norms, and partner type specific absorptive capacity are not required in such an environment. Instead, division of labour and standardized interfaces facilitate routinized inter-organizational transactions in the context of modular industrial environments (Schilling, 2000). While in more fully integrated production systems, familiarity and experience can facilitate mutual adjustment and customization, knowledge exchange and interactions are much more transparent in more modular environments (Hoetker et al., 2007).

As a result, we expect that in more modular environments the benefits associated with partner type relevance are lower for all levels of that relevance (as compared to less modular environments). Moreover, we expect that in more modular environments benefits associated with partner type relevance increase at a lower rate, hence, reduce the steepness of the benefits curve. Given these reduced benefits, we expect an inward shift in the turning point of the inverted U-shaped association between partner type relevance and firm innovation performance. Again, we focus on the changes in the benefits associated with partner type relevance and assume that the costs remain unchanged. Hence:

> Hypothesis *3b*: The degree of modularity in the external knowledge environment negatively moderates the inverted U-shaped association between partner type relevance in a firm's alliance portfolio and firm innovation performance.

Scope of External Knowledge Distribution. The distribution of knowledge available in the industrial environment strongly influences the effectiveness of alliance portfolios (Grant and Baden-Fuller, 2004; Lakhani et al., 2013). In particular, the richness of externally available knowledge is shaped by the scope of knowledge distribution at an industry level (Pavitt, 1984; Plasmans and Lukach, 2010; Scherer, 1982). The scope of knowledge distribution can be captured in terms of two dimensions. First, it captures how widely knowledge is distributed across different origins or sources of knowledge, i.e., across different types of actors (i.e., customers, suppliers, competitors, universities, and research centres). Second, knowledge can be distributed more widely or more narrowly across those firms that access these knowledge sources. In other words, knowledge distribution does not only refer to the sources of knowledge but also to the degree to which these sources are accessed more or less equally by the firms competing in an industry.

If knowledge is broadly distributed, the combinatory and recombinatory value of an alliance portfolio characterized by high partner type variety becomes greater. Collaborating with diverse partners among which knowledge is widely distributed increases variation in a firm's problem-solving repertoire and thereby raises the chances of finding new combinations that positively influence innovation performance (Grant and Baden-Fuller, 2004; Lakhani et al., 2013).

In addition, to the extent that knowledge is broadly distributed and not specific to the production of a single product, firms accessing knowledge from different partner types can benefit from economies of scope (Grant and Baden-Fuller, 2004). More specifically, access to broad knowledge resources of different partner types enables firms to transfer fungible knowledge resources into new products and markets (Pil and Cohen, 2006). Hence, in addition to creating valuable combinations of knowledge resources, a broader scope of external knowledge distribution allows firms to transfer these combinations into new products and markets, thereby increasing their innovation performance.

As such, we expect that the scope of industry knowledge distribution enhances the positive effects of partner type variety on firm innovation performance. In environments with broader scope of knowledge distribution, the benefits derived from partner type variety will, at higher levels of this variety, increase relative to the costs that firms face. As a result, we expect that a broader scope of knowledge distribution is associated with an outward shift in the turning point of the inverted U-shaped association between partner type variety and innovation performance (similar to the effect of modularity presented in Figure 1). Hence:

Hypothesis 4a: The scope of knowledge distribution in the external knowledge environment positively moderates the inverted U-shaped association between partner type variety in a firm's alliance portfolio and firm innovation performance.

Second, we expect the benefits associated with higher partner type relevance to decrease in a broader knowledge distribution setting. As knowledge is less likely to reside in one place (i.e., with one partner type), investing resources to develop relational depth with specific partner types and internalizing their knowledge is likely to be less valuable. The returns derived from experience and familiarity with a particular partner type are lower in settings that are characterized by a broader knowledge distribution. Similarly, the benefits derived from common language and ways of working with a particular partner type are likely to be reduced when knowledge is distributed more broadly across different institutions. Instead, common language and absorptive capacity with a specific partner type and the internalization of the partner type's knowledge may even hinder a focal firm to interpret and understand knowledge that is distributed more broadly across different types of actors.

As such, we expect that a broader scope of industry knowledge reduces the benefits associated with partner type relevance and thus, leads to an inward shift of the curvelinear association between partner type relevance and firm innovation performance. Therefore:

Hypothesis 4b: The scope of knowledge distribution in the external knowledge environment negatively moderates the inverted U-shaped association between partner type relevance in a firm's alliance portfolio and firm innovation performance.

DATA AND METHODS

The empirical context of this paper is provided by the Community Innovation Surveys (CIS) that, since 1996, have been conducted every two years by the Central Bureau of Statistics (CBS) in the Netherlands. CIS is part of a comprehensive data collection effort undertaken by Eurostat aimed at collecting harmonized data on firm innovation activities in the EU. The CIS data form a basis for official EU R&D statistics and are collected in accordance with international guidelines for collecting innovation data from the private sector. CIS surveys contain questions concerning firms' innovative activities and engagement in collaborative technology development distinguished by partner type. Technology cooperation in the surveys relates to joint development efforts and R&D collaboration.

The longitudinal sample of our study consists of over three thousand firms representing 11 manufacturing industries for the period 1996–2010. One advantage of this CIS-based sample is the diversity of firms that include large R&D intensive firms as well as small and medium enterprises. Hence, the use of these data avoids the oversampling of large firms. A notable weakness of these data is that they do not reveal the identities of focal firms or the individual partners. Also, there is no information on the exact number of partnerships of each type as well as the systematic information on discontinued partnerships.

Measures

Dependent variable. The dependent variable *innovation performance* is the ratio of sales from products that are new to the market over total sales. Sales of innovative products is an appropriate and often used indicator of innovations that have successfully found their way to the market (Lokshin et al., 2010). New to the market products can be seen as more 'radical' compared to improved products, in the sense that products are not just new to the firm, but also putting the firm ahead in its industry. As such, our understanding of innovation performance clearly falls within the Schumpeterian tradition that considers innovation in the context of firms seeking an innovative edge through the successful introduction of new products (Freeman and Soete, 1997; Schumpeter, 1980 [1934]).

Independent and moderating variables. *Partner type variety* refers to the number of different partner types that a focal firm collaborates with in its alliance portfolio. The CIS surveys ask whether the focal firm had any cooperation arrangements for innovation activities in the previous two years with the different partner types: customers, suppliers, competitors, commercial laboratories, research institutes, and universities. We use a simple count of partner types that is different from the measure used by e.g., Laursen and Salter (2006) as we focus on the actual inter-organizational collaborations rather than on a larger number of external knowledge sources.

Partner type relevance refers to the actual importance of a focal firm's partners. In a separate survey question, management of the focal firm was asked to rate the importance of customers, suppliers, competitors, commercial laboratories, research institutes, and universities as sources of information used in its innovation activities. We only consider those cases where firms value certain sources of information (e.g., suppliers, customers, competitors) if they have also actually collaborated with such partners. In other words, any level of partner type relevance only matters if firms indicated in the preceding survey question (see partner type variety) that they actually collaborated with such partners. We first recoded each of the five partner types with value one when the firm reported that it used this source to a high degree and zero in the case of no, low, or medium use (see Garriga et al., 2013; Laursen and Salter, 2006) and then added them to obtain our *partner type relevance* measure. We included squared terms for both *partner type variety* and *partner type relevance* to test for the hypothesized curve-linear associations.

We derive information on the extent of industry *modularity* based on data kindly provided by Melissa Schilling. To the best of our knowledge, this measure as applied in Rosenkopf and Schilling (2007) is the only indicator available for modularity across a wide range of industries. This measure captures the degree to which an industry is characterized by modularity in terms of the extent to which its products' components may be separated and combined. To generate this measure, a list of 103 industries was created. Rosenkopf and Schilling then asked a group of 13 scholars in strategy and entrepreneurship to identify ten industries they felt exhibited the highest levels of modularity in their innovative activities. These nominations were then aggregated into a count for each industry (industries that received no nominations received a zero). Scores on this measure reach from 0 to 9. Given the high correlation (0.76) of this measure with a second indicator on separability, the internal reliability for this measure is very high.

The *scope of industry knowledge distribution* measure, based on the CIS surveys, refers to a) variety of the external knowledge in terms of its origin from different *types* of actors and b) differences among industry firms in (advantageous) use or access to it, i.e., disparity (Harrison and Klein, 2007). The former is computed as a Blau index of the industry-average scores on importance for innovation of customers, suppliers, competitors, universities and research centres. The latter is a coefficient of variation of relevance of knowledge residing in each of these actors, among firms in an industry. We use the reverse of this variable so that the higher values correspond to a wider and more equal knowledge distribution. These two variables capture two dimensions of knowledge distribution: the first dimension refers to distribution of knowledge sourced from the different types of actors and the second dimension refers to the knowledge distribution among firms competing in an industry.

Control variables. At the firm level, we control for *R&D intensity* (R&D expenditures scaled by sales) as a key input into the innovation process. In-house R&D increases a firm's capacity to recognize, value, and to assimilate external knowledge (Cohen and Levinthal, 1990). We also control for *firm size*, measured as the logarithm of the firm's employees (Cohen and Klepper, 1996). We further include a *foreign multinational* dummy, which takes a value of one (zero otherwise) if a firm has headquarters in another country. International research facilities can provide a focal firm with knowledge and information it lacks in the local market (Isobe et al., 2000). This knowledge and information could influence the innovativeness of the focal firm and diminish the need for external collaborative activities. Being a member of a larger *business group* can provide similar input to innovative activities of the focal firm. Therefore, we also incorporate a dummy for firms that are part of a domestic business group in the regressions.

In our analysis, we control for several aspects at the industry level. First, technology-related turbulence is borne by the speed of technological change that makes firm's existing knowledge obsolete and may therefore, have an impact on both alliance portfolios and innovation performance (Teece, 2007). To control for the *speed of technological change*, at the two-digit industry level, we included in the regressions the ratio of the number of firms that report they introduced products new to the market to the number of firms that did not introduce new products, weighted by firm size (Belderbos et al., 2004). To account for a general research and innovation-driven environment in which firms operate, we also included the *industry R&D intensity* (see also Czarnitzki and Toole, 2007). Furthermore, as the degree of competition in an industry may influence firm's innovation process (e.g., McGrath and Nerkar, 2004), we control for the degree of competition by including a measure of *market concentration* constructed as the Herfindahl-Hirschman index based on firms' shares of total market sales at the two-digit industry level. Finally, we control for the strength of the *IP regime* at the industry level. Research by Anand and Khanna (2000) suggests that the strength of the IP regime in industries impacts the degree to which firms are willing to engage in cooperation. We exploit the CIS survey question on whether a focal firm has used any formal (i.e., patents, trademarks, copyrights, design rights) and informal IP (i.e., secrecy, lead time, product complexity) measures in the previous two years. To measure the strength of IP regime within an industry we take a ratio of formal IP to informal IP and aggregate this measure across all firms operating in an industry. Time-varying firm-level and industry-level variables are lagged one period to alleviate endogeneity problems.

RESULTS

We estimate our models with the Tobit regression method, which accounts for the censored nature of the dependent variable, on a sample of 6775 observations on 3148 innovating firms. The use of lagged explanatory variables requires that a firm has responded in at least two consecutive survey years. Given the partially random sampling in each year for smaller firms, we do not often observe firms for the entire period (1996–2010) and the panel is unbalanced in nature. Table I provides descriptive statistics and Table II reports bivariate correlations among the variables used in the estimation. We have predominantly small and medium-sized firms in our sample with a mean of 221 employees. The average share of innovative sales due to products that were new to the market is nearly 5 per cent. A large share of firms is part of a business group (72 per cent) and 44 per cent of sample firms report to have their headquarters outside of the Netherlands. Somewhat low values of industry concentration suggest that sample firms operate in a relatively competitive environment. In addition, nearly 19 per cent of firm-year observations in our sample represent cases in which firms engage broadly with two or more types of partners. For over 6 per cent of firm-year observations, relevant collaborations are reported with two or more types of partners. The correlation table (Table II) suggests that, among the control variables, the speed of technological change and industry R&D (0.70) and business group and foreign multinational (−0.83 by

Table I. Descriptive statistics

	Mean	*S.D.*	*Min*	*Max*
1 Innovation performance (in %)	4.93	11.01	0.00	100.00
2 Market concentration	0.09	0.12	0.01	0.57
3 Speed technological change	0.27	0.10	0.07	0.48
4 Industry R&D	0.07	0.08	0.01	0.23
5 IP regime	3.52	0.94	2.00	5.00
6 Modularity	1.94	2.16	0.00	9.00
7 Scope of knowledge distribution	0.06	0.96	−4.73	2.16
8 Firm size (log sales)	9.40	1.42	0.69	17.24
9 Firm size (number of employees)	221.18	907.22	10.00	40128
10 R&D expenditures (K. Euros)	1856.78	2661.62	0.00	975617
11 R&D expenditures/Sales (in %)	1.12	3.58	0.00	69.59
12 Business group	0.72	0.45	0.00	1.00
13 Foreign multinational	0.44	0.50	0.00	1.00
14 Partner type variety (count)	0.65	1.31	0.00	5.00
15 Partner type relevance (count)	0.38	0.88	0.00	5.00

design) are highly correlated. The bivariate correlation between our two focal variables is 0.84 and to mitigate concerns that the results are affected by collinearity, we present our estimated models in a step-wise fashion. The mean variance inflation factor (VIF)

Table II. Pairwise correlations

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1 Innovation performance (in %)												
2 Market concentration	0.05											
3 Speed technological change	0.20	0.15										
4 Industry R&D	0.11	0.24	0.70									
5 IP regime	0.01	0.05	−0.04	0.09								
6 Modularity	0.12	0.22	0.37	0.41	0.19							
7 Scope of knowledge distribution	0.04	0.12	0.19	0.29	−0.12	0.09						
8 Firm size	0.17	0.03	0.06	0.04	−0.02	0.04	−0.03					
9 R&D intensity (in %)	0.10	0.06	0.08	0.20	−0.01	0.09	0.06	0.12				
10 Business group	0.01	−0.06	−0.06	−0.08	0.07	−0.08	0.04	−0.07	−0.00			
11 Foreign multinational	0.02	0.11	0.03	0.09	−0.08	0.10	−0.04	0.17	0.01	−0.83		
12 Partner type variety	0.18	0.07	0.13	0.07	−0.08	0.07	0.07	0.33	0.23	−0.03	0.06	
13 Partner type relevance	0.18	0.03	0.13	0.07	−0.06	0.08	0.08	0.32	0.20	−0.02	0.06	0.84

Notes: The descriptive statistics are sample means for the years 1996–2010 for the variables used in the estimation. The number of observations is 6775. All time-variant explanatory variables are measured in t-2 (i.t. taken from the previous CIS survey).

value is 3.62 for model 2 and 2.92 for model 3 and VIF values for individual variables are well below the commonly used threshold of 10 (with the exception of partner type variety squared and partner type relevance squared which, in combination, are above 10).

The empirical results of the Tobit regression models of the relationship between partner type variety and relevance, both moderated by external knowledge characteristics, and the innovation performance of firms are reported in Table III. Model 1 serves as a point of comparison for the other models. Variables related to the hypotheses are subsequently added in models 2–4. According to likelihood ratio tests, each model extension is a significant improvement with the full model providing statistically the best fit for the data.

Results from the basic specification (model 1) indicate a significant effect of firm size, R&D intensity, and the business group dummy. Speed of technological change is positive and significant, while R&D intensity measured at the industry-level, market concentration and IP regimes are insignificant. In models 2–3, we added firm-level variables related to partner type variety and relevance in alliance portfolios. Both variables have positive and statistically significant coefficients, while their respective squared terms are negative and significant – in model 2, the estimated coefficient of squared partner type variety is ($\beta_2 = -0.009$, $p < 0.01$) and in model 3, the coefficient of the squared term of partner type relevance is ($\beta_2 = -0.007$, $p < 0.01$). We also verified that both turning points are statistically significant ($p < 0.01$) and are located within the data range (Haans et al., 2016). These patterns confirm, in support of Hypothesis 1a/b, that both partner type variety and relevance have a beneficial effect on firm innovation performance only up to a certain point, after which further diversifying the alliance portfolio will reduce performance and suggest that at some levels of both partner type variety and relevance costs prevail over the associated benefits.

Model 4 is a full non-linear specification that includes the interaction terms between partner type variety and relevance. Based on the estimated coefficients in this specification, the optimal number of partner types for the variety dimension is 3 and the optimal number of partner types for the relevance dimension is 1. Both turning points are statistically significant at 1 percent. Figure 3 illustrates the relationship between diversification in alliance portfolios and predicted innovation performance (on the vertical axis). The graphs are drawn when partner type relevance is taken, respectively, at the mean minus one standard deviation ('low level' of partner type relevance) and at the mean plus one standard deviation ('high level' of partner type relevance). While partner type variety can have a substantial performance effect until the optimal level of diversity, at higher levels of partner type relevance, the curve is flatter, the maximum performance effect is smaller, and this maximum is reached at lower level of partner type variety. Calculations show that a standard deviation increase in partner type relevance from its mean value could reduce innovation performance by 4 percentage points, when all other variables are held at their mean values. A standard deviation increase in partner type variety from its mean value could reduce innovation performance by 8 percentage points, when all other variables are held at their mean values. These patterns are consistent with Hypothesis 2.

Table III. Partnership portfolios and firm innovation performance

	Model 1	*Model 2*	*Model 3*	*Model 4*
Intercept	−0.580***	−0.490***	−0.505***	−0.487***
	(0.057)	(0.068)	(0.067)	(0.067)
Industry level				
Market concentration	−0.028	−0.036	−0.039	−0.036
	(0.039)	(0.041)	(0.041)	(0.040)
Speed technological change	0.286***	0.228***	0.217***	0.227**
	(0.087)	(0.084)	(0.084)	(0.084)
IP regime	−0.007	−0.007	−0.015	−0.007
	(0.020)	(0.023)	(0.022)	(0.023)
Industry R&D	−0.056	−0.070	0.070	−0.057
	(0.260)	(0.294)	(0.284)	(0.288)
Firm level				
Firm size	0.041***	0.030***	0.031***	0.029***
	(0.003)	(0.004)	(0.004)	(0.004)
R&D intensity	1.132***	0.943***	0.968***	0.936***
	(0.092)	(0.165)	(0.165)	(0.162)
Business group	0.033**	0.034**	0.035**	0.036**
	(0.016)	(0.016)	(0.016)	(0.016)
Foreign multinational	0.009	0.015	0.015	0.017
	(0.017)	(0.018)	(0.018)	(0.018)
Partner type variety		0.068***		0.088***
		(0.009)		(0.017)
Partner type variety SQ		−0.009***		−0.016***
		(0.002)		(0.004)
Partner type relevance			0.066***	0.150***
			(0.010)	(0.061)
Partner type relevance SQ			−0.007**	−0.066*
			(0.003)	(0.040)
Partner type variety x Partner type relevance				−0.124***
				(0.040)
Partner type variety SQ x Partner type relevance				0.020***
				(0.007)
Partner type variety x Partner type relevance SQ				0.048**
				(0.020)
Partner type variety SQ x Partner type relevance SQ				−0.007***
				(0.003)
σ_u	0.242***	0.240***	0.240***	0.239***
	(0.004)	(0.004)	(0.004)	(0.004)
No of obs.	6775	6775	6775	6775
Log-likelihood	−2006.03	−1937.14	−1949.97	−1926.79
R^2	0.18	0.20	0.20	0.21
χ^2 of improved model fit		137.78***	112.12***	82.78***

Notes: Robust (clustered) standard errors in parentheses, *p < 0.1, **p < 0.05, ***p < 0.01. All models include time and industry dummies. All time-variant explanatory variables are measured in t-2 (i.t. taken from the previous CIS survey). Log-Likelihood (constant only-model) = −2434.03.

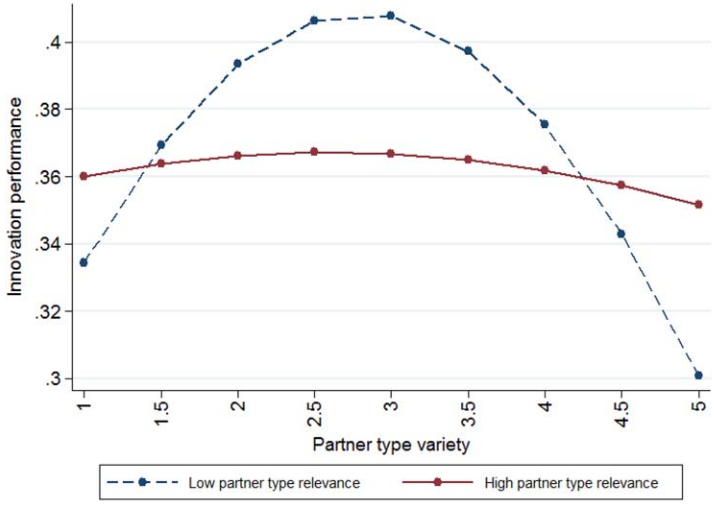

Figure 3. Partner type variety moderated by partner type relevance: impact on innovation performance [Colour figure can be viewed at wileyonlinelibrary.com]

We re-estimated models 5–8 presented in Table IV on low-modularity (narrow scope of knowledge distribution) and high-modularity (broad scope of knowledge distribution) sub-samples, respectively. Figures 4 and 5 illustrate the resulting consequences for the relationship between diversification in alliance portfolios along both dimensions and predicted innovation performance.

The relationship between partner type variety and innovation performance moderated by the degree of modularity is depicted in Figure 4a and can be summarized as follows. Partner type variety can have a substantial performance effects until the optimal level of diversity. However, in low modular environments, the maximum performance effect is smaller and this maximum is reached at lower level of partner type variety. On the other hand, as illustrated in Figure 4b, while partner type relevance can also have a substantial performance effects until the optimal level of diversity, it is the low modular environment that allows reaping most performance benefits from this type of portfolio diversity. These patterns are consistent with Hypotheses 3a/b.

The relationship between partner type variety and innovation performance moderated by the scope of knowledge distribution is depicted in Figure 5a. It illustrates that broad scope of knowledge distribution allows firms to benefit more from partner type variety in their portfolios: the curve is steeper, the maximum performance effect is larger, and the maximum is reached at higher levels of partner type variety. Contrary to our expectations, the marginal effects for partner type relevance are similar: when knowledge is distributed broadly, the curve is steeper, the maximum performance effect is larger, and the maximum is reached at higher levels of partner type relevance (Figure 5b). Overall, these patterns show support for Hypotheses 4a but not hypothesis 4b.[1]

Robustness and Supplementary Analysis

To test the robustness of our findings we considered a number of alternative specifications of our model. First, we tested the robustness of our knowledge distribution variable

Table IV. Partnership portfolio and firm innovation performance – moderated effects

	Model 5	*Model 6*	*Model 7*	*Model 8*	*Model 9*	*Model 10*	*Model 11*	*Model 12*
	Low Modularity	*Low Modularity*	*High Modularity*	*High Modularity*	*Low Scope KD*	*Low Scope KD*	*High Scope KD*	*High Scope KD*
Industry level								
Market concentration	−0.007 (0.056)	−0.015 (0.055)	−0.038 (0.069)	−0.043 (0.070)	−0.010 (0.060)	−0.008 (0.060)	−0.053 (0.058)	−0.053 (0.058)
Speed technological change	0.126 (0.090)	0.130 (0.090)	0.418** (0.213)	0.417* (0.212)	0.243 (0.172)	0.239 (0.173)	0.248** (0.104)	0. 248** (0.103)
IP regime	0.005 (0.021)	0.002 (0.043)	−0.067 (0.051)	−0.075 (0.051)	0.009 (0.020)	0.007 (0.020)	−0.112** (0.044)	−0.121*** (0.043)
Industry R&D	−0.332 (0.368)	−0.345 (0.363)	0.193 (0.486)	0.256 (0.489)	−0.403 (0.335)	−0.398 (0.334)	−0.722 (0.668)	0.759 (0.670)
Firm level								
Firm size	0.029*** (0.004)	0.030*** (0.004)	0.030*** (0.007)	0.032*** (0.007)	0.024*** (0.005)	0.026*** (0.005)	0.033*** (0.006)	0.034*** (0.006)
R&D intensity	1.199*** (0.250)	1.224*** (0.238)	0.744*** (0.215)	0.769*** (0.217)	1.419*** (0.306)	1.438*** (0.307)	0.717*** (0.161)	0.752*** (0.161)
Business group	0.000 (0.019)	−0.000 (0.020)	0.084*** (0.028)	0.086*** (0.028)	0.041** (0.018)	0.041*** (0.018)	0.025 (0.031)	0.025 (0.031)
Foreign multinational	−0.013 (0.021)	−0.016 (0.021)	0.056* (0.030)	0.058* (0.030)	0.028 (0.020)	0.028 (0.020)	0.003 (0.033)	0.002 (0.033)
Partner type variety	0.067*** (0.010)		0.064*** (0.016)		0.049*** (0.011)		0.078*** (0.012)	
Partner type variety SQ	−0.009*** (0.002)		−0.007* (0.004)		−0.008*** (0.003)		−0.009*** (0.003)	
Partner type relevance		0.056** (0.011)		0.082*** (0.022)		0.050** (0.014)		0.075*** (0.014)
Partner type relevance SQ		−0.004 (0.003)		−0.011 (0.007)		−0.008* (0.005)		−0.007* (0.004)
σ_u	0.216*** (0.004)	0.216*** (0.008)	0.271*** (0.013)	0.271*** (0.013)	0.222*** (0.011)	0.221*** (0.011)	0.253*** (0.012)	0.253*** (0.012)
No of obs.	4308	4308	2467	2467	3403	3403	3372	3372
Log-likelihood	−1074.86	−1080.98	−818.21	−821.92	−927.08	−932.10	−952.69	−958.20
R^2	0.22	0.22	0.20	0.19	0.17	0.16	0.27	0.27

Notes: Robust (clustered) standard errors in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.01. All models include a constant, time and industry dummies. All time-variant explanatory variables are measured in t-2 (i.t. taken from the previous CIS survey).

by comparing it with a patent-based measure used in Plasmans and Lukach (2010) based on the frequency of backward USPTO citations to patents of the firms within an industry. As such, the variable scope of industry knowledge distribution reflects the extent of knowledge flows within and between industries in The Netherlands. This alternative measure produces results somewhat similar to our survey-based measure. However, we prefer our survey based measure because the patent-based alternative is time-invariant since the frequencies of backward citations per industry are more or less constant in this period. Second, we examined potential reverse causality by performing a fixed-effects regression of the forward values (taken from the next CIS survey) of portfolio variables on the share of innovative sales and a set of year dummies. We found the coefficient of innovative sales to be insignificant. Third, we obtained qualitatively similar results when

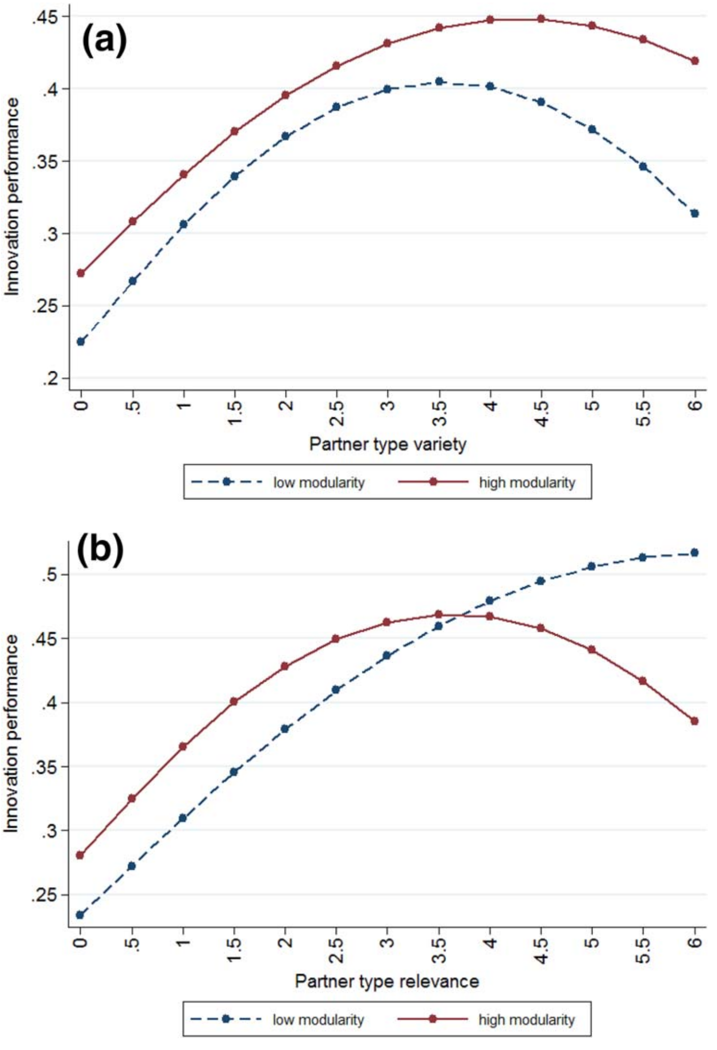

Figure 4. (a) Partner type variety moderated by modularity: impact on innovation performance. (b) Partner type relevance moderated by modularity: impact on innovation performance [Colour figure can be viewed at wileyonlinelibrary.com]

running the linear mixed models (HLM) that contain both fixed effects and nested random effects. Via random effects we controlled for heterogeneity among firms across time (level 1), for variation within industries (level 2) and for variation between industries (level 3) accounting for firm and industry-specific grouping of the data (e.g., Raudenbush and Bryk, 2002). This specification produces results very similar to those we report. Fourth, a substantial number of firms in the sample does not introduce products that are new to the market. Consequently, the variable for the sales share of new to the market products contains zeroes because some R&D performers either have incremental innovations or are non-product innovators (these firms are still required to fill in the entire questionnaire). Since not all innovators are internal R&D performers in our sample, we also estimated a type II Tobit models using the Heckman two-step

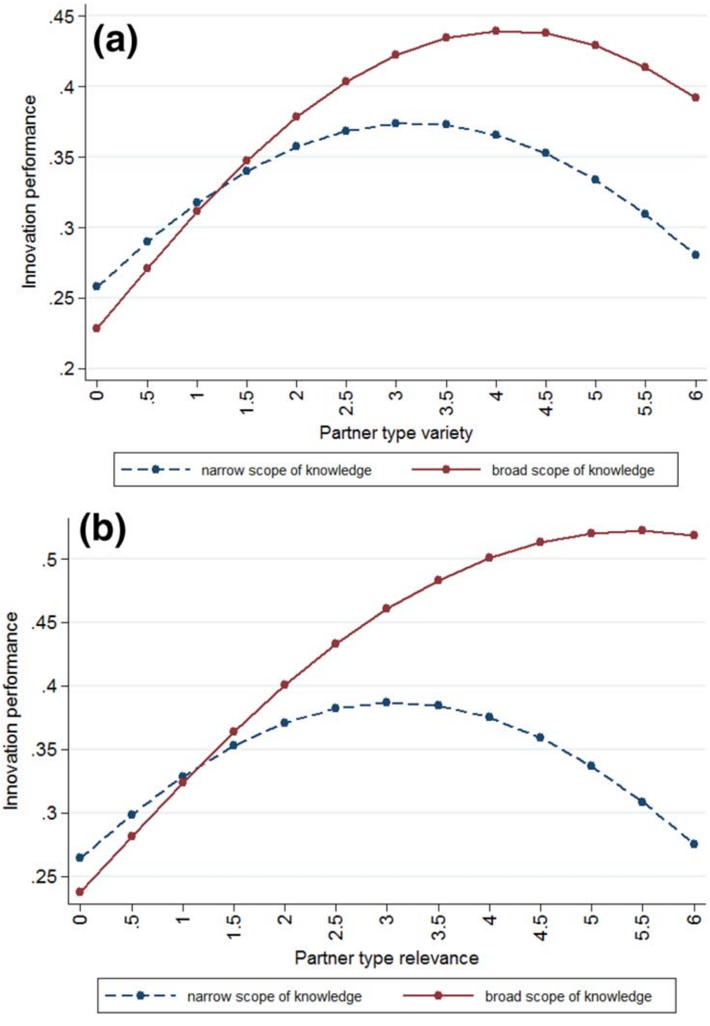

Figure 5. (a) Partner type variety moderated by scope of knowledge distribution: impact on innovation performance. (b) Partner type relevance moderated by scope of knowledge distribution: impact on innovation performance [Colour figure can be viewed at wileyonlinelibrary.com]

procedure. We first ran a Probit model to select the firms that perform internal R&D and derived from it an inverse Mill's ratio (IMR), which we then introduced in the Tobit equation. These regressions produce results similar to those reported in Table III, while the inverse Mill's ratio is negative and marginally insignificant.

DISCUSSION

Adopting a KBV perspective of alliance portfolios, this study investigates the influence of partner type diversity on firm innovation performance. Based on a more nuanced understanding of portfolio diversity, in terms of partner type variety and relevance, our results reveal separate as well as joint effects of these dimensions on innovation performance and further show how the effectiveness of these diversity dimensions is moderated by characteristics of the external knowledge environment. Theoretically, we extend existing research on a knowledge-based understanding of the configuration of alliance portfolios and their deployment in different external knowledge environments. In particular, we evaluate how partner type variety and relevance of alliance portfolios (via separate knowledge sharing mechanisms) and external knowledge characteristics (modularity and scope of knowledge distribution) co-determine firm innovation performance. Our focus on separate dimensions of partner type diversity as well as the consideration of external knowledge characteristics as contingency factors generates a number of contributions to the alliance portfolio literature. We structure our discussion around two core contributions.

Multidimensional Perspective of Alliance Portfolio Diversity

Our study extends the alliance portfolio literature that has treated portfolio diversity as a relatively homogeneous construct (Bruyaka and Durand, 2011; Caner and Tyler, 2013; De Leeuw et al., 2014; Goerzen and Beamish, 2005). Given the increasing number of actors that are participating in a more distributed innovation process (Faems et al., 2010; Garriga et al., 2013; Laursen and Salter, 2006), we focus on partner type diversity as a strategically relevant kind of diversity. We then look inside the partner type diversity concept and disentangle two separate dimensions; i.e., partner type variety and partner type relevance. Building on the KBV (e.g., Kogut and Zander, 1992; Grant, 1996a, 1996b) and specifically work by Grant and Baden-Fuller (2004) we connect these two dimensions to different knowledge sharing mechanisms; i.e., knowledge access and knowledge integration, that help to explain how variety and relevance in partner type diversity contribute to firm innovation performance.

Adopting a balanced perspective of both benefits and costs that are associated with external knowledge access (via partner type variety) and external knowledge integration (via partner type relevance), we suggest that partner type diversity contributes to innovation performance only up to a certain point. We find support for curve-linear relationships, which suggests that at some point, the costs involved with accessing external knowledge through increasing partner type variety and integrating knowledge through partner type relevance prevail over the benefits. These results support prior work that suggests that alliance portfolios do not only entail value-enhancing but also cost-increasing effects (Faems et al., 2010; Goerzen and Beamish, 2005; Hottenrott and Lopes-Bento, 2016; Jiang et al., 2010; Sampson, 2007).

Our results further complement prior studies that investigated associations between different measures of alliance portfolio diversity and firm performance (Baum et al., 2000; De Leeuw et al., 2014; Nieto and Santamaria, 2007; Srivastava and Gnyawali, 2011; Wuyts and Dutta, 2014). While this literature already indicates that partner type diversity in alliance portfolios impacts firm performance, little is known about the performance implications of different dimensions of this diversity. Whereas prior studies investigated different kinds of diversity (e.g. functional diversity, governance diversity, technological diversity) (e.g., Jiang et al., 2010; Van de Vrande, 2013), we add to this literature by suggesting that even within the same kind of diversity (i.e., partner type diversity) there are multiple dimensions to be considered. In particular, we add the important dimension of partner type relevance to the diversity construct and reveal its implications for innovation performance. This multidimensional perspective also allows us to highlight two distinct knowledge-sharing mechanisms that explain how partner type variety and relevance influence firm innovation performance. We add to previous studies that emphasized knowledge internalization as the main intent of alliance portfolios (Lorenzoni and Lipparini, 1999; Vasudeva and Anand, 2011) by arguing that the variety dimension of alliance portfolio diversity aims at a different knowledge sharing mechanisms, i.e., knowledge access. By connecting the diversity dimensions to different knowledge sharing mechanisms (see Grant and Baden-Fuller, 2004), we contribute to a theoretical foundation of the alliance portfolio diversity – innovation performance relationship.

This multidimensional perspective further allows us to investigate under-researched interdependencies in the diversity of alliance portfolios (Lee et al., 2017; Wassmer, 2010; Wassmer et al., 2017) and the implications for firm performance (Lavie, 2007). Indeed, we find that high levels of both partner type variety and relevance may diminish the effectiveness of alliance portfolios due to increased complexity of coordination and conflicting routines. Implementing partner type variety and relevance simultaneously, focusing on both accessing and integrating external knowledge, undermines innovation performance compared to a situation when partner type variety and relevance are pursued independently. This negative interaction emphasizes the importance to differentiate between separate dimensions of partner type diversity. In particular, homogeneous treatment of variety and relevance within one diversity construct may obscure the negative impact of pursuing high diversity on both dimensions. It further supports the KBV notion that different knowledge sharing mechanisms, i.e., knowledge access through partner type variety and knowledge integration through partner type relevance, are based on distinct organizational routines that require an efficient and selective use (Grant, 1996a, Grant and Baden-Fuller, 2004). These insights contribute to the alliance portfolio literature, since they go beyond portfolio size (Hoffmann, 2007; Koka and Prescott, 2002) and complement a more recent discussion on the management and potential trade-offs of multiple dimensions and objectives in an overall alliance portfolio (Stettner and Lavie, 2014; Wassmer et al., 2017).

Boundary Conditions of Partner Type Diversity – External Knowledge Characteristics

So far, boundary conditions of alliance portfolios were mostly limited to environmental dynamism (e.g., Goerzen, 2007; Zheng and Yang, 2015). Extant literature has been relatively silent regarding the conditions under which diversity is most likely to materialize and little is known about how characteristics of the external knowledge environment shape the effectiveness of alliance portfolio diversity dimensions. Our paper suggests the benefits of a systemic investigation of how the external knowledge environment in which firms operate influences the effectiveness of alliance portfolio diversity dimensions.

Interestingly, the importance of differentiating between alliance portfolio diversity dimensions becomes reinforced as we consider contingencies in the external knowledge environment. This is because modularity and scope of knowledge distribution influence the two diversity dimensions differently and even more pronounced in opposite directions. First, higher industry modularity is associated with a shift to higher optimal partner type variety that results in higher innovation performance compared to the optimal partner type variety in a lower modularity setting. Hence, high partner type variety and high modularity would be one of the preferred combinations in terms of firm innovation performance. Modularity, however, has a very contrasting influence on partner type relevance. While firms would want to increase partner type variety in a modular setting, a decrease of partner type relevance would be desirable in a similar industrial setting. This is because the turning point occurs at lower levels of partner type relevance as well as at lower levels of innovation performance.

Similarly, the scope of knowledge distribution is also associated with a shift to higher optimal partner type variety. This optimal partner type variety is associated with higher innovation performance compared to the optimal partner type variety in a setting of a narrower scope of knowledge distribution. Hence, high partner type variety and a broad scope of industrial knowledge distribution would also be a preferred combination in terms of firm innovation performance. However, our research does not indicate that, as expected, lower levels of partner type relevance are optimal in the context of a broader scope of knowledge distribution or that the turning point occurs at lower levels of innovation performance. Hence, while modularity influences the effectiveness of partner type variety and relevance in opposing directions, we do not find the same results regarding the scope of knowledge distribution. A possible explanation for the insignificant finding of Hypothesis 4b could be that we assume that the costs associated with partner type relevance remain unchanged across different breadths of knowledge distribution. Differences in the shape of the convex cost curve across environmental settings may explain our results.

Overall, these results are theoretically congruent with an extended KBV perspective that suggests that it is not only knowledge deployment but also knowledge characteristics that are fundamental in the context of knowledge sharing (Grant, 1996b). Our results confirm that both the degree of modularity and the scope of knowledge distribution, at the industry-level of analysis, influence the effectiveness of knowledge sharing in alliance portfolios. These results also shed light on the configuration of an alliance portfolio so that it can provide maximum performance (Faems et al., 2005; Hoffmann, 2007). In configuring an effective alliance portfolio, firms do not only need to consider interdependencies between different dimensions of diversity, but also need to consider external knowledge characteristics at the industry-level that co-determine the effectiveness of this multi-dimensional alliance portfolio diversity. This study, thereby contributes to literature that emphasizes alliance portfolio management capability as a critical factor for performance (Kale et al., 2002; Sarkar et al., 2009).

PRACTICAL IMPLICATIONS FOR MANAGING ALLIANCE PORTFOLIOS

This study urges managers to consider the partner type diversity of their firm's alliance portfolio as it may have both beneficial as well as cost-increasing effects on innovation performance. While innovation performance is initially increased by higher partner type diversity in alliance portfolios, our findings suggest that managerial complexity and resource constraints set in when the portfolio becomes too diverse, in terms of both partner type variety and relevance. Future research should explore to what extent sequential alliance strategies or dedicated organizational coordination efforts could mitigate this and further enhance the benefits of diverse knowledge-sourcing portfolios. We further direct managerial attention to the multi-dimensional nature of partner type diversity. The managerial ability to disentangle partner type variety and relevance and carefully manage the trade-offs between these two dimensions will have important implications for innovation performance. Our results suggest that especially the degree of modularity in the external knowledge environment (and to a lesser extent the scope of knowledge distribution) determines the effectiveness of partner type diversity and relevance. Notably, these characteristics of the external knowledge environment influence the effectiveness of partner type variety and relevance in opposing directions – thus, reinforcing the need to differentiate between the two dimensions of partner type diversity. So, the configuration of alliance portfolios should not be seen through a 'one size fits all' approach but the choices, that firms make as they create a diverse alliance portfolio, work out quite differently across industrial settings.

LIMITATIONS

Limitations of this study point to a number of opportunities for future research. First, this study is restricted in terms of number of partner types. While more traditional partner types, such as customers, suppliers, and universities, are integrated in our analysis, new partner types, such as innovation intermediaries, should be considered in future studies. Second, the CIS data used in this study bears several limitations in itself. For instance, we could not identify individual partners of our focal firms. Also, the relatively small time dimension for which we observe many of the sample firms in our unbalanced panel rules out our ability to take a longer view on dynamic alliance portfolio patterns. Moreover, in our multi-industry setting we bring out heterogeneity in types of partners, however we cannot infer causality and one challenge for future work is to integrate performance and the analysis of the antecedents of alliance portfolios within a single framework. Third, while this study concentrates on how the external knowledge environment affects the benefits associated with partner type variety and relevance, a more comprehensive assessment could consider how the costs associated with partner type variety and relevance are affected by these moderating variables. Fourth, this study adopts a somewhat static perspective that investigates optimal partner type variety and relevance across industrial settings. Recent research points at a more longitudinal perspective that researches the reconfiguration of alliance portfolios over time (e.g. Asgari et al., 2017). Fifth, we assume that modularity and the scope of knowledge distribution at the industry level are exogenous. Research by amongst others Jacobides et al. (2006) suggests that it may be possible for firms to develop strategies to actively shape these characteristics of their external knowledge environment. Future research should address how firms can possibly shape their external knowledge environment such that they benefit most from their alliance portfolios. Finally, in this context it may also be worthwhile to consider a broader set of characteristics regarding the external knowledge environment, such as complexity or technological discontinuities (see also Asgari et al., 2017) in order to understanding their impact on alliance portfolio effectiveness.

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Note

[1] The estimated coefficients support a horizontal shift of the curve in a hypothesized direction for all hypotheses with the exception of Hypothesis 4b (see Haans et al., 2016 for the technical discussion on horizontal and vertical shifts of non-linear curves). However, the Wald test narrowly rejected the significance of these expressions. The calculated differences in the predicted innovation performance (vertical shifts), on the other hand, are statistically significant at 5 per cent level.

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