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Returns to alliance portfolio diversity: The relative effects of partner diversity on firm's innovative performance and productivity

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ABSTRACT

This study considers the impact of diversification in types of technological alliances, resulting in alliance portfolio diversity, on various dimensions of a firm's performance, as they relate to exploration and exploitation. Using a large panel of innovative firms in the Netherlands, this study shows that partner type diversity in a firm's alliance portfolio has an inverted U-shaped relationship with productivity and radical innovative performance and a positive relationship with incremental innovative performance. Moreover, the results suggest that a lower level of diversity is needed to achieve an optimal level of productivity compared to radical innovative performance, whereas for incremental innovative performance a higher level of portfolio diversity appears to give the best performance.

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1. Introduction

Both practitioners and scholars agree that technological alliances, aimed at a purposeful exchange of technological resources or joint R&D is a ubiquitous phenomenon (Contractor & Lorange, 2002). Several factors such as product complexity, growing importance of time-to-market, increasingly geographically dispersed technological knowledge, as well as the rising costs of R&D, have led to a strong increase in the number of alliances between firms (De Man & Duysters, 2005; Li, Qian, & Qian, 2013). This overall growth in alliance formation coincides with an increase in the number of technology alliances that a single firm maintains (e.g., De Man, Duysters, Krijnen, & Luvison, 2011).

Due to the increased speed and sophistication of technological change a single alliance or partner type is unlikely to provide all the necessary solutions. Extant research has argued that firms increasingly adopt alliance portfolio practices, by augmenting the number and types of actors with which they interact, e.g., customers, suppliers, and research institutions and, with that, the level of diversification in their alliance portfolio. When firms maintain multiple alliances at the same time, a focus on the egocentric network of the firm or the so-called alliance portfolio is called for (Wassmer, 2010). In the alliance portfolio context, diversification (APD for short) and its implication for firm performance has recently attracted attention in the literature on alliances (e.g., Baum, Calabrese, & Silverman, 2000; George, Zahra, Wheatley, & Khan, 2001; Goerzen & Beamish, 2005; Jiang, Tao, & Santoro, 2010; Lee, 2007; Sarkar, Aulakh, & Madhok, 2009; Terjesen, Patel, & Covin, 2011; Wassmer & Dussauge, 2011). This line of research, central to this study, looks outside the boundaries of the firm and considers the diversification of external partners as a vehicle to access external-party resources that are not otherwise available (Das & Teng, 2000; Lavie, 2006).

Previous studies usually focused on the relationship between APD and one performance dimension at a time, e.g., financial performance (Faems, De Visser, Andries, & Van Looy, 2010; Lavie & Miller, 2008; Mour, Sarkar, & Frye, 2012; Wassmer & Dussauge, 2011), innovative performance (Duysters & Lokshin, 2011; Srivastava & Gnyawali, 2011; Wuys & Dutta, in press), or firms’ exit via sell-off and shutdown (Bruyaka & Durand, 2012).

In practice, firms simultaneously pursue multiple performance objectives, such as productivity, and radical and incremental innovation. Often this requires balancing between strategies aimed at maximizing exploration and exploitation (e.g., Cao, Gedajlovic, & Zhang, 2009; Venkatraman, Lee, & Iyer, 2007). Configuring an alliance portfolio in such a way to maximize firm performance is important in this context. Although previous studies have shown the significant relationship between APD and firm performance, most of these studies have focused on only one performance measure. This study puts forth that the relationship between APD and varying performance indicators is not uniform. In particular, from the previous APD literature little is known about the differences in the optimal level of APD for different performance outcomes. In other words, which level of APD is optimal for which performance dimension? Specifically, surprisingly little research has gone into understanding the significance of a diverse alliance...
portfolio for firms’ radical and incremental innovative performance. Yet, this is important as this contributes to the understanding of the performance implications of the balancing act as a firm strives to maximize exploitative and exploitative performance.

Investigation of this research question via a comparative analysis, such as a meta-analysis of the existing studies (see Parmigiani & Rivera-Santos, 2011 for one such attempt), is complicated due to differences in APD operationalization, industry coverage and time periods, which may preclude meaningful conclusions. In contrast, considering several performance dimensions within the framework of one study enables establishing the relative performance effects of APD and uncovering the differences in its impact on multiple performance indicators, as they relate to firm’s exploration and exploitation.

The aim of this paper is to fill this gap in the extant APD literature by examining the relative performance effects of diversity in a firm’s technological alliance portfolio by considering three performance measures: radical innovation, incremental innovation and productivity. Following previous literature (e.g., Duysters & Lokshin, 2011), this study defines APD in terms of direct alliance partner types a focal organization is engaged with. Second, we put forth that benefits of APD are subject to decreasing returns, indicating a point where additional diversification in the types of actors with which a firm interacts becomes unproductive. Finally, this study advances that different performance-maximizing levels of APD are required for radical and incremental innovation as well as for productivity. The paper proceeds as follows. The next section provides a literature background. The subsequent section develops a set of hypotheses that propose a relationship between APD and each of the performance measures, followed by the data and methods section, which explains the empirical approach. The paper concludes with the discussion and the practical implications of the results.

2. Theoretical background and hypotheses

2.1. Alliance portfolio diversity and alliance types

The APD concept, which has recently received much scholarly attention, consists of two elements. The first is the alliance portfolio, which in line with previous research is defined as the set of focal firm’s active formal alliances (e.g., Baum et al., 2000; Ozcan & Eisenhardt, 2009). The alliance portfolio approach to studying alliances enables scholars and practitioners to investigate the (dis)synergistic effects between multiple alliances maintained by a firm at one point in time (Wassmer & Dussauge, 2011, 2012). This feature of the alliance portfolio is highly relevant because of the growing evidence that firms frequently maintain multiple alliances at one point in time (e.g., De Man et al., 2011) and that alliance synergies indeed have an effect on the value derived from the alliances (Belderbos, Carree, & Lokshin, 2006; Wassmer & Dussauge, 2012).

The second element of APD is diversity, which in general refers to the distribution of differences in relation to an attribute “X” (Harrison & Klein, 2007). Prior literature has considered such attributes as, organizational size, age, geographical location or partner type (e.g., Isobe, Makino, & Montgomery, 2000; Wuys & Dutta, in press). These contributions have established, for instance, that larger firms have more abundant resources and may handle more easily the management of multiple technology alliances with firms of different size (e.g., Belderbos et al., 2006; Duysters, Lokshin, Heimeriks, Meijer, & Sabidussi, 2012). The concept of diversity of firm age is related to firm experience and learning. Wuys and Dutta (in press) show that a firm’s past strategies for internal knowledge creation can be a source of experience that increases the firm’s capability to leverage extramural knowledge. Diversity with respect to geographical locations of partners can provide the focal firm with highly sophisticated, specialized, and partially tacit knowledge from local sources (Meyer-Krahmer & Regier, 1999).

This paper refers to APD as the diversity of firms’ alliance types (different categories of firms, universities, and other research or technology institutions) that represent different channels that firms rely upon in order to improve their innovative and productive performance. The focus is on different types of (national and foreign) alliance partners because different partner types can serve different purposes such as providing the focal firm with different resources, knowledge, and expertise useful for improving innovative performance and productivity (e.g., Aschhoff & Schmidt, 2008; Belderbos, Carree, Drieder, Lokshin, & Veurigers, 2004; Teece, 1980).

The importance of collaborative strategies is demonstrated in various studies. These studies investigate the extent to which different alliance types lead to improvement in firm’s performance outcomes (e.g., Belderbos, Carree, & Lokshin, 2004; Köhler, Sofka, & Grimpe, 2012; Laursen & Salter, 2006; Salge, Farchi, Barrett, & Dopson, 2013). Cooperation with suppliers, for instance, has been shown to help improve exploitation-related performance, such as input quality improvements, process innovations, and cost reductions because suppliers may possess knowledge related to the actual production processes (Sobrobo & Roberts, 2002). Customers, on the other hand, can provide the focal firm with product and service feedback that could be used for product, process, and service improvements or development of altogether new products (Lee & Wong, 2009; Von Hippel, 2007). Customers can reduce the uncertainty that is associated with new market introductions. Their input may be essential for market expansions and for adaptations in products and services (Tether, 2002). Competitors can provide the focal organization with access to industry-specific knowledge and could share (research) facilities (Kim & Higgins, 2007) and (research) costs (Miotti & Sachwald, 2003). Alliances with competitors could also be used to deal with industry standards and regulations (Nakamura, 2003). However, collaboration with competitors can have a downside due to an increased risk of outgoing knowledge spillovers because competitors (compared to other partner types) are better able to use unintended knowledge spillovers (Park & Russo, 1996). Cooperation with universities and public research institutions can be an important source of new scientific and technological knowledge. Prior research has demonstrated that university collaboration can, for instance, lead to development of new (radical) applications of already existing technology (Archibugi & Coco, 2004; Arvanitis, Kubli, & Woerter, 2008; Drejer & Jorgensen, 2005). Universities and research centers can be attractive for industry partners providing low-cost access to generic R&D (Arranz & Arroyabe, 2008; Beers, Berghall, & Poot, 2008; Mototashi, 2005).

Taken together, the alliance types described above make up a focal firm’s alliance portfolio. This is in line with for instance Faems, Van Looy, and Debackere (2005) and Oerlemans, Knoben, and Pretorius (2013). In sum, the alliance partner diversity concept assumes diversity between alliance partner types because different partner types can differ in their categorical attributes, i.e., their resources, capabilities, competences, and industrial backgrounds. Due to possible (dis)synergies between the alliance partner types, APD can impact the focal firm’s performance above and beyond the effect of individual alliances.

2.2. APD and firm performance

Prior research on the diversity of alliance partners suggests that having heterogeneous partners can lead to performance benefits, because different types of organizations provide access to more diverse information and resources (e.g., Beckman & Hauschild, 2002; Wuys, Dutta, & Stremersch, 2004). Other research shows that alliance partner diversity can have negative effects on firm performance (e.g., Faems et al., 2010; Goerzen & Beamish, 2005). Notwithstanding that diversity can lead to more information and resources, too much diversity and the corresponding (cognitive) distance between the focal firm and their partners hinders the exchange and integration of information and resources. Other studies found an inverted U-shaped relationship between the diversity of alliance partners and various performance dimensions, suggesting that diversity is beneficial to a certain point, after which further...
increasing diversity has a negative effect on performance (e.g., Duysters & Lokshin, 2011; Koka & Prescott, 2002). In the section below, drawing on resource based view (RBV), transaction cost economics and the attention-based view, we develop hypotheses concerning the performance consequences of alliance partner diversity and derive predictions on the optimal level of APD for each performance outcome.

2.3. APD and innovative performance

From the RBV perspective, firms collaborate with external partners to complement their internal innovation efforts (Deeds & Rothaermel, 2003; Poot, Faems, & Vanhaverbeke, 2009). Since resources and capabilities, as argued above, are likely to vary between different partner types, different relationships lead to diverse and non-redundant resources and information (Burt, 1980, 1992). Superior innovation performance thus can be achieved by combining the resources of partners in the alliance portfolio and exploiting possible complementarities and synergies (Belderbos et al., 2006; Nieto & Santamaria, 2007). An illustration of this is an alliance with a research institute to develop a new product idea, and simultaneous alliances with consultants, suppliers, and customers to develop a new production process and to find a market for the new product. Hence, increasing the level of APD provides more resources and more information for the focal firm.

However, according to Burt (1992, p. 49) the optimal network non-redundancy is determined by a "budget equation ... [that] has an upper limit set by the [focal firm’s] time and energy." The focal firm thus makes a trade-off between the benefits obtained from diverse partner types and the resources required to maintain productive relationships. Alliances require substantial monitoring and control (e.g., Faems, Janssens, Madhok, & Van Looy, 2008; Gulati & Singh, 1998) and as a consequence the focal firm may not be able to deal with high levels of APD (Hoffmann, 2005). Moreover, attention based view suggests that high levels of APD could lead to information overflow. Related, koput (1997) provides three reasons for the negative effect of information overflow on firm performance. Firstly, at high levels of APD too many different ideas could reach the focal firm and hence managers may have difficulty to manage and choose from these ideas (the absorptive capacity problem). Secondly, resources and ideas could reach the firm at the wrong time or place to be fully exploited (the timing problem). Thirdly, when too many different ideas reach the firm, few are taken seriously and receive the attention necessary for successful development and implementation (the attention allocation problem). With increased APD, the ability to take optimal advantage of learning opportunities may thus decrease. Firms may furthermore not forego such learning opportunities but may additionally fail to guard against leakage or knowledge spillovers to its multiple partner types (Jiang et al., 2010).

Combining the various positive and negative effects we argue that APD has a positive effect on firm innovation performance up to an optimum point, after which further increasing APD has a detrimental effect. Beyond the optimum the resource limitations of the focal firm and the possible other negative effects outweigh the benefits gained from having higher levels of APD, hence:

Hypothesis 1. APD has an inverted U-shaped relationship with innovative performance.

2.4. APD and productivity

A firm can increase productivity when it combines, invests in, or exchanges skills, assets, and knowledge with different alliance partner types (Dyer, 1996; Nootbeoom, 1999). When the focal firm transacts with complementary partner types such as customers–suppliers, these benefits can become larger. The focal firm could for instance use knowledge obtained from the customers about a forecasted demand to inform the supplier of the needed supplies and thereby reducing supply deviations and thus costs. Rosenzweig, Roth, and Dean (2003) provide empirical evidence that collaboration with partner types in the supply chain leads directly to improved productive performance.

The expansion in number of different partner types, on the other hand, may increase the risk of opportunistic behavior (Combs & Ketchen, 1999; Teece, 2002). Transaction-cost economics suggests that firm's investment in the partner-specific relationship and development of partner-specific assets and skills makes extraction from an unproductive alliance expensive and time-consuming (Aharoni, 1966). Moreover, investments in partners' assets increase the level of bilateral dependence between the alliance partners (Teece, 1986). Such "liabilities of collective action" (Barnett, 1994) or over-embeddedness can lead to negative effects on firm performance (Uzzi, 1997). If unforeseen events occur (such as an unforeseen exit) the embeddedness and corresponding dependency can hamper the focal firm's performance (Lokshin, Hagedoorn, & Letterie, 2011; Singh & Mitchell, 1996).

In addition, high levels of APD may increase the likelihood of inefficient resource allocation. For example, matching the focal firm's (production) activities with the activities of all kinds of partner types may be difficult (Goerzen & Beamish, 2005). Taken together, the arguments suggest that collaboration with different partner types has a positive effect on productivity up to a certain point after which the negative effects related to risks and partner type dependency outweigh the benefits. Hence:

Hypothesis 2. APD has an inverted U-shaped relationship with productivity.

2.5. Different optima per performance dimension: productivity

This section presents arguments which claim that different levels of APD are beneficial for different performance dimensions. With regard to productivity, Dyer and Singh (1998, p. 662) argue that firms can gain “a supernormal profit [that is] jointly generated in an exchange relationship - that cannot be generated by either firm in isolation and can only be contributed by joint idiosyncratic contributions of the specific alliance partners.” This profit and productivity improvement is possible when partners combine, invest in, or exchange skills, assets, and knowledge (Nootbeoom, 1999). Investments in specialized skills and assets in conjunction with the skills and assets of the partners are thus potential sources of improved productivity or financial performance (Amit & Schoemaker, 1993; Carney, 1998).

Productivity can be improved for both alliance partners by increasing relationship-specific assets, i.e., investments in site assets, physical assets, and human assets (Rosenzweig et al., 2003; Williamson, 1985). Site specificity ensures that the partners’ (production) facilities are located to economize on transportation, and inventory costs or to take advantages of processing efficiency (Dyer, 1996). Site specificity may also improve coordination and knowledge sharing (Nobel & Birkinshaw, 1998). Physical asset specificity such as investments in production processes and technology may increase the productivity of the partners. For instance, Holm, Eriksson, and Johanson (1999) provide evidence that systems of workflow interdependence have positive effects on organizational performance. Human asset specificity involves the development of know-how through interaction between the partners. Repeated interaction with alliance partners improves knowledge sharing, communication, and the absorptive capacity which is beneficial for the utilization of process innovation and product development (Lane & Lubatkin, 1998; Mowery, Oxley, & Silverman, 1996). Human asset specificity can thus lead to cost reductions and improved productivity for the alliance partners. Extending this dyadic argument to APD, we posit that synergies can emerge when the focal firm collaborates with complementary types of actors (e.g., Belderbos et al., 2006).

In sum, from a transaction-cost economics perspective, the investments in relationship-specific assets can lead to higher levels of productivity. Often, such investments in production stages and the production process call for partner types who are active mainly within the supply chain.
chain such as customers and suppliers. The positive impact on firm’s productivity could therefore be achieved by collaboration with a limited number of partner types within the value chain. Adding more partner types outside the supply chain, is expected to have a limited added value, although the costs of these kinds of investments are high. Hence, relatively low levels of APD could be sufficient to maximize productivity.

Another argument in favor of a relatively low optimal level of APD for productivity, i.e., alliances with limited partner types, comes from the role of uncertainty about product demand. Prior studies have shown that firms use alliances to jointly forecast the production level: Metters (1997) provides evidence that a “bullwhip effect”, i.e., deviations between the forecast and the actual demand, can have a serious negative effect on productivity. A large deviation can lead to over- or under-production. The former can lead to large inventory costs and the latter can result in lower levels of sales that would have been possible. Preventing or limiting these demand distortions could, according to Metters (1997), increase product profitability by 10–30%. Firms therefore form alliances with partner types in the supply chain to improve demand forecasting and to limit demand distortions. A limited number of partner types like customers could provide the focal organization with information about the demand. Collaborating additionally with suppliers to match the demand with supply might be sufficient. Adding more partner types does not add more information, but does bring additional costs.

To summarize, firms enter alliances with partner types in the supply chain to overcome uncertainty and reduce risk, ensure a stable inflow of resources and outflow of products and this can directly lead to improved productivity especially when relationship-specific investments are made. Thus, the positive impact on productivity can be achieved by collaborating with a limited number of partner types mainly in the supply chain, such as suppliers and customers, and as such relatively low levels of APD could suffice.

2.6. Different optima per performance dimension: radical innovative performance

In addition to distinguishing between productivity and innovative performance as such, this study considers radical as well as incremental innovation performance. The fundamental difference between radical and incremental innovation is the degree of novelty of a product or service. While radical innovations are referred to as revolutionary and technologically new products or services, incremental innovations are based on evolutionary improvements in existing offerings. Firms usually have to invest considerable resources to develop radical innovations. These radical innovations have high levels of uncertainty (Garcia & Calantone, 2002) but the potential gains of such innovations are high, and they thus offer “the carrot of spectacular reward or the stick of dis- tinction” (Schumpeter, 1942). For incremental innovations the necessary investment and the risk are lower, but the potential gains are also smaller (Marsili & Salter, 2005).

Radical innovations significantly extend the firm’s competences (Voss, Sirdeshmukh, & Voss, 2008) and therefore the knowledge base of the focal firm must usually be adapted (Cohen & Levinthal, 1990). If the innovation is developed by or jointly with a partner, this partner has a lot of in-depth knowledge about the innovation. This kind of in-depth knowledge, also known as tacit knowledge, may not be easily codified and transferred to the focal organization. The required adaptation of the knowledge base of the focal organization therefore may be difficult (Sampson, 2007). When the focal firm has to simultaneously manage other alliances with different partner types, this may require considerable resources to manage a high level of APD. The resources devoted to the management of different partners cannot be used to integrate the knowledge base of the innovative firm with that of the focal firm (Maurer & Ebers, 2006), and this can hamper the radical innovative process. Maintaining alliances with a medium number of partner types and focusing all attention on these alliances will hence benefit successful radical innovations the most.

Empirical research has shown that early in the innovation life-cycle a limited number of partner types (and hence a medium level of APD) is optimal because a narrow range of partner types, usually lead users and research institutes, is sufficient to provide the focal firm with ideas for radical innovations (e.g., Belderbos et al., 2006; Riggs & Von Hippe, 1994; Zucker, Darby, & Brewer, 1998). Alliances with other partner types albeit overall important are less relevant for radical innovations, and require firm’s resources to maintain these alliances.

This is in contrast with the lower optimal level of APD for productivity: the optimization of productivity is in part based on improving the supply chain by forming alliances with partners in the chain, such as customers and suppliers. The process of radical innovation involves these partner types and adds others, such as research institutes and universities. Therefore, we expect the optimal APD point where additional diversity becomes unproductive to be reached quicker for productivity than for radical innovative performance.

A further argument for a higher optimal level of APD in case of radical innovation performance compared to productivity could be made based on the recombination idea of Schumpeter. This suggests that different partner types could provide the focal organization with ideas and resources that can be combined into a radical innovation. According to Laursen and Salter (2006), the search for such an innovation involves scanning a wider range of sources, but the development of the innovation involves drawing deeply from a narrower range of sources. In practice this will result in alliances with fewer partner types.

Furthermore, since radical innovations have unpredictable returns, firms may experience difficulty adapting their management processes to such projects. The attention-based theory of the firm (Ocasio, 1997; Simon, 1947) suggests that managerial attention is one of a firm’s most important resources. To optimize radical innovative performance and to achieve sustained performance, decision-makers need to “concentrate their energy, effort and mindfulness on a limited number of issues” (Ocasio, 1997, p. 203).

In a similar vein, from perspective of maximum span of control (see March, 1978; Simon, 1957) the focal firm has a limited ability to effectively manage the alliance portfolio. For high levels of APD, the firm’s limits are quickly reached (Dyusters et al., 2012). Therefore, too high a level of APD is expected to have a negative effect on radical innovative performance, resulting in a medium tipping point.

Further extending the level of APD will also increase the risk of unobserved and unintended knowledge spillovers (Combs & Ketchen, 1999; Jiang et al., 2010; Teece, 2002). Learning races can occur between different partner types when a firm attempts to extract as much information as possible from its partner while divulging as little as possible (Hamel, 1991; Larsson, Bengtsson, Henriksson, & Sparks, 1998). These negative effects are particularly relevant for radical innovation because when a partner copies an innovation the potential competitive advantage is greatly reduced. Based on the above arguments we propose:

Hypothesis 3. The benefits of alliance portfolio diversity are subject to decreasing returns for both radical innovation and productivity. For
radical innovative performance the optimum will be at a higher level of APD compared to productivity.

2.7. Different optima per performance dimension: incremental innovative performance

To improve incremental innovative performance firms rely on broader information search (Feller, Pathankagas, & Smeds, 2007; Garriga, von Krogh, & Spaeth, 2013; Laursen & Salter, 2006). This can be best achieved by engaging in alliances with multiple partner types. Since this form of innovation entails fine-tuning an existing product, process, or service for which a dominant design has already emerged and the market for the innovation expands, the number of partner types with relevant knowledge increases. Therefore, more partner types have information that is valuable to the focal firm and the focal firm therefore does not need to limit the collaboration to the few partner types.

Additionally, the negative effect of having alliances with many different partner types, which we argued applied for radical innovative performance, does not play a role for incremental innovative performance. For instance, there is no need for knowledge base adaptation in case of incremental innovative performance. The focal firm has a lot of experience and knowledge about their existing product, process or service. Incremental innovative ideas of different partner types can thus more easily be related to the focal firms’ knowledge base.

A higher optimal level of APD for incremental compared to radical innovations is supported by prior work of Feller et al. (2007) and Laursen and Salter (2006). The former provide evidence from the telecommunications industry that radical innovators collaborate with fewer (types of) alliance partners compared to incremental innovators; the latter emphasized that in-depth collaboration with a limited number of partners is associated with radical innovation.

In contrast to radical innovative performance where a limited number of specific partner types provide the key knowledge for innovation, in incremental innovation partners may be substitutable and can provide similar information or resources. Moreover, all partner types can provide the focal firm with ideas, information, and resources for the innovation. In these knowledge-rich environments, it is important for the firm to work with and integrate information from many different types of firms (Pavitt, 1998).

Taken together, all partner types represent different search channels that firms rely upon in order to improve their innovative activities. Therefore, the optimal APD point where additional diversity becomes unproductive is likely to be reached quicker for radical innovative performance than for incremental innovation performance. Hence we propose:

Hypothesis 4. The benefits of alliance portfolio diversity are subject to decreasing returns for both radical and incremental innovation. For incremental innovation performance the optimum will be at a higher level of APD compared to radical innovative performance.

Jointly, the arguments presented for Hypothesis 3 (radical innovation and productivity) and Hypothesis 4 (radical and incremental innovation) lead us to the following final proposition:

Hypothesis 5. The benefits of alliance portfolio diversity are subject to decreasing returns for both productivity and incremental innovation. For incremental innovation performance the optimum will be at a higher level of APD compared to productivity.

3. Data and methods

3.1. Context and data

The hypotheses are tested on a panel data set constructed from five consecutive Community Innovation Surveys (CIS) conducted in 1996, 1998, 2000, 2004, and 2006 by the Central Bureau of Statistics (CBS) in the Netherlands. The 2002 survey is excluded because of differences in formulation of some questions compared to other years. The sampling methodology and the harmonized questionnaire are described in the OECD Oslo Manual (OECD, 1997). Before implementation, extensive piloting and pre-testing established the interpretability, reliability and validity of the surveys. Laursen and Salter (2006) report that the CIS data have been used in over 60 academic articles on innovation. The CIS contain data concerning firms’ innovation activities and engagement in collaborative technology development distinguished by partner type. The technology alliances in the survey relate to joint development efforts and collaboration on R&D.

Since the interest is on the effect of partner diversity in a portfolio of technology alliances, the analysis is confined to firms engaging in this type of alliances. One advantage of the data used is the diversity of firms included in the sample, i.e., large R&D intensive firms as well as small and medium enterprises are included from a wide spectrum of industries. The unbalanced sample includes 13,909 observations on 11,279 innovating firms from a wide range of industries (we distinguish 26 industries at the 2-digit level). There are fewer observations in the innovation performance models, due to missing values in the innovative output variables.

3.2. Measures

Productivity Performance is measured as the logarithm of sales per employee. This measure is widely used in prior research (e.g., Chowdhury & Lang, 1996; Mol & Birkinshaw, 2009) and captures improvements in efficiency either by increasing turnover with the same workforce or realizing the same amount of sales with a smaller workforce.

To measure firm’s innovative performance the CIS question that asks firms to indicate (in percentages) the shares of unchanged, new-to-the-firm, and new-to-the-market products, processes and services in their total sales is used. The two latter categories are mutually exclusive and together with the share of unchanged products—add up to 100%.

3.2.1. Radical innovative performance

Radical innovations are defined as really new, i.e., technologically new products, services, or processes and operationalized based on the percentage of turnover due to new or significantly improved products and services, that were new-to-the-market.

3.2.2. Incremental innovative performance

Incremental innovations involve adaptations and refinements in existing products, services, or processes largely building on existing technological knowledge. Incremental innovative performance is operationalized as the percentage of turnover due to products and services that were new or improved, that were only new-to-the-firm. A similar approach was used to analyze radical and incremental innovation in e.g., Faems et al. (2010), Laursen and Salter (2006), and Oerlemans et al. (2013).

3.2.3. Alliance portfolio diversity

To construct this variable the CIS question that asked if the focal firm had any cooperation arrangements for innovation activities in the previous two years is used. Cooperative agreements are distinguished by means of the seven (national and international) partner types:

1. To make sure respondents interpret these categories the same way and to improve construct validity, definitions of incremental and radical innovation were included with the CIS.
2. The time lag between APD (year t – 2 and the year of the survey) and innovation (year of the survey) was introduced because it can take some time before the resources obtained through alliances find their way into innovative products and/or services. This time lag therefore facilitates the causal interpretation (reduces reverse causality) of the relation between APD and innovative performance, and reduces problems of endogeneity and thereby improves the internal validity of this research.
customers, suppliers, competitors, commercial laboratories, research institutes, universities, and subsidiary firms. The focus is on alliance partner diversity\(^5\) and not portfolio size. Using this question, the focal variable, APD, as in Oerlemans et al. (2013) is created by taking the ratio of the number of partner types in the firm's alliance portfolio and the maximum possible number of partner types (\(7 \times 2\)) and then squaring the result.\(^6\)

A number of control variables are included in the model. \(R&D \text{ intensity}\) (R&D expenditure as share of sales) is included because R&D engagement increases a firm's capacity to recognize, value, and assimilate external knowledge from partners (Cohen & Levinthal, 1990). R&D-intensive firms are also more likely to engage in technological collaboration projects but with diminishing propensity (Belderbos, Carree, Diederan et al., 2004; Belderbos, Carree, & Lokshin, 2004).

The literature indicates that the Firm Size plays a role in the propensity to be engaged in collaboration. Larger firms have more abundant resources and may be better able to handle multiple innovation objectives and the management of multiple technology collaborations (e.g., Belderbos et al., 2006; Cohen & Klepper, 1996). To control for firm size the logarithm of the number of employees is included. Firm Age, is included because older firms may have established more capabilities to handle and benefit from more alliance partner types. Furthermore, APD Experience is incorporated to account for the fact that when firms have experience with APD this may influence the effectiveness and performance gained from APD. A dummy variable with the value of one (zero otherwise) was created if the focal firm had an APD larger than zero in the previous survey wave.

A firm's innovative performance can be influenced by Resource Constraints such as a shortage of qualified staff or lack of financial resources (Oerlemans et al., 2013). A dummy with value of one if resource constraints were experienced and 0 otherwise is included.

Another control variable is the Use of Codified External Information Sources, because these sources can influence innovative performance and because they provide firms with external information and/or knowledge (Oerlemans, Buys, & Pretorius, 2006). The managers of the focal firm ranked on a scale of zero (not used) to three (very important) the extent they use three external information sources—patents, electronic information, and professional literature—for technological innovations. This variable is calculated by taking the ratio of the total score and the maximum possible score.

A MNE dummy (MNE) takes the value of one (else zero) if a firm has headquarters in another country. The international research facilities could provide the focal firm with knowledge and information not available in the local market (Isobe et al., 2000). Other members of a domestic group can have a similar influence on the innovativeness of the focal firm. Therefore a dummy for firms that are Part of a Domestic Group is also included. In line with Mohnen, Mairesse, and Dagenais (2006) the following R&D dummies are also included: Basic Research with a value of one (zero otherwise) when firms indicated their main focus is on basic research, Performing R&D with a value of one (zero otherwise) when firms indicated they performed any kind of internal/external R&D, Continuous R&D with a value of one (zero otherwise) when the firms indicated they worked continuously on R&D and Outsourcing/Buying R&D with a value of one (zero otherwise) when firms outsourced or bought R&D externally. Finally, 25 two-digit Industry Control variables are included, because different industries have different propensities to innovate.\(^7\)

3.3. Statistical method

The goal of the empirical analyses is to determine whether returns to APD are different for productivity and innovation performance (incremental and radical). To examine this effect the analyses controls for the effect of own R&D efforts, and the impact of incoming knowledge flows, as well as for other determinants of innovation output. We estimate random effects panel data models and account for unobserved heterogeneity by allowing for an individual effects. A Random effect rather than a fixed effect specification is used because random effects allow us to retain firms with only one observation and retain time-invariant variables. Because of censoring in the innovation output variable, measured as percentage, a type one Tobit models is used for the innovation performance equations.

4. Results

Table 1 presents the descriptive statistics. This table shows that APD has a mean of 0.04 and given the nonlinear specification this indicates about three partner types.\(^7\) Further, Table 1 shows relatively low bivariate correlations between the variables; these are not a cause for concern.

The first column of Table 2 presents results from pooled OLS regression of APD and productivity, without controlling for individual effects. Column 2 of Table 2 presents the results from the random-effect GLS regression. The individual effects are jointly statistically significant. The results show that overall the model is significant (\(p < 0.001\)) and has an explanatory power above 17%. The linear APD term has a positive and significant coefficient, while APD squared has a negative and significant coefficient. Together, they indicate an inverted U-shaped relationship between APD and productivity, in support of Hypothesis 2.

Columns 3 and 4 of Table 2 show the results of the Tobit model of APD and radical innovation performance. Column 3 presents the results from a pooled Tobit analysis, while column 4 presents the results from the panel estimator, controlling for unobserved heterogeneity. Overall, the model is significant (\(p < 0.001\)). The results show a significant positive coefficient for the linear APD term and a significant negative coefficient for APD squared. These results support Hypothesis 1, indicating and inverted U-shaped relationship between APD and radical innovative performance.\(^8\)

Columns 5 and 6 of Table 2 show the results from the Tobit model for incremental innovation performance. Column 5 presents the results from a pooled Tobit analysis, while column 6 presents the results from the panel estimator, controlling for unobserved heterogeneity. The coefficient signs of the linear APD and APD squared are positive and negative, respectively. However, the negative APD squared coefficient is not significant, indicating a positive relationship between APD and incremental innovative performance.

Among the control variables resource constraints are positive and significant in the radical and incremental innovative performance equations. This, at first seemingly unexpected result is in line with some recent findings in the APD literature (Oerlemans et al., 2013) and resource constraint literature (e.g., Hoegl, Gibbert, & Mazursky, 2008; Mosakowski, 2002) that suggests that resource constraints can unleash creativity and innovative behavior.

The results show a marginally significant positive relationship between R&D intensity and incremental innovative performance, whereas for radical innovative performance no significant impact is found. This difference might indicate that the internal knowledge base of the focal

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\(^5\) The CIS does indicate one or more alliances per partner type, distinguishing whether the partners were national or foreign but does not account for the total number of alliances per partner type.

\(^6\) The argument for squaring is that an increase at a higher level (e.g., from 10 to 11 types) is seen as larger than an increase at low levels (e.g., from 2 to 3 types). Alternative specifications are I: a linear increase, which means no expected differences between increases in the partner types and II: a root squared specification, which corresponds to a larger increase at low levels and a smaller increase at high levels. The results are comparable to the linear specification, which was analyzed as a robustness check.

\(^7\) Because of the nonlinear relationship between the number of partner types and APD, APD was calculated as the sum of the 14 possible partner types divided by 14 and then squared. Given the APD, to calculate the number of partner types one take the square root of the value and multiply this by the maximum number of partners (14).

\(^8\) As a robustness check all models were also analyzed with a cubic term included, but the cubic term was not significant.
firm plays a more important role in incremental innovation and supports the earlier claim on the adaptation of the knowledge base necessary for radical innovation.

4.1. Different optima of the three performance dimensions

The combined coefficients of the APD linear and APD squared terms in Table 3 indicate tipping points in the relationships between APD and both productivity and radical innovative performance but no significant tipping point in the relationship between APD and incremental innovative performance. After calculating the tipping points the corresponding optimal number of partner types9 is obtained.

Table 2 includes the differences in tipping points for the two significant performance dimensions; interesting is whether or not these differences are statistically significant. Because the square APD term is not statistically significant in the relationship between APD and incremental innovative performance, no meaningful comparison can be made between this tipping point and the others. However, the tipping point for productivity can be compared with that for radical innovative performance. To test whether these tipping points differ significantly a Hausman-type test as described in (Weesie, 1999) is used.

The results show a difference of 3.39 (11.45 − 8.07) between radical innovative performance and productivity, with a corresponding standard error of 1.14. This difference is significant (p = 0.003) providing support for Hypothesis 3. This hypothesis stated that the tipping point for radical innovative performance will be at a higher level of APD than that for productivity. The results suggest no negative returns to APD for incremental innovative performance, while for radical innovative performance returns to APD become negative at higher levels of APD than that for productivity. The results suggest no negative returns to APD become negative at higher levels of APD for incremental innovative performance, while for radical innovative performance this increase leads to a growth in the share of turnover from 10.60% to 19.97%. An increase of 7.49% (24.45 − 16.96) is achieved for incremental innovative performance. The figure additionally shows that increasing APD beyond the tipping point is not beneficial for the radical innovative and productivity dimensions, but for productivity this results in a performance level even lower than the performance at minimum levels of APD. Furthermore this figure shows that increasing APD results in the largest performance increase for incremental innovative performance.

5. Discussion and conclusions

This paper has explored the relationship between APD and three firm performance measures: productivity, and radical and incremental innovation. Despite a growing alliance portfolio diversity literature, with a few exceptions (e.g., Bowers, Pharmer, & Salas, 2000) most relevant contributions studied the effect of APD on performance measures in isolation. The results of random-effects panel data analyses suggest that the relationship between APD and both productivity and radical innovative performance is concave. However, the results reveal a positive relationship between APD and incremental innovative performance. Given that the fine-tuning of existing innovations is less complex than the development of radical innovations the findings suggest that a much broader portfolio, including all partner types helps to improve incremental innovative performance. Explorative activity, such as radical innovation, on the other hand, requires a focus on the knowledge base adaptation and therefore benefits from a limited number of partner

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9 The tipping points can be calculated by dividing the negative APD linear coefficient by 2 x the APD squared coefficient. This can be derived for the following quadratic formula: f(x) = ax² + bx + c. The intercept with the x-axis occurs at f'(x) = 2ax + b = 0, so Xtop = −b/2a, where b corresponds to the APD linear coefficient and a to the APD squared coefficient. To calculate the number of types one reverses the calculation of the APD (the square root of the APD tipping point is multiplied by the maximum number of partner types, N = 14).

10 To reverse the log transformation of productivity, these values were raised to the power of 10. The numbers on the horizontal axis of Fig. 1 and the coefficients presented in all the Tobit analyses cannot be fully interpreted as effect sizes. The coefficients of Tobit analysis capture the conditional mean in the non-censored domain (McDonald, 2009) as well as the likelihood that an observation is not censored at all. The relative effects of the coefficients are, however, equally affected by these dual effects, and therefore the shapes of the curves in this figure are reliable and interpretable.
types. This focus, which could lead to a negative influence of higher levels of APD, is much less important for exploitation.

With respect to the tipping point, a significant difference is found between productivity and radical innovative performance. Depending on the performance dimension, different resources and thus different partner types necessitate different levels of APD. This does suggest that productivity, radical innovative, and incremental innovative performance benefit differently from alliance portfolio diversity and this may explain why previous research found mixed results between different performance dimensions when studying the effect of APD on firm performance.

As such, the findings of this study contribute to a better understanding of how firms should configure their alliance portfolio when prioritizing their objectives with respect to performance. The results of this study demonstrate that to realize exploitative performance objectives, such as improvement in productivity a firm needs a much narrower scope of alliance portfolio compared to explorative objectives, such as radical innovation. When comparing radical to incremental performance, this study shows that to maximize incremental innovation a broader set of actors with which a focal firm interacts is needed. The differences that are found between the three performance dimensions make this study a first step toward a more integrated view of the relationship between APD and different dimensions of organizational performance.

This study also has some practical implications and should be of interest to alliance and innovation managers, especially because the results show that different levels of APD are optimal for different outcomes and process stages. Managers can benefit from continuously assessing their portfolio in a holistic way. Because different levels of APD are beneficial for different outcomes, the authors suggest that when the desired performance outcome changes, the alliance portfolio should be redesigned—a demanding but potentially rewarding task.

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These findings have also implications for future research. First, these findings have implications for the exploration/exploitation research. The simultaneous pursuit of exploration and exploitation is an inherently complex task because that which drives the former is profoundly different from that which drives the latter and the resulting tensions may ultimately undermine performance (O’Reilly & Tushman, 2008; Raich, Birkinshaw, Probst, & Tushman, 2009; Tushman & O’Reilly, 1996). The results of this study demonstrate that an alliance portfolio has to be configured differently depending on the firm’s priority with respect to exploration and exploitation activities.

Second, the results provide implications for alliance portfolio research. This study clearly shows a need to study APD as a more dynamic construct, in part because the effectiveness of a new partner type depends on the current level of APD. In other words, the existing level of APD can influence the performance of future alliances. The results thus have implications for the process of partner selection. A firm should not only assess the match with a potential partner, although this remains important, but could be better off when also assesses the potential partner’s contribution to, and (dis)synergies with, the alliance portfolio. In line with Hoffmann (2005), firms benefit from developing and implementing an alliance portfolio strategy.

Despite the interesting findings, a number of limitations in the analysis merit a further mention. No distinction could be made between alliance portfolio size and APD (cf. Duysters & Lokshin, 2011; Laurens & Salter, 2006; Oerlemans et al., 2013). Due to the anonymous nature of CIS no additional sources for alliances information could be added to the database, which could have been used to supplement the data. Previous studies based on other datasets have shown a relative moderate to high correlation between APD and alliance portfolio size, for example 0.64 in the case of Wuys and Dutta (in press). This correlation indicates some overlap between these two constructs.

Second, this research focuses specifically on one dimension of APD. However, as argued by Wassmer (2010), APD is multidimensional, stemming from combining the partner types with the governance modes. Ji et al. (2010) were among the first to operationalize APD as a multidimensional construct. Their results showed that different dimensions of APD such as governance diversity and functional diversity have different effects on firm performance. A study of the influence of these dimensions on multiple performance dimensions would be a valuable extension of this research.

However, despite the need for further research and some of the shortcomings of this study, the current analysis does provide a number of interesting new insights into the alliance portfolio diversity of innovating firms and its effect of three different performance indicators. The perspective that is introduced in this paper by considering these dimensions in one framework provides an interesting outlook for further work on alliance portfolios that remains to be done.

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