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Configurations of strategic R&D decisions and financial performance in small-sized and medium-sized firms

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ABSTRACT

This paper links the strategic decisions made in R&D during the financially turbulent period of 2009 to the firm's financial health in the period 2010–2013. The focus is on decisions made in R&D-active small and medium-sized enterprises in terms of absorptive capacity, open innovation, type of R&D, and the organizational structuring of R&D. Based on a representative set of R&D-active firms in Belgium, qualitative comparative analysis reveals that the outcomes in terms of financial performance related to optimal configurations of strategic R&D decisions depend on the firm's size and on the time-lag under consideration. Managers in small-sized firms are advised to pay particular attention to a more functionally-structured R&D approach in configurations of strategic R&D decisions. To increase medium-term financial performance, managers in medium-sized firms benefit from more engagement in research-oriented activities, more in-house innovation, and the enhancement of absorptive capacity in sets of strategic R&D decisions.

1. Introduction

The economic and financial crisis which started in 2008 was global in nature, but it particularly affected Europe (OECD, 2012). The crisis reached its peak in 2009, with negative changes in real GDP approaching −3% in the United States; −3.5% for OECD countries, and up to −4.5% in the Euro Area (OECD, 2016). From 2010 onwards, a gradual improvement took place with positive real GDP growth, but it deteriorated again in 2012 and 2013. Belgium, a small open economy in Western Europe, followed this trend with a negative real GDP growth of 2.4% in 2009, growth rates of 2.7% and 1.8% in 2010 and 2011 respectively, and stagnating (approaching 0% change) real GDP in 2012 and 2013 (OECD, 2016). This paper focuses on R&D-active firms in Belgium and links configurations of firm-level strategic decisions made in R&D in the year 2009 with the financial performance of firms in the period 2010–2013. In debate regarding the relationship between R&D and the financial performance of firms, the empirical literature is inconclusive concerning the role of firm size and time-lags between R&D inputs and financial outputs (see e.g. Kostopoulos, Papalexandris, Papachroni, & Ioannou, 2011). This paper addresses these issues by differentiating between small-sized and medium-sized firms and by including time-lags ranging from one to four years.

Venkatraman and Ramanujam (1986) refer to the multidimensional construct of firm performance including business performance, organizational effectiveness, and financial performance. Business performance measures market-related items including market share, growth, diversification and product development. It is a mixture of growth in existing business and future positioning in terms of new product development and diversification. Organizational effectiveness considers stakeholders and refers to quality and social responsibility. Financial performance is at the core of organizational effectiveness and is a necessary condition to define overall effectiveness (Bacidore, Boquist, Milbourn, & Thakor, 1997). Insights into the relationship between R&D and firm performance are limited and the results remain contradictory (Cañibano, Garcia-Ayuso, & Sanchez, 2000; Sundaram, John, & John, 1996) and depend on the time-frame under consideration (Latham & Braun, 2009). However, a positive link between innovation and financial performance can be expected for at least three reasons. First, firms responding to customer demands and impulsive consumer preferences are more likely to attain higher levels of sales and firm growth (Srinivasan, Pauwels, Silva-Risso, & Hanssens, 2009). Second, continuous innovation can yield indirect benefits in terms of being able to recognize and acquire new knowledge, with potentially new innovations leading again to financial benefits (Cohen & Levinthal, 1990). And third, the penetration of segments with high financial margins can allow the offsetting of potential costs relating to targeting and attracting new customers (Bayus, Erickson, & Jacobson, 2003).

The paper investigates what sets or combinations of strategic R&D decisions during a financially and economically turbulent period can be associated with successful outcomes in terms of the firm's future financial performance. It adds to the existing

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literature in three ways. First, attention is paid to shortcomings in the measurement of financial performance. Klingenberg, Timberlake, Geurts, and Brown (2013) question the appropriateness of return on assets (ROA), return on sales (ROS) or return on equity (ROE) — the most popular indicators used to measure financial success in terms of current profitability — to determine the link between research and the firm's financial performance. Lome, Heggeseth, and Moen (2016) use revenue growth and measure this for different time-lags over the period 2004–2009. In line with Fosfuri and Tribó (2008) and Lome et al. (2016) I use time-lagged financial indicators drawn from a separate database and an alternative measurement for financial performance is proposed based on simple intuitive models (Ooghe & Van Wymeersch, 2008). These ratios make use of four basic elements of financial health (liquidity, solvency, profitability, and value added), offer a more balanced measurement of the firm's financial position, and are largely available.

Secondly, the inconclusive empirical findings regarding the role of firm size and time-lag in the relationship between R&D decisions and financial performance are addressed (Kostopoulos et al., 2011). The focus is on a broad set of R&D decisions made during the financially turbulent period of 2009. The relationship between R&D and financial performance should be seen within a particular timeframe and depends on the period of analysis (Lantz & Sahut, 2005; Lome et al., 2016). In contrast with most studies that — due to data constraints — focus on short time-lags, time-lags up to four years are included to study the relationship between these R&D decisions and financial performance (in line with Nooteboom, Vanhaverbeke, Duysters, Gilsing, & van den Oord (2007) and Lome et al. (2016)). The firm size dimension is addressed by focusing on small-sized and medium-sized firms and by distinguishing between both size groups.

Thirdly, R&D is a broad concept and over the past decades, ample attention has been paid to management-related and organizational aspects of R&D. Insights from the literature on open innovation (Chesbrough, 2003), absorptive capacity (Cohen & Levinthal, 1990), the functional organization of R&D (Engelen & Brettel, 2012), and the focus on R versus D (OECD, 2002) are integrated. Since little is known about the interplay between these strategic dimensions, qualitative comparative analysis (QCA) is relied upon to investigate the relationship between sets of managerial R&D decisions and the financial performance of firms. Following Ragin (2008) and Woodside (2013) — fuzzy-set — QCA is used to analyse multivariate data. QCA makes it possible to examine the relationship between the outcome variable (financial performance) and all binary (Boolean) combinations of multiple R&D strategy-related predictors. This approach makes it possible to bring forward different combinations of causal variables providing separate pathways to arrive at given outcomes (or "equifinality" — see e.g. Wu, Yeh, Huan, & Woodside, 2014). QCA enables multiple pathways to an outcome and is highly appropriate to test models (each possible combination of factors at specific levels with a given outcome) involving a multitude of interacting factors. The QCA approach is highly relevant in strategic management research because it provides the ability to analyse complex relationships between different corporate-level mechanisms in predicting business success (Greckhamer, Misangyi, Elms, & Lacey, 2008).

The analysis is based on a representative sample of small-sized and medium-sized firms described as being R&D-active in 2009 in the official R&D repertory of the OECD business R&D survey for Belgium. Financial performance is taken from the firms' annual accounts for the period 2009–2013.

Section 2 reviews the literature on the relationship between the underlying strategic R&D dimensions and financial performance at firm level. Section 3 presents the empirical model and data. The results of the empirical analysis can be found in Section 4. Conclusions are made in Section 5.

2. Literature review

The literature review presents insights into the relationship between R&D and the financial performance of firms. Next, it addresses the theoretical arguments linking the four strategic R&D decisions to the firm's financial performance. It concludes by presenting the research framework.

2.1. R&D and the firm's financial performance

In comparison with innovation, the relationship between R&D investments and firm performance needs to be seen in a longer-term perspective. Lantz and Sahut (2005) report a short-term negative relationship between R&D investments and financial return. They highlight the role of R&D expenditures to 'announce' the strategic positioning of firms, but also indicate that these expenditures can significantly decrease financial performance in terms of net income, return and risk. Lome et al. (2016) report differences in the correlation between R&D and the firm's revenue growth depending on the time-lag under consideration. They report stronger effects after a three year time period. Innovating firms, in general, have strong growth, but potentially incur problems of liquidity and even bankruptcy, in particular if these firms are small and do not have the financial strength to absorb a crisis. This is especially the case in specialized laboratories in the manufacturing industry and for technological companies whose activities are based on the economic exploitation of R&D results (Lantz & Sahut, 2005). Also, involuntary spillovers can allow competitors to gain competitive advantage at a lower cost by means of imitation.

Cañibano et al. (2000) report a positive relationship between R&D expenditures and future firm profits, whereas Sundaram et al. (1996) arrive at the opposite conclusion. One of the factors explaining different results is that the findings depend on the period of study (Lantz & Sahut, 2005). Recessions represent one of the most significant environmental threats to an organization's continued profitability and survival (Pearce & Michael, 2006), and a firm's effective management of financial resources may be particularly amplified within such a context. Two opposite views exist (Audia & Greve, 2006). According to prospect theory, risk-taking will be stimulated when facing impending losses implicated by threatening environments (Kahneman & Tversky, 1979). By contrast, threat-rigidity suggests risk aversion behaviour and a tendency to focus on protection of the organization's position (Sitkin & Pablo, 1992). Latham and Braun (2009) reveal an important timing dimension. They find that firms with a higher degree of slack resources react more slowly to economic shocks, but by transferring resources to strategic activities (especially R&D) during recession, managers can smooth over short-term disturbances in the environment and speed recovery to secure a post-recessionary head start.

2.2. Strategic R&D decisions

In the R&D and innovation management literature, four relevant strategic R&D decisions can be identified when studying the relationship between R&D and financial performance. These include absorptive capacity, type of R&D, internal organization of R&D activities, and degree of openness in the R&D strategy.

2.2.1. Absorptive capacity

The tacit nature of innovation and the risks associated with loss of technological competitiveness require sufficient internal R&D activity (Cohen & Levinthal, 1990). The resource-based view of the firm demonstrates how innovation depends on the development and accumulation of internal capabilities (Spithoven & Teirlinck, 2015).

To absorb knowledge from the external environment, a firm needs organizational integration in which employees function as

interfaces with the environment (Helper, MacDuffie, & Sabel, 2000). These employees have to possess the skills to screen, interpret and assimilate knowledge and transfer it through internal communication and diffusion on the work floor (Cohen & Levinthal, 1990). The narrower the interfaces to the external environment, the less knowledge and ideas are absorbed, the less internal employees learn about external ideas, and the smaller the chance that they will succeed in their innovative efforts (Lam, 2000). Apart from skills that can be developed on the work floor, skills obtained through education exert a decisive influence on external networking. Highly qualified employees are associated with higher R&D investment levels (Roach & Sauermann, 2010) and education and training are found to be of crucial importance to innovation (Lam, 2000). High educational levels facilitate the detection and management of relevant external knowledge flows, which are key ingredients in absorptive capacity (Roach & Sauermann, 2010). Absorptive capacity is closely related to longer term research activities (compared to experimental development) and the employment of highly qualified researchers and their abilities to adapt to new technologies (Zahra & George, 2002). This technological capital strengthens the firm's ability to overcome cognitive distance to absorb knowledge.

2.2.2. Organizational structuring of R&D

For a long time, the centralized in-house R&D lab has been (considered) the main source of ideas or knowledge. Cohen and Levinthal (1990) relate R&D structure to the ability of an organization as a whole to stimulate and organize the transfer of knowledge across departments, functions, and individuals. Daghfous (2004) highlights the importance of the organizational structure of a firm and cross-functional communication leading to improved knowledge-sharing among departments and individuals within a firm (see e.g. Lane & Lubatkin, 1998). Organizational structure can also be closely linked to human resources and knowledge management (including e.g. the formation of functional teams and stimulation of job rotation) and related knowledge flows (Daghfous, 2004).

Organizing R&D in a separate division refers to a functional structure of the organization including strengths in terms of absorptive capacity (Veugelers, 1997), and a maintained traditional firm design fostering the development of in-depth knowledge, standard career paths, and project team members remaining connected with their functional group. Potential weaknesses include functional siloing, a lack of customer focus, a longer time taken for projects, and sub-optimized projects (Pinto, 2012).

Engelen and Brettel (2012) empirically test patterns of cross-functional integration between the R&D department and other departments and look at the performance consequences of cross-functional integration. The argument in favour of a centralized unit is stronger control over directions and resources of the organization (Pfeffer & Salancik, 1978) and stronger power in influence tactics in terms of recommendation, coalition formation, information exchange and requests to other organization members (Engelen & Brettel, 2012). In relation to financial performance, a separate R&D department is more able to demonstrate the financial outcomes of its activities and can illustrate financial outcomes for the overall organization (accountability — Engelen & Brettel, 2012) . Engelen and Brettel (2012) report a significantly negative relationship (losing influence) for small- and medium-sized firms in terms of the integration of the R&D department with other departments and the influence of R&D activities on the financial performance of the firm.

2.2.3. Type of R&D

R&D can be divided into basic research, applied research and experimental development (OECD, 2002). The main difference between basic and applied research lies in the aim of the research. Basic research is without any particular application or use in mind, while applied research is directed towards a specific practical aim or objective. From a business perspective, the emphasis is on research (R) versus development (D) without going into further detail on the research component (OECD, 2002). R and D present some economically relevant differences. First, the degree of risk between both kinds of activities varies, with research involving a higher degree of uncertainty in the output and a more limited integration into the business plan. Development, on the other hand, is less risky because the intended commercial application is known. Moreover, the risk for development is merely a market risk rather than a technical one, and the time horizon for development tends to be shorter than that for research (OECD, 2002). In the absence of commercialization of research outputs, tangible financial results will not be achieved (Kostopoulos et al., 2011). This does not discount the role of absorptive capacity for the commercial application of acquired knowledge (Cohen & Levinthal, 1990; Lane, Koka, & Pathak, 2006). Hence, in the event that the focus is on R versus D, different time-lags need to be taken into account.

2.2.4. Open innovation

Complexity, increased knowledge intensity of, and the mounting competitive pressure for developing new products and processes, force the R&D-active company to look outside its own boundaries to supplement internal R&D efforts (Chesbrough, 2003). Formal and informal research cooperation are prominent ways to do this (Chesbrough, Vanhaverbeke, & West, 2006). Research cooperation may be a means to explore new research areas with relatively less – or better spread – capital and lower risk involvement in the event of failure, but may also risk dissipation of essential knowledge (Narula, 2004; Veugelers, 1998).

Teirlinck and Spithoven (2013) consider the particularities for small- and medium-sized firms in terms of generating new knowledge and exchanging existing knowledge previously developed within the firm (based on Veugelers, 1997) and make the link with the availability of research managers and R&D experts (complementary with the views on the necessity of an internal knowledge base — Narula (2004)). Katz and Ordover (1990) link this to the tacit nature of innovation and the potential loss of technological competitiveness requiring management skills for an appropriate knowledge protection and increased attention to the productivity of knowledge assets, which is particularly important for small- and medium-sized firms (van de Vrande, de Jong, Vanhaverbeke, & de Rochemont, 2009).

2.2.5. Research framework accounting for firm size and for time-lags

The research is exploratory in nature in the sense that I did not find theoretical, nor empirical evidence pertaining to the relationship between the financial performance of firms and sets of strategic R&D decisions. However, from the above description it is clear that the strategic R&D decisions are inter-related. Also, from a managerial perspective and with a view to building a balanced R&D strategy (scoreboard), a focus on configurations of strategic R&D decisions and financial performance is highly relevant, rather than focusing on a strategic decision in isolation. Moreover, the literature review is unclear on the role of firm size and on the time-lags to be used to understand the relationship between sets of R&D decisions and financial performance.

For firm size, significant but inconclusive empirical findings are presented with regard to the link with R&D expenditures and the financial performance of firms (Kostopoulos et al., 2011; Li & Hwang, 2011). Serrano Cinca, Mar Molinero, and Gallizo Larraz (2005) also report differing ratio patterns according to firm size, and Lantz and Sahut (2005) relate R&D and risk with firm size to explain financial performance. The underlying argument is that firms must exert high expenditures for uncertain future return. In a situation of market-related informational asymmetry, small

firms in particular risk lacking control of contents and prospect for future profit. Moreover, small firms experiencing strong growth risk problems of liquidity and bankruptcy due to the absence of financial strength which is necessary to absorb a crisis. R&D-active small firms are also in a vulnerable financial position due to technological (technological rupture brutally makes the discovery obsolete) and competitive (discovery does not become market standard) risk. Finally, as argued by e.g. Engelen and Brettel (2012), in contrast to the considerable diversity in large firms, small and medium-sized companies form a more homogeneous group in terms of power relationships across business units. This prompts me to perform a separate analysis for small-sized and for medium-sized firms. Small-sized firms have limited manpower, substitutes for lack of sales, and financial resources. Medium-sized firms have larger financial, technological, and other sources to invest in R&D and benefit from advantages of scale and risk diversification. However, they present less flexibility to deal with unexpected original outcomes hampering disruption (Nooteboom et al., 2007) and favouring specialization along existing technological trajectories (Ahuja & Lampert, 2001; Levinthal & March, 1993). Large (in Belgium, mainly multinational) firms are left out of the analysis because of their particularities in terms of financial constructions and inter-group transactions which artificially influence the firm's financial performance. R&D-active micro-sized firms are also excluded since this category mainly involves young innovative companies. These firms often have specific requirements in terms of financing and often long time-lags exist between R&D and profit making (Schneider & Veugelers, 2010).

Besides firm size, the time of the financial effect of R&D is an important issue. Zhu and Huang (2012) use a one-year lagged financial performance as a dependent variable and point to contradictory results for the incidence of R&D expenditures on the firm's financial performance. Xu and Tang (2010) found a positive relationship; whereas Li, Vanhaverbeke, and Schoenmakers (2008) suggested the absence of any significant relationship between R&D expenditures and profitability. Nooteboom et al. (2007) refer to a moving window of five years as an appropriate time-frame for assessing the impact of technology. After five years, R&D and patents lose most of their economic value. Following Latham and Braun (2009) and Lome et al. (2016) I consider different time-frames (time-lags) over the period 2009-2013 to study the relationship between sets of strategic R&D decisions and financial performance at firm level.

As noted previously, the interplay between different strategic R&D decisions and the financial performance of firms is not well understood and inconsistent findings can be related to limitations inherent to the classical regression models used (Li & Hwang, 2011). Therefore, the research question can be formulated as follows: "What sets or combinations of strategic R&D decisions can be associated with successful outcomes in terms of the firm's future financial performance?". I answer this question both for small- and for medium-sized firms and by considering different time-lags.

3. Method and descriptives

3.1. Sample

Bedford and Sandelin (2015) highlight the importance of appropriately defining the sample population. The authors highlight the fact that QCA does not require a sample that is representative of the relative distribution of configuration types, but there should be enough valid cases for inclusion in the analysis. This can be closely linked to the debate on the control variables to be included. Although purposive sampling can be accepted for QCA (Bedford & Sandelin, 2015), a representative sample approach is followed in this paper.

The unit of analysis is the R&D-active firm. The data are drawn from the biannual OECD business R&D survey for Belgium for the reference year 2009, complemented with financial account data retrieved from the official annual accounts of the companies (Belfirst database — accessed June 2015). The target population includes all (quasi-) permanent R&D-active firms in Belgium. It is the result of a frequently updated list of regular R&D spenders (as collected by the statistical support service of the concertation group between the federal and regional authority levels — Committee for "Federal Cooperation" (CFS/STAT)). The repertory in 2009 consists of 1158 (quasi-) permanent R&D-active firms, including 455 small-sized firms and 304 medium-sized firms. 189 small-sized firms (10–49 employees) and 185 medium-sized firms (50–249 employees) provided all the information required to conduct the analysis.

The paper's focus is on the – optimal configurations of – the four strategic R&D decisions. Absorptive capacity includes internal R&D in terms of human resources (e.g. Lam, 2000; Stock, Greis, & Fischer, 2001). Degree of open innovation takes into account knowledge exchange and knowledge development in R&D cooperation (Chesbrough, 2003; Veugelers, 1997). R&D structure is proxied by whether or not the R&D is organized in a separate (functional) R&D lab (Pinto, 2012; Veugelers, 1997). Type of R&D is measured as the share of R&D related to development (OECD, 2002).

A comparison (*T*-tests) between companies in and outside the sample revealed that firms that were in a weaker financial position at the moment the survey was organized (2011) are somewhat underrepresented in the sample. No differences are found in terms of the four strategic R&D decisions. *T*-tests applied on the variables presented in Table 1 reveal significant differences between small-sized and medium-sized firms in terms of three of the four strategic R&D decision variables: R&D intensity, organizing of R&D in a functional department, and development orientation.

3.2. Data

Following the insights of Klingenberg et al. (2013) and Delen, Kuzey, and Uyar (2013) regarding the use of appropriate indicators for measuring financial performance, the dependent variable — the financial performance of firms — is constructed based on 'simple intuitive models' (SIM). These models start from the four basic elements of financial health: liquidity (net cash ratio, short term financial debt ratio), solvency (level of self-financing; level of financial independence), profitability (net return on equity after taxes, net return on the company assets before taxes, cash flow on equity) and value added (gross value added divided by cost of employment) (Ooghe & Van Wymeersch, 2008). The selection of the ratios used in the model is based on empirical performance analysis, choosing the best performance model with the smallest unweighted average error. The eight ratios referred to in Table 1 are used in the simple intuitive model and have an equal weighting. To compare the ratios, a rescaling of the values between 0 and 1 is performed (Ooghe & Van Wymeersch, 2008: $\text{Li} = 1/(1+e^{-\text{Ri}})$ with 'Li' the logit value of ratio Ri, and 'Ri' = positive or negative value of ratio i (in decimals)). The SIM score is calculated as the unweighted average of the logit values of the different ratios. Higher scores imply better financial performance. Since the dependent variable is a proportion, the data are logit-transformed ($\ln(y/(1-y))$).

3.3. Method

Bedford and Sandelin (2015) highlight the advantage of set theoretic methods to consider connections between attributes and outcomes in terms of sets and set relationships (rather than the average effect of an increase or decrease of one variable on another). Qualitative comparative analysis (QCA) is relied upon to examine

Table 1
Financial performance, strategic R&D decisions, and control variables: small-sized and medium-sized R&D active firms.

	Description	Small-sized firms ($N = 189$)	Medium-sized firms ($N = 185$)
Financial performance (F)			
SIM 2013	Financial performance ratio measured as an unweighted average of 8 ratios (each converted in a score between 0 and 1): gross value added divided by cost of employment; net return on the company assets before taxes; net return on equity after taxes; level of self-financing; level of financial independence; short term financial debt ratio; coverage of equity by cash flow; net cash ratio.	0.69 (0.15)	0.65 (0.17)
SIM 2012		0.69 (0.14)	0.65 (0.16)
SIM 2011		0.70 (0.14)	0.67 (0.16)
SIM 2010		0.67 (0.16)	0.62 (0.18)
Management decision to invest in absorptive capacity (A)			
R&D intensity	R&D personnel as a share of total employment	0.25 (0.23)	0.15 (0.13)
Management decision with regard to the internal structuring of R&D (M)			
Functional department	The firm organizes its R&D activities in a separate R&D department	Yes: 69% No: 31%	Yes: 85% No: 15%
Management decision with regard to engagement in research versus development (T)			
Development	Share of R&D expenditures related to development (compared to research)	0.37 (0.35)	0.45 (0.36)
Management decisions to engage in open innovation (O)			
Coop	The firm engaged in R&D collaboration aimed at knowledge exchange or knowledge development with other partners ("0" = no knowledge exchange nor development; "1" knowledge exchange or development; "2" knowledge exchange and development)	2: 23% 1: 18% 0: 59%	2: 27% 1: 17% 0: 56%
Control variables			
SIM 2009 (L)	Financial performance ratio measured as an unweighted average of 8 ratios (each converted in a score between 0 and 1): gross value added divided by cost of employment; net return on the company assets before taxes; net return on equity after taxes; level of self-financing; level of financial independence; short term financial debt ratio; coverage of equity by cash flow; net cash ratio.	0.66 (0.14)	0.62 (0.15)
Manufacturing	The firm is active in the manufacturing industry (compared to services): yes/no	Yes: 62% No: 38%	Yes: 75% No: 25%
Age	Age of the firm in the year 2009	23.7 (18.0)	28.4 (20.0)
Group	The firm belongs to a group in the year 2009 (yes/no)	Yes: 52% No: 48%	Yes: 55% No: 45%

Note: Unless otherwise mentioned variables refer to 2009 (2008–2009 for cooperation).

company members of the set of financially high-performing organizations. QCA uses Boolean algebra and algorithms to logically reduce the numerous and complex causal conditions and sufficient configurations into a reduced (more parsimonious) set of configurations that (most likely) lead to the desired financial performance outcome. The set relationships need to fulfil both a sufficiency (be most likely to lead to high financial performance) and a necessity (no other attribute combinations lead to high financial performance either) criterion.

Since the research is explorative in terms of the combinations of variables that lead to a successful outcome, QCA is an appropriate method to apply since it allows both hypothesis testing and discovery, is capable of penetrating complex phenomena and higher-order interactions, and enables analysis of equifinality or multiple causation (Bedford & Sandelin, 2015). QCA test statistics are reflected in coverage (empirical relevance of a solution, the higher the better — comparable to an *r*-squared score in regression analysis) and consistency (degree to which the observations agree on the financial outcome — comparable to a *p*-value). The inclusion of time-lags for the outcome variable largely addresses the issue of causality faced in cross-section analyses using QCA (Bedford & Sandelin, 2015).

For each size group (small-sized and medium-sized firms), set memberships are assigned based on a fine-grained analysis (in comparison to binary outcome variables) — given the interval or continuous measurement of most of the causal attributes (Fiss, 2007) — based on fuzzy sets (Ragin, 2008). Variables are transformed into sets according to their degree of membership to each of the conditions and calibration is used to obtain the fuzzy set score (Ragin, 2008). In line with Ragin (2008) fuzzy sets are created ranging from 0 to 1 based on rank-ordered variables and then for all variables, standardized ranking is applied by dividing the difference between the ranked variable and the minimum of the ranked variable by the difference between the maximum of the ranked variable and the minimum of the ranked variable. Given the homogeneity of the R&D-active companies and absence of outliers (due to the specification of the attributes — see Table 1) no a priori theoretical breakpoints need to be defined, and the typical breakpoints of 0.95 for full membership and 0.05 for full non-membership are followed for the calibration of original values into membership values (see e.g. Alegre, Mas-Machuca, & Berbegal-Mirabent, 2016). The only exception variable for which an anchor has been defined is the age variable (for which the relevance of variation e.g. between a firm aged 100 years and one existing for 25 years can be argued). For this variable an anchor of 10 years is set (this refers to young, innovative or new technology-based companies — in line with generally accepted classifications — see e.g. Schneider & Veugelers, 2010). The age variable was not further considered in the analysis because it did not turn out to fulfil the sufficiency and necessity condition. Crossover points for all attributes were fixed at 0.5 (Longest & Vaisey, 2008; Ragin, 2008). The crossover points to assign membership in the configuration have been carefully checked for all variables. For open innovation (O), the crossover point is 0.67 (i.e. more in than out of the cooperation set — which is in line with the theoretical insights in open innovation). The crossover point for inclusion makes that firms engaging in whatever form of cooperation

(values 1 or 2 — see Table 1) pass this point. The crossover point for absorptive capacity (A) approaches an R&D intensity of 0.1, which corresponds to the definition of a highly intensive R&D-active firm (Schneider & Veugelers, 2010). For a structured research approach (M), the crossover point includes the presence of a separate R&D department (in line with Engelen & Brettel (2012)). For research versus development (T) the crossover point approximates 40% of the budget devoted to development (which is in line with theoretical expectations on a good balance between R and D — Belderbos, Faems, Leten, & Van Looy, 2010). The crossover points are quite stable in each of the models and no a priori theoretical arguments exist to differentiate the calibration process for the different attributes and models.

Next, a truth table is constructed in which each firm is assigned to a row corresponding with membership scores on the causal attributes. The table has two to the power five rows (four strategic R&D decision attributes and the lagged financial performance, see further). In line with Ragin (2008), a frequency threshold (minimum number of empirical instances for a row to be considered valid empirical evidence) equal to 80% of the sample is set. In addition, it is required that *y* consistencies (positive outcome) are significantly larger than *n* consistencies (negation of the outcome), and that a consistency threshold (degree to which cases within the row agree with the outcome) of at least 0.8 is reached. The sets are logically reduced based on coverage and consistency by applying the Quine-McCluskey algorithm.

4. Empirics

In line with the research frame for testing optimal configurations of strategic R&D decisions for future financial performance of firms, a distinction is made between small-sized and medium-sized R&D-active firms, and time-lags between one and four years are considered. By way of a control, the optimal configurations with the inversed outcome variable are generated and attention is paid to differences between small- and medium-sized firms.

4.1. Final reduced sets for small-sized and for medium-sized firms

For each size class and for each year (time-lag) a coincidence and sufficiency and necessity matrix (Table 2 — for reasons of space only the results for a four year time-lag are presented) is generated to get a sense of the relationship between the strategic R&D attributes and the financial performance measure. Each of the attributes can clearly be associated with financial performance, although some similarities as well as differences by size and year can be identified. For small-sized firms, above-median absorptive capacity (A) and highly structured R&D (M) sets overlap by respectively 58% and 47% of their possible shared area with above-median financial performance in 2013. The coincidence scores for these factors are high throughout the entire period. Engagement in open innovation (O) presents the lowest overlap in relation to financial performance, but the coincidence increases over time. For medium-sized firms, absorptive capacity is high and stable in terms of coincidence with future financial performance, whereas the coincidences of research orientation and open innovation with financial performance tend to decrease over time. The coincidence levels between the strategic attributes range between 23% and 57% for small-sized and between 27% and 53% for medium-sized firms. This indicates that the attributes are linked, but not to an extent that there is duplication and risk of model misspecification. The sufficiency and necessity matrix provide justification for inclusion of each of the selected attributes in the analysis.

Potentially influential control variables, including age, sector, group, and lagged financial performance have been tested. Only lagged financial performance was revealed to be most highly associated with future financial performance (in line with Kostopoulos et al., 2011). Not surprisingly, the coincidence of good past performance (slightly) diminishes over time, both for small-sized and medium-sized firms. The fact that the other control factors (age, sector, group) do not contribute significantly can be considered an indication that the sample split into small-sized and medium-sized R&D-active firms is an appropriate approach to obtain homogeneous groups of firms. For parsimonious reasons these variables are excluded from the analysis.

The starting point of the analysis is a truth table containing all logically possible combinations ("rows" — 2 to the power 5 (attributes)). These configurations are reduced to an optimal set of combinations by only including configurations with *y* consistencies significantly greater than 0.8, as well as significantly greater than their *n* consistencies (inclusion versus non-inclusion in *y*; a significant *p*-value means that the *y* consistency and *n* consistency of a particular configuration are statistically different). Weakest link reasoning further reduces the set of configurations, i.e. membership in a combined set cannot be higher than the minimum membership in any of the constituent sets (Ragin, 2009). For example, in the case of small-sized firms and outcome 2013, limited diversity is hardly found in the sense that only one row (combination) is not empirically represented in the sample (it is common that some combinations are not represented – Gerdin, 2005). Eight "best-fit" configurations include 5% or more of the cases (the maximum percentage amounts to 8.5). Over 45% of the firms in the best-fit configurations have a configuration including high absorptive capacity and a highly structured R&D approach (AM — a capital letter refers to an above-median presence of the attribute in the configuration, a lower-case letter refers to a below-median level of the attribute). About 5% of the firms are likely to experience all of the independent measures at above-median levels (AMTOL). Based on the Quine-McCluskey algorithm, we logically reduce these configurations to three minimum final reduction sets based on coverage (empirical relevance of a solution) and consistency (extent to which cases that share similar conditions yield the same outcome).

The first configuration includes low absorptive capacity, absence of functional R&D structuring, high development, and high open innovation. The other configurations include a functionally structured R&D approach, combined with a successful past financial performance, leading to financial success in combination with restricted absorptive capacity and below-median development orientation, or in combination with limited engagement in open innovation. For all firm size and time-lag combinations this procedure is followed and the final reduction sets for small-sized and for medium-sized firms and for all years under consideration are reported in Table 3.

The coverage of the final reduction sets ranges from 0.26 (medium-sized firms 2013 outcome) to 0.91 (small-sized and medium-sized firms in 2010). The decrease in coverage over time can largely be explained by the decrease in the coincidence of past financial performance over time (Table 2). An above-median past financial performance (L) is a key attribute in all but one of the successful configurations, confirming that lagged financial performance needs to be taken into account when considering the link between strategic R&D decisions and future financial performance. The coverage of the final reduced sets also diminishes with the time-lag. The consistency indicates the degree to which observations agree on the outcome. The solution consistency is high (0.70 or more) for each of the final reduction sets. Conjunctural causation is confirmed in the sense that a combination of causal attributes generates the financial outcome. In other words, the attributes are interdependent, and equifinality (producing the same outcome) is found for different sets of attributes.

Table 2
Coincidence and sufficiency and necessity matrix, by size class, 2013.

	Small-sized firms						Medium-sized firms					
	F	A	M	T	O	L	F	A	M	T	O	L
F	1.000						1.000					
A	0.576	1.000					0.519	1.000				
M	0.468	0.488	1.000				0.450	0.530	1.000			
T	0.455	0.478	0.340	1.000			0.430	0.479	0.476	1.000		
O	0.313	0.335	0.313	0.230	1.000		0.273	0.365	0.369	0.267	1.000	
L	0.642	0.563	0.432	0.449	0.285	1.000	0.598	0.505	0.427	0.445	0.275	1.000
	Small-sized firms						Medium-sized firms					
	F	A	M	T	O	L	F	A	M	T	O	L
F	1.000	0.717	0.717	0.560	0.386	0.776	1.000	0.725	0.852	0.612	0.379	0.732
A	0.691	1.000	0.709	0.553	0.390	0.671	0.646	1.000	0.885	0.623	0.448	0.622
M	0.574	0.589	1.000	0.414	0.356	0.539	0.488	0.569	1.000	0.514	0.387	0.464
T	0.709	0.725	0.654	1.000	0.333	0.696	0.591	0.674	0.865	1.000	0.366	0.592
O	0.623	0.660	0.718	0.426	1.000	0.574	0.495	0.658	0.884	0.496	1.000	0.485
L	0.788	0.707	0.685	0.559	0.362	1.000	0.766	0.730	0.846	0.642	0.388	1.000

Note 1: F: Financial performance (year *t*); A: Management decision to invest in absorptive capacity in the year 2009; M: Management decision to structure R&D activities in a separate R&D department; T: Management decision with regard to engagement in research versus development in the year 2009; O: Management decision to engage in open innovation in the year 2009; L: SIM in the year 2009.
Note 2: for reasons of space we only report the matrices for 2013.

More specifically for small-sized firms, high similarities exist in the aMtL and the MoL model configuration for both the financial output in 2012 and 2013. The MoL configuration also holds for the financial performance in 2011. In addition to models including a highly structured R&D approach and good past financial performance, for financial performance in 2013, a combination of development and open innovation orientation in an absence of absorptive capacity and of a functionally structured R&D approach is beneficial. With a one year time-lag (financial performance 2010), lagged financial performance is present – together with absorptive capacity or with a structured R&D approach, or in an absence of high involvement in open innovation – in each of the three optimal configurations.

For medium-sized firms a different set of successful configurations is identified. Entirely consistent for 2012 and 2013, it is a combination of high absorptive capacity, a functionally structured R&D approach, and good past financial performance – and an absence of (or modest involvement in) open innovation and development orientation – that leads to above-median financial performance. On a shorter term notice, a broader set of configurations is equifinal to achieve good financial performance. In each of these combinations, good past financial performance is a decisive factor. In contrast with the results for 2012 and 2013, on a shorter-term notice, absorptive capacity (implemented in a functionally structured way) is not required to lead to successful outcomes. Moreover, only if combined

Table 3
Final reduction sets for strong financial outcome performance, by year and firm size.

	A	M	T	O	L	Raw coverage — unique coverage — solution consistency
Small-sized firms						
Financial performance (F) — 2013	0	0	1	1		0.266 – 0.102 – 0.595
(Total coverage: 0.685 – Solution consistency: 0.695)	0	1	0		1	0.415 – 0.043 – 0.817
		1		0	1	0.525 – 0.168 – 0.763
Financial performance (F) — 2012	0	1	0		1	0.427 – 0.056 – 0.838
(Total coverage: 0.602 — Solution consistency: 0.791)		1		0	1	0.545 – 0.174 – 0.785
Financial performance (F) — 2011		1		0	1	0.555 – 0.555 – 0.803
(Total coverage: 0.555 — Solution consistency: 0.803)						
Financial performance (F) — 2010				0	1	0.757 – 0.060 – 0.914
(Total coverage: 0.908 — Solution consistency: 0.888)		1			1	0.730 – 0.037 – 0.898
	1				1	0.602 – 0.027 – 0.917
Medium-sized firms						
Financial performance (F) — 2013	1	1	0	0	1	0.260 – 0.260 – 0.904
(Total coverage: 0.260 — Solution consistency: 0.904)						
Financial performance (F) — 2012	1	1	0	0	1	0.275 – 0.275 – 0.897
(Total coverage: 0.275 — Solution consistency: 0.897)						
Financial performance (F) — 2011	1	0	1	0	1	0.045 – 0.045 – 0.973
(Total coverage: 0.505 — Solution consistency: 0.900)		1	0	0	1	0.321 – 0.273 – 0.890
		1	1	1	1	0.188 – 0.139 – 0.908
Financial performance (F) — 2010	1		1	0	1	0.369 – 0.023 – 0.936
(Total coverage: 0.913 — Solution consistency: 0.906)	0		0		1	0.542 – 0.026 – 0.942
	0			1	1	0.379 – 0.009 – 0.931
		1			1	0.811 – 0.177 – 0.900

Note: F: Financial performance (year *t*); A: Management decision to invest in absorptive capacity in the year 2009; M: Management decision to structure R&D activities in a separate R&D department; T: Management decision with regard to engagement in development versus research in the year 2009; O: Management decision to engage in open innovation in the year 2009; L: SIM in the year 2009.

with shorter-term development activities, absorptive capacity leads to more successful outcomes in the short run.

These results confirm that both firm size and differences in time-lag need to be taken into account when studying the relationship between R&D and financial performance (Latham & Braun, 2009). The latter corroborates the findings by Fosfuri and Tribó (2008) who studied financial performance outcomes by using time-lagged financial indicators drawn from a separate database. The financial position in a one to four year time-lag after the R&D decision reference period is highly influenced by the initial financial position. Hence, the need to include this position, as suggested by Kostopoulos et al. (2011), in line with predictive power in terms of future firm performance accorded to financial ratios (see e.g. Delen et al., 2013).

Especially for medium-sized firms, in a three to four year time-span, absorptive capacity embedded in the employment of highly qualified employees together with a functionally structured R&D approach and a solid past financial performance basis, and combined with limited engagement in development-oriented and open innovation practices, is a key factor to explain financial success. These results confirm earlier findings that highly qualified R&D employees are deemed to possess skills that help them to function as interfaces facilitating the detection and management of relevant external knowledge flows (Roach & Sauermann, 2010) and facilitating innovation (Lam, 2000). This influences the firm's financial performance (Bayus et al., 2003; Srinivasan et al., 2009), but only in conjunction with a structured (functional) R&D approach (Engelen & Brettel, 2012). Our findings support the insights by Levinthal and March (1993) that more exploitation-driven activities are only beneficial in the shorter run, and only if combined with above-median levels of absorptive capacity and good past financial performance, and limited engagement in open innovation practices. The modest findings for engagement in open innovation could indicate that a four-year time span for benefits from knowledge exchange and knowledge development in cooperation (in line with Lantz & Sahut, 2005) is too short. Alternatively, it could point to a lack of in-house knowledge which cannot be remedied by collaboration with external research specialists. These findings are in line with Belderbos et al. (2010) who focus on large firms and use (co-)patents as a proxy for collaborative technological success and found the firm's market value to be negatively related with collaborative technological activities.

4.2. Post-estimation checks

As control tests, the suggestion by Bedford and Sandelin (2015) is followed to run QCA for both the presence of the financial outcome variable and the absence of it, which makes it possible to assess whether the row in the truth table meets the consistency threshold in both analyses. This is done by negating (inversing) the outcome variable (assuming that the presence and absence of the outcome is calibrated symmetrically). Consequently, the optimal configurations revealed by the qualitative comparative analysis leading to good financial performance (Table 3) are compared with those brought in relation to highly probable mediocre financial performance (Table 4). Inconsistencies are assessed in terms of truth table rows (combinations) meeting the consistency threshold in each analysis. This also makes it possible to identify causal asymmetry in the sense that if an increase in an attribute is associated with higher financial performance, then a decrease will result in lower performance. However, this does not necessarily imply that inverting the attributes that lead to high performance may not imply low or lower performance.

An initial finding, based on Table 4, is the – in comparison with strong financial performance (Table 3) – larger number of configurations of the strategic R&D dimensions leading to weak financial performance. For small-sized firms, three unique combinations were identified in 2012–2013 for strong financial performance, compared to six for weak performance. Also, weak performance is more highly influenced by an absence of strategic R&D decision-making in terms of building up absorptive capacity and in the event of below-median past financial performance. The coverage of the models is higher in the more recent period (compared to the coverage for good financial performance). No systematic patterns are identified for small-sized firms in the years 2010 and 2011. However, for 2012 and 2013, consistency is found for low performance in terms of the "mol" combination (absence of a functionally structured R&D approach, limited or no involvement in open innovation, and weak past financial performance).

Also for medium-sized firms, far more combinations lead to weak financial performance (four combinations compared to one unique combination for 2012 and 2013 for good financial performance). Here as well, similarities exist between 2013 and 2012, with half of the combinations being equal for both years. Firstly, it concerns the combination of no functionally structured R&D approach, the decision of limited engagement in open innovation, and weak past financial performance. Secondly, it is the combination of high absorptive capacity, a structured R&D approach, low development orientation, high open innovation involvement, and low past financial performance. In contrast with good financial performance, small-sized and medium-sized firms present more similarities in combinations leading to weak performance. In particular, the mol and the aMTOl combinations are valid both for small- and medium-sized firms, and this respectively for 2013 and for 2012 and 2013.

Causal asymmetry between good and weak financial performance reveals an interesting difference in the combination AMtOl leading to weak financial performance for medium-sized firms in 2012 and 2013, and the unique AMtoL configuration for good performance in 2012 and 2013. Thus, a functionally structured approach in combination with absorptive capacity and below-median focus on development leads to good performance if combined with an absence of open innovation and good past financial performance, whereas it leads to weak financial performance if combined with larger engagement in open innovation and low past financial performance. On a shorter-term notice, for medium-sized firms in 2010, a combination of good past financial performance and a functionally structured R&D approach leads to better financial results, whereas a functionally structured approach in combination with weak past financial performance is associated with weaker financial performance. Similarly, for 2011, the successful combination of high absorptive capacity, good past financial performance and above-median development orientation is negative in the event of more modest development orientation and weak past financial performance.

As a second post-estimation test, a comparison is made between the configurations for medium-sized and for small-sized firms in each of the outcome years. Table 5 reveals some interesting differences between both size groups. First, a significantly higher consistency exists for small-sized compared to medium-sized firms for the 2013 financial performance outcome for the configuration Amtol. Also, the combination AmtoL is found to be more consistent for small-sized firms, and this both for the 2013 and 2010 financial outcome. This means that the decision to build up absorptive capacity, both in combination with good and weak past financial performance, and in an absence of high engagement in the other strategic R&D decisions, leads to more successful financial outcomes for small-sized firms. For the same period, the decision not to functionally structure R&D activities within the organization seems to allow more freedom (slack resources) leading to higher financial performance in small-sized firms. For the 2012 and 2010 financial outcome this also is the case for the configuration AmtOl. On a shorter-term notice (2010 and 2011) the set scoring high on each of the strategic R&D decisions in combination with good past financial performance (AMTOL) significantly differs. These findings justify the need to distinguish between small-sized and medium-sized firms.

Table 4
Final reduction sets for weak financial outcome performance, by year and firm size.

	A	M	T	O	L	Raw coverage — unique coverage — solution consistency
Small-sized firms						
Financial performance (F) — 2013	0	1	1	1	0	0.094 – 0.018 – 0.956
(Total coverage: 0.523 — Solution consistency: 0.891)	1	1	0	0	1	0.168 – 0.082 – 0.890
	0		0	0	0	0.299 – 0.150 – 0.904
		0		0	0	0.179 – 0.082 – 0.877
Financial performance (F) — 2012	0	1	0	1	0	0.155 – 0.113 – 0.879
(Total coverage: 0.547 — Solution consistency: 0.899)	0			0	0	0.391 – 0.208 – 0.921
		0		0	0	0.184 – 0.043 – 0. 885
Financial performance (F) — 2011	0	1		0	0	0.401 – 0.053 – 0.888
(Total coverage: 0.632 — Solution consistency: 0.821)	1		0		0	0.274 – 0.064 – 0.912
			1	0	0	0.491 – 0.104 – 0.805
Financial performance (F) — 2010	1			0	0	0.500 – 0.031 – 0.955
(Total coverage: 0.886 — Solution consistency: 0.894)		1			0	0.729 – 0.073 – 0.911
			0		0	0.701 – 0.076 – 0.893
Medium-sized firms						
Financial performance (F) — 2013	0	1	1	1	0	0.094 – 0.018 – 0.956
(Total coverage: 0.523 — Solution consistency: 0.891)	1	1	0	1	0	0.168 – 0.082 – 0.890
	0		0	0	0	0.299 – 0.150 – 0.904
		0		0	0	0.179 – 0.082 – 0.877
Financial performance (F) — 2012	1	1	0	1	0	0.155 – 0.113 – 0.879
(Total coverage: 0.547 — Solution consistency: 0.899)	0			0	0	0.391 – 0.208 – 0.921
		0		0	0	0.184 – 0.043 – 0. 885
Financial performance (F) — 2011	0	1		0	0	0.401 – 0.053 – 0.888
(Total coverage: 0.632 — Solution consistency: 0.821)	1	0	0		0	0.274 – 0.064 – 0.912
			1	0	0	0.491 – 0.104 – 0.805
Financial performance (F) — 2010	1			0	0	0.500 – 0.031 – 0.955
(Total coverage: 0.886 — Solution consistency: 0.894)			0		0	0.729 – 0.073 – 0.911
		1			0	0.701 – 0.076 – 0.893

Note: F: (Below median) Financial performance (year *t*); A: Management decision to invest in absorptive capacity in the year 2009; M: Management decision to structure R&D activities in a separate R&D department; T: Management decision with regard to engagement in development versus research in the year 2009; O: Management decision to engage in open innovation in the year 2009; L: SIM in the year 2009.

5. Conclusions and limitations

The literature on the relationship between R&D and financial performance at firm level is inconclusive. Some studies (e.g. Xu & Tang, 2010) report a positive relationship, whereas others (e.g. Lantz & Sahut, 2005; Li et al., 2008) find a short-term negative relationship between R&D investments and financial return. Methodological issues with regard to the use of indicators (Klingenberg et al., 2013) and the time-frame under consideration (Latham & Braun, 2009; Pearce & Michael, 2006) turn out to be important determinants to explain these contrasting findings.

Table 5
Comparison of *y*-consistency for above median financial performance between small-sized and medium-sized firms, 2010–2013.

Year	Model	Small	Medium	F	P
2013	Amtol	0.950	0.664	12.92	0.000
	AmtoL	0.981	0.796	8.08	0.005
2012	AmtOl	0.957	0.722	5.11	0.024
2011	AmToL	0.973	0.837	9.81	0.002
	AMTOL	0.936	0.795	6.76	0.010
2010	AmtoL	0.995	0.941	5.83	0.016
	AmtOl	1.000	0.948	6.17	0.013
	AMTOL	0.985	0.916	6.49	0.011

Note 1: F: Financial performance (year *t*); A: Management decision to invest in absorptive capacity; M: Management decision to structure R&D activities in a separate R&D department; T: Management decision with regard to engagement in research versus development; O: Management decisions to engage in open innovation; L: SIM 2009.
Note 2: The differences between the estimated and proposed average increase in consistency levels for small-sized firms compared to medium-sized firms are normally distributed (fulfilling the – approximately – normality condition to perform the Wald test).

This paper adds to the debate in several ways. First, inspired by Delen et al. (2013) and Klingenberg et al. (2013), to measure financial performance, use was made of a simple intuitive model ratio. This ratio includes a broad set of liquidity, solvency, profitability and value added indicators (Ooghe & Van Wymeersch, 2008). Second, different time-lags to measure the relationship between R&D and financial performance at firm level were taken into consideration (inspired by Latham & Braun, 2009; Lome et al., 2016; Nooteboom et al., 2007). Third, based on unexplained differences depending on firm size in previous studies (see e.g. Kostopoulos et al., 2011) a distinction has been made between small-sized and medium-sized firms. Fourth, based on the most influential topics in the R&D management literature, a set of strategic R&D decisions including absorptive capacity (Cohen & Levinthal, 1990), type of R&D (research versus development – OECD, 2002), open innovation (Chesbrough, 2003), and the way of structuring R&D within the organization (Engelen & Brettel, 2012) has been accounted for. Fifth, a fuzzy qualitative comparative analysis approach offering configurations of strategic R&D decisions in 2009 leading to good financial performance in the period 2010–2013 has been followed, based on a representative set of R&D-active companies in Belgium.

The analysis revealed that R&D as an input is a multi-faceted concept with different underlying dimensions, and different configurations of these dimensions lead to equifinal future financial performance outcomes. The optimal sets depend on the time-frame (in line with earlier findings by Lantz & Sahut, 2005) and the size (small-sized versus medium-sized — in line with e.g. Kostopoulos et al., 2011) of the firm under consideration, and include a lagged (above-median) financial performance indicator (Kostopoulos et al., 2011).

The main highlights of the analysis are that, in a three to four year time-span, high consistency is found for a limited set of equifinal

configurations leading to good financial performance. This time-frame identified in an analysis focused on sets of R&D decisions during a financially and economically turbulent period is in line with the time-frame identified by Lome et al. (2016) for decision-making during an economically and financially more prosperous period. As such, it can be questioned if the relationship between R&D decisions and firm performance depends on the economic or financial turbulence of the period under consideration (somewhat in contrast to the idea of specificities of periods of economic crises — Latham & Braun, 2009). The optimal R&D decision configurations differ for small-sized and medium-sized firms (confirming insights by Kostopoulos et al., 2011 and Li & Hwang, 2011). More specifically, small-sized firms benefit from configurations including a functionally structured R&D approach and good past financial performance, combined with low involvement in open innovation, or combined with low absorptive capacity investment and low development orientation in R&D. From a managerial point of view, this is conducive for putting in place a more formal structuring of R&D within the company (during a financial crisis), confirming the argument by Engelen and Brettel (2012) in favour of a more structured approach to R&D and related influence consequences in terms of financial performance. High engagement in open innovation or shifting between longer-term research and shorter-term development can be questioned as appropriate strategies. The former contradicts the significant attention given to open innovation (Chesbrough, 2003) over the past decade and the belief that engagement in this kind of activities enhances firm performance. The latter contributes to the exploration versus exploitation debate (see e.g. Belderbos et al., 2010; Levinthal & March, 1993) in favour of sufficient attention to exploration, also in view of relatively short-term financial performance for small-sized firms. For medium-sized firms a unique optimal configuration is identified, including high investment in a functionally structured R&D department with high absorptive capacity (Cohen & Levinthal, 1990) and relatively low engagement in development and open innovation activities in terms of knowledge exchange and development in research cooperation. The latter indicates that also for the group of medium-sized R&D-active firms, little support is found for the idea that strong commitment in open innovation activities leads to continued good financial performance. For this group of firms, a strong requirement exists in managerial decisions to build absorptive capacity during economically turbulent periods with a view to medium-term financial performance. On a shorter-term notice (one to two year time-lags), a broader pallet of successful configurations is identified, all including good past financial performance. The latter indicates a lower importance of managerial decisions in R&D configurations in medium-sized firms with regard to shorter-term financial performance of firms (in line with the argument by Lome et al. (2016) that the effects of R&D to emerge need a time-lag of at least three years).

Compared to strong financial performance, more (diverse) combinations lead to weak financial performance. Causal asymmetry is found in the sense that for medium-sized firms, the same combination as for strong financial performance but with high involvement in open innovation is a strong predictor for continued weak financial performance. For small-sized firms, continued weak performance is mainly found if there is an absence of a functionally structured R&D approach and low engagement in open innovation. Also, the decision to build up absorptive capacity, both in combination with good and weak past financial performance, and in an absence of high engagement in the other strategic R&D decisions, leads to more successful financial outcomes.

These findings highlight the need to look at configurations of strategic R&D decisions rather than focusing on decisions in an individual domain, and provide guidance for managers with regard to the implications of strategic decision-making in R&D during financially and economically difficult periods, and organizational effectiveness in terms of short and medium term future firm performance. They offer managers insights both into the development of scorecards in R&D decision-making and its potential time-related financial outcomes. Moreover, it is emphasized that configurations of R&D decisions should be seen in conjunction with the initial financial position of the firm (fully in line with the argument by Kostopoulos et al. (2011) not to ignore past financial performance in explaining future financial performance at firm level). The results also invite research concerning the effects of strategic R&D decisions not to ignore connections between attributes in order to explain financial outcomes, and to refrain from relying on the average effects of positive or negative influences of one variable on another (in line with Bedford & Sandelin, 2015).

Additional research is needed in terms of further refinement of the measurement concepts of strategic R&D decisions and the enhancement of financial performance. In particular the concept of open innovation could be further extended by distinguishing cooperation (see e.g. Belderbos, Carree, Diederen, Lokshin, & Veugelers, 2004) and R&D outsourcing (see e.g. Teirlinck, Dumont, & Spithoven, 2010) by type of partner, with a major distinction between science partners and private partners. The former, on average, being more long-term research oriented, the latter, on average, being more short-term market related. The results presented here for a single country should also be tested in other countries to check for generalizability. Moreover, further research is required to understand the causality between strategic R&D decisions and the financial performance of firms since time-lags can be country, sector, and period dependent. Although the focus in this paper is on rather homogeneous sets of small and medium-sized R&D-active firms, improved data in terms of availability of additional control variables is recommended; such as for example underlying firm motivations for growth, product and market characteristics (e.g. Lome et al., 2016), R&D department influenced factors (Engelen & Brettel, 2012), more fine-grained indicators (in addition to age) of the life-cycle stage a firm is in (Li & Hwang, 2011), and even broader factors such as corporate social responsibility (e.g. Saeidi, Sofian, Saeidi, Saeidi, & Saaeidi, 2015). Another avenue for further research is to investigate whether the successful configurations presented in this paper hold for other dimensions of firm performance, including business performance and organizational effectiveness (Venkatraman & Ramanujam, 1986).

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