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Partner selection, information use, and industry cycles: How firms can profit from R&D cooperation

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Abstract

Partner selection, information use, and industry cycles: How firms can profit from R&D cooperation Ann Weiland (Dresden University of Technology), ann.weiland@tu-dresden.de, Year of Enrolment: 2015, Expected final date: 31.08.2019 State-of-the-art The accelerating pace of the industrial evolution makes firms to develop new products and technologies with different partners to mitigate risk and create value for long-term growth (Powell et al. 1996). Since the enormous financial requirements within the industrial stage outstrip the capacities of firms (Cainarca et al. 1992), they continuously need investments from shareholders that cautiously assess the profits and risks from R&D partner types and information use (Chan et al. 1997). However, R&D cooperation is still a rare event with substantial failure rates (Harrigan 1986) and partner configurations can induce value destroying effects (Un et al. 2010) that affect the perception of shareholders (Mazzucato 2003). Literature often distinguishes between science- and market-based partners (Un et al. 2010) on the international or domestic market (Duysters and Lokshin 2011). Research gap Previous studies have rarely taken into account the shareholder value from science-based partners (Chan et al. 1997) and devoted less attention to different cooperation levels (Ahuja et al. 2012) during the evolution of the industry ecosystems (Ter Wal and Boschma 2011). Furthermore, many cooperation studies only provide empirical evidence from mature industries (Hagedoorn and Schakenraad 1994). This ambiguity of value enhancing and appropriation questions the direction for firms to select the most valuable partner along industry cycles, which calls for additional research on the value of partner information (Biemans and Langerak 2015; Wu et al. 2015). This paper seeks to answer the research questions: (1) What are the stock market returns to market- and science-based partners in the announcement of R&D cooperation? (2) Do investors reward domestic or international R&D cooperation? (3) How do industry cycles affect the R&D cooperation? Theoretical arguments Building upon contingency theory (Mintzberg 1979) and signaling theory (Spence 1973), investors interpret the cooperation announcement as signal of the efficiency of partner configuration in the industry cycle. It is hypothesized that R&D cooperation with market- and science-based partners achieves positive stock market returns (Un et al. 2010). During industry growth, firms seek to broaden their networks with different international partners to reduce uncertainty (Powell et al. 1996). Domestic use of information is valued in the maturity stage through market-based horizontal partners whereas shareholders reward vertical partners during decline to ensure efficiency in the face of falling demand (Cainarca et al. 1992). Method and data Analyzing 149 R&D announcements of 18

manufacturers in the German Photovoltaic Industry over a 10-year period, I tested industry, partner and stock market data using the market model in event study methodology (Fama 1991) with a fixed-effects specification to control for firm-specific and time-varying influences. Results The results show that shareholders reward domestic R&D cooperation with market-based partners during industry growth. Whereas in maturity, horizontal cooperation achieves positive stock market returns, vertical partners become important during industry decline. Surprisingly, investors associate international and science-based partners with low efficiency throughout the industry cycles. References Ahuja G, Soda G, Zaheer A (2012) The Genesis and Dynamics of Organizational Networks. Organ Sci 23:434–448. doi: 10.1287/orsc.1110.0695 Biemans W, Langerak F (2015) More Research Priorities: From the Editor. J Prod Innov Manag 32:2–3. doi: 10.1111/jpim.12255 Cainarca GC, Colombo MG, Mariotti S (1992) Agreements between firms and the technological life cycle model: Evidence from information technologies. Res Policy 21:45–62. doi: 10.1016/0048-7333(92)90026-Z Chan SH, Kensinger JW, Keown AJ, Martin JD (1997) Do strategic alliances create value? J Financ Econ 46:199–221. doi: 10.1016/S0304-405X(97)00029-9 Duysters G, Lokshin B (2011) Determinants of Alliance Portfolio Complexity and Its Effect on Innovative Performance of Companies. J Prod Innov Manag 28:570–585. doi: 10.1111/j.1540-5885.2011.00824.x Fama EF (1991) Efficient Capital Markets: II. J Finance 46:1575–1617. doi: 10.1111/j.1540-6261.1991.tb04636.x Hagedoorn J, Schakenraad J (1994) The effect of strategic technology alliances on company performance. Strateg Manag J 15:291–309. doi: 10.1002/smj.4250150404 Harrigan KR (1986) Matching vertical integration strategies to competitive conditions. Strateg Manag J 7:535–555. doi: 10.1002/smj.4250070605 Mazzucato M (2003) Risk, variety and volatility: Growth, innovation and stock prices in early industry evolution. J Evol Econ 13:491–512. doi: 10.1007/s00191-003-0167-7 Mintzberg H (1979) The structuring of organizations: A synthesis of the research. Prentice-Hall, Englewood Cliffs, N.J Powell WW, Koput KW, Smith-Doerr L (1996) Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology. Adm Sci Q 41:116. doi: 10.2307/2393988 Spence M (1973) Job Market Signaling. Q J Econ 87:355. doi: 10.2307/1882010 Ter Wal ALJ, Boschma R (2011) Co-evolution of Firms, Industries and Networks in Space. Reg Stud 45:919–933. doi: 10.1080/00343400802662658 Un CA, Cuervo-Cazurra A, Asakawa K (2010) R&D Collaborations and Product Innovation. J Prod Innov Manag 27:673–689. doi: 10.1111/j.1540-5885.2010.00744.x Wu Q, Luo X, Slotegraaf RJ, Aspara J (2015) Sleeping with competitors: The impact of NPD phases on stock market reactions to horizontal collaboration. J Acad Mark Sci 43:490–511. doi: 10.1007/s11747-014-0396-3

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Partner selection, information use, and industry cycles: How firms can profit from R&D cooperation

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ABSTRACT The industrial evolution causes firms to select the cooperation partners that complement the development of products and technologies to create value. Value can arise from investors that assess the profits and risks of cooperation announcements and immediately react on the firm's stock price. Previous studies produce ambiguity of value enhancing and appropriation in R&D cooperation, which questions the direction for firms to choose between market- and science-based partners. However, literature has devoted less attention to the evolutionary processes. The industrial progress further impacts the use of information in R&D cooperation. Building upon contingency and signaling theory, this paper analyzes 149 R&D announcements of 18 manufacturers in the German Photovoltaic Industry over a 10-year period using event study methodology. The results show that shareholders reward domestic R&D cooperation with market-based partners during industry growth. Whereas in maturity, horizontal cooperation achieves positive stock market returns, vertical partners become important during industry decline. Surprisingly, investors associate international and science-based partners with low efficiency throughout the industry cycles.

KEYWORDS: R&D cooperation, partner, industry life cycle, shareholder value

1. Introduction

The accelerating pace of the industrial evolution makes firms to develop new products and technologies with different partners to mitigate risk and create value for long-term growth (Powell et al. 1996). Since the enormous financial requirements within the industrial stage outstrip the capacities of firms (Cainarca et al. 1992), they continuously need investments from shareholders that cautiously assess the profits and risks from R&D partner types and information use (Liu et al. 2016). For instance, Deutsche Lufthansa AG discloses its new cooperation partners that support the strategic development and growth path to sustain value creation over the industry cycle (Hagenbring et al. 2013). Literature often

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distinguishes between science- and market-based partners (Sivadas and Dwyer 2000; Un et al. 2010; Belderbos et al. 2010a) on the international or domestic market (Duysters and Lokshin 2011). However, it has rarely taken into account the shareholder value from science-based partners (Chan et al. 1997; Das et al. 1998) and devoted less attention to different cooperation levels (Gulati 1995; Ahuja et al. 2012) during the evolution of the industry ecosystems (Un et al. 2010; Ter Wal and Boschma 2011; Biemans and Langerak 2015). R&D cooperation is still a rare event with substantial failure rates (Harrigan 1986) and partner configurations can induce value destroying effects (Du et al. 2014; Un et al. 2010; Belderbos et al. 2010a) that affect the perception of shareholders (Mazzucato 2003). Furthermore, many cooperation studies only provide empirical evidence from mature industries (Hagedoorn and Schakenraad 1994; Das and Teng 2003). This ambiguity of value enhancing and appropriation questions the direction for firms to select the most valuable partner along the industry life cycle (Wu et al. 2015). The industrial evolution further impacts the use of information from domestic and international partners (Duysters and Lokshin 2011). Firms aim at mitigating market risk through the exploration of new knowledge in international R&D partnerships during industry growth (Pyka 2002). In maturity, they exploit the existing technological potential in the cooperation with horizontal network partners, but rationalize structures through vertical partners in later stages (Cainarca et al. 1992).

While industry dynamics and cooperation structures are inextricably interwoven, this research area is surprisingly unexplored (Ter Wal and Boschma 2011). There is a strong need for additional research on the longitudinal effects (Wu et al. 2015) and mechanisms that help firms to innovate (Un et al. 2010) particularly within less competitive environments or at later industry stages (Oliver 2001). According to one of the recent research priorities for innovation studies (Biemans and Langerak 2015), this paper sheds light on the shareholder value of R&D cooperation partners and use of information along the growth, maturity and decline phase of the industry life cycle. It seeks to answer the following research questions:

(1) What are the stock market returns to market- and science-based partners in the announcement of R&D cooperation?

(2) Do investors reward international or domestic R&D cooperation?

(3) How do industry cycles affect the R&D cooperation?

This paper starts with a theoretical conception on the value of R&D partner configuration, use of information and the industry life cycle. Building upon contingency theory (Mintzberg 1979) and signaling theory (Spence 1973), investors interpret the cooperation announcement as signal of the efficiency of the R&D cooperation in the particular industry stage. It derives hypothesis on partner choice and information use along the industrial evolution, followed by an explanation about the data and methods.

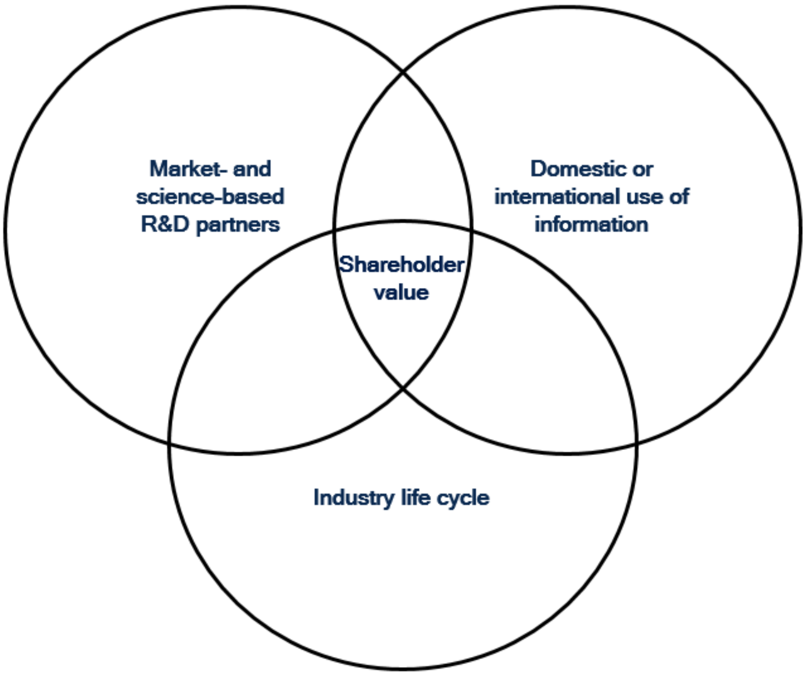
The last chapter provides the results and implications for management and policy. It concludes with the summary, limitations and guidance for further research.

2. Literature Streams

Shareholder value from R&D cooperation partners and use of information along industry cycles affects three literature streams (Figure 1). The theoretical basis concerning the firm's locus of R&D cooperation has moved from a transaction cost (Williamson 1991) to a systems perspective comprising learning networks (Powell et al. 1996), the resource-based view (Mowery et al. 1998) and knowledge-based view (Grant 1996). The approaches emphasize different aspects, but all investigate the motivations, nature and outcomes of the interplay between R&D partners underlining the benefits in information use (Oliver 2001). R&D cooperation underscores learning advantages (Hamel 1991) and efficiency gains through resource pooling (Das and Teng 2003). Shortened innovation cycles (Pisano 1990), the development of industry standards and support from government subsidy policies impact the performance of R&D partnerships (Benfratello and Sembenelli 2002). Recent studies distinguish between market- and science-based partners, i.e. suppliers, competitors, research institutes and universities (Du et al. 2014; Gesing et al. 2015; Hohberger et al. 2015) that exert an influence on shareholder value (Liu et al. 2016). Horizontal partners are market-based organizations that belong to the same industry and vertical cooperation occurs along the value chain (Chan et al. 1997). In recent years, a stream of literature on innovator networks projects the locus of R&D partners to the industry (Rosenberg and Nelson 1994; Hagedoorn 1995). Regarding the partner as source of information, it explores the differences in the determinants (Miotti and Sachwald 2003) and implications for R&D cooperation (Belderbos et al. 2004). In contrast, the literature on industrial organization theory scrutinizes the relation between R&D cooperation, investment and interorganizational information use in consideration of information spillover (De Bondt 1997).

Several researchers stress the importance of information use across and within industries that result in firm performance (Srivastava et al. 1999). The literature on national innovation systems refers to the domestic use of information and explicates the firm-specific efforts to expand R&D resources in the international environment to gain competitive advantage upon national trajectories (Miotti and Sachwald 2003). Literature on alliance portfolio differs between international and domestic partners and gives priority to less complex networks due to smaller management costs (Duysters and Lokshin 2011) and bounded rationality (March 1978).

FIGURE 1: OVERVIEW ON LITERATURE STREAMS

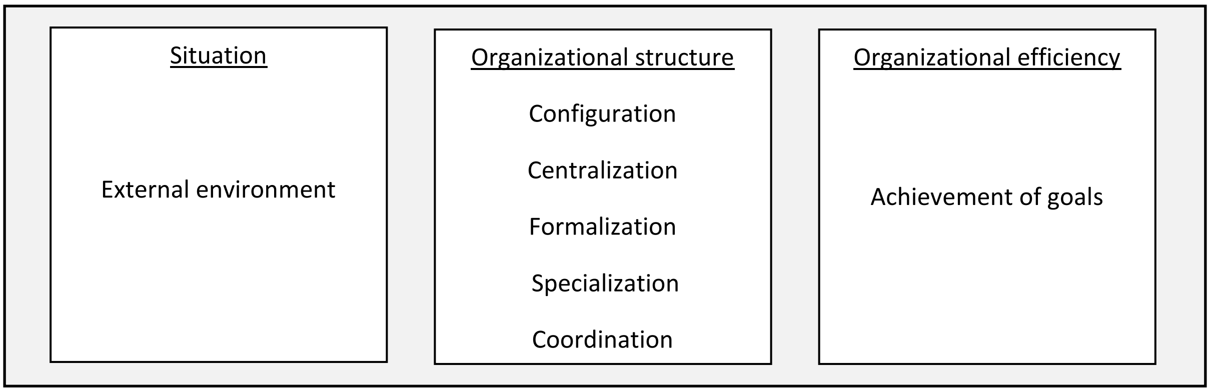


The industry life cycle depicts the industrial evolution by illustrating the trajectories and outcomes of the changing network patterns over time. The literature entails numerous life cycle models that originate from Gort and Klepper's five stages of industry evolution (1982). With important implications for firm strategies, R&D cooperation can drive value during the industrial progress (Dosi 1982). Blankenberg and Dewald (2016) provide a comprehensible overview of industry cycle theories that encompass shakeout (Utterback and Suárez 1993), submarket (Klepper and Thompson 2006) and unified frameworks (Bhaskarabhatla and Klepper 2014). They conclude that the unified model best describes the evolution of the German Photovoltaic Industry. In the industry birth, new variations of the first product innovations lead to new submarkets and bring firms to invest in process innovation during growth. In the maturity, the product price drops and the demand increases in one submarket causing firms to leave the industry during decline due to intense competition. The industry life cycle comes to its shakeout when other submarkets disappear (Bhaskarabhatla and Klepper 2014).

3. Contingency and Signaling Theory

Contingency theory provides an alternative theoretical explanation to the transaction cost and systems perspective for how the pattern of partner types and information use affects the shareholder value along different industry cycles. Mintzberg (1979) claims that the efficiency of an organization depends upon the formal structure, which has to be adapted to the particular situation. There is no one best way of management, performance is rather a consequence of the fit between the organizational structure and the contingency factors of the uncertain and instable environment that requires complex change in the relationships (Tosi and Slocum 1984). Figure 2 depicts the key dimensions of contingency theory.

FIGURE 2: ASPECTS OF CONTINGENCY THEORY



The external environment takes the central role in the situation and comprises all factors outside the firm (Lawrence and Lorsch 1967). From a systematic perspective, Katz and Kahn (1966) specify the environment as users of output, input sources and external regulators. There are specific environmental subsectors such as capital sources and technology that interact with the organization in a complex way (Tosi and Slocum 1984). The organizational structure includes configuration, centralization, formalization, specialization and coordination (Pugh et al. 1968). Configuration regards the sum of decision-making actors that shape the organizational pattern (Mintzberg 1979). Centralization and formalization describe the allocation of tasks and the use of rules to complete them, specialization indicates the degree of differentiation among the tasks and coordination aligns the organization to its primary goals (Pugh et al. 1968). Tosi and Slocum (1984) expand the theoretical model by the individual or group, strategic choices and cultural factors. The efficiency of the organization is contingent on the achievement of its goals (Mintzberg 1979). Organizations primarily seek to survive and be effective within their environments, whereas structural adaptation takes place over time and varies in its degree as new environments are entered (Tosi and Slocum 1984).

Signaling theory explains the communication process between the organization and its external actors when information is asymmetric (Lee et al. 2016). The more informed sender gives a signal to the less informed receiver that interprets the information in the particular situation (Spence 1973). The sender aims at the reduction of uncertainty and informs the external parties about its ability to achieve efficiency that is reflected in the adaptation of its organizational structure. The receiver construes the signal as the organizational ability to develop products or processes and survive in the long run (Lee et al. 2016). The external actor reacts on the stock market according to the perceived valuation of the structural adaptation to the environment and induces the achievement of the organizational goals.

4. Hypothesis Development

4.1. R&D cooperation with market- and science-based partners

Since the overarching goal is survival and profitability, firms require organizational efficiency for continuous product and process development to reduce risks and costs during the industrial progress (Powell et al. 1996). According to contingency theory (Mintzberg 1979), the generation of shareholder value reflects the organizational profitability as primary indicator of the effective adaptation of the formal structure to the external environment (Tosi and Slocum 1984). Therefore, firms have to adapt their organizational structure in form of different dimensions to the particular situation (Pugh et al. 1968). This paper focuses on the configuration of the structure that describes the sum of market- and science-based partners shaping the R&D network. In R&D cooperation, it is assumed that the central actor, who is often the coordinator in public subsidy programs, sufficiently allocates the tasks in their degree of specialization and formalization. Self-enforced R&D projects often have a less formalized character than public subsidies. Signaling theory suggests firms to communicate the R&D partner choice to shareholders for reducing their uncertainty and increasing stock market returns to achieve organizational profitability (Lee et al. 2016). Shareholders have asymmetric information and interpret the cooperation signal by reacting on the firm's stock price as response to the perceived efficiency of the partner configuration and information use (Spence 1973).

Despite the growing importance of embedding science-based partners in R&D cooperation, literature has paid little attention to their value generation potential and industry still expresses concerns (Bstieler et al. 2015). However, some researchers point to the positive outcomes of science-based network configurations in providing evidence towards R&D expenditures and employment (Scandura 2016), patents (Miotti and Sachwald 2003) and new innovations to the market (Lööf and Heshmati 2002; Monjon and Waelbroeck 2003), e.g. in the number (Tether 2002; Un et al. 2010) and sales of radical products (Belderbos et al. 2004; Faems et al. 2005; Arvanitis et al. 2008). Science-based organizations are less susceptible to opportunistic behavior and possess different knowledge than market-based partners (Bercovitz and Feldman 2007). They characterize central knowledge brokers that access, coordinate and allocate deep and complex knowledge from multidisciplinary areas to a broad network (Un et al. 2010). R&D cooperation with science-based partners offers firms specialized and complementary capabilities necessary to create radical innovations (Tether 2002). The fundamental nature of basic research (Rosenberg and Nelson 1994) that is on the technological frontier (Miotti and Sachwald 2003) makes universities more successful in commercializing innovations (Agrawal 2006). In order to maximize spillovers (Sakakibara 1997), provide learning opportunities and strengthen the competitiveness of firms (Kapoor and McGrath 2014), science-based organizations are often supported by formalized public funds. Firms increasingly favor science-based partners and intend to prove network efficiency by giving information about the R&D cooperation to the stock market. Shareholders are expected to reward this science-based configuration as positive signal and invest in the firm.

Recent research investigates how shareholders value the network configuration of market-based partners in R&D cooperation. Chan et al. (1997) examine 345 strategic alliances in the period from 1983 to 1992 and found a positive average stock market reaction for horizontal and vertical partners. R&D cooperation with vertical partners has a positive influence on labor productivity growth (Belderbos et al. 2004), product innovations (Un et al. 2010) that are new to the market (Kaufmann and Tödtling 2001) and innovative products in turnover (Miotti and Sachwald 2003). Suppliers contribute specialized knowledge on technologies and markets to the R&D cooperation (Takeishi 2002) and bear lower risks than horizontal partners (Miotti and Sachwald 2003). They focus on incremental innovation (Belderbos et al. 2004), coordinate input quality improvements and cost reductions to realize organizational efficiency (Clark 1989; Tether 2002; Kapoor and McGrath 2014). Vertical R&D cooperation is not useful for developing new knowledge (Miotti and Sachwald 2003), but it is rather critical to commercialization of technologies (Clark 1989). This distinct knowledge is easily allocated due to common goals of the partner consortia (Un et al. 2010). Shareholders assess the network configuration with vertical partners and are expected to value its efficiency with increasing stock market returns.

Current event studies underline horizontal network structures in technology (Boyd and Spekman 2008; Wu et al. 2015) and marketing (Swaminathan and Moorman 2009; Thomaz and Swaminathan 2015) and emphasize their value enhancing effects. Das et al. (1998) analyze 119 cooperation events between 1987 and 1991 and prove higher stock market returns for horizontal than vertical partners. There is a positive relation between coopetitive firms and innovations (Lööf and Heshmati 2002) that are new to the market (Tether 2002; Miotti and Sachwald 2003), labor productivity growth and growth in sales of new products (Belderbos et al. 2004). Competitors enable coordinated actions (Nalebuff and Brandenburger 1996) particularly in large projects with reduced costs and risks (Miotti and Sachwald 2003; Belderbos et al. 2004; Un et al. 2010). By pooling and allocating complementary knowledge, firms tend to learn from their rivals and generate organizational efficiencies (Sakakibara 1997; Miotti and Sachwald 2003) over the technology life cycle (Kapoor and McGrath 2014). However, firms can face additional risks if competitors exploit involuntary spillovers (Hamel 1991), pursue different goals or behave opportunistically (Sivadas and Dwyer 2000). The unfavorable allocation of knowledge due to limited breath, restricted access or differences between the cooperation partners causes short-term negative effects on innovation (Un et al. 2010). However, the empirical evidence on shareholder value implies that horizontal network cooperation exerts a positive influence on the organizational efficiency. Investors rigorously assess the value of partners from the same industry where organizational gains outweigh the potential risks. In accordance with prior research, it is hypothesized that R&D cooperation with both market-based partners (Chan et al. 1997; Das et al. 1998) and science-based partners (Un et al. 2010; Dedrick and Kraemer 2015) achieves positive stock market returns:

> H1. R&D cooperation with science- and market-based partners has a positive impact on shareholder value.

4.2. Domestic or international use of information

Use of information between market- and science-based partners differs in the degree of specialization. Domestic organizations tend to exploit specialized information within the national system and explore information with international partners (Tallman and Phene 2007; Duysters and Lokshin 2011). With the aim of uncertainty reduction and value generation, organizations inform shareholders about domestic or international use of information in R&D cooperation (García-Canal and Sánchez-Lorda 2007). Shareholders interpret the cooperation signal and respond to the stock market according to the perceived valuation of information specialization (Spence 1973).

Building upon the resource-based and relational view, García-Canal and Sánchez-Lorda (2007) provide evidence on the positive stock market reaction of international cooperation announcements between competing firms from the European telecom industry between 1986 and 2001. They argue that international alliances allow for the access of heterogeneous resources and quick internationalization. In the examination of shareholder value in international joint ventures, Merchant and Schendel (2000) show that investors perceive international formations negatively when firms face low levels of competition. The greater the cultural differences between the partners, the lower the stock market returns (Chatterjee et al. 1992; Datta and Puia 1995). Miotti and Sachwald (2003) use the same reasoning for the probability of partner selection in R&D cooperation that is decreasing by its distance to the organization. Not only cultural but also institutional differences impair the trust between the partners (Gulati 1995). Lavie and Miller (2008) agree to the advantages in the access of resources. However, they found that international partners typically achieve lower market returns regardless of the cross-national distance. As Ramirez-Aleson and Espitia-Escuer (2001) conclude, the costs of entering international markets overcome its benefits. Since investors seek to maximize their profits in the evaluation of cooperation announcements, they are expected to associate international partners with larger risks and lower efficiency due to increasing international competition while reducing the firm's stock price:

> H2a. International R&D cooperation with market- and science-based partners has a negative impact on shareholder value.

Due to lower costs, firms tend to prefer partners within the national innovation system (Miotti and Sachwald 2003). Domestic partners provide similar resources at reasonable premiums and forgo additional investments in communication or transportation that lead to better firm performance (Lavie and Miller 2008). Hamel (1991) refers to asymmetric skill endowments of firms in international competition, which alter the bargaining power and underline the decrease in risks of undesirable spillovers and misappropriation of resources in domestic cooperation. Due to larger efficiencies and lower risks and costs, shareholders perceive the intention of R&D cooperation within the home country as positive signal and invest in the firm:

> H2b. Domestic R&D cooperation with market- and science-based partners has a positive impact on shareholder value.

4.3. Partner choice and information use along the industry life cycle

As situational factor in contingency theory (Lawrence and Lorsch 1967), the industry life cycle denotes the external environment of the organization. Along with its network structures, the firm evolves in its size, technology infrastructure and behavior along trajectories through different industry stages over time (Gort and Klepper 1982). The unified model (Bhaskarabhatla and Klepper 2014) depicts the industry evolution from the first product over new variations to process innovation and the creation of submarkets until firms and submarkets disappear. Firms inform their shareholders about the R&D partner configuration and information use through signals to reduce uncertainty and achieve organizational efficiency (Spence 1973). Shareholders, in turn, reward the adoption of the configuration structure with increasing stock market returns contingent on the perceived organizational efficiency in the particular industry cycle.

In her study of risk, variety and volatility in the early evolution of the US automobile and PC industry, Mazzucato (2003) shows that the more radical the technological change in the external environment, the more volatile the organization's relative growth rate and stock price. On the contrary, Park and Mezias (2005) investigate the stock market reaction of 75 allying e-commerce firms before and after the technology sector crash. They found that cooperations in the less munificent years create larger shareholder value compared to those announced in the more munificent period.

Firms aim at mitigating the high risk and uncertainty in the growth stage of the industry life cycle through risk sharing and network formation (Pyka 2002; Kapoor and McGrath 2014), which leads to an increase in shareholder value (Srivastava et al. 1999). In the exploration-learning phase, organizations tend to explore international cooperations to specify their R&D options (Oliver 2001; Beckman et al. 2004). The increasing pace of the market growth creates high technological opportunities that pave the way for radical innovations (Hagedoorn 1995). At the same time, it exceeds the firm's capabilities, which underlines the need to access complementary technological, manufacturing, and commercial assets (Cainarca et al. 1992). The technical imbalances of the early industry stages require coordinated actions by market-based partners (Rosenberg and Nelson 1994), but also science-based cooperation to manage the fast technological development (Belderbos et al. 2010b). In order to create short-term value during industry growth, firms should cooperate with different partners to expand their internal R&D capacity (Powell et al. 1996). Since shareholders reward the global exploration of new technological opportunities to meet the increasing international market pressures and access valuable resources, it is hypothesized that both international market- and science-based R&D partners and stock market returns have a positive relation during industry growth:

> H3a. In the industry growth, international R&D cooperation with market- and science-based partners has a positive impact on shareholder value.

Even though demand and output rise in one submarket, the product price significantly falls during maturity (Bhaskarabhatla and Klepper 2014). Uncertainties in the external environment continuously disappear, technological options decrease and market structures consolidate while firms manipulate the rules of competition (Cainarca et al. 1992). The revitalized incremental technical progress leaves a high innovation potential to exploit (Cainarca et al. 1992). Firms seek operational efficiency and competency leveraging, they are less focused on risk aversion (Elg 2000). During maturity, R&D cooperation often occurs between direct competitors that allow for complementary skills and extend the application horizon (Cainarca et al. 1992). Horizontal cooperation enables the establishment of industry standards (Miotti and Sachwald 2003) or the entering into new markets (Un et al. 2010). Since rivals have similar product portfolios, they tend to exploit the use of information (Krammer 2016). It is assumed that shareholders positively assess the network configuration of direct competitors and invest in the R&D cooperation to contribute to organizational efficiency in the maturity stage:

> H3b. In the industry maturity, domestic R&D cooperation with horizontal partners has a positive impact on shareholder value.

Bhaskarabhatla and Klepper (2014) argue an increasing competition during decline that brings firms to leave the industry. Production and market structures are rationalized, the innovative potential of technological trajectories exhausted (Cainarca et al. 1992). A dominant design has established, industry standards and operational processes get more specialized (Kapoor 2013). There is a higher propensity for firms to cooperate with suppliers since they have gained more knowledge over the industry life cycle (Clark 1989) and own distinct components (Kapoor and McGrath 2014). Vertical cooperation contributes to quality improvements and cost reductions (Clark 1989; Tether 2002) due to diversified product offerings and process innovation (Hagedoorn 1995; Fritsch and Lukas 2001). To ensure efficiency in the face of falling demand during decline (Cainarca et al. 1992), it expects shareholders to value domestic information use from vertical partners that support organizational efficiency of the firm's R&D capabilities (Belderbos et al. 2010b):

H3c. In the industry decline, domestic R&D cooperation with vertical partners has a positive impact on shareholder value.

5. Data and Method

5.1. Sample

Partner, stock market, and industry data are analyzed using 149 R&D announcements of 18 manufacturers in the German Photovoltaic Industry over the period from 2004 to 2014. An overview on the variables including name, definition and source can be found in Table 1. Previous research mainly investigates the biotechnology or semiconductor industry, which calls for the necessity of empirical evidence on another industry (Kapoor and McGrath 2014; Wu et al. 2015). The German Photovoltaic Industry provides several advantages in the study of R&D cooperations and networks such as high cooperation intensity (Cantner et al. 2016).

TABLE 1: VARIABLE OVERVIEW

Variable Name	Definition	Source
Shareholder Value (SV_{iT})	Sum of stock market returns across the specified event period	German Stock Index (DAX): COMPUSTAT
R&D Cooperation Partner (Science-based, Market-based)	Total sum of partners in terms of partner type	Self-enforced: Company Homepage, Factiva Public: CORDIS, Förderkatalog, Factiva
Use of Information (International, Domestic)	Origin of external information source on the international or domestic level	Self-enforced: Company Homepage, Factiva Public: CORDIS, Förderkatalog, Factiva
Industry Cycles (Growth, Maturity, Decline)	Periods of the industry life cycle in the R&D cooperation announcement, multiplied by the sum of R&D cooperation partner	Literature, Commercial Registry
Age	Count of years passed since company foundation	Commercial Registry
Firm Size (Small, Medium, Large)	Number of firm employees	Commercial Registry
Return on Assets (ROA)	Profit on investment over a year, expressed as proportion of the original investment	COMPUSTAT
Firm and Project Investment	Investment in R&D project on the firm and government level	Förderkatalog
Project Costs	Sum of EU subsidies in R&D project	CORDIS

5.2. Dependent variable

Event study methodology is based on signaling theory (Spence 1973) that assumes efficient capital markets (Fama 1991) on which the rise or decline of the firm's stock price is a result of the investor reactions to the R&D cooperation announcement. The dependent variable *Shareholder Value* (SV_{iT}) is calculated as sum of the cumulative firm returns (*CAR_{it}*) that define the actual returns (*R_{it}*) minus the expected stock market returns (*$E(R_{it})$*) for firm *i* across the specified event period *Ţ* (MacKinlay 1997) on basis of the market model (Lee et al. 2016):

$$SV_i[Ţ_1;\ Ţ_2] = \sum_{Ţ_1}^{Ţ_2} CAR_{it} = \sum_{Ţ_1}^{Ţ_2} R_{it} - E(R_{it}) = \sum_{Ţ_1}^{Ţ_2} R_{it} - (\alpha_i + \beta_i R_{mt} + \varepsilon_i), \qquad (1)$$

where $E(R_{it})$ is the expected daily return for firm *i* on day *t*, R_{mt} denotes the daily return of the market portfolio, α_i and β_i are the coefficients of the variables and ε_i is the normally distributed error term (Brown and Warner 1985; MacKinlay 1997).

The calculation of the stock market return is as follows:

$$R_{it} = \frac{P_{it} - P_{i(t-1)}}{P_{i(t-1)}}, \qquad (2)$$

where R_{it} denotes the stock price return for firm *i* on day *t*, P_{it} is the stock price for firm *i* on day *t* and $P_{i(t-1)}$ is the stock price for firm *i* on the prior day t_{-1} (Sood and Tellis 2009).

Before the cooperation is announced in *t(0,0)*, investors have already gathered information and react on the stock market (MacKinlay 1997). The particular time of response is tested by different event windows throughout *t(-20,20)*. A comparison between the results of the t-test (Brown and Warner 1985) and the two-tailored generalized sign Z-test (Swaminathan and Moorman 2009) resulted in *SV(-2,2)* (see Table 2).

TABLE 2: IDENTIFICATION OF EVENT WINDOW

Event window	N	t-value	sign Z-value
SV (-20 + 20 days)	6273	1.432	.233
SV (-2 + 2 days)	765	4.832***	2.087*
SV (-2 + 1 days)	612	4.126***	2.530*
SV (-2 + 0 days)	459	3.137**	1.173
SV (-1 + 3 days)	765	3.364***	1.280
SV (-1 + 2 days)	612	3.021**	1.451
SV (-1 + 1 days)	459	2.480*	.530
SV (0 + 3 days)	612	3.452***	.463
SV (0 + 2 days)	459	3.260***	.319
SV (0 + 1 days)	306	2.922**	.326

*** The correlation is on the level of .001 (two-tailored) significant.
** The correlation is on the level of .01 (two-tailored) significant.
* The correlation is on the level of .05 (two-tailored) significant.

5.3. Independent variables

Since many firms use different *R&D cooperation partner* at the same time (Miotti and Sachwald 2003; Belderbos et al. 2004; Duysters and Lokshin 2011), this study involves the sum of market-based suppliers (vertical) and competitors (horizontal), and science-based partners such as research institutes and universities (Du et al. 2014; Gesing et al. 2015; Hohberger et al. 2015). *Use of information* is derived from international and domestic information sources (Tallman and Phene 2007; Duysters and Lokshin 2011). The *industry cycles* comprises the periods of the industry cyclical phases of growth, maturity and decline (Bhaskarabhatla and Klepper 2014), conceptualized as moderator in the relation between the sum of R&D cooperation partners and stock market returns (Tosi and Slocum 1984; Lumpkin and Dess 2001). The industry life cycle stages are determined by the growth rate and its variation over time and the level of technological opportunities (Cainarca et al. 1992). Given an industrial stagnation during the industry birth until 1998, Blankenberg and Dewald (2016) found that the German Photovoltaic Industry had only a few market entries over 40 years from the 1950s on. There was a moderate rise in the number of producers from 1998 to 2004, where R&D subsidies on both the international (EPIA 2011) and national level (Böhme 2010; BMWi 2012) triggered the evolution (Jacobsson and Lauber 2006). Between 2004 and 2008, the German Photovoltaic Industry experienced a fast growth in the number of manufacturers (Blankenberg and Dewald 2016). In 2009, it is one of the fastest growing technology markets (EPIA 2011; BMWi 2012) with an annual growth rate of about 50% (Böhme 2010). The number of manufacturers reaches its peak and induces the industry maturity. Since 2011, the consolidation and increasing competition leads the German Photovoltaic Industry into a recession (BMWi 2012). From now on, there are more firm exists than entries (Blankenberg and Dewald 2016).

5.4. Control variables

This paper uses *Firm Age,* i.e. the count of firm years passed since founding, as fixed effect (Xiong and Bharadwaj 2011). It controls for *Firm Size* on an annual basis *Y* as the number of firm employees, which are coded as the binary variables *Small, Medium*, and *Large* to predict firm performance (Lee et al. 2016). To include firm productivity, *Return on Assets (ROA)* is the profit on investment over a year (Lavie 2007). Since the German Photovoltaic Industry is strongly funded by government and EU programs (EPIA 2011; BMWi 2012), the estimation includes *Firm* and *Project Investment* and *Project Costs* to account for the distortions from the funded or invested amount of money by the firm or public institution.

5.5. Model specification

As the assumptions of OLS regression are violated resulting in biased and inconsistent estimates, fixed-effects specification leads to higher variance reduction in unbalanced panels with unobserved heterogeneity in firm-specific and time-invariant effects (Wooldridge 2005). In contrast to random-effects specification, the fixed-effects model allows for the correlation between the firm-specific effects and the independent variables, which needs to be verified by the Hausman test (Swaminathan and Moorman 2009).

The fixed-effects model estimates the impact of the independent variables on shareholder value arising to firm *i* at time *T*, *Y* and *t* respectively as follows:

Shareholder Value$_{iT}$	$= \beta_0 + \beta_{1\text{-}3}$ *(Firm Size Dummies$_{iY}$)*	Control Variables
	$+ \beta_4$ *(Cooperation Experience$_{iY}$)*	
	$+ \beta_5$ *(ROA$_{iY}$)*	
	$+ \beta_6$ *(Firm Investment$_{it}$)*	
	$+ \beta_7$ *(Project Investment$_{it}$)*	
	$+ \beta_8$ *(Project Costs$_{it}$)*	
H1	$+ \beta_9$ *(Science-based Partner$_{it}$)*	Partner Variables
	$+ \beta_{10}$ *(Market-based Partner$_{it}$)*	
H2	$+ \beta_9$ *(International Partner$_{it}$)*	
	$+ \beta_{10}$ *(Domestic Partner$_{it}$)*	
H3	$+ \beta_9$ *(Science International Partner$_{it}$)*	
	$+ \beta_{10}$ *(Domestic Partner$_{it}$)*	
	$+ \beta_{11}$ *(Market Vertical International Partner$_{it}$)*	
	$+ \beta_{12}$ *(Vertical Domestic Partner$_{it}$)*	
	$+ \beta_{13}$ *(Horizontal Partner$_{it}$)*	
	$+ \beta_{11\text{-}13/14\text{-}16}$ *(Partner x Industry Life Cycle Variables$_{it}$)*	Moderator
	$+ \beta_{14\text{-}39/17\text{-}42}$ *(Age$_{it}$)*	Fixed Variable
	$+ v_{it}$.	Error Term

The error term v_{it} results from the sum of the firm effect y_i, the time effect z_t, and the remaining error x_{it} (Swaminathan and Moorman 2009). To avoid multicollinearity, this study uses several alternative measures and excludes variables that show high correlation, which produces robust estimations (Greene 2008). For instance, large firm size is correlated with shareholder value because most of the stock companies have a large number of employees exerting an influence on firm performance (Xiong and Bharadwaj 2011). After excluding this control variable, the test for multicollinearity indicated no problems (Table 3). The tolerance level exceeds the threshold of 0.2 and the variance inflation factor (VIF) is below 10 (O'brien 2007). Alternative influences on shareholder value such as patent outcome as measure for firm innovativeness (Sandner and Block 2011) are tested supporting the robustness of the analysis. Swaminathan and Moorman (2009) raise concerns on the different stock market returns from private and public partners. Since the sample controls for R&D subsidies and includes an almost equal share of self-enforced (53%) and publicly funded R&D cooperations (47%), the results are robust across the two groups.

TABLE 3: COLLINEARITY STATISTICS

Variables	Tolerance	VIF
Project Investment	.377	2.651
Market-based Vertical International Partner	.379	2.639
Firm Age	.467	2.141
Science-based International Partner	.497	2.012
Project Costs	.508	1.968
Market-based Horizontal Partner	.521	1.921
Market-based Vertical Domestic Partner	.534	1.874
Science-based Domestic Partner	.541	1.849
ROA	.610	1.640
Firm Size – Medium	.669	1.495
Cooperation Experience	.704	1.420
Firm Size - Small	.750	1.333
Firm Investment	.851	1.174

6. Results

Table 4 shows the descriptive statistics and correlation matrix and table 5 provides the regression results of the stock market returns from R&D cooperation partners and information use. The general model (H1-H2) investigates the influence of market- and science-based partners and use of information on shareholder value. The growth, maturity and decline model (H3a-c) include the industry life cycle stages as moderators in the relation. The models are significant (log-likelihood ratio $\chi 2 > 8.762$, $p < .001$) and the adjusted R^2 is reasonable (> 26.5%). The coefficient of R&D cooperation with science-based organizations is negative and statistically significant and the coefficient of market-based R&D cooperation (H1) is positive but not statistically significant, not supporting H1. The coefficient of international use of information (H2a) is negative and statistically significant, supporting H2a. The coefficient of domestic information use (H2b) is not statistically significant, not supporting H2b. The coefficients of R&D cooperation with market- and science-based partners using international information during industry growth (H3a) are not statistically significant, not supporting H3a. As hypothesized, the coefficient of domestic R&D cooperation with market-based horizontal partners during industry maturity (H3b) is positive and statistically significant, providing support for H3b. In the industry decline, the coefficient of domestic R&D cooperation with market-based vertical partners is positive and statistically significant (H3c), supporting H3c. Considering the control variables, firm size, ROA, firm investment and project costs influence shareholder value depending on the industrial stage. Project investment and cooperation experience have no impact on stock market returns throughout the industry cycles.

TABLE 4: DESCRIPTIVE STATISTICS AND CORRELATION MATRIX

Variables	*Mean*	*Std. Dev.*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
Shareholder Value	.033369	.2023251	1.000														
Age	18.74	10.618	.021	1.000													
Firm Size – Small	.02	.140	.068	-.242**	1.000												
Firm Size – Medium	.19	.391	.040	-.278**	-.069**	1.000											
Firm Size – Large	.79	.406	-.062	.351**	-.280**	-.939**	1.000										
Cooperation Experience	6.44	4.871	-.102**	.393**	-.229**	-.153**	.227**	1.000									
ROA	-2.984	25.416	.010	.020	-.072**	-.143**	.163**	-.355**	1.000								
Firm Investment	259931.07	650140.56	.121**	.276**	-.098**	-.074**	.105**	.075**	-.016	1.000							
Project Investment	2689483.93	2390092.59	.059	.435**	-.086**	-.069**	.098**	.141**	.106**	.259**	1.000						
Project Costs	314672.21	1889723.66	.138**	.093**	-.029*	-.012	.021	-.027*	-.027*	-.140**	.172**	1.000					
Science-based Intern. Partner	.48	1.693	.102**	-.147**	.224**	.041**	-.116**	-.217**	.084**	-.193**	.166**	.541**	1.000				
Science-based Domestic Partner	.99	2.365	.214**	.002	.076**	-.013	-.014	.063**	.021	.448**	.437**	.107**	.295**	1.000			
Market-based Intern. Partner	.78	1.558	-.143**	-.281**	.262**	.181**	-.265**	-.014	-.057**	-.480**	-.146**	.312**	.493**	-.259**	1.000		
Market-based Vertical Partner	1.03	1.703	.162**	.174**	.095**	-.064**	.028*	-.103**	.006	.406**	.502**	.228**	.109**	.444**	-.298**	1.000	
Market-based Horizontal Partner	.64	1.371	.175**	-.136**	.123**	.072**	-.112**	-.080**	-.067**	.416**	.323**	.040**	.180**	.436**	-.127**	.273**	1.000

*Sign.: ** < 0.01, * < 0.05*

TABLE 5: ESTIMATION RESULTS

Variables	General Model (H1)	(H2)	Growth Model (H3a)	Maturity Model (H3b)	Decline Model (H3c)
Firm Size - Small	-.308**	-.192	.410**	-.477***	-.997***
Firm Size - Medium	.144***	.187***	.008	.156**	.079
Cooperation Experience	.005	.005	.005	.007	.006
ROA	.003**	.003***	.000	.002	.003**
Firm Investment	4.574E-8***	3.608E-8**	3.597E-8***	5.371E-8***	6.742E-8***
Project Investment	1.125E-9	-7.288E-9	-7.576E-9	-9.918E-9	5.911E-9
Project Costs	2.613E-8***	4.711E-8***	8.051E-9	4.043E-8***	8.287E-9
International Information Use		-.032***			
Domestic Information Use		-.004			
Science-based Partner	-.045***				
International			-.008	-.062***	-.019
Domestic			-.030*	-.039	-.156***
Market-based Partner	.006				
Vertical International			.005	-.012	-.120***
Vertical Domestic			.025*	.020	.056**
Horizontal			.026**	.031**	.002
Adjusted R^2	28.5	26.5	56.0	31.2	38.8
Log-likelihood χ^2	9.243***	8.762***	16.035***	10.323***	12.100***
df	34	34	40	43	43

Dependent variable: Shareholder Value
*Sign.: *** < 0.01, ** < 0.05, * < 0.1*

7. Discussion

7.1. Theoretical implications

Firms can achieve shareholder value through R&D cooperation by adapting the partner configuration and use of information during the industrial progress. In contrast to our hypotheses and the findings of Chan et al. (1997) and Das et al. (1998), the results indicate that the R&D cooperation with neither market- nor science-based partners leads to positive stock market returns. In consistence with the present industry concerns (Bstieler et al. 2015) and research on the organizational star scientists (Groysberg and Lee 2009), shareholders perceive the announcement of science-based partners as negative signal of the network configuration and lower the stock price, while they do not react on market-based R&D cooperation at all. An explanation for this missing valuation effect is the relevance of information use that influences the firm's profits (Srivastava et al. 1999), but also depends on the external environment (Miotti and Sachwald 2003). Only if the firm sends the signal of domestic information use, investors respond to market-based partners in a positive way. Firms prefer domestic partners that have a similar cultural and institutional understanding and cause lower costs but improved efficiency (Lavie and Miller 2008) that lead to positive short-term effects. International cooperation, in contrast, involves larger distances (Chatterjee et al. 1992; Datta and Puia 1995) and higher costs (Ramirez-Aleson and Espitia-Escuer 2001; Miotti and Sachwald 2003) which are detrimental for firm valuation. Shareholders associate domestic R&D partners with low uncertainty and high profitability leading to larger stock market returns.

This paper emphasizes the necessity of firms to adapt its partner configuration strategies over the industry growth, maturity and decline. In the case of domestic R&D cooperation, investors reward the use of information with market-based partners during industry growth. This complies with the findings of Cainarca et al. (1992) and Powell et al. (1996) that highlight the firm's need for complementary technological, manufacturing and commercial assets to meet the high technological opportunities in the risky and highly uncertain growth stage. But it contradicts the arguments for explorative global learning during industry growth (Oliver 2001; Beckman et al. 2004). Surprisingly, investors associate science-based partners with low efficiency throughout the industry cycle. Whereas in maturity, domestic horizontal cooperation achieves positive stock market returns, vertical partners become important during industry decline. In agreement with Cainarca et al. (1992), Elg (2000) and Miotti and Sachwald (2003), the industrial progress requires the trustful cooperation with direct competitors during industry maturity to extend the application horizon, establish industry standards and foster efficiency, which will be rewarded by shareholders. During industry decline, production and market structures are rationalized and the innovation potential exhausted (Cainarca et al. 1992), paving the way for market-based vertical cooperation. Suppliers contribute to quality improvements and cost reductions (Clark 1989; Tether 2002), diversified product offerings and process innovation (Hagedoorn 1995). Investors perceive market-based vertical partners as efficiency gains in the partner configuration and value the R&D cooperation with increasing stock market returns during decline.

7.2. Managerial implications

For increasing shareholder value, firms should avoid R&D announcements that only point to the type of cooperation partner, particularly when it is science-based. They should rather focus on domestic information use in market-based R&D cooperation to signal configuration efficiency to the stock market. In view of the investors that rigorously assess the profits and risks of cooperation announcements, managers should keep their hands off international partners due to larger distances, greater uncertainty and higher costs. During industry growth, it recommends firms to choose market-based domestic R&D partners from the same or different industries for value enhancing effects. Stock market returns from R&D announcement with science-based partners are continuously negative giving a warning signal to value pursuing firms that require short-term investments. In the industry maturity, firms are encouraged to cooperate with market-based horizontal partners and exploit their complementary capabilities to achieve positive stock market returns. For boosting shareholder value during industry decline, firms should seek R&D cooperation with vertical partners within the national innovation system.

7.3. Policy implications

As Kapoor and McGrath (2014) claim, policy needs to ensure technological progress by providing the ability to invest in R&D cooperation. Firms require enormous financial investments within the different industrial stages that outstrip their capacities but enable the development of new products and technologies for long-term growth. To allow for increasing investments in firm value, the findings imply that policy makers should support firms to engage in domestic R&D cooperation with market-based partners from the same or different industries. In the industry growth, R&D funding programs should target market-based organizations located within the national innovation system to combine complementary capabilities for risk and cost reduction. It is recommended to contemplate market-based horizontal R&D cooperation in the industry maturity to improve use cases and establish industry standards. During decline, policy should direct R&D subsidies at domestic market-based R&D cooperation with vertical partners that distinguish themselves through providing distinct assets for rationalization (Cainarca et al. 1992) and process improvements (Fritsch and Lukas 2001). Policy should keep in mind that R&D partners and information use can have short-term value destroying effects when supporting inadequate partner configuration structures or ignoring the evolutionary processes of the external environment.

8. Conclusion

Literature disagrees on the value enhancing and value destroying effects of partner selection in R&D cooperation (Das and Teng 2003; Un et al. 2010; Belderbos et al. 2010b), but it mainly disregards the industrial progress (Vanhaverbeke et al. 2015). The perceptions of shareholders on the upside benefits and downside risks vary over time (Mazzucato 2003) and cloud the direction for firms to select the most valuable partner over different industry cycles (Wu et al. 2015). This study underlines the relevance of R&D cooperation configuration and information use for firm valuation and long-term growth during the industrial progress. In particular, it contributes to the shareholder value of R&D partner types and use of information during the growth, maturity and decline of the industry life cycle. It addresses the research call for disentangling the value enhancing effects of market- and science-based partners and information use on different cooperation levels (Gulati 1995; Ahuja et al. 2012) over time (Un et al. 2010; Vanhaverbeke et al. 2015; Wu et al. 2015) and during changing external environments (Malerba 2006; Ter Wal and Boschma 2011; Biemans and Langerak 2015). This paper gives a novel theoretical explanation on the value of R&D partner types and information use by applying contingency and signaling theory. It provides empirical evidence for the positive stock market response from market-based partners and domestic information use along different industry cycles. This recommends firms to adapt the selection of R&D cooperation partners and information use for increasing shareholder value and supports politics for continuously ensuring investments that support long-term growth along the industry life cycle.

However, this paper has several limitations. In the theoretical part, it focuses on the interplay between partner configuration and external environment that results in organizational efficiency. Further studies could elaborate on the specific role of centralization, formalization, specialization and coordination in the organizational structure to determine the value enhancing effects of R&D cooperation. Since this study investigates partner configuration and information use in one industry, the generalizability of the results need to be extended to other environments. The industry life cycle consists of five different stages (Gort and Klepper 1982), but this study focuses on growth, maturity and decline. This calls for the necessity to investigate the relevance of partner types and information use during birth and shakeout phases of the industry. Last, event study methodology is restricted to listed and mainly large firms (MacKinlay 1997). Further research should overcome these limitations in order to involve different organizational forms.

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