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The Relationship Between Knowledge Transfer, Top Management Team Composition, and Performance: The Case of Science-Based Entrepreneurial Firms

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The increased pressure put on public research institutes to commercialize their research results has given rise to an increased academic interest in technology transfer. We assess under which conditions tacit knowledge transfer contributes to the performance of academic spin-offs. Using an inductive case study approach, our evidence suggests that tacit knowledge is most effectively transferred when a substantial part of the original research team joins the new venture as founders. Commercial expertise and mindset are also required in the team on the condition that the cognitive distance between the scientific researchers and the person responsible for commercialization is not too large.

Introduction

Over the past decade, there has been a substantial increase in the creation of academic spin-offs or what are more generally termed as science-based entrepreneurial firms (SBEFs) (Clarysse & Moray, 2004; Wright, Clarysse, Mustar, & Lockett, 2007). This rise stems from the pressure faced by public research institutes (PRIs), including universities, to commercialize at least part of their research results through licensing and/or new

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ventures. Not surprisingly, a stream of research has followed identifying the drivers of technology transfer and commercialization including intellectual property (Di Gregorio & Shane, 2003; Siegel, Waldman, & Link, 2003; Thursby & Thursby, 2002), contract research (Poyago-Theotoky & Beath, 2002), graduate and researcher mobility (Argote & Ingram, 2000), the role of the technology transfer office (Debackere & Veugelers, 2005; Wright, Clarysse, Lockett, & Knockaert, 2008), and science parks and incubators (Phan, Siegel, & Wright, 2005).

What is less clear from this growing body of literature is what drives *successful* technology transfer and commercialization particularly from the perspective of SBEFs. While success from the perspective of the PRI has been studied by examining the drivers of licensing revenues and new venture creation rates (Bray & Lee, 2000; Lawton Smith & Ho, 2006; Lockett & Wright, 2005; Markman, Gianiodis, Phan, & Balkin, 2005), understanding the performance of SBEFs that emerge from these PRIs has been largely neglected (Colombo & Grilli, 2005). Addressing this gap remains a major policy issue since the performance of many SBEFs has been limited, not to say disappointing (Siegel & Wright, 2007; Wright et al., 2007).

Understanding the processes underpinning performance is important since the development of SBEFs emerging from PRIs faces distinctive challenges. First, SBEFs are characterized by high levels of innovation in new and rapidly changing markets (Ittner & Larcker, 1997), and the exploitation of technologies that are radically new, disruptive and often early stage and general purpose (Christensen, 2003; Danneels, 2004; Nelson, 2001). Second, the early stage high tech nature of the technology may mean that SBEFs face barriers when trying to attract VC financing, given that capital providers find it hard to evaluate the technology (Wright, Lockett, Clarysse, & Binks, 2006). A third, and perhaps most important, challenge facing SBEFs refers to the human resource and knowledge base. Ensley and Hmieleski (2005) and Franklin, Wright, and Lockett (2001) indicate that top management team composition in SBEFs remains, to a large extent, homogeneous. They argue that founders of academic spin-offs mainly select team members from sources with whom they share network ties and thus lack commercial experience, resulting in top management team composition remaining to a large extent homogeneous in terms of education, industry experience, functional expertise, and skills. Related to this human resource gap, Lockett, Siegel, Wright, and Ensley (2005) argue that it is appropriate to take a knowledge-based view (KBV) perspective when studying SBEFs. By accessing, developing, and integrating new and existing knowledge, spin-offs will be able to reconfigure the nature of their capabilities, which could potentially enhance their performance (Lockett et al.). SBEFs are usually formed around a technology and the very specific knowledge that is inextricably linked to that technology, which is typically embodied in the academic scientists and entrepreneurs (Clarysse, Wright, Lockett, Mustar, & Knockaert, 2007; Markman, Siegel, & Wright, 2008; Wright et al.). As the technology is rarely market-ready, knowledge surrounding the technology is needed to modify or tailor the technology and associated products/services to meet customer requirements (Di Gregorio & Shane, 2003; Zucker, Darby, & Brewer, 1998). Despite recognition of knowledge gaps both in the routines of technology transfer offices (TTOs) (Lockett et al.) and in the skills of academic entrepreneurs (Franklin et al.; Mosey & Wright, 2007), understanding remains limited concerning how knowledge might best be transferred and effectively utilized in the context of SBEFs. Indeed, Markman et al. indicate that studies on research and technology commercialization have so far neglected identifying the most effective configurations of entrepreneurial teams for the commercialization of research.

This study presents a first attempt to bring together insights relating to different types of knowledge and their transfer required to develop SBEFs. Specifically, we address the following broad research question: How can knowledge be transferred and employed in SBEFs in order to enhance SBEF performance?

In order to address this research question, we conduct a longitudinal inductive study by drawing on knowledge-based theory and upper echelons theory (and related top management team literature), as well as nine case studies of SBEFs. The SBEFs studied here originated from Inter University Micro Electronics Centre (IMEC), a top research institute in the area of micro-electronics situated in Belgium. IMEC provides an important context for our purpose since in each of the SBEFs, the research institute held equity positions, which were either sold or lost their value, allowing objective measurement of performance. Interviews were carried out with founders of the SBEFs at multiple points in time. Their views were corroborated with evidence from the IMEC TTO.

The article is structured as follows. The following section situates our study within the context of knowledge-based and upper echelons theories. It is worth noting that given the nature of this research, the focus of theory and associated literature was informed not only by our research question but also by our data. Analysis of the data resulted in the need to explore a variety of different theoretical avenues. For presentation purposes, however, we present the theory up front. We then present the research design and methodology, followed by a description of the cases. Next, we present the results of an iterative process of analyzing our data and comparing it with extant literature and theories on top management teams and knowledge. Finally, we reflect on our findings and discuss their implications for scientist entrepreneurs, technology transfer officers in PRIs, as well as wider policy issues.

Theoretical Perspectives

Organizational theory has offered two contrasting explanations for why organizations act as they do (Hambrick & Mason, 1984). The first explanation, indirectly supported by population ecologists (Hannan & Freeman, 1977), suggests organizations are swept along by events or somehow run themselves (Hall, 1977). Even when strategic processes are studied, these are typically viewed as flows of information and decisions, detached from the people involved (Aguilar, 1967; Allen, 1979). The alternative explanation is that organizational outcomes are partially predicted by managerial background characteristics, and are thus reflections of the values and cognitive bases of powerful actors in the organization (Hambrick & Mason). Each decision maker brings his or her own set of "givens" to an administrative decision (March & Simon, 1958). These givens reflect the decision maker's cognitive base (Hambrick & Mason). Cognition is seen as a forward-looking form of intelligence premised on an actor's beliefs about the linkage between the choice of actions and the subsequent impact of those actions on outcomes (Gavetti & Levinthal, 2000). It denotes a broad range of mental activity, including proprioception, perception, sense making, categorization, inference, value judgments, emotions and feelings, which all build on each other (Nooteboom, Van Haverbeke, Duysters, Gilsing & van den Oord, 2007). Thus, researchers in the second stream have argued that people use mental models of the world to evaluate choices or frame discussions (Carley & Palmquist, 1992; Holland, Holyoak, Nisbett, & Thagard, 1986).

Given that (academic) entrepreneurship and new technology is intrinsically unpredictable (Tushman & Rosenkopf, 1992) and involves a large set of strategic decisions (Meyer & Heppard, 2000), our research follows the second research stream. It is important to note, however, that strategic issues are rarely diagnosed and/or addressed by a single individual (Dutton, Fahey, & Narayanan, 1983) but rather by a top management team. As different individuals have access to various data and interpret the data differently, each possesses only a part of the "jigsaw" puzzle (Quinn, 1980). It is for this reason that we draw on theories and literature that can explain how multiple decision makers and their associated cognition/knowledge influences SBEF performance. In particular, we draw on knowledge-based theory and upper echelons theory as well as associated literatures. In this section, we explain how these perspectives can be used to understand SBEF performance.

Knowledge-Based Theory

The knowledge-based view of the firm sees access to, and the development, protection and transfer of knowledge as a means of creating and preserving competitive advantage (Grant, 1996; Henderson & Cockburn, 1994; Liebeskind, 1996). Knowledge-based theories suggest that a firm's success will depend on how well it can (1) enhance its own knowledge base; (2) integrate knowledge (Cohen & Levinthal, 1990); and (3) apply knowledge to either successfully develop new products/services or improve current products and processes (Grant; Kessler, Bierly, & Gopalakrishnan, 2000; Nonaka & Takeuchi, 1995).

Knowledge theorists often distinguish between explicit and tacit knowledge. Explicit knowledge has the qualities of being relatively easier to codify and communicate in a formal, systematic language (Nonaka & Takeuchi, 1995; Polanyi, 1966; Simonin, 1999). In the research institute context, explicit knowledge typically takes the form of publications and patents (Hong, 2008) and can be transferred through arms-length contracting such as licensing. However, there is often a considerable body of knowledge not captured in patents and licenses; that is, the tacit component. Polanyi claims that all knowledge is "*either tacit* or *rooted in tacit knowledge*. A *wholly* explicit knowledge is unthinkable" (original emphasis). Tacit knowledge is acquired by and stored within individuals and is embedded in a social and cultural context (Nonaka & Takeuchi; Osterloh & Frey, 2000).

In a technology transfer context, the transfer of explicit knowledge alone may not result in the successful transfer of knowledge, and hence, competitive advantage for the new firm. Indeed, Nelson and Winter (1982) and Barney (1991) state that the knowledge that underlies skilful performance is to a large extent tacit. Thus, the success of SBEFs is likely to be linked strongly to both technology and knowledge transfer where knowledge transfer involves the movement of knowledge from one group to another (Argote, 1999; Carlile & Rebentisch, 2003). In SBEFs, tacit knowledge is typically embodied in the inventor/researchers (Lowe, 2006). Its transfer requires interpersonal communication (Ounjian & Carne, 1987) involving what Roberts (2000) calls "show-how." However, due to its very nature, tacit knowledge is difficult to communicate. Considerable interaction is required between parties to ensure that new codes and formulae to describe the technology are developed so that knowledge can be transferred from one party to the other (Zucker, Darby, & Armstrong, 2002). Continued collaboration between the new venture and the original researchers has been linked to venture success (Zucker et al., 1998, 2002) suggesting that collaboration may be key to the efficient transfer of tacit knowledge.

The discussion above highlights that in an academic spin-out process, transfer of explicit and tacit knowledge will have to be taken care of simultaneously in order to secure new venture success. While knowledge-based theories offer insights into the nature of knowledge and its relationship to firm performance, it provides limited explanation in terms of how knowledge might best be shared or transferred. We argue that upper echelons theory and associated literature on top management teams may offer complementary insights into how knowledge might best be shared and transferred.

Upper Echelons Theory and Top Management Team Literature

Organizational outcomes are a function of the characteristics of the top management team (TMT) (Hambrick & Mason, 1984). Entrepreneurship scholars have highlighted the relationship between venture success and the composition of the entrepreneurial team, defined as the group of people involved in the creation and management of a new venture (Colombo & Grilli, 2005; Cooper & Daily, 1997; Forbes, Borchert, Zellmer-Bruhn, & Sapienza, 2006; Francis & Sandberg, 2000; Vanaelst et al., 2006; Wright et al., 2007). Yet, it remains unclear how teams should be structured in order to enhance new venture success. Scholars appear to be divided on the potential merits of heterogeneity within the top team. Some argue that teams including members with different functional and work backgrounds, training, and cognitions are likely to have at their disposal diverse perspectives, knowledge bases, and expertise, which in turn can lead to improved decision making (Bantel & Jackson, 1989; Cox & Blake, 1991; Pelled, Eisenhardt, & Xin, 1999). Indeed, heterogeneous teams are viewed as beneficial for strategic change (Lant, Milliken, & Batra, 1992; Wiersema & Bantel, 1992), greater strategic consensus (Knight et al., 1999), and enhanced performance (Bunderson & Sutcliffe, 2002).

In contrast, others have argued that heterogeneity can lead to less common ground between team members, stimulating dysfunctional conflict (Amason, 1996; Kamm & Nurick, 1993; Miller, Burke, & Glick, 1998). A certain degree of homogeneity may thus strengthen the relational fabric between team members. The TMT literature is not conclusive on whether heterogeneity or homogeneity leads to success (e.g., Miller et al.; Simons, Pelled, & Smith, 1999). A contingency perspective suggests that routine problem solving is best handled by a homogeneous group, and ill-defined, novel problem solving is best handled by a heterogeneous group in which diversity of opinion, knowledge, and background allows a thorough airing of alternatives (Filley, House, & Kerr, 1976). Since the creation of an academic spin-out can hardly be defined as a routine problem, SBEFs may benefit from more heterogeneous teams. Indeed, academic entrepreneurial teams have been criticized for their homogeneity in terms of technical experience and background (Ensley & Hmieleski, 2005; Franklin et al., 2001; Lockett et al., 2005). Yet, little evidence exists on the most effective composition of top management/entrepreneurial teams in academic spin-outs. Even in a broader setting, Nooteboom et al. (2007) state that "the basic question 'where do heterogeneous resources come from and how do they affect a firm's innovation performance?' has essentially remained unaddressed so far."

Though it is clear that academic spin-outs often lack commercial experience, it may be insufficient to add one or more people to fill the "commercial gap" within the team. The unique nature of the technology in academic spin-outs may mean that not just any commercial person can understand the technology. The corollary is that the inventors in the founding team are likely highly technically specialized, with limited knowledge about markets or industries. A simple focus on the number and dispersion of the functions covered by the TMT may thus fail to capture important interactions between team members that are necessary for knowledge to be transferred. Rather, there is a need to consider the degree to which knowledge, experience, skills, frames of reference and cognition across team members is different or overlapping. In other words, there may need to be some degree of "cognitive distance" between team members (Wuyts, Colombo, Dutta, & Nooteboom, 2005). According to this view, people perceive, interpret, understand, and evaluate the world according to mental categories (Johnson-Laird, 1983) that they have developed in interaction with their physical and social environment. High levels of cognitive distance between technical and commercial founding team members likely interfere with effective knowledge sharing and combination necessary to commercialize technology as individuals with one set of knowledge and experience are unable to “read” the codes of their fellow team members with a different knowledge and experience set (Cowan & Foray, 1997). The literature, however, provides little indication of the most effective overlap in the knowledge and skills of team members and of cognitive distance, and the consequences for SBEF performance.

Methodology

Inductive Case Study Approach

Our study employed an inductive case study approach to understand under which conditions tacit knowledge was effectively transferred from the PRI to the SBEF to lead to SBEF success. With a few exceptions, much of the extant literature on technology transfer from public institutions has been quantitative. Qualitative case studies, however, may be highly complementary by shedding light on how and why questions (Yin, 2003). Further, they are well suited to research that involves observations over time. Our case studies were designed to allow investigation into the way each of the individual enterprises was created and developed, and how tacit knowledge was transferred and eventually turned into a financial success or failure from the point of view of the research institute. Our approach of examining the ventures from gestation to exit by the research institute allows us to explain how a sequence of events unfolded over time to produce a given outcome (Van de Ven, 2007).

Within the typology of case study approaches, the design adopted here is multi-case, embedded research. The term embedded refers here to the duality of the units of analysis, namely the research institute and the spin-off (see also Pettigrew’s 1973 triangulation methodology using multiple respondents). Given that we only study ventures that originated from a research institute that specializes in one field, namely microelectronics, we avoid the impact of sectoral differences on knowledge transfer and venture performance (Kessler & Chakrabarti, 1996).

While our approach is inductive in nature, this should not be seen to imply that we ignored extant literature/theories. On the contrary, we followed an iterative process involving a back-and-forth journey between the data collected and existing literature and theories (Van Maanen, Sorensen, & Mitchell, 2007). This approach was complemented by our multiple case analysis. Cases can be treated as a series of independent experiments (Brown & Eisenhardt, 1997), allowing for the adoption of “replication”/“comparative” logic (Yin, 2003, and Eisenhardt, 1989a, respectively). This refers to the way in which evidence is accumulated through comparing cases where similar aspects exist, a process yielding theoretical replication (Yin). According to Suddaby (2006), one of the difficulties in grounded theory or inductive research lies in the fact that the research is conducted iteratively, by analyzing and collecting data simultaneously, whereas the presentation is typically sequential: “in pure form, . . . research would be presented as a jumble of literature consultation, data collection, and analysis conducted in iterations . . . and theory would be presented last.” The norm that has evolved is to present inductive research in the traditional discrete categories and in the same sequence as quantitative research. This is also the case in this article. Even though we present the theory up front, we would stress that the selection of theory and its development emerged from the empirical research.

Identification of Cases and Data Collection

The cases used in this study all originated from one research institute in Belgium, the Inter University Micro Electronics Centre (IMEC). IMEC originated in 1982 and is based in Leuven, Belgium. IMEC was set up following a program of the Flemish government in the field of microelectronics. Today, IMEC is Europe's leading independent research center in the field of microelectronics, nanotechnology, enabling design methods, and technologies for ICT systems. Given its long-established nature and its track record of realizations, IMEC provides an interesting context to address our research question. Further, selecting IMEC as a single case is appropriate for various reasons. First, given that extensive data collection is needed on different levels, this research is ideally handled in the context of one PRO. Second, the fact that IMEC focuses on one technology domain enhances the unit of homogeneity in the case design, which is important to draw valid conclusions. Third, single-site studies have been successfully applied by other researchers (Shane & Stuart, 2002; Zhang, 2009).

We draw on nine cases where the phenomenon of interest (i.e., SBEF performance) is "transparently observable" (Eisenhardt, 1989a). Using a finite number of cases, usually between four and ten, allows the researcher to balance the need to generate rich theory with large amounts of data (Brown & Eisenhardt, 1997). Data were collected from a variety of sources but primarily using in-depth face-to-face or telephone interviews with the founder and/or CEO of each of the nine companies. Each interview lasted between one and two hours. The data were verified and supplemented with that obtained from the TTO of IMEC and for some cases co-founders, members of the current management team, and/or the leading professor of the research group at the PRI from which the venture's technology originated. This process allowed for triangulation (Yin, 2003) and helped minimize the effects of retrospection. The interview transcripts and documentary evidence were read and reread as data were collected and emerging themes were refined as this process progressed. To avoid confirmation biases, two of the authors were kept at a distance from the data-collection process (Doz, 1996).

There is limited consensus surrounding how firm performance generally (for an overview, see Serarols & Urbano, 2008) or spin-off performance specifically should be measured. Although the use of financial and nonfinancial yardsticks to measure spin-off performance is consistent with the entrepreneurship literature (Chandler & Hanks, 1993; Robinson, 1998), some measures may not be appropriate for high tech spin-offs. This is, for instance, the case for growth measures, which have been extensively used in entrepreneurship research (for an overview, see Davidsson, Steffens, & Fitzsimmons, 2007). Davidsson, Steffens & Fitzsimmons (2008), however, argue that it is descriptively wrong to portray SME growth as "success" and that growth is per definition an antecedent for neither profitability nor sustainability. Further, technology-based ventures often make strategic choices that result in employment growth before sales growth occurs (Delmar, Davidsson, & Gartner, 2003), questioning the use of sales-based performance measures. In this study we use an objective measure of SBEF performance by measuring the valuation of the SBEFs at the moment the PRI's shares are sold to investors or industrial parties or at the moment of liquidation. We only selected those cases where the investments had been exited by IMEC. We avoid the problem of success bias as we include SBEFs that had either experienced a trade sale, were sold to a financial investor, or had been liquidated or went bankrupt. An additional advantage of our performance measure is that it sheds light on when PRIs benefit financially from spinning off ventures. It allows us to generate more fine-grained insights compared with using success or failure as measure used by other authors (Nerkar & Shane, 2003; Shane & Stuart, 2002). Further, our approach has the added advantage that the exit value of the investments by the PRI can be objectively measured, in comparison to internal rate of return (IRR) estimations before exit, which tend to be overvalued (Dittmann, Maug, & Kemper, 2004).

In four cases, IMEC sold its shares, either through trade sale, or through sales to another investor at values that were above historic cost (or the price at which IMEC's TTO acquired shares in the company). We call these the success cases since they allowed the investors to realize a positive return on their investment. In three of these cases, the exit route was through trade sale and, in one case, the TTO's interest was sold to a venture capital fund. In the remaining five cases, IMEC's interest was sold below historic cost. We call these failed cases, since they did not allow the TTO to recoup the initial investment. Four of these ventures went bankrupt, while another was sold below historic cost to a venture capital fund. An important and unusual feature of our study is that we were able to obtain access to the founders of failed ventures as well as those who founded successful enterprises. The ninth column in Table 1 indicates the venture outcome for each of our cases.

The Cases

Table 1 provides an insight into the companies, their core technology, start of the research project, founding date, and whether the companies were product or service companies at the moment of start-up. For confidentiality reasons, we replaced the company names by SBEF1 up to SBEF9.

The table also provides an insight into the main resources of the SBEFs at founding, such as the stage of product development at founding, the financial resources (capital after 12–18 months), and size of the founding team, since these may, under certain conditions, lead to competitive advantage and subsequently affect performance (Moray & Clarysse, 2005). The table shows that all SBEFs raised considerable amounts of financing, except for SBEF4 (a success, S) and SBEF6 (a failure, F), taking into account that the average capital raised by high-tech start-ups in the same region and over a similar period equals 234 KEuro (Moray & Clarysse). Further, whereas Moray and Clarysse found the average number of founders over the same time in the same region to equal 1.8, most of the SBEFs in our sample have larger teams, except for SBEF6 (F) and SBEF9 (F).

Results

Our results provide insights that inform our primary research question. The following discussion is organized to present our findings in relation to (1) the observed types of knowledge transfer between PRI and SBEF and their impact on SBEF performance; and (2) the importance of the knowledge composition of the top management team and the role of cognitive distance among team members. A diagrammatic representation of the three sets of propositions that form the model that arises from our analyses is presented in Figure 1.

Types of Knowledge Transfer and SBEF Performance

Table 2 provides an insight into codified and tacit knowledge transfer from IMEC to the SBEFs. The cases show little heterogeneity in codified knowledge transfer: in each of the cases, IMEC either closed a license agreement, or transferred the technology to the new venture in return for shares. Only in the case of SBEF4 (S), no formal technology transfer took place.

The analysis shows that effective tacit knowledge transfer was crucial for SBEF performance. Our analysis points to the importance of post-founding speed to first product

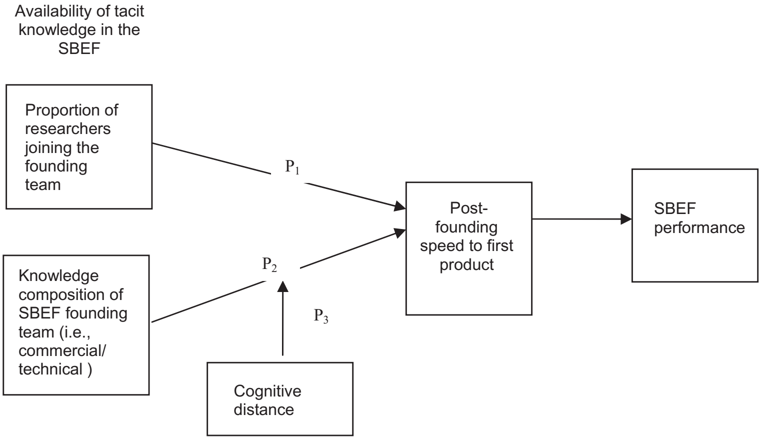
Table 1

Characteristics of Cases

Name of spin-off	Research project start date	Founding date	Technology	Product or service company at start-up	Stage of product development at founding	Capital after 12-18 months (in KEuro)	Number of founders	Venture outcome (Success/Failure)	Time till exit for IMEC
SBEF1	1992	1996	Chips for satellite communication	Product	Alpha prototype	745	4	S (acquired)	5 years
SBEF2	1990	1996	Software tools for system level designs	Product	Alpha prototype	4416	7	S (sold to VC)	7 years
SBEF3	1993	1999	Image sensors	Product	Product/service ready	4600	11	S (acquired)	4 years
SBEF4	No research project	1991	System-on-chip design services	Service	Product/service ready	198	4	S (acquired)	9 years
SBEF5	1993	1996	Design technologies for embedded software in electronic systems	Product	Alpha prototype	372	4	F (sold to VC)	7 years
SBEF6	1980	1992	Measurement technology for reliability of electronic components	Product	Pre-prototype	75	1	F (bankrupt)	8 years
SBEF7	1996	2002	Fixed wireless access	Product	Pre-prototype	1000	3	F (bankrupt)	1 year
SBEF8	1998	1998	Electronic nose manufacturer	Product	Pre-prototype	410	3	F (bankrupt)	3 years
SBEF9	1993	1996	Image sensors	Product	Alpha prototype	766	1	F (bankrupt)	3 years

Figure 1

Model of Relationship Between Tacit Knowledge, Top Management Team Composition, and SBEF Performance



or service after founding and the importance of effective tacit knowledge transfer in generating sufficient speed. In what follows, we first elaborate on the importance of speed to first product/service, and subsequently discuss how tacit knowledge can be effectively transferred in order to generate this speed.

Post-Founding Speed to First Product/Service

The cases show differences in the level of product development at the moment of founding and post-founding speed to first product. Whereas two companies started up with a product or service that was market-ready, four started up with an Alpha-prototype, and three companies were founded without a functioning prototype. For those companies without a market-ready product at the time of founding, we find substantial differences in the time to product or service. Two companies that started with an Alpha prototype had developed a marketable product after half a year. The two other companies that had a similar technological starting position both required 3 years in order to develop a product out of the technology. Where the technology was still in a pre-prototype phase, it took one of the companies 7 years to finalize the product. In the two other cases, the technology never reached a product phase.

Further, we also find that successful cases generated higher post-founding speed than failed cases, irrespective of the pre-founding speed. For instance, it took SBEF1 and SBEF2 in the pre-founding period, respectively, 4 and 6 years to arrive at an Alpha prototype, compared to 3 years for SBEF5 and SBEF9. It, however, took SBEF1 and SBEF2 only half a year to arrive at the first product, whereas it took SBEF5 and SBEF9 an additional 3 years.

Our analysis shows that those SBEFS that generated sufficient speed to product/service after founding were more successful than those who did not generate this speed, which confirms previous research. Schoonhoven, Eisenhardt, and Lyman (1990) for instance indicated the time between the date of founding and the time to ship a first

Table 2

Codified and Tacit Knowledge Transfer

	Tacit knowledge transfer							
Name of spin-off	Founding Team size	Number of researchers joining spin-off	Proportion of founding team that were original researchers	Other tacit knowledge transfer mechanisms	Codified knowledge transfer	Time between start research project and founding	NPD stage at founding	Time between founding and first product/service
SBEF1	4	3 out of 10	75%	—	Non-exclusive license agreement	4 years	Alpha prototype	0.5 years
SBEF2	7	6 out of 6	86%	—	License agreement	6 years	Alpha prototype	0.5 years
SBEF3	11	8 out of 8	73%	—	Patent transfer in return for shares	6 years	Product/service ready	0 years
SBEF4	4	4 out of 4	100%	—	None	Not applicable	Product/service ready	0 years
SBEF5	4	4 out of 10	100%	—	License agreement	3 years	Alpha prototype	3 years
SBEF6	1	0	0%	Research contract with 2 FTEs at the PRI	License agreement	12 years	Pre-prototype	7 years
SBEF7	3	1 out of 20	33%	8 PRI employees contracted	License agreement	6 years	Pre-prototype	Never finalized
SBEF8	3	2 out of 3 (but left the company early)	67% down to 0%	—	Exclusive license agreement	0.5 years	Pre-prototype	Never finalized
SBEF9	1	0	0%	—	Non-exclusive license agreement	3 years	Alpha prototype	3 years

product for revenues to be an important entrepreneurial event. According to Schoonhoven et al., fast products are important in an early stage high tech context for (1) gaining early cashflow for greater financial independence, (2) gaining external visibility and legitimacy as soon as possible, (3) gaining early market share, and (4) increasing the likelihood of survival. The interviews confirmed the importance of the post-founding speed to first product for SBEF success as the following illustrates.

In the case of SBEF7, both the TTO and CEO attributed the failure of their company to lack of speed to first product. The TTO comments:

> The technology that SBEF7 had developed was outstanding. Besides, at the moment that they started up, it was clear that there was a window of opportunity. This window however closed very fast, with many parties entering the market and speed to market was crucial. SBEF7 did not have the resources to generate the speed it needed to develop the opportunity. It is painful to see how technologies that were inferior to that of SBEF7 are currently dominating the market.

Similarly, SBEF6 had a proof of concept far from a working prototype at founding. Two years later, the first measurement equipment was ready, but there was little market interest since the need was for a full set of measurement equipment. It took the company 7 years from start-up to develop a full set of three measurement products ready for sales.

These results confirm previous research findings on the importance of speed to first product, especially in high tech contexts. Our analysis however also indicates the importance of tacit knowledge transfer to reach this speed and shows how tacit knowledge can be effectively transferred. We discuss this issue next.

Tacit Knowledge Transfer and Post-Founding Speed to First Product/Service

Our data reveal three interesting patterns concerning the effect of tacit knowledge transfer on speed to first product.

First, where no tacit knowledge is transferred, post-founding speed to first product is affected negatively, with products or services being introduced on the market too late, or never finalizing the process from technology to product, thus resulting in the failure of the SBEF. Successful knowledge transfer is more likely if the original scientists who worked on developing the technology are also involved in the venture (See Table 2). Even with codified knowledge surrounding the technology there is likely also a tacit component. Close interaction with the original scientists will make the transfer of the tacit knowledge more likely.

SBEF1, SBEF2, SBEF5, and SBEF9 all started with an Alpha prototype. SBEF1 started up with an Alpha prototype of a chip. Six months after founding, the company sold the first chip to two large industrial companies. SBEF2 also took half a year after founding to reach the product phase. In both cases, a significant portion of the founding team comprised the original researchers. In SBEF2, the entire research group stepped into the new venture. The CEO of SBEF2 comments:

> At the time of spin-off creation, it was crucial to have the people who developed the technology within the team because the technology was in their heads. Even more important was to ensure that they remained with the company throughout time. Therefore it was important to let those people grow with the company.

In contrast, none of the researchers joined SBEF9. Despite having an Alpha prototype, SBEF9 struggled to develop a market-ready product and went bankrupt after 3 years. It is interesting to compare SBEF9 with SBEF3 as they were both based on the same technology. Although SBEF3 was slightly more advanced in terms of technological development as it had a market-ready product/service, in contrast to SBEF9, it had the added advantage of having the entire research group in its founding team. Despite the "technology being fantastic and promising," the CEO of SBEF9 attributed their failure to the absence of original researchers within the founding team:

> The fact that the original developers did not join was problematic for the new venture, since the technology proved to be still in a laboratory phase and needed a lot more development. . . . The existing software of potential customers needed to be adapted in order to read the signal of the image sensors and also the hardware needed some adaptations. . . . It was hard to find good technical people with this specific knowledge on the labor market.

Having learned from the mistakes made in SBEF9, IMEC opted for a different strategy with SBEF3 by ensuring that the original researchers joined the venture. This strategy had also proved successful with SBEF4 several years earlier, even though the TTO comments on the drawbacks for the research institute as follows:

> The transfer of the researchers to the new venture was not an easy decision. Even though we knew that it was crucial for the future success of the company, for IMEC it meant losing top researchers, who had been with the organization for many years, losing knowledge and technology and losing potential contract research budgets.

Second, our data suggest that a critical mass of tacit knowledge is needed. We find that only where the majority of the initial researchers joined the SBEF as founders was tacit knowledge transferred effectively and sufficient speed to first product achieved. SBEFs in which only the minority of the initial researchers joined, or which relied on research contracts with the initial researchers to access tacit knowledge, failed to generate sufficient speed. As many of the technologies in question were developed with teams where team members were inter-dependent and complementary to one another, being able to draw on some team members and not others appeared to result in incomplete tacit knowledge transfer.

The (former) CEO of SBEF7 states:

> At the time of start-up, only one of the researchers stepped into the new venture. We definitely lacked R&D capacity to develop the technology into a product. Besides, standards were set in the sector, and we missed the people who could engage in the discussion on the standards.

In this case, in order to secure access to valuable knowledge, eight researchers from the original research team were employed by the venture. SBEF7, however, shows that research contracts between original researchers and the new venture are ineffective in reaching sufficient speed to first product. This brings us to our third finding.

Besides *access* to tacit knowledge through close interaction with the original scientists, the *manner in which* tacit knowledge is transferred from the PRI to the SBEF appears to be particularly important. Osterloh and Frey (2000) argue that intrinsic motivation is particularly important in the transfer of tacit knowledge. If individuals are solely motivated by extrinsic rewards (or penalties), they will only focus on aspects of knowledge transfer that are rewarded, which favors explicit knowledge transfer (because this is more readily observable). This suggests that accessing the knowledge held by the original scientists through arms-length employment contracts may help transfer explicit knowledge but to a lesser extent tacit knowledge. In contrast, intrinsically motivated scientists are likely to be more engaged with the venture. Joining the founding team will involve greater participation in the venture and suggest greater emotional commitment. Emotional commitment and personal involvement are important drivers of tacit knowledge transfer (Glynn, 1996). Participation signals an agreement on common goals and leads to greater perceived self-determination, which strengthens intrinsic motivation (Osterloh & Frey).

Hence, those original scientists who display greater participation in the venture will facilitate the transfer of tacit knowledge. In several of the successful cases (SBEF2, SBEF3, and SBEF4) all researchers from the research institute joined the spin-off as founders. The above discussion leads to the following proposition:

> **Proposition 1:** The greater the proportion of the original research team joining the SBEF as founders, the greater will be the transfer of tacit knowledge and, hence, the greater the chances of reaching sufficient post-founding speed to first product that will lead to enhanced SBEF performance.

Top Management Team Composition, Cognitive Distance, and SBEF Performance

Our data reveal that alongside the *extent* of tacit knowledge about the technology embodied in the number of original researchers transferring to the founding team, it is important for the SBEF team to also include a commercial mindset for gaining sufficient speed to first product. A common concern with entrepreneurs from a research background (e.g., academic entrepreneurs) is that they often lack commercial experience, resulting in a tendency to focus only on the technical aspects of innovation (Franklin et al., 2001). Commercial knowledge is needed in the venture to ensure that the founding team is alert to external market cues. Information from outside the venture needs to be received, processed, and then responded to, to ensure that the product/service meets market requirements.

Table 3 shows that, generally, the founding team had someone who had commercial experience as well as technological experience. The exceptions were SBEF4 (S) and SBEF8 (F). SBEF4 was an unusual case because it was a service company. Although the four founders did not possess considerable commercial experience, two of the founders worked for large microelectronics companies (Philips and Alcatel) while the other two founders worked for IMEC and a university. Further, as the TTO commented, they rapidly developed a commercial attitude. All founders were able to access customers relatively quickly through their contacts from prior employers. Further, the board of directors included members brought in to provide further access to customers.

In SBEF8, one of the founders, on paper, had some commercial experience as he already owned another business. However, the TTO at the time commented that:

> He did not show any industrial spirit or reflection. . . . It was impossible to convince him that the technology he worked on and developed was not sufficient to build a company around. He was convinced that his work was done, the sensor was tested and ready. The economic reality proved that it wasn't. Up to this moment he was convinced that SBEF8 had a product that could be brought to the market in a profitable way.

SBEF8 illustrates the importance of having commercial experience and also making sure that a commercial mindset develops alongside the experience gained. The CEO of SBEF1 illustrates the meaning of a commercial mindset as follows:

Table 3

Commercial Mindset and Indicators of Cognitive Distance in the TMT

	P2: Commercial mindset	P3: Cognitive distance optimizers	
Name company	Did the TMT integrate at least one person with commercial experience and mindset? (0/1)	Did the commercial person have a technical background and/or experience? (0/1)	Did the commercial and technical team members have joint working experience at IMEC? (0/1)
SBEF1	1	1	1
SBEF2	1	1	1
SBEF3	1	1	1
SBEF4	0	N/a	N/a
SBEF5	1	1	1
SBEF6	1	1	1 (10 years earlier)
SBEF7	1	0	0
SBEF8	0	N/a	N/a
SBEF9	1	1	0

Note: N/a = Not applicable (since no people with commercial experience were on board, it was not possible to look at cognitive distance between commercial and technical team members).

The team just needed someone who would just pick up the phone and talk to people. Who knew how to approach a company, when to talk to management and when to talk to people in the field. I did not really need experience in the same sector of SBEF1 in order to do that; my industry experience had just taught me how to act in commercial contacts, irrespective of the sector.

The CEO further elaborates on the importance of the commercial function in SBEFs:

Often when you talk to (potential) customers, they talk about their "problem of the day." They do that in order to test your knowledge, and because they are really facing that problem at that moment. If I had had the technical people doing those meetings on their own, they would probably have thought that the "problem of the day" was the critical issue and would have spent months of development in order to solve it . . . only to discover that the "problem of the day" was not the main issue of the customer after all and that they had lost valuable time on a non-core problem. My industry experience helped to distinguish between core and non-core issues, and to help the technical people focus on the core developments.

This discussion leads to the following proposition:

Proposition 2: The more that the SBEF team incorporates both tacit knowledge about the technology and a commercial mindset, the greater the chances of reaching post-founding speed to first product that will lead to enhanced SBEF performance.

Integration of the tacit knowledge in the technology and commercial experience of the founding team will only occur if there is overlap of knowledge, experience, and frames of reference. In other words, when the cognitive distance between technical and commercial team members is not too large. Cognitive distance relates to differences in environments and conditions in which people have been raised that makes them interpret, understand, and evaluate the world differently (Berger & Luckmann, 1966). Some cognitive distance will allow people to stimulate and help each other to stretch their knowledge for the purpose of bridging and connecting diverse knowledge (Nooteboom et al., 2007). However, at the same time, cognitive distance cannot be too large, as mutual understanding is needed for collaboration and absorptive capacity (Cohen & Levinthal, 1990), and familiarity breeds trust (Gulati, 1995).

Our cases provide initial insights on cognitive distance in an academic spin-out context. Following Nooteboom et al. (2007) and Wuyts et al. (2005), for purposes of theory building, we abstract from many of the different dimensions of cognition and adopt indirect measures of cognitive distance relevant to our focus on the transfer of knowledge in the context of spin-outs. Specifically, we measure the different environments in which individuals within spin-outs have developed in order to obtain insights into their shared language, vision, cultures, frames of reference and conceptual filters, beliefs, and narratives. First, with respect to the ability of team members to read the codes and understand the frames of reference of other team members, we go beyond a simple count of the spread of functions across the team often used in previous studies to document whether there was a presence of particular commercial members in the team who also had technological knowledge. Second, we build on Beckman's (2006) insights regarding the role of common prior affiliations. As all our cases involved spin-outs from one research institute, we document whether the members had worked together before at IMEC. We then from our interviews provide evidence on how these measures were related to the interactions between team members. These measures are presented in Table 3. Our interviews then enabled us to explore more deeply the interactions between team members.

Common to our successful cases (except for SBEF4, see above) was the observation that team members with commercial experience also tended to have a technical background and/or expertise as well as experience working with IMEC. This commonality might reduce cognitive distance among team members. For instance, the CEO of SBEF1 comments on the interaction between him and an individual in the technical team as follows:

> The technical person and I thought of things in a different way. We would go to talk to customers, and when discussing the meeting afterwards, we often came to the conclusion that we had understood different things. But we could explain our visions to each other, and in the end, we always agreed on one common vision. At the time of acquisition of the company, the acquirers asked when the last time we had had an argument was. We could not think of any. We just had "fellow feeling" while at the same time thinking of things in different ways, and mutually enforcing each other.

On the importance of his technical background, the CEO of SBEF1 elaborates:

> I did not have any experience in the microelectronics industry, but I did have a technical background, which allowed me to understand the technology. It took me months to get familiar with it, but it allowed me to talk to the technical people. I needed to understand the technology to identify and contact the right people on the market, even though I would always have one of the technical people join me in meetings.

The CEO of SBEF3 provided similar explanations on why the commercial person should have technical knowledge. The commercial person in SBEF3 had also been the head of the research team at IMEC. He added the following on the importance of technical knowledge in the commercial function:

> You can only engage in high tech marketing and sales if you know what the limitations and potential of the technology are. First, customers are not only looking for good technology, but are also looking for a partner they can trust. If you know what they are talking about and understand their problem that will help to build trust. Second, you need to be able to narrow down the customer's request for technology to the core. Customers often do not need all things they ask for. And third, if you have a technical background, the technical team cannot fool you. I experienced that engineers are often risk-averse, and sometimes will tell you that what you want to realize is impossible. If you then understand the technology, that helps to offset their arguments.

Further, our cases point to the importance of previous joint working experience for reducing cognitive distance between commercial and technical people. The CEO of SBEF1 elaborates:

> It was a good thing that I and the technical people had worked together at IMEC before, even if that was only for one year. We had at least gone through a similar working experience before starting the spin-off, and it created a common ground, a type of mutual understanding that may have contributed to the "fellow feeling" we had.

The CEO of SBEF3 confirmed this view and added:

> If you have worked together before, you know what you can expect from each other, you know how to interpret each other's behavior and communication. Probably if we had worked together at another institute than IMEC, it would have worked out too.

Our evidence suggests that mutual understanding of the technology is a necessary condition for successful commercialization. The technical knowledge does not have to be identical, but the commercial person on the team needs the background to absorb the core technical knowledge and communicate it. In this way, the commercial person, who is the spokesperson for the company in first contacts with customers, can identify the right parties to talk to given the nature of the technology, and exclude costly loss of time through incorrectly targeted market efforts. Similarly, it is likely to help if the commercial person knows what is technically feasible. Therefore, there should be some cognitive distance (generated by the heterogeneity in the team), but this cognitive distance cannot be too large, and the cognitive maps of team members have to overlap at the level of technical knowledge.

Further, familiarity seems to breed trust, with previous joint working experiences between team members enhancing further collaboration, in line with Tsai and Ghoshal (1998), suggesting that founding team members with common prior company affiliations have a shared language, culture, and narratives. The fact that technical and commercial team members also had different working experiences induces sufficient cognitive distance to tell something new, but not so distant as to preclude mutual understanding, in line with suggestions made by Gulati (1995). As such, our indirect measures of cognitive distance indicate that knowledge overlaps originating in the commercial person's technical background and common prior working experience enhance post-founding speed to first product, whereas our case evidence suggests *how* these overlaps result in an enhanced performance.

Based on the above discussion we propose the following:

Proposition 3a: Overlaps in cognitive maps between commercial and technical team members originating in the commercial person's technical background will enhance post-founding speed to first product that will lead to enhanced SBEF performance.

Proposition 3b: Overlaps in cognitive maps between commercial and technical team members originating in common prior working experience will enhance post-founding speed to first product that will lead to enhanced SBEF performance.

Conclusions

This study has presented a first attempt to bring together insights relating knowledge transfer, TMT composition, and SBEF performance. We used a novel longitudinal inductive study comprising nine case studies of SBEFs that originated from IMEC, a top research institute in the area of microelectronics situated in Belgium. Our analysis shows that a higher proportion of inventors in the founding team and a knowledge composition in the team that involved both technical and a commercial mindset was associated with the transfer of the tacit knowledge required for higher speed to first product. However, we also show that the cognitive distance between the possessors of tacit knowledge surrounding the technology and the commercial people cannot be too large. Those SBEFs where the people who had commercial experience also had prior technical expertise and/or a technical background, as well as previous joint working experience were the most successful in achieving requisite speed to first product.

Implications

This research has a number of implications for TTOs, science-based entrepreneurs, the venture capital community, policy makers, and the academic community.

Implications for TTOs

For TTOs our results show that when speed to first product is important (which is often the case for high tech ventures [Eisenhardt, 1989b]), the transfer of the researchers who developed the technology will be crucial. Our research also confirms the importance of assembling a founding team whose members have complementary skills. In particular, consistent with prior research we find that a commercial mindset is also needed in the new venture. However, our study goes beyond previous research by revealing that the benefits of this commercial mindset will be maximized if the team member with commercial experience also has some technical expertise or background and if commercial and technical team members had joint working experiences.

Our results suggest that it will be hard to achieve successful commercialization by "pushing" the technology into the market without the commitment of the scientists who discovered/invented the technology. An important role for the TTO will lie in the stimulation of researchers to commercialize their technology and the creation of awareness of entrepreneurship as a potential career move within research communities. A bigger challenge facing TTOs, however, is how to balance the need to transfer scientists to new ventures while considering the implications of losing teams of researchers from the PRI.

TTOs should also be aware of the importance of assessing the stage of development of the technology at the time of founding, and the challenges that new ventures face when they are launched at an early stage of technological development. Nowadays, at IMEC, no spin-offs are created without prototype. This requires the availability of sufficient resources to finance the development of the prototypes.

Implications for Science-Based Entrepreneurs

Our study suggests that science-based entrepreneurs should be aware that their involvement and commitment will be crucial for the successful commercialization of the technology they developed. They should also be aware of the need to add commercially minded people to the founding team. Science-based entrepreneurs may be wary of team members with a commercial background, fearing that they will not understand the technology and will try to “push” the product to market prematurely. Our cases suggest that science-based entrepreneurs may be able to alleviate their concerns by introducing team members who have a technical background but who have also been able to acquire commercial expertise. Yet, commercial experience on paper does not necessarily mean that the team member has a commercial mindset. TTOs may have an important role to play in coaching team members to develop more of a commercial orientation in approaching problems and opportunities relating to the technology.

Implications for Venture Capitalists

For the venture capital community, our findings have implications for the screening of investments. The composition of the team is among the main features that venture capitalists look at when screening and evaluating an investment opportunity, yet this is particularly a problematical area in spin-outs from PRIs (Wright et al., 2006). Managerial and entrepreneurial experience of the team members is often given much greater credence than technical experience (Shepherd & Zacharakis, 1998; Tyebjee & Bruno, 1984). While the former types of experience are clearly important, the importance of technical knowledge (in particular tacit knowledge) should not be underestimated, especially in SBEFs. Our research shows that it is not sufficient for an investor to check the strength of the appropriation regime of the technology, which refers to the codified knowledge in the new venture, but also to look at the tacit knowledge, which will be crucial for translating the technology into a marketable product or service. Our research therefore calls for an increased attention by investors to the founding team as a whole, and for an increased attention to assessing the commitment of the initial developers of the technology and their cognitive distance to the person exerting the commercial role.

Implications for Policy Makers

Our research also has a number of implications for policy makers who have to a large extent directed their efforts on policy toward technology transfer. Much of the policy work on commercialization through spin-offs has been oriented toward the transfer of codified knowledge (Siegel, Veugelers, & Wright, 2007). Our research calls for greater attention by policy makers to the design of initiatives that may promote and support greater tacit knowledge transfer. We believe that governments have an important role to play in awareness creation toward commercialization in the research community, for instance, by setting up educational programs that specifically focus on commercialization of research results.

Implications for Research

We add to academic understanding, in the specific context of science-based entrepreneurial firms that are spin-outs from research institutes, of where knowledge resources come from (Ahuja & Katila, 2004). By providing a model for when knowledge in SBEFs is important and how it can be transferred effectively from the research institute to the SBEF, we contribute to Lockett et al. (2005)'s call to adopt KBV when studying SBEFs. The KBV of SBEFs suggests that a broader view of technology transfer needs to be assumed; one that includes the transfer of knowledge surrounding the technology. Apart from joining Lockett et al.'s concerns for an increased interest in knowledge and knowledge transfer, it indicates what type of knowledge and knowledge transfer matter under which conditions (cognitive distance) for successful commercialization. Prior theoretical developments have stressed the need to introduce commercial expertise into SBEFs spun-off from research institutes (Franklin et al., 2001; Vohora, Wright, & Lockett, 2004) as this introduces novel skills and knowledge that enables the firm to break away from the path dependence of the research institute environment (Ahuja & Katila). However, our insight is that there is a need to recognize a downside in that introducing commercial expertise without understanding the technology may introduce excessive cognitive distance such that there is insufficient absorptive capacity to transfer knowledge successfully. Being in possession of technical knowledge (e.g., having some technical experience and/or background) may help the commercial team members' interactions with customers because they understand if and how the product/service can be tailored to suit customer demands.

We also add to understanding of the nature of cognitive distance in the context of technological knowledge. Nooteboom et al. (2007) focused on the cognitive distance in the technological knowledge of alliance partners involving mainly established firms. In considering within-firm knowledge in new spin-out firms, we show that it is not only the distance with respect to technological knowledge that is important but also its juxtaposition with commercial knowledge. If cognitive distance is too great, the commercial team member may be unable to explain the relevance or implications of market information to the technical members. Not only does our research point to the importance of limited cognitive distance between heterogeneous team members, it also shows *how* this cognitive distance can be optimally reached.

Team members could be close with respect to technological knowledge but if someone does not possess commercial knowledge (specifically a commercial mindset), then performance will likely be adversely affected. Further, previous working experience between technical and commercial team members enhanced their mutual understanding. As such, we complement and extend previous research (Beckman, Burton, & O'Reilly, 2007; Ensley & Hmieleski, 2005) on team diversity, by illustrating *how* different types of team diversity (originating in background and prior joint working experience) affect team interaction and subsequently venture performance.

Overall, our insights contribute to the beginnings of a contingency perspective on the determinants of performance in SBEFs by integrating knowledge and upper echelon theories with cognitive distance.

Limitations and Directions for Further Research

This research has a number of limitations that lead to different directions for further research. First, our results included SBEFs that were spun off at an early stage of development and which failed. Further research should study a matched sample of SBEFs in these early stages of development that failed and succeeded in order to complement our findings on top management teams and SBEF performance.

Second, given that we measured success and failure using data on exit of the investment by the research institute, our findings do not allow us to draw conclusions on the long-term viability of the science-based entrepreneurial ventures. This is, however, only the case for two of the ventures studied, which are still in the VC portfolio. Yet, given that these two were in a commercialization phase at the moment that IMEC exited the investments, studying these cases in relation to their later performance probably would not change the conclusions of this research.

Third, this research allowed assessment of the effectiveness of the tacit transfer mechanisms that IMEC used, but does not assess any other transfer mechanisms. For instance, in Israel, at the Weiszman Institute in Tel Aviv, an incentive system exists that requires that the original researchers remain at the research institute, but do receive part of the proceeds of the venture that originates from the research activities. In this way, intrinsic motivation for tacit knowledge transfer is in place, without physically moving the original researchers to the new venture. Further research should assess the extent to which these new and specific types of tacit knowledge transfer are effective in enhancing SBEF performance.

Finally, as our focus is on theory building, further research is needed both to formulate the propositions we have developed into testable hypotheses and to go on to test those hypotheses on large samples. In terms of examining the relationships between tacit knowledge, cognitive distance, founding speed, and performance at the SBEF level, our study has identified some objective measures of tacit knowledge, such as the number of researchers joining the spin-off and the proportion of founding team that were original researchers. We have also identified indirect measures of cognitive distance between team members, notably whether the commercial person had a technical background and whether the technical and commercial people had joint working experience. Following Page West (2007), measuring cognition induces a number of methodological challenges, but more micro-oriented research could usefully develop psychometric scales to measure cognitive distance between team members more directly in a large-scale study.

Nevertheless, we have extended prior research that has focused on the TTO level to identify the most effective configurations of entrepreneurial teams for the commercialization of research, and in particular to understanding the link between knowledge, top management team composition, and venture success, at the SBEF level.

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