

Exploring the Impact of Technological Competence Development on Speed and NPD Program Performance

Nuran Acur, Destan Kandemir, Petra C. de Weerd-Nederhof, and Michael Song

With growing levels of competition across industries, technological competence is increasingly viewed as crucial for businesses to maintain their long-term competitive advantage. Although there are many theoretical arguments about how firms' competences can yield competitive advantage and performance improvement, we have a limited understanding of where the capabilities originate in the context of NPD or what kind of product portfolios, internal climate, and strategic alignment are required to build them. Moreover, empirical evidence for technological competence development is limited and comes primarily from case studies, anecdotal evidence, and management impressions. Accordingly, this research addresses these gaps by presenting and testing a conceptual model of technological competence development in NPD. This study makes advances in applying a dynamic capability approach to technological competence development in NPD, and investigates the impact of innovative climate, technological alignment, and project portfolio management on technological competence development as well as NPD speed. Moreover, the factors that might influence NPD program performance are also investigated. The analysis, based on data collected from 111 firms, shows that a firm's innovative climate, technological alignment, and portfolio management are positively associated with technological competence development. While technological alignment was found to be negatively related to NPD speed, portfolio management, and technological competence development were found to have positive effects on speed. However, innovative climate had no significant impact on speed. Moreover, technological competence development and portfolio management were found to be positively related to NPD program performance. Finally, no support was found for the relationship between speed and NPD program performance.

Introduction

With the growing levels of competition across industries, technological competence is increasingly viewed as crucial for businesses to maintain their long-term competitive advantage (Atuahene-Gima, 2005; Garcia, Calantone, and Levine, 2003; Li and Calantone, 1998; Nelson, 1991). Technological competences urge firms to acquire, develop, and use technology to achieve competitive advantage and to stay close to their customers (Hobday and Rush, 2007; McEvily, Eisenhardt, and Prescott, 2004). Technological competence development in new product development (NPD) reflects the values of the “technological push,” which emphasizes the development of technologically superior products and services (Gatignon and Xuereb, 1997). Such competences are intangible and interaction based and so are usually difficult for competitors to trade, imitate, or duplicate (Coombs and Bierly, 2006; Day, 1994; Nelson, 1991).

Dynamic capability literature has examined the determinants of technological competence development and their impact on performance. To date, the effect of technological competence on firms' performance has been studied primarily in the technology management literature. These studies have consistently showed that technological competences impact on the best performance (e.g., Coombs and Bierly, 2006; Danneels, 2007; McEvily et al., 2004; Pisano, 1994; Song et al., 2005; Zahra, 1996). In other words, firms with superior technological competences tend to be more innovative and thus develop better product performance (McEvily et al., 2004). Although there are many theoretical arguments about how firms' competences can yield competitive advantage and performance improvement, we have a limited understanding of where the capabilities originate or what kind of product portfolios, internal climate, and strategic flexibility to search new (technological alignment) are required to build them. On the other hand, evidence for competence development in NPD is limited and comes primarily from case studies, anecdotal evidence, and management impressions (Montoya-Weiss and Calantone, 1994; Song et al., 2005). This

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paper addresses these gaps in the research by presenting and testing a conceptual model of technological competence development in NPD.

BIOGRAPHICAL SKETCHES

Dr. Nuran Acur is senior lecturer in operations and innovation strategy at the University of Strathclyde in Glasgow, United Kingdom. She received her Ph.D. in strategic management from the University of Strathclyde. Previously, she worked at Aalborg University and Bilkent University. She has been serving as a board member of European Operations Management Association since 2006. She has published articles in the areas of operations strategy, product innovation, and service innovation. Her work has appeared in the *Journal of Product Innovation Management*, *International Journal of Operations & Production Management*, *Creativity and Innovation Management*, *Supply Chain Management: an International Journal*, and other scholarly journals.

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By synthesizing technology management, strategic management, and NPD literature, this paper attempts to link technological competence development with the strategic dimensions of firms' dynamic capabilities. This includes portfolio management, technological alignment and innovative climate, and the impact on NPD speed and program performance. In recent research, Parry et al. (2009) studied the impact on perceived cycle time of six variables that reflect a business unit's NPD strategy, NPD environment, product strategy, and NPD process. This paper expands on that research by examining three strategic dimensions of dynamic capabilities and their impact on NPD speed and technological competence development and NPD. This study makes advances in applying a dynamic capability approach to technological competence development by assessing its importance to the relationship between the dimensions of dynamic capability and NPD speed and program performance. The study examines the direct effects of the dynamic capability's dimensions on NPD.

The hypotheses are tested using data collected from 111 European firms. The findings indicate that portfolio management, innovative climate, and technological alignment are antecedents to both technological competence development and NPD speed, which in turn are antecedents to NPD program performance.

The next section reviews the literature, highlighting the importance and multiple dimensions of technological competence development. Drawing on a dynamic capability perspective, the paper advances the relationship among dynamic capabilities dimensions, NPD speed, and technological competences development in the NPD context. It then presents a study empirically testing these hypotheses, followed by a discussion of findings and their managerial and academic implications.

Background

The notion of competences is rooted in the resource-based, dynamic capability and knowledge-based theories. All of these theories explain how competences, such as technological competences, create competitive advantages in markets; however, they underline different levels of dynamism (McEvily et al., 2004).

The development of a resource-based view (RBV) provides a clearer understanding of when resources and capabilities are likely to have positive effects on new product outcomes and developing and maintaining

competitive advantage (Kleinschmidt, de Brentani, and Salomo, 2007; Wernerfelt, 1984). The RBV views the firm as a bundle of resources and emphasizes that firms are heterogeneous due to their unique resources, capabilities, and endowments (Barney, 1991; Grant, 1991). The dynamic capabilities view underlines that competences need to change over time to respond to changing environments to attain and sustain competitive advantage (Eisenhardt and Martin, 2000; Helfat, 1997; Sanchez and Heene, 1997; Teece, Pisano, and Shuen, 1997). This view also places more emphasis on learning and innovation (Nelson and Winter, 1982; Prahalad and Hamel, 1990; Teece et al., 1997). The knowledge-based view of the firm suggest that organizations can play a critical role in articulating and applying different types of knowledge (e.g., technological, market) through transfer or replication as well as integration and coordination efforts (Galunic and Rodan, 1998; Grant, 1996; Kogut and Zander, 1992).

Most scholars consider technological competence as a firm’s ability to make effective use of technological knowledge and learning to develop and improve products and processes (Kim, 1997; McEvily et al., 2004). Therefore, this paper’s approach draws mainly on a dynamic capabilities approach to investigate the role of technological competence development in the new product development context. In a similar vein, technological competences, for the purpose of this research, are defined as the set of activities and behaviors implemented to detect and shape opportunities and threats, to seize opportunities, and to maintain competitiveness through enhancing, combining, protecting and, where necessary, reconfiguring firms’ tangible and intangible resources.

Conceptual Model

Dynamic capabilities are seen as a vehicle for creating or renewing the organizational capabilities or specifically technological capabilities of firms (Easterby-Smith and Prieto, 2008; Eisenhardt and Martin, 2000; Teece et al., 1997). Many scholars (ibid.) claim that dynamic capabilities help firms not only to identify opportunities but also to formulate responses to opportunities to implement courses of action. Therefore, investigating performance effects of technological competence development as an element of a firm’s strategic dimensions can be approached from the dynamic capabilities perspective (Eisenhardt and Martin; Teece and Pisano, 1994; Teece et al., 1997). Furthermore, Teece et al. also emphasize that capabilities can be assembled together from internal and external sources, which can also be considered part of a firm’s strategic dimensions of dynamic capabilities. Figure 1 shows the internal (i.e., innovative climate, project portfolio management) and external (i.e., technological alignment) sources of a firm’s dynamic capabilities, technological competence, and performance constructs.

Three strategic dimensions of dynamic capabilities are considered: positions, path dependency, and processes (Schreyögg and Kliesch-Eberl, 2007; Teece and Pisano, 1994; Teece et al., 1997). Position refers to a firm’s internal and external positions. The internal position associates with the available set of a firm’s soft and hard resources (i.e., financial, technological, innovative climate, reputation), whereas external position refers to its specific market position (Teece et al.). Innovative climate is considered one of a firm’s soft resources (Salomo, Talke, and Strecker, 2008).

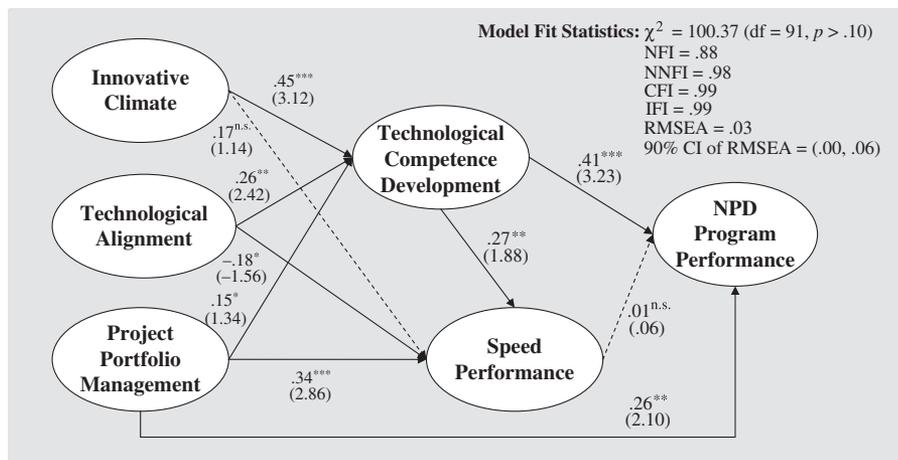


Figure 1. Antecedents and Consequences of Technological Competence Development in NPD^a
^an.s., not significant (one-tailed test). *t*-values in parentheses. NFI, normative fit index. NNFI, nonnormative fit index. CFI, comparative fit index. IFI, incremental fit index. RMSEA, root mean square error of approximation.

Employees in an innovative climate are more open to new ideas and more willing to change and adapt to emerging technological and market trends (Hurley and Hult, 1998). Thus, “internal position” is related to *innovative climate*.

Path dependency refers to the strategic alternatives available to firms today and also their future directions depending on current paths and how different forces have already shaped their preferences (Schreyögg and Kliesch-Eberl, 2007; Teece and Pisano, 1994). At any time, firms follow certain path dependencies. Specifically, technological path dependencies initiated by a firm’s technological choices orientates it into a specific technological trajectory (e.g., Ruttan, 1997; Schilling, 1998). Clearly, “path dependency” closely relates to *technological alignment*. Technological alignment refers to a firm’s ability to foresee and develop new product technology and related processes. Hence, technological alignment increases an organization’s awareness of technological competence development possibilities, which are then communicated to the NPD function through the NPD–technological interface (Li and Calantone, 1998). Accordingly, firms tend to advocate a commitment to a better technological alignment with NPD.

Processes refer to coordinating and integrating available resources (Schreyögg and Kliesch-Eberl, 2007) or organizational learning, local searches, feedback, experience curves, and the reconfiguration of resources (Helfat and Raubitschek, 2000; Zollo and Winter, 2002). With regards to the coordination and integration of NPD activities to development competences, processes relate to *portfolio management*, which can be described as a dynamic decision process that involves the coordination of available resources across new product projects, which are selected based on their potential value to business (Cooper, Edgett, and Kleinschmidt, 2001).

In NPD, dynamic capability research considers performance measures in relation to competitive advantage. Taking this into consideration, this paper focuses on both internal operational efficiency (e.g., speed) capturing more short-term benefits within organizational contexts (Brown and Eisenhardt, 1995; Dröge, Jayaram, and Vickery, 2004), and long-term, external competitiveness criteria (e.g., NPD program performance). Specifically, some researchers have stated that competences have a positive impact on NPD performance outcomes, namely, the proportion of new product speed and new product success in the marketplace (Dröge et al., 2004).

Following the conceptual model, these capability dimensions are suggested to represent firms’ proactive strategic abilities to cope with competitive challenges and to generate the best NPD performance through technological competence development. In addition, these strategic dimensions are also critical catalysts of short- and long-term NPD performance. Technological competence development is suggested to increase firms’ speed and NPD program performance. Hence, the conceptual model proposes both a positive direct performance effect on strategic dimensions of firms (i.e., portfolio management, technological alignment, and innovative climate) and a mediated performance effect via technological competence development in NPD.

Hypotheses

Innovative Climate

Siguaw, Simpson, and Enz (2006, p. 560) characterize innovative climate as “composed of a learning philosophy, strategic direction, and transfunctional beliefs that, in turn, guide and direct all organizational strategies and actions, including those embedded in the formal and informal systems, behaviors, and competencies, and processes of the firm to promote innovative thinking and facilitate successful development, evolution, and execution of innovation.” Accordingly, firms with a more positive innovative climate are expected to be more likely to increase their technological competence development as well as NPD speed.

Innovative firms focus on identifying and exploiting new product market opportunities and are more likely to pursue really new and radical innovations, which require state-of-the-art technology (Calantone, Garcia, and Dröge, 2003). Consequently, such firms proactively scan their environments and are more willing to make necessary investments to acquire, integrate, and reconfigure their technological knowledge to support innovation even though their efforts might result in costly failures (Grupp, 1998). Because the learning aspect of innovative climate encourages openness to innovation (Zaltman, Duncan, and Holbek, 1973) and risk-taking behavior (Amabile, 1997; Atuahene-Gima and Ko, 2001), it stimulates experimentation with new technological ideas as well as organization-wide learning (Siguaw et al., 2006). Finally, innovative climate underlines the unification of various functions guided by the shared future

concept of the firm and considers innovation as critical to success, which thereby leads to technological competencies (ibid.). On the basis of this discussion, the following is proposed:

H1a: The higher the innovativeness of a firm, the greater its technological competence development.

The positive contribution of innovative climate to NPD speed has been noted by researchers (Calantone et al., 2003; Gupta and Wilemon, 1990; Sigauw et al., 2006). Innovative firms can be characterized by their capacity to introduce new products and their willingness to devote the necessary related NPD effort and resources. The learning philosophy aspect of innovative climate reinforces openness to new ideas, allows employees to work together, and gives them the freedom to make their own decisions (Brown and Eisenhardt, 1995; Cooper, Edgett, and Kleinschmidt, 2004), which altogether can lead to higher levels of NPD speed. Moreover, innovative climate is strategically planned to stimulate organization-wide commitment to faster innovations (Amabile, 1997; Hurley and Hult, 1998; Worren, Moore, and Cardona, 2002). Finally, innovative climate encourages the dissemination of common beliefs, values, and understandings so that firms act as collective bodies (Amabile; Worren et al.) and thus achieve time efficiency in carrying out their NPD activities. Accordingly, the following is proposed:

H1b: The higher the innovativeness of a firm, the higher the speed of its NPD process.

Technological Alignment

This paper defines *technological alignment* as the extent to which technological developments guide a firm's NPD activities (Gatignon and Xuereb, 1997; Voss and Voss, 2000; Zhou, Yim, and Tse, 2005). Firms systematically monitor trends in existing technologies, identify the latest technologies, and allocate resources to product development projects accordingly to achieve an alignment between their NPD strategy and activities and technological environment (Chiesa, Coughlan, and Voss, 1996; Gatignon and Xuereb, 1997). Deriving from organizational learning theory, the present study argues that technological alignment should affect the information that a firm acquires, evaluates, and ultimately accepts or rejects. Organizational learning can be characterized as a process involving knowledge acquisition, distribution,

and use activities through which a firm's behavior changes (Huber, 1991). Researchers note that technology orientation encourages knowledge-learning behaviors (Noble, Sinha, and Kumar, 2002; Zhou et al., 2005) and enhances competence development. Similarly, Gotteland and Boulé (2006) report a positive relationship between technological orientation and the use of knowledge about technology in NPD. In line with these studies, the present research further investigates this relationship and suggests that technological alignment should stimulate a firm's development of technological competence in NPD. Firms that underline the critical role of technological alignment in NPD are heavily committed to research and development (R&D) and the application of new technologies. As technological alignment becomes more important for firms, they seek to acquire new technologies and ideas and thus increase the level of dissemination and integration of technological knowledge in NPD (Gatignon and Xuereb, 2007; Gotteland and Boulé, 2006). Accordingly, the following is proposed:

H2a: The better the technological alignment of a firm, the greater its technological competence development.

NPD speed refers to the time taken to bring a product from idea generation to market launch (Barczak, Sultan, and Hultink, 2007). Driven by the learning orientation literature, previous research has suggested that technological alignment should accelerate the information processing of firms (Noble et al., 2002; Zhou et al., 2005). That is, firms with a good level of technological alignment continuously collect information about the latest technological developments and sense the technological changes in their environment; thus, they can quickly integrate new and better technological solutions into their product development. Moreover, technological alignment enables firms to have a clearer sense of which technological areas to direct their product development activities and what direction to pursue. This accelerates the product development activities ranging from initial development efforts to ultimate commercialization. In accordance with this view, Eisenhardt (1989) also suggests that real-time information about a firm's environment should speed decision making. However, Eisenhardt draws attention to the distinction between real-time information and planning information and argues that planning information might have adverse effects on decision-making speed because it attempts to predict the future. Based on Eisenhardt's argument, it would be expected that

firms emphasize technological alignment to search for information about future technological trends and developments and focus on planning information. Consequently, technological alignment should slow down the NPD process. Therefore, the following is hypothesized:

H2b: The better the technological alignment of a firm, the lower the speed of its NPD process.

Project Portfolio Management

Project portfolio management can be defined as “a dynamic decision process, whereby a business’s list of active new product (and R&D) projects is constantly updated and revised” (Cooper et al., 2001, p. 31). A study by Barczak, Griffin, and Kahn (2009) shows that the most popular techniques used by firms to review their portfolios are rank ordering of projects, discounted cash flow, and payback periods (used 65%, 61%, and 61% of the time, respectively). Although the benchmarking evidence has identified portfolio management as one of the critical NPD practices employed by the best-performing firms (Barczak et al.; Cooper, 2009; Cooper et al., 2001), there is very little, if any, empirical research on the role of portfolio management in NPD. Consequently, this study explores the link from project portfolio management to technological competence development, NPD speed, and NPD program performance.

Deriving from a dynamic capabilities perspective, which considers organizational learning as critical in creating rent-generation capabilities, this study describes technological competence development as a continuous process involving the acquisition, integration, and reconfiguration of technological knowledge leading to new products (Teece et al., 1997). It has been suggested that technological competencies require many years to become developed and thus should be based in long-term planning (Scott, 2001). Accordingly, portfolio reviews become critical for firms to be able to balance short- and long-term goals associated with NPD strategy (Cooper et al., 2001). Managing a portfolio provides firms with a strategic direction in selecting and planning new product projects and hence determines which technologies should be acquired and developed for organization-wide learning. Moreover, portfolio management enables people to understand why they are working on a certain project by providing visibility for all projects and eliminates the communication barriers between

functions and thus enhances organization-wide learning (ibid.). As such, R&D teams are observed to gain better skills and be more successful when they are guided by portfolio planning (Kleinschmidt and Cooper, 1995). In line with these arguments, it would be expected that portfolio management to stimulate technological competence development. Accordingly, the following is posited:

H3a: The better the portfolio management of a firm, the greater its technological competence development.

This paper also proposes that portfolio management increases the speed of NPD process. Poor portfolio management might result in a pipeline of many marginal-value projects and thus might decrease the amount of resources available for the best projects (Cooper et al., 2001). Insufficient resources, in turn, will slow down the NPD process. In contrast, effective portfolio management can enable firms to achieve the right balance between resource availability (e.g., people, days, money) and the number of projects (Barczak et al., 2009; Cooper, Edgett, and Kleinschmidt, 2004). For example, a study by Kessler and Chakrabarti (1999) shows that new product projects progress faster as the firm has fewer projects in its pipeline competing for resources. Moreover, portfolio reviews enable firms to select and prioritize the high-value projects and accelerate them by allocating resources accordingly (Cooper, 2009). In sum, firms can reduce the time to market or increase the speed of NPD processes by focusing their resources on the “right” projects (Cooper et al., 2001). Therefore, the following is proposed:

H3b: The better the portfolio management of a firm, the higher the speed of its NPD process.

Finally, portfolio management is expected to increase NPD program performance. Cooper et al. (2004) show that best performers can be distinguished by their portfolio management practices. Such firms seek to create a portfolio that contains profitable, high return NPD projects for the business. Consequently, they can attain a better focus by allocating resources to the right projects. Portfolio management also enables firms to achieve the right balance in the number of incremental versus radical projects and short-term versus long-term projects so that they can simultaneously proceed with several NPD projects at different phases and continuously introduce new products. Based on this discussion, this study argues that portfolio management allows firms to maximize the value

of the product portfolio, to efficiently allocate resources, and thus to increase the return on R&D spending (Cooper et al., 2001). Moreover, by achieving the right balance and focus, firms are more likely to meet customer requirements in the marketplace and increase sales (Cooper et al., 2001; Kahn, Barczak, and Moss, 2006). Therefore, the following is proposed:

H3c: The better the portfolio management of a firm, the better its NPD program performance.

Technological Competence Development

Firms can develop technological competence by either refining or extending their existing technological knowledge (i.e., exploitation) or acquiring entirely new technological knowledge (i.e., exploration) (Atuahene-Gima, 2005; March, 1991). Thus, competence development involves additions to as well as modifications of a firm's existing technological knowledge, skills, or related routines (Bond and Houston, 2003; Day, 1994; Kogut and Zander, 1992). Building on the resource-based notion of valuable resources, a knowledge-based view suggests a positive link between competence development and a firm's performance (Grant, 1991). Thus, it would be expected that a firm with unique capabilities to create and exploit technological competence to achieve a higher NPD speed as well as NPD program performance. In support of this argument, there are studies acknowledging the positive effects of experiential learning or process knowledge on NPD speed (Ganesan, Malter, and Rindfleisch, 2005; Hult et al., 2000; Miner, Bassoff, and Moorman, 2001). In addition, a study by Hult, Ketchen, and Arrfelt (2007) reports partial support for the positive association between knowledge development and cycle time performance.

Moreover, technological competence development might lead to better NPD program performance by enabling a firm to achieve a product advantage that cannot be easily imitated by competitors (Cooper, 1985; Gatignon and Xuereb, 1997). Previous research provides evidence for the positive relationship between technological competence and NPD program performance (Calantone and Di Benedetto, 1988; Calantone, Schmidt, and Song, 1996; Song and Montoya-Weiss, 2001; Song and Parry, 1997). In sum, the following is hypothesized:

H4a: The greater the technological competence of a firm, the higher the speed of its NPD process.

H4b: The greater the technological competence of a firm, the better its NPD program performance.

Speed

As noted by several researchers (Carbonell and Rodriguez, 2006; Chen, Reilly, and Lynn, 2005; Kessler and Bierly, 2002), there is little empirical research on the consequences of NPD speed. Furthermore, the existing research produces inconsistent results about speed outcomes. Some studies indicated that speed has positive effects on NPD performance (Carbonell and Rodriguez, 2006; Kessler and Bierly, 2002; Lynn, Skov, and Abel, 1999), whereas others found no significant results for this relationship (Meyer and Utterback, 1995). In their study, Swink and Song (2007) investigated the relationship between the speed of each product development stage (i.e., business market analysis, technical development, product testing, and product commercialization) and project performance and found that only the speed of technical development stage is positively related to project profitability. This study further examines this relationship and suggests a positive relationship between speed and NPD program performance. The underlying premise here is that because faster new products are likely to contain the latest market ideas and technologies (Atuahene-Gima, 2003), they are more likely to be perceived as more current than competitors' (Ali, Krapfel, and LaBahn, 1995; Kessler and Bierly, 2002). Accordingly, firms with a speedy NPD process are expected to attain a better fit of its new product offerings with the market as well as higher financial results (i.e., sales and profitability) (Brown and Eisenhardt, 1995). Moreover, shorter cycle times implies that firms use resources efficiently and waste fewer resources on marginal activities (Swink and Song), thereby achieving greater returns. Thus, the following is proposed:

H5: The higher the speed of a firm's NPD process, the better its NPD program performance.

Methodology

Data Collection

The sampling frame consisted of 4,527 randomly selected firms from all nonservice firms listed in the European databases *EPO*, *Nnerhverv*, *Voitto*, *FME*, *Chamber of Commerce*, *Diagnose* and *DUNS*. A presurvey telephone inquiry was made to all 4,410

firms to verify the suitability of the company in terms of number of FTE in the NPD function and for requesting preapproval of participation. The study's sampling frame consists of 1,597 suitable companies that were identified. Of these 1,597 companies, 445 firms agreed to participate and provided a contact person. The surveys were administered separately by research coordinators in each of the countries, and data were pooled in a common database. An English version of the questionnaire was used in all four countries.

In administering the final survey, the total design method for survey research was followed (Dillman, 1978). The first mailing packet included a personalized letter, the survey, a priority postage-paid envelope with an individually typed return address label, and a list of research reports available to participants. The survey was sent to 445 firms that agreed to participate. The contact person (president, division manager, strategic business manager, new business program manager, or R&D director) was asked to distribute the questionnaire to a manager who has been involved in developing new products in their organization or who has knowledge of overall new product programs in their organization.

To increase the response rate, four follow-up mailings to the companies were sent. One week after the mailing, a follow-up letter was sent. Two weeks after the first follow-up, a second package with the same content as the first package was sent to all nonresponding companies. After two additional follow-up letters, questionnaires from 220 firms were received, representing a response rate of 49.44% (220/445). Of these 220 filled-in questionnaires, 111 questionnaires contained no missing values and represent this study's final sample.

The industries represented in the final samples are chemicals and related products; electronic and electrical equipment; pharmaceutical, drugs, and medicines; industrial machinery and equipment; telecommunications equipment; food, automotive, semiconductors, and computer-related products; and instruments and related products. The annual sales ranged from 1 million to 2.3 billion euros, and the total number of employees in the business unit ranged from 4 people to 14,000 people.

Measures

Multiple-item scales were developed based on new product development and strategic management literature. When predefined scales were unavailable to measure the factors in the present research, new measures were developed using the framework proposed

by Churchill (1979). Constructs were defined, an item pool was generated, and measurement formats determined. A list of items that would be potentially useful as measures was developed from the literature. The initial item pool was reviewed by a number of experts in academia and industry. On the basis of this review, some statements were dropped and others modified.

Innovative climate was measured by five items adapted from Ekvall's (1996) and Glick's (1985) studies. These items assessed the level of a firm's informal organizational arrangements that exist in its NPD system. *Technological alignment* was measured based on three items adopted from Cooper et al. (2004) and Albright and Kappel (2003). Together these items capture the degree to which a firm emphasizes the importance of identifying technological trends and areas in its NPD-related activities. *Project portfolio management* was measured using a five-item scale adopted from Cooper and Kleinschmidt's (1995) and Cooper et al. (2004) best practice scales. The three-item scale assessed the use of systematic project portfolio management by a firm's NPD function. In measuring innovative climate, technological alignment, and project portfolio management, a seven-point Likert scale ranging from 1 = strongly disagree to 7 = strongly agree was used.

Technological competence development was measured by five items adopted from Kessler and Bierly (2002) and Yam et al. (2004). This measure assesses firms' capabilities to acquire new technologies and ideas as well as to disseminate this knowledge throughout their organizations. *Speed performance* was measured using five items, which were adopted from previous new product development research (Griffin, 1997; Kessler and Bierly). According to Griffin's study, NPD processes involve five stages: concept generation, project evaluation, physical product development, manufacturing development, and commercialization. Accordingly, *NPD speed* in the present study is operationalized as the elapsed time between initial development efforts and the ultimate commercialization of the product relative to schedule. Finally, three items adopted from de Brentani and Kleinschmidt (2004) and Chiesa et al. (1996) were used as indicators of *NPD program performance* relative to objectives. These items assessed the sales, profitability, and fit of the NPD program with market. Seven-point Likert scales were used ranging from 1 = not at all achieved to 7 = very well achieved to measure technological competence development as well as speed and NPD program performance.

Analysis and Results

The Measurement Model

The psychometric properties of the measures were evaluated by using a confirmatory factor analysis (CFA) (Bagozzi, Yi, and Philips, 1991; Gerbing and Anderson, 1988). The CFA was fitted using the maximum likelihood estimation procedure with the raw data as input in EQS 6.1 (Bentler, 1995). After some items were dropped that had low factor loadings or high cross loadings, the confirmatory model fitted the data satisfactorily. Table 1 details the constructs and retained items.

The convergent and discriminant validity of the focal constructs was assessed by estimating a six-factor confirmatory measurement model. Each measurement item loaded only on its latent construct. The chi-square test for the theoretical variables was not statistically significant ($\chi^2_{(89)} = 99.88, p > .10$). Also, the ratio of chi square

to the degrees of freedom was 1.12 (89/99.88), which was below 4. The Bentler-Bonett normed fit index (NFI), Bentler-Bonett nonnormed fit index (NNFI), the comparative fit index (CFI), Bollen's incremental fit index (IFI), and the root mean square error of approximation (RMSEA) indicated a good fit with the hypothesized measurement model (NFI = .88, NNFI = .98, CFI = .99, IFI = .99, and RMSEA = .03) (Hu and Bentler, 1999) (Table 1). Furthermore, all the factor loadings were statistically significant ($p < .01$), and the composite reliabilities of all constructs were equal to or greater than the threshold value of .70 (Nunnally, 1978). Thus, it could be concluded that the measures demonstrated adequate convergent validity and reliability.

Discriminant validity was examined by calculating the shared variance between all possible pairs of constructs verifying that they were lower than the average variance extracted for the individual constructs (Fornell and

Table 1. Results of the Confirmatory Factor Analysis^a

	Scale Items	Standardized Loading	<i>t</i> -Value ^b
Innovative Climate AVE = 50.6% HSV = 33.0% CR = .70	1. There is time for people to develop unplanned new ideas.	.61	5.43
	2. There is a strong support for further development of new ideas.	.80	6.61
Technological Alignment AVE = 74.8% HSV = 18.0% CR = .90	1. We clearly identify technological areas that focus our NPD efforts.	.88	8.34
	2. Future technological trends are important in our NPD planning.	.85	8.11
Project Portfolio Management AVE = 67.9% HSV = 20.0% CR = .90	1. We have clearly defined goals for all our individual new products.	.80	9.24
	2. Systematic project portfolio management is in place.	.80	9.24
	3. The project portfolios are aligned with the business strategy.	.87	10.36
Technological Competence Development AVE = 67.2% HSV = 33.0% CR = .90	1. Our competence to explore new technological developments from inside the BU is well developed.	.76	8.74
	2. We can pass lessons learned on across organizational boundaries.	.92	11.52
	3. We can pass lessons learned on over time.	.77	8.97
Speed Performance AVE = 61.4% HSV = 20.0% CR = .80	1. Scheduled time is in line with total development time (TT).	.65	7.02
	2. Our Development time (DT) is satisfactory.	.72	7.92
	3. Our Total Time (TT) is satisfactory.	.95	11.30
NPD Program Performance AVE = 55.9% HSV = 26.0% CR = .80	1. Our new products meet customer requirements.	.73	7.79
	2. The impact of our NPD program on our sales level is positive.	.85	9.40
	3. We get good returns from our NPD program relative to our spending on it.	.65	6.85
Model Fit Statistics: $\chi^2 = 99.88$ (df = 89, $p > .10$)			
NFI = .88			
NNFI = .98			
CFI = .99			
IFI = .99			
RMSEA = .03			
90% CI of RMSEA = (.00, .07)			

^a AVE, average variance extracted. HSV, highest shared variance with other constructs. CR, composite reliability. NFI, normative fit index. NNFI, nonnormative fit index. CFI, comparative fit index. IFI, incremental fit index. RMSEA, root mean square error of approximation.

^b The *t*-values from the unstandardized solution.

Larcker, 1981). These results showed that the average variance extracted by the measure of each factor was larger than the squared correlation of that factor's measure with the measures of all other factors in the model (Table 1). Given these values, it was concluded that all the factors in the measurement model possess strong discriminant validity. In light of this evaluation, it was possible to conclude that all factors in the measurement model possessed both convergent and discriminant validity and that the CFA model fitted the data adequately (Table 1).

Hypothesis Testing

The hypothesized model was estimated by using structural equation modeling with the EQS 6.1 program. The results of the hypothesis testing are provided in Figure 1, along with parameter estimates, their corresponding *t*-values, and the fit statistics. Although the chi-square test was not statistically significant ($\chi^2_{(91)} = 100.37, p > .10$), the ratio of chi-square to the degrees of freedom was 1.10 (100.37/91), which was below 4. NFI, NNFI, CFI, IFI, and RMSEA indicated that the theoretical model had a good fit to the data (NFI = .88, NNFI = .98, CFI = .98, IFI = .99, and RMSEA = .03) (Hu and Bentler 1999) (Figure 1).

As reported in Figure 1, a firm's innovative climate ($\beta = .45; p < .005$) was found to have a significant effect on technological competence development, in support of H1a. However, its effect ($\beta = .17; p > .10$) on speed was not significant. Thus, H1b was not supported. In accordance with H2a, a firm's technological alignment was found to be positively associated with technological competence development ($\beta = .26; p < .05$). In contrast, technological alignment was negatively associated with speed ($\beta = -.18; p < .10$). H2b was supported as well. Project portfolio management was found to be positively associated with technological competence development ($\beta = .15; p < .10$), speed ($\beta = .34; p < .005$), and NPD program performance ($\beta = .26; p < .05$). Thus, H3a, H3b, and H3c were supported.

Technological competence was found to have positive effects on speed ($\beta = .27; p < .05$) and NPD program performance ($\beta = .41; p < .005$), in support of H4a and H4b. Finally, speed was found to have no significant effect on a firm's NPD program performance ($\beta = .01; p > .10$). Thus, H5 was not supported.

Discussion

This study adopts a dynamic capability view to show the drivers and performance outcomes of technolog-

ical competence development. Such competence developments are particularly challenging in a current dynamic environment. This is because little is known about the defining features or attributes of technological competence development that are unique to each firm. These are intangible and interaction based and so mistakes are costly and timely, and regaining lost ground on competitors is difficult. Moreover, this study suggests that this happens in conjunction with, and is facilitated by, a set of firms' strategic dimensions of resources and capabilities. Apart from two hypotheses, all others proposed in this study are supported by data.

Several of the hypotheses focus on how the strategic dimensions of firms' dynamic capabilities impact on technological competence development and accelerate NPD performance. For example, the creation of an appropriate climate enhances the technological competence development (H1a) and speed of its NPD process (H1b). The result is an innovative work environment that enables firms to seize and exploit new technological knowledge in line with product and market opportunities (Miles and Snow, 1978). Contrary to this study's expectations, innovative climate does not lead to higher levels of speed. This result also indicates that an innovative environment does not directly impact on NPD speed, although a strong indirect performance effect was observed. This result differs from the findings of previous studies that confirm that a strong orientation toward innovation allows employees to work together and give them the freedom to make their own work-related decisions as well as the time to enhance new product success (Calantone et al., 2003; Gupta and Wilemon, 1990; Parry et al., 2009; Zhou et al., 2005). For example, Calantone et al.'s study also confirmed that innovativeness is positively related to NPD speed. The development of technological competence might have a mediating role relating to changes in the environment. One explanation for the indirect performance effect could be that for developing technological competence, where goals are often unclear, there needs to be a certain amount of time and effort to determine all possible alternatives. Occasional divergent interpretations and subsequent conflicts between employees might also impede this enhancement and development process. It can be concluded that developing an innovative NPD climate increases NPD speed through developing technological competence.

Drawing from the broader learning literature (i.e., organizational learning and learning orientation), this

study offers a link from technological alignment to technological competence development and speed (H2a and H2b, respectively). The results were in accordance with expectations. Technological alignment is found to increase technological competence development, which is consistent with Danneels's (2002) suggestion that when a firm performs a broad technological search for NPD the learning activities add new competences for the firm. Also as expected, technological alignment appears to reduce NPD speed. This is in line with Kessler, Bierly, and Shanthi's (2000, p. 215) suggestion that "the process of external learning will slow down the new product development process in the later stages, such as technology development, than the earlier stages, such as idea generation." Hence, aligning technology too tightly with a product strategy, emphasizing the frequent and systematic monitoring of trends in existing technologies to identify emerging technologies, could lead to reduced NPD speed (Chiesa et al., 1996).

Several of the hypotheses describe how portfolio management positively influences technological competence development, speed, and NPD program performance (H4a, H4b, and H4c). These findings are critical to understanding the role of portfolio management in NPD. That is, firms that are able to implement the portfolio method are more likely to identify, integrate and reconfigure their technological knowledge (Cooper, 2009; Parry et al., 2009; Quiantana-Garcia and Benavides-Velasco, 2008). The data suggest that managers experience reduced NPD speed when they favor portfolio management in their technological competence development process. Furthermore, good portfolio management practices in NPD help firms to prioritize their projects as well as guide them about how to allocate human and other resources (Kahn et al., 2006; Parry et al.). On the other hand, if firms fail to manage project portfolios and cannot make efficient and effective resource allocation decisions, they might expect long cycle times, high failure rates, and unsustainable new program failures over a period of time (Barczak, Kahn, and Moss, 2006; Cooper, Edgett, and Kleinschmidt, 1998).

Finally, the findings are not consistent with an earlier study by Calantone et al. (2003) that predicted a positive relationship between NPD speed and NPD program performance (H5). A little surprising is the study's finding that the duration of NPD processes suffers from poor NPD program performance when dynamic capabilities dimensions vary. It would be preferred to expect that firms that have the capabil-

ities to switch technology when needed and that follow their technological competence trends and developments will enhance their program performance. It could be, however, that such firms are instead primarily focusing on organizational competence development (Winter, 2003) or market competence development (Day, 1994). Such competence development does not necessarily meet the quality, delivery, and price expectations of customers immediately (Christensen, 1997) because the technology and markets are new and unfamiliar for new product development, which could increase elapsed times.

Conclusions and Future Work

Based on a review of the dynamic capabilities and NPD literature, this study examined the factors that impact technological competence development and NPD speed and how they affect NPD success. A dynamic capability perspective used the following to explain these factors: innovative climate, technological alignment, and portfolio management. Past research studies have largely ignored the relationship between the strategic dimensions of dynamic capabilities, and firms' technological competence development and success in the context of NPD.

The analysis, based on data collected from 111 firms, show that the creation of an appropriate climate for innovation, the better technological alignment with NPD and the use of project portfolio management all contributed to the development of technological competence. The model also specified that innovative climate, technological alignment, and portfolio management are antecedents to both technological competence development and NPD speed, which in turn are antecedents to NPD program performance. The results also found that the indirect effects of innovative climate, technological alignment, and portfolio management on NPD speed occur through technological competence development.

Research contributes to the debate on how to define and measure technological competence. This study extends the technological competence development conceptualization from its application to research and development expenditures, citations counts, and patents (Coombs and Bierly, 2006; Hobday and Rush, 2007) to a more comprehensive measure. This paper adopts a conceptualization of technological competence to develop arguments

about where they originate and how they evolve through organizational learning. Coombs and Bierly showed that practitioners and academics recognize that there are many possible measures of technological competence, each of which might be appropriate for different types of products, contexts, and firms. The dynamic capability perspective on competence development presented in this paper elaborates on the rationale behind learning, opportunity recognition and reconfigurations of firms' resources.

Furthermore, previous research on new product development has generally considered the development process factors or organizational competence development as antecedents of new product performance (Brown and Eisenhardt, 1995). Few if any studies have investigated the nature of technological competence development as antecedent of new product performance. Our study contributes to this research stream by broadening it beyond the more prosaic factors to highlight the important role that technological competence development plays in enhancing new product speed and NPD program performance.

This study has several managerial implications. These findings could serve as a guide for technological competence development in NPD. Technological competence development is one of a firm's most important dynamic capabilities. It requires understanding and sensing opportunities as well as a collective, organization-wide learning for new product development. It is about finding new ways to reconfigure firms' tangible and intangible resources. In particular, these findings highlight three essential drivers of a firm's ability to develop technological knowledge and competences: technological alignment, innovative climate, and portfolio management. Firms need to concentrate their efforts on these three drivers. Since there are complementary interrelationships as well as conflicts between these drivers, managers need to develop a better understanding of which drivers they need to build and emphasize the most to seize and detect opportunities or how to enhance and reconfigure resources to remain competitive.

Implications for Future Research

This analysis indicates that the different internal (i.e., innovative climate, portfolio management) and external (i.e., technological alignment) dimensions of dynamic capabilities significantly influence technological

competence development. The three dynamic capabilities dimensions analyzed in this paper offer different but complementary paths to various types of NPD speed and program performance. The specific links between them and technological competence development will be extended in future research.

One research limitation was the geographic scope, which was restricted to European firms. Future work should extend the analysis of the observed mediated role of technological competence to other geographic regions. For example, how does the innovativeness of firms appear in Far Eastern, North American, South American, or Pacific Rim nations? What are their product portfolios? How do these factors (i.e., innovativeness and project portfolio management) affect technological competence development, and what are their effects on speed and NPD program performance? Since the data used in this study are cross sectional, the firms included in the sample might be at various stages of technological competence development. To avoid this, future research should consider longitudinal data to understand how technological competence development takes place and accumulates over time. With multitime data, it would be possible to address such questions as (1) how does technological competence actually develop over time from concept to implemented reality, and (2) do firms acquire competences in different processes sequentially?

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