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Effectiveness of technology investment: Impact of internal technological capability, networking and investment's strategic importance

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ABSTRACT

This study considers a firm's technological capabilities and the strategic importance of technology investment as critical factors affecting the effectiveness of technology investment. Drawing upon a sample of 139 Greek manufacturing SMEs the study presents arguments and formulates hypotheses concerning the individual and interaction effects of internal technological capability and networking on technology investment effectiveness. It also examines the direct and moderating effects of strategic importance of technology investment. Results suggest that internal technological capability is a powerful determinant of technology investment effectiveness. Networking appears to complement internal capability creating synergistic effects whereas it cannot act as a substitute of it. Strategic importance of technology investment seems to have an important direct influence. It also moderates positively the relationship between networking and technology investment effectiveness. These results highlight the factors behind successful technological change and provide evidence on the working of "interactive dynamic capabilities" in the context of technology investment.

1. Introduction

Questions about the relationship between technology investment and its outcomes have entangled researchers and managers for long. The assumption is that the benefits from or effectiveness of technology investment, apart from the properties of the investment per se, depend on an organization's ability to integrate technology into its operations. Technology investment effectiveness depends on a set of technological capabilities that are simultaneously positively correlated with both the investment itself and performance (Aral and Weill, 2007; Brynjolfsson and Hitt, 1995). The accumulation of such technological capabilities concerns the development of deeper forms of knowledge that is essential to maximize effectiveness of any technology investment (e.g. Zhou and Wu, 2010; Basant and Chandra, 2002; Bell and Pavitt, 1993).

Previous research has suggested that antecedents to technological capabilities can be found at the firm and network level (e.g. Grimpe and Kaiser, 2010; Lin et al., 2009; Rothaermel and Alexandre, 2009; Bell and Pavitt, 1993). However, empirical evidence in the issue is limited. Relatively little research has focused on evaluating the contribution of the simultaneous development of both internal technological capability and networking on effectiveness of technology investment. Although the independence of internal capability and networking has been addressed (e.g. Veugelers, 1997), the question of whether their interactions are complementary or substitutive in nature merits further investigation (Rothaermel and Hess, 2007; Cassiman and Veugelers, 2006). Furthermore, although it has been implied that technology investment properties (such as size or importance) can affect effectiveness when properly combined with technological capabilities (Oh and Pinsonneault, 2007), to our knowledge, no attempt has been made to examine the direct and interactive effects of strategic importance of technology investment.

The present study focuses on technology investment projects based upon evidence from manufacturing firms, with one project per firm. Drawing upon the resource based-view (Barney, 1991; Penrose, 1959) and the interactive dynamic capabilities perspective (Von Tunzelmann and Wang, 2007) it attempts to empirically verify: (a) the direct and interaction effects of an organization's internal capability and networking on technology investment effectiveness, and (b) the impact of strategic importance of technology investment, as perceived by the organization's managers, both directly and through interactions with both types of capabilities.

The study differs from previous work in three ways. First, by focusing on effectiveness as the "end result" or "outcome" of technology investment, it argues that there is a combination of

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both internal capability and networking that together, through their interaction, generate the knowledge necessary for effective technology investment. As already mentioned, extant research generally focuses on the analysis of the effects of only one type of these capabilities on successful technology investments. Concentrating on only one type implicitly assumes that most of the heterogeneity is located at the chosen type, whereas the alternate type is considered to be more or less homogenous. Furthermore, when focusing either on internal capability or on networking, researchers take it for granted that the focal type of capabilities is more or less independent from interactions with the other (Rothaermel and Hess, 2007). Taken together the assumption of homogeneity in and independence from alternate levels of technological capabilities are serious concerns that could lead to spurious empirical findings. Our study suggests that technology investment effectiveness depends very much on the interplay of an organization's internal technological capability with its networking. Furthermore the study, opting for the complementarity between the two, argues that an adequate level of internal capability is a prerequisite for the exploitation of resources and knowledge through networking.

Second, the study focuses on significant technology investments, such as establishment or expansion of production facilities with various levels of perceived importance for the overall competitiveness of the firm. It argues that "perceived strategic importance" of the technology in which a firm invests is a significant attribute, which influences the benefits the firm receives from investing in the technology in question. Previous research has either looked at technology in the aggregate, or lumped apparently diverse technologies together (Heine et al., 2003), without making any distinction according to their particular significance or strategic importance. This, however, blurs the findings and makes it difficult to interpret the results about effectiveness of technology investment. One possible explanation of why technology investments of the same size perform differently could be that they present different levels of perceived importance reflecting different levels of managerial attention and resources dedicated to the investment. Thus, the present study suggests that the impact of strategic importance of technology investment on its effectiveness may come directly but also through interactions with internal capability and networking.

Third, the study uses three different measures of technology investment effectiveness, related to "direct" contribution of investments. The investigation of technology investment value is often muddled by confusion over what is the value created (Hitt and Brynjolfsson, 1996; Kohli and Devaraj, 2003). In some cases, seemingly contradictory results are not contradictory at all because different measures of performance are being used, which are logically distinct, such as productivity improvement or profitability. Because different researchers have used different measures and different data sets, it is not easy to determine the cause of seemingly contradictory results (Hitt and Brynjolfsson, 1996). In this study, by employing three measures of technology investment effectiveness to the same data set we try also to investigate possible variations across distinct measures.

In order to empirically examine the questions pertaining to technology investment effectiveness the study is using data collected from 139 Greek manufacturing firms. Evidence from Greece, a small – by global market standards – country in the periphery of the EU, which is at the same time a member of the Eurozone, presents a particular interest because it can enrich the relevant literature. Most of the published studies use data from large developed economies rather than smaller ones. Besides, manufacturing firms in Greece are in a long process of adaptation in an attempt to play a more active role in open and highly competitive markets. During the early stages of post-war industrialization (1960s–1970s), many Greek firms have tried to compete in a relatively protected environment, based initially on low cost strategies. This was founded on the competitive advantage of low labour costs that countries such as Greece traditionally enjoyed over more advanced economies (Spanos et al., 2004). In the 1990s however the situation changed. The integration of Greece into the EU, its accession to the Eurozone and the opening to global competition has put pressures on the Greek firms to differentiate and become more efficient.

Success in this endeavour, however, required new approaches to company management and processes aiming at successful anticipation, acquisition and implementation of technology. In this context, technology investment is becoming a crucial issue for upgrading the business and its competitiveness. Nevertheless, research regarding the firm behaviour and the conditions to be fulfilled for successful technology investments remains limited. Viewed in this light, the present paper attempts to make a contribution to decision-making at the business level as well as to policy making.

The remainder of the paper is structured as follows. Theoretical background and hypotheses are developed in Section 2. Research methodology is presented in Section 3, followed by data analysis and results in Section 4. The results are discussed in Section 5. Conclusions and indications for future research are presented in the last section.

2. Theoretical background and hypotheses

2.1. Literature review and conceptual framework

Effectiveness of technology investment refers to the business value that is generated from the incorporation of a technology that is new to the adopting organization. It refers, therefore, to technologies that are being used for the first time by an organization, whether or not other organizations have previously employed them. Technology investment is generally intended to contribute to the performance of an organization (for a review of models presenting the impact of technology on performance see Heine et al., 2003), a fact that impel firms to invest important sums of money, expecting a substantial payoff. Yet evidence as to whether these expected benefits materialize is often contradictory (Brynjolfsson, 1993).

Explanations provided to account for the inconsistent results in the relationship between technology investment and performance have, among others, revealed issues associated with the lack of consensus on the specific factors driving this relationship. This partly results from the use of divergent theoretical frameworks (Oh and Pinsonneault, 2007).

The resource-based view of the firm (Barney, 1991; Penrose, 1959), typically considers technology investment itself to be a valuable resource that can directly influence a firm's performance when properly combined with other organizational resources and capabilities (Oh and Pinsonneault, 2007). For instance, several studies have shown that the scale of technology resources (e.g. size of technology investments) is strongly linked to performance (e.g. Barua et al., 1995). Yet establishing a direct relationship between the size of technology investment and performance can be problematic or even misleading (Soh and Markus, 1995) as technology capital per se cannot constitute the valuable, rare, inimitable and non-substitutable resource conditions that, according to the resource-based view, confer a competitive advantage to a firm. On this account several studies place less emphasis on the size of the technology investments and focus instead on the importance and scope of technology resources (e.g.

properties of technology investment) to assess the relationship between technology and performance (e.g. Bharadwaj, 2000).

The dynamic capabilities framework (Teece et al., 1997), extending the resource-based view, stresses the importance of tangible and intangible "specific assets positions" in shaping firm resources. Under this perspective, firms invest in particular types of technology resources and learn how to use them over time by developing asset specific skills and accompanying routines (Cohen and Levinthal, 1990). These technology resources are placed at the heart of a firm's competitive advantage because they are difficult to imitate, for two reasons. First, firms are unaware of their competitors' technology resource allocations and how they contribute to performance and second because technological capabilities development and learning opportunities are tied to firm's specific asset positions (path dependencies) (Dierickx and Cool, 1989). Viewed in this light, differences in technology investment allocations and differences in technological capabilities help shape the heterogeneous technology resources firms develop and explain variations in firm's performance (Aral and Weill, 2007).

While the resource based view provides a helpful theoretical perspective from which to evaluate the heterogeneity of firm performance, the existing technology literature suffers from two deficiencies. First, there is often an ambiguity in the definition and conceptualization of technology resources (Aral and Weill, 2007). Most current conceptualizations of technology resources equate potentially heterogeneous technology investments across firms by measuring total technology intensity, whereas some empirically confound resources with capabilities by not measuring both technology investments and technological capabilities simultaneously (Aral and Weill, 2007). Second, by focusing on the importance of the internal asset base of the firm researchers often neglect that network relationships may allow firms to create unique technology resource combinations (Rothaermel and Hess, 2007). Previous research highlights that the ability to leverage external networks can create relation specific assets and complementary capabilities (e.g. Dyer and Singh, 1998; Hernandez-Espallardo et al., 2011; Todtling et al., 2009). Yet, only a few studies have attempted to simultaneously examine the effects of both internally and externally generated capability on performance, providing mixed results. For instance, Nicholls-Nixon and Woo (2003) showed that internal and external R&D are related to different types of biotechnology-based output. Cassiman and Veugelers (2006) showed that internal R&D and external knowledge acquisition, in Belgian manufacturing industry, are complementary innovation activities, with the degree of complementarity being sensitive to various elements of the firm's strategic environment. In the same vein, Lin et al. (2009) provided evidence for the moderating role of an organization's internal capability on the relationship between network embeddedness and performance in R&D consortia in Taiwan. Lin et al. (2012) showed that R&D alliances are a complement rather than substitute for a firm's internal R&D. In addition, Rothaermel and Alexandre (2009) demonstrated that the relationship between the mix of internal and external technology sourcing and firm performance is an inverted U-shape. Such a relationship found also support by Grimpe and Kaiser (2010).

In an attempt to deal with these issues Von Tunzelmann and Wang (2007) have extended earlier interpretation of the meaning of dynamic capabilities, embedding them in a time-dependent and context-dependent environment. The authors challenge the view of the progenitors of the dynamic capabilities approach (Teece et al., 1997), who ally themselves more with the resource-based perspective and approach instead dynamic capabilities as "generalizing both the internalist, backward-looking, firm-level orientation of the RBV, seeing firm heterogeneity as rooted in non-imitable competences, and the externalist, forward-looking,

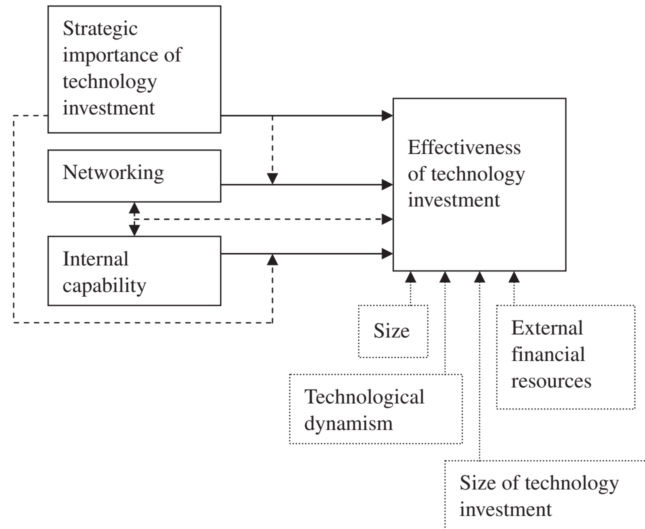

Fig. 1. Effectiveness of technology investment.

industry-level strategic management theories, on the grounds of the need to be abreast of and arguably ahead of the game" (Von Tunzelmann and Wang, 2007, p. 203). In this sense, they advance the notion of "interactive dynamic capabilities" as involving the extent to which the capabilities of an organization influence or are influenced by the capabilities of other organizations (e.g. suppliers, customers) occurring in real time. Technology investments form the proper ground for testing such interactions.

In this study we focus on specific technology investment projects. Technology investment decisions in this context are by their nature manifestations of strategic intent (Hamel and Prahalad, 1989), reflecting higher or lower levels of strategic importance. The firm's internal technological capability as well as existing and investment-specific networking relationships may affect the impact of technology investments per se and help to explain variation in their effectiveness. Fig. 1 depicts schematically our conceptual framework.

We investigate the effects of the firm's internal technological capability and networking separately but also interactively. These refer primarily to the existing skills of an organization, are antecedents to the advance of a specific investment project and may affect the way technology is adopted and absorbed. We further investigate the direct and moderating effects of strategic importance of technology investment. This reflects the level of attention the investment receives and may affect the level of resources and capabilities dedicated for the success of the focal investment.

As we shall argue later, all hypotheses here assume that the effects of internal capability, networking and strategic importance are positive. In addition to the direct effects, the level of networking may moderate positively the relationship between internal capability and technology investment effectiveness. Also the level of strategic importance may moderate positively the relationship between capabilities (both internal and networking) and the effectiveness of technology investment. Finally, the size of technology investment, firm's size, technological dynamism and external financial resources are used as controls affecting the effectiveness of technology investment.

2.2. *Hypotheses*

2.2.1. *Internal technological capability effects*

Internal technological capability refers to an organization's internally generated skills, experience and knowledge needed to initiate and manage change in the technologies used by the firm. The accumulation of such skills and stock of knowledge depends upon an organization's cumulative efforts and investments in both production activities and initiatives toward innovation (Dahlman et al., 1987). It is manifested as learning through the repeated performance of internal or endogenous technology related activities, thus involving learning that might take place within a firm in a variety of departments—not just R&D (Von Tunzelmann and Wang, 2007).

Most previous literature has focused mainly on R&D to express this internal capability (e.g. Coombs and Bierly III, 2006; Narayanan and Bhat, 2009). Focus on R&D efforts produces an intermediate good: firm-specific knowledge, which plays a dual role: first, it exerts an impact on the firm's ability to screen and access the available technological options; and second it enables the firm to put them in productive use and exploit technology benefits (Grimpe and Kaiser, 2010; Nicholls-Nixon and Woo, 2003). However, beyond R&D as a formally organized activity, an organization's technological knowledge is strengthened by the evolutionary acquisition and assimilation of information provided through continuous activation in the day-to-day technological activities of the firm (Jonker et al., 2006). Firms that systematically try to work-out internally their technological problems and adapt or upgrade their technological equipment without relying on third parties, increase their technological learning, which yields important intangible ''assets-stocks'', resources that cannot be instantaneously developed. In other words, further than learning based on in-house R&D (Von Tunzelmann and Wang, 2007) a firm internally generates also learning-by-doing (Arrow, 1962) and learning-by-using (Rosenberg, 1982).

Continuous investment in internal capability contributes to successful technology investment. It creates new and also expands existing technological knowledge and builds the skills required to identify, assimilate and exploit effectively the technological options offered to the firm (Cohen and Levinthal, 1990). More than adoption, it may involve significant adaptation and modification of technologies (Zahra and George, 2002), strengthening the ability to generate still more technology, thus facilitating the success of technical progress (Von Tunzelmann and Wang, 2007).

This internal knowledge is accumulated over time, implying that internal technological capability is path dependent and thus failure to invest in it at a given time may foreclose future options in technology (Cohen and Levinthal, 1990; Zahra and George, 2002; Cuervo-Cazurra and Annique Un, 2010). Therefore, heterogeneous distributions of internal capability across firms tend to persist over time (Helfat, 1994) and may constitute the basis for a pragmatic explanation of variations in the success of technology investments. Firms with high levels of internal technological capability have the potential to keep abreast of the latest technological developments, and are enabled to recognize, appraise and assimilate new technologies, so as to accomplish successfully any process of technological change (Helfat, 1997; Rothaermel and Hill, 2005). On the contrary, firms with a limited internal capability have poor judgment and enact a narrow set of necessarily simpler technological options. They consequently have fewer chances to evaluate the potential posed by advanced technologies and exploit the associated benefits (Schilling, 1998; Lin et al., 2009).

Thus, internal technological capability is implicitly the kind of valuable, rare, inimitable, and non-substitutable, resource that according to the resource based-view can form the basis of superior performance (Barney, 1991). Based on the above discussion we formulate the following hypothesis:

Hypothesis 1. The higher the level of a firm's internal technological capability the higher the effectiveness of the technology investment made by the firm.

2.2.2. *Networking effects*

Networking refers to an organization's fostering of external technological linkages that provide the basis for learning by interacting (Lundvall, 1992) and can contribute to the building of technological capabilities.

We have argued above that a firm's internal technological capability consists of accumulating the technological skills, experience and knowledge that are necessary for the successful investment in technologies.

While emphasizing the central role of internal generation, one must not assume that individual enterprises are isolated across the process of technological accumulation. An important part of the process of accumulating technological capabilities involves building various kinds of linkages within which firms can interact in leveraging unique technological resources combinations (Chen et al., 2011; Grimpe and Kaiser, 2010; Freel and De Jing, 2009; Lin et al., 2009; Rothaermel and Alexandre, 2009). Interaction may take place for the purpose of gathering information about technologies and markets, and also for obtaining various other inputs to complement the internal knowledge (Yam et al., 2011; Romijn and Albaladejo, 2002), such as part and components, external staff training, consulting services. Some of these linkages involve suppliers–customers relationships, others involve a wide range of technology collaboration arrangements between competing as well as complementary firms and others involve interactions with public assistance or other research institutions (e.g. Zeng et al., 2012; Romijn and Albaladejo, 2002). Through such linkages firms increase their network resources (Gulati, 1999) thus obtaining access to informational advantages and assets that create value, are not available for purchase in markets and require time to build up (Ahuja, 2000; Gulati, 1999).

For firms that lag in accumulation of internal technological capability, it is only logical to assume that they look to other organizations that have made substantial related investments in the past and seek to learn from their accumulated competence. But also for firms that enhance their efforts towards expansion of their capability it may be virtually impossible to keep abreast of all the relevant technological advances solely through internal generation. In industries characterized by complex and rapidly expanding knowledge basis, the locus of innovation often lies within a network of learning composed of various organizations rather than within the boundaries of individual firms (Powell et al., 1996; Nicholls-Nixon and Woo, 2003). In this context, the technological knowledge required for a firm to be able to choose an appropriate technology and efficiently assimilate it in order to maximize the benefits of its use, shifts outside the firms' internal capability.

A network of intense, embedded, technological ties positively affects technology investment effectiveness by providing opportunities for shared learning, transfer of know-how and resource exchange (Goes and Park, 1997). It seems logical that this tendency becomes more pronounced as the linkages in the network, in which a firm belongs, become more intense and as the number of the members of the network that have adopted the focal technology increases. This implies that a firm's network resources depend both on the intensity of its ties and the identity of its partners. Hence, we formulate the following hypothesis:

Hypothesis 2. The greater the extent of a firm's technological networking, the higher the effectiveness of technology investment made by the firm.

2.2.3. *Interaction between internal technological capability and networking effects*

Although we have implicitly hypothesized independent direct effects of internal capability and networking on effectiveness of technology investment, an interaction of these influences seems likely. This is to say that networking in the presence of internal capability is likely to have a particularly strong influence on effectiveness of technology investment.

It could be argued that the availability of networks assisting an organization to accumulate skills and knowledge may discourage and hence substitute for investment in internal technological capability (e.g. Cuervo-Cazurra and Annique Un, 2010). Viewed in the light of a constrained optimization decision, firms facing limited financial and managerial resources might need to choose between the accumulation of alternative types of technological capabilities in a discriminating fashion (Rothaermel and Hess, 2007). On the other hand, there are also arguments that stress the complementarity between investing in internal capability and networking. The desire to assimilate external knowledge creates a positive incentive to invest in internal capability. The existence of technological networks may stimulate rather than substitute the investment in internal capability especially when the latter is being optimally tuned to facilitate absorbing effectively knowledge through networks. Internal capability may reduce some of the inefficiencies and problems associated with leveraging unique resource combination through networks (Grimpe and Kaiser, 2010). However, when a firm does not emphasize the link between in-house development and through networks acquisition of technological capabilities, investing in internal capability may hamper rather than stimulate effective external linkages (Veugelers, 1997).

Without sufficient internal capability firms are not likely to recognize important development outside of their existing competencies (e.g. Kang and Park, 2012; Cohen and Levinthal, 1990) and this may limit their ability for successful technology investments. Moreover, a level of commonality between the firm's internal and network's capability may be necessary for successful knowledge exchange (Lane and Lubatkin, 1998; Rothaermel and Hess, 2007; Ahuja et al., 2009). In conclusion, technological capabilities needed for successful technology investment located at the intersection between the firm and network level complement one another (Cassiman and Veugelers, 2006) so that interactions across levels are positive and thus increase effectiveness of technology investment. Thus, we formulate the following hypothesis:

Hypothesis 3. Networking will have a greater influence on effectiveness of technology investment when internal technological capability is high.

2.2.4. Strategic importance of the technology investment effects

Strategic importance of the technology investment refers to the managers' and decision makers' perceptions of the potential strategic benefits resulting from the investment in a particular technology. These benefits relate to an organization's economic and broad competitive considerations.

Increased strategic importance enhances the perception that investing in such technology would improve an organization's competitiveness in the future. Perceived strategic importance of the investment may be seen as a subordinate expression of desired end-states that exerts a causal influence as antecedent to its implementation. Managers would direct their actions toward those desired-end-states (Van de Ven and Poole, 1995) supporting technology investment in multiple ways. This would be attributed to increased managerial attention (Ocasio, 1997) affecting the level of resources that the management team dedicates to the focal investment.

In this light, strategic importance may increase managerial efforts towards the implementation of the technology investment and strengthen the organization's implementation climate (see for example Klein and Sorra, 1996). Managers would support and pay more attention to integrate the technology in the organization's operation, yielding likely improvements in policies and practices (such as training and incentives for technology use). This would augment technology acceptance by organizational members (Davis et al., 1989). Furthermore, organizational members' confidence with values congruent with technology increases with the perceived importance of the technology in question. This has an impact on employees' attitudes affecting their commitment and appropriate use of the technology (Klein and Sorra, 1996), which in turn influence technology investment effectiveness. In other words, strategic importance reflects the degree of strategic intent (Hamel and Prahalad, 1989), explicit or latent that the technology investment possesses, which may be a significant determinant of effectiveness of technology investment.

We therefore suggest the following hypothesis:

Hypothesis 4. The higher the strategic technology importance, the higher the effectiveness of technology investment.

2.2.5. Interaction between capabilities and strategic importance effects

Apart from the direct effects of strategic importance, on effectiveness of technology investment, moderating effects through its interactions with internal capability and networking are likely. In other words both types of technological capabilities in the presence of strategic importance are likely to have a higher influence on effectiveness of technology investment.

As noted above, strategic importance encompasses the level of attention (Ocasio, 1997) the managers put in a technology investment, affecting their behaviour. However, in enacting a technology investment, a firm's capacity for action resides in its technological capabilities (e.g. Verona, 1999). Thus, while acknowledging the role of managers' intentions (e.g. Lin et al., 2009), their actions revolve around existing technological capabilities.

Technological capabilities either internally generated or through networking reflect the existing skills and routines of the host organization. They are antecedents to the advance of any technology investment project and may affect the way technology is absorbed and adapted in the specific context. However, the level of exploitation of those capabilities may depend upon the strategic importance of the investment. Managers will dedicate more efforts and resources in a specific technology investment project if the latter is perceived as important. Just the fact that an organization has the knowledge and capabilities to realize an investment does not guarantee that it will do so successfully. It could turn out to be a less successful investment because it did not attract sufficient attention by the managers so as to dedicate sufficient resources and capabilities to the relevant project.

In other words it seems that strategic importance mobilizing managerial attention and behaviour interacts with technological capabilities (generated either internally or through networks) and determines investment performance. Using Verona (1999) metaphor "players are essential in playing a game because without players there is no game… but once you have players ready to run the process, you also need to use the knowledge and leverage capabilities to play and win" (Verona, 1999: 138). In fact, managerial attention drives managers to devote resources and capabilities. Capabilities are leveraged by managers, while at the same time influencing their actions. Capabilities contribute to structuring the attention of individuals shaping organizational behaviour and, therefore, affect performance over time (Ocasio, 1997).

Thus we formulate the following hypotheses:

Hypothesis 5a. Strategic importance of technology investment has a greater impact on its effectiveness when internal technological capability is high.

Hypothesis 5b. Strategic importance of technology investment has a greater impact on effectiveness of technology investment when networking is high.

3. Methodology

3.1. Sample and data collection

The data utilized in this study have been obtained from a sample of 139 Greek firms drawn from seven manufacturing industries: food and beverages, textile, rubber and plastics, metal products and structures, non-metal products, paper and products, electric and electronic equipment. One technology investment project per firm was identified, for which data were collected. So the study focuses on the technology investment project as the unit of analysis with the firm and its environment providing the context in which the investment is enacted.

The sampling process, which resulted in the selection of the 139 firms, was completed in several steps, following a procedure similar to that described by Newbold (1995). First, the population of interest was defined to be the total of Greek manufacturing firms, belonging to the seven aforementioned industries and employing more than 30 employees. Firms employing less than 30 employees were excluded from the population for a number of reasons. Such very-small firms are less likely to have developed structures to deal with the issues of the current research that focused on major technology investments. Also data for very small firms are likely to be less reliable with gaps. Thus, the total population consists of 1173 manufacturing firms, as they were registered in the Greek financial directory "ICAP". Second, from this overall population of 1173 firms, 400 were randomly selected. Third, the CEOs of the 400 randomly selected firms were contacted via telephone-calls and the research instrument (i.e. questionnaire) was sent to them via e-mail or fax. Fourth, follow-up telephone calls were made after a couple of weeks following initial dispatch of the questionnaires. This was done in order to remind CEOs to respond providing also explanations about the purpose of the research. Finally, 139 CEOs agreed to participate in interviews and to provide the data used in the study. As seen in Section A.1 of , a sample of 139 firms is considered to be sufficient to make inferences about the general population. It should be noted also that there are no reasons to imply that the firms participating in the study are in any significant way different from the general population. Statistical *t*-tests to compare the sales distribution of the sample firms with the average in the population confirmed that the sample is at least structurally, reasonably representative.

To ensure data quality, the questionnaire used in the study was pre-tested twice before use in the normal course of data collection. In its draft form, it under-went a pre-test with two firms. Based on the first pre-test, several modifications were made, and the questionnaire was tested once more with two different firms. Following some minor modifications, we reached at a final form. Using this final questionnaire, personal interviews were conducted in the 139 firms that had agreed to participate in the study. The interviews were conducted by experienced researchers led by one of the authors.

The responders in each firm included the CEO and a top manager, who was familiar with the technology investment project. Thus the second respondent was either the top production/operations manager of the company or the project manager. The CEO provided data on the broader context of the firm (i.e. external environment, external linkages, strategies, management practices, firm capabilities, etc.) and identified the most significant technology investment decision made by the firm during the last 3 years (such as establishment or expansion of production facilities). The second responder provided then data concerning the details of the technology investment project in question. Finally, both respondents, in most of the firms, provided data about technology investment effectiveness, as they were both in appropriate positions to evaluate it.

The technology investment project, which was named by the CEO, was identified on the basis of the following two criteria. First, it had to be identified as the most significant among the portfolio of investments made by the firm in the last 3 years. Second, it had to be sufficiently recent (i.e. less than 3 years old) so that the respondent could recall all adequate information related to it but old enough (more than one year) to have an indication about its effectiveness.

3.1.1. Validity considerations

A study based on participant memory recall may have inherent limitations. The use of two key informants, the CEO and another manager, and the identification of the most significant technology investment decision, helped to reduce both single source bias and to enhance memory recall (Kumar et al., 1993).

Following received practice, we have paid considerable attention in this study to issues of content and construct validity. Content validity demands the identification of measurement items that represent the construct of interest. To ensure content validity we: (a) constructed most measures from existing and validated scales, (b) pre-tested the questionnaire, before its final use, to establish relevance with practice and eliminate wording problems and (c) addressed different parts of the questionnaire to different respondents to avoid common source bias, as it is already mentioned.

Construct validity requires the evaluation of the extent to which the empirical indicators actually measure the construct of interest. After an initial examination to eliminate items with low-item to construct correlation, we employed Confirmatory Factor Analysis to test the validity of our measures. As seen from Section A.1 of , the results provide reasonable confidence that our measures are valid and reliable.

Especially for technology investment effectiveness data were obtained, in most of the firms, from both respondents, allowing us to assess inter-respondent reliability. Overall, we received responses from two respondents in 81 firms (58% of the sample). A correlation analysis was conducted using the responses of the two interviewees in each firm. This analysis was performed for the three measures of technology investment effectiveness. Correlations coefficients ranged from 0.76 to 0.94 and were significant at the 0.05 level. These results provide strong support for inter-respondent reliability, suggesting that our measures for effectiveness of technology investment are reliable and do not reflect individual characteristics of one respondent.

3.2. Variables

Most of the measures of interest in the study were tapped with multiple questionnaire items, and were derived and adapted from existing validated scales. Respondents rated each item in one-to-seven Likert-type scales in which higher values were always associated with higher levels of the construct. Most of our measures have a perceptual character, because, due to their nature, they cannot be assessed objectively. The use of perceptual measures is supported by arguments made by many authors (see for example, Weick and Roberts, 1993; Dess and Robinson, 1984). These arguments maintain that people behave in accordance with their perceptions, and not with ostensibly objective data. It is also true that for most of the concepts in our study it is not possible to collect objective data at least for small and medium sized companies. However, given the heterogeneous sample used in our analysis and the potential significantly different accounting and investments adjustments during the time period in this study, the use of perceptual instead of archival data is even preferred (Powell, 1995). After all, the use of perceptual data is common in this type of research.

3.2.1. Dependent variable

Previous research on effectiveness of technology investment has used a variety of measures, depending on the level of analysis and its purpose. Effectiveness of technology investment has been examined at various levels of analysis encompassing individuals (Davis et al., 1989; Klein and Sorra, 1996), processes (Mukhopadhyay et al., 1997) or the entire organization (Swamidas and Kotha, 1998). Different questions have often been asked (Hitt and Brynjolfsson, 1996) with different implications for how managers, researchers and policy makers should view technology investments. For example, technology effectiveness has been often evaluated by an increase in productivity or by an improvement in business profitability. However, these measures are logically distinct (Hitt and Brynjolfsson, 1996). The first examines whether technology enables the production of "more output" for a given quantity of "inputs". The second considers whether firms are able to use technology to earn higher profits than they would have earned otherwise. The lack of uniformity of the measures for technology effectiveness further hampered by their use in different data sets makes it difficult to determine the cause of seemingly contradictory results (Hitt and Brynjolfsson, 1996).

The present study investigates technology effectiveness as the direct contribution of the technology in question instead of focusing on firm performance as the outcome of the technology investment. First, such a focus avoids the problem of reverse causality as it is not clear whether firm performance is the determinant or the outcome of the technology investment. Second, the contribution of technology investment to overall firm performance cannot be easily separated. As it is well known firms advance a number of technology investment decisions, which have synergy effects and permeate the whole organization.

To measure technology investment effectiveness we used the following three constructs.

3.2.1.1. Contribution to achievement of objectives. To measure the variable "contribution to achievement of objectives", we followed a four-step procedure, adapted from that developed by Dean and Sharfman (1996). First, informants were asked to identify, from a predetermined list, business objectives to which the technology investment was expected to contribute at the time the decision for the technology investment was made. Objectives included cost reduction, quality, product reliability, design, volume and product flexibility, speed, production capacity, brand name and new product introduction. Second, respondents were asked to evaluate each of these objectives in terms of their importance for the organization in a one to seven scale (1: not at all important, 7: extremely important). Third respondents were asked to rate satisfaction with the contribution of technology investment to the achievement of the previously identified objectives in a one to seven scale (1: insignificant contribution, 7: very significant contribution). Fourth, we calculated effectiveness of technology investment using the following formula, adapted from Dean and Sharfman (1996):

$$\sum_{i=1}^{n}\left[\left(W_i/\sum_{i=1}^{n}W_i\right)O_i\right]$$

where W_i is the importance of the ith objective, at the time the decision for technology investment was made; O_i the contribution of the technology investment to the achievement of the ith objective; n the total number of different objectives

This is our first dependent variable.

3.2.1.2. Improvement of productivity. Our second measure focuses on performance as conceived by improvement of productivity. This measure is often used to capture the value of technology investment (Hitt and Brynjolfsson, 1996). Respondents were asked to rate in a 1–7 scale their satisfaction with the impact of the technology investment to the organization's productivity.

3.2.1.3. Overall satisfaction. Our third measure focuses on overall satisfaction. The underlying assumption is that overall satisfaction is a desirable behaviour implying better performance (Davis et al., 1989). Respondents were asked to evaluate in a 1–7 scale overall satisfaction with the technology investment reached.

3.2.2. Independent variables

3.2.2.1. Internal technological capability. A composite measure was devised to capture the firm's internal technological capability adapted from the scale developed by Zahra et al. (2007). Respondents were asked to indicate, in a 1–7 scale, their assessment along five statements capturing multiple facets of their internal capability, thus offering a comprehensive measure of the construct. The five items used to capture internal capability refer to the capability of improving the equipment and the production process, ability to upgrade technology related to the firm's main products, skills in conducting R&D and overall self-generating technological capabilities (see Table A.1 of for details on the items). Actual R&D expenditures were not used as a surrogate for internal capability because not all internal capability is accumulated through explicitly acknowledged R&D projects (Schilling, 2002). The respondents' scores on the 5 items were summed and the total divided by five. This average score was used in the analysis. The overall index was reliable ($\alpha = 0.80$).

3.2.2.2. Networking. The networking measure reflects the extent of technological linkages formed by the firms of our sample. Although those linkages refer to standing collaborations built by the firms over time rather than linkages formed on the level of the specific technology investment project, they form the background to project linkages so they are directly associated to the effectiveness of technology investment.

The measure was adapted from Lee et al. (2001) and Romijn and Albaladejo (2002). Respondents were asked to indicate in a 1–7 scale the extent/intensity of their collaboration with five types of organizations: suppliers, customers, infrastructure and service providers, other firms with which the focal firm collaborates for technology development, universities or research institutions with which the firm collaborates in R&D projects and technology exchange programs. The respondents' scores on the 5 items were summed and the total divided by five. This average score was used in the analysis. Cronbach alpha equals 0.796.

To test the moderating effect of the networking variable we calculated the product term of networking with internal capability.

3.2.2.3. Strategic importance of technology investment. This measure uses a three-items scale, which captures the strategic importance attributed to the technology investment by managers at the time the decision was made. Respondents were asked to evaluate, in a 1–7 scale, the level of the benefits expected from investing in the technology for the competitiveness of the firm (see Table A.1 of for details on the items). The overall index was reliable ($\alpha = 0.78$).

To test the moderating effect of the strategic importance we calculated the product terms of strategic importance with internal capability and networking respectively.

3.2.3. *Control variables*

We also included four control variables that may contribute to the explanation of technology effectiveness, namely: size of technology investment, firm's size, environmental technological dynamism and availability of external to the firm financial resources.

The *size of technology investment* was used as a control variable because previous research has often considered technology capital as an independent production input that can affect a broad range of performance measures (see for example Barua et al., 1995). Several studies have reported a positive relationship between technology capital and technology outcomes. On the other hand drawing upon the resource-based view, which emphasizes the importance and scope of technology resources; there are arguments against establishing a direct link between the size of technology investment and its effectiveness. We take upon Bharadwaj et al. (1999) assertion that the size of technology investment is a necessary although not a sufficient factor that affects performance. We include in our analysis the size of technology investment measured by the amount of million euros spent for it to control for possible effect on effectiveness of technology investment.

The influence of *firm's size* in effectiveness of technology investment is postulated on the ground that large firms are in a better position to appropriate the returns of technology investments. "Company size might affect the rate firms develop their technological capabilities as well as their abilities to keep them cutting edge and competitive" (Zahra et al., 2007, p. 1075). Moreover large firms by definition own considerably more resources to allocate to technology investment in comparison with small firms. Because effective technology incorporation involves the use of human and organizational resources and capabilities, it may be suggested that larger firms are in a favourable position to manage a more effective technology investment (Damanpour, 1996). In this line size is expected to have a positive effect on technology effectiveness. Size was measured using the natural log of full-time employees.

Technological dynamism relates to the rate of changes taking place in the industry environment with respect to elements such as production processes, product features, and intensity of R&D activity. Technological responsiveness, which refers to the ability of firms to adjust their knowledge and skills in changing technological regimes, is becoming imperative for competitive survival. It may be argued that firms operating in a dynamic technological regime would have the opportunity to choose the right technologies. At the same time they face a chance of choosing the wrong technologies, which in turn could lead to bad performance. Several arguments have been advanced to show that established firms encounter difficulties when the technological basis of an industry is modified failing to adapt successfully to evolutionary technological changes (Christensen, 1997). Hence, we included technological dynamism to control for the effects that this may have on technology effectiveness. To measure this environmental dimension we adopted the scale developed by Spanos and Voudouris (2009). Technological dynamism was gauged by using a composite measure of three items (all of them in a 1–7 scale). It refers to the rate of change taking place in the market environment with respect to: production equipment and processes, product features and performance and R&D activity in the industry. Cronbach's alpha equals 0.780, providing a support for the reliability of the measure.

Finally, the *availability of external to the firm financial resources* was used as a control variable on the premise that easy access to financial resources may drive success in technology investment. It would lead to higher commitment and mobilization of adequate resources during the selection and incorporation phase of the specific investment, thus improving the benefits from the technology use. In general, financial resources are found to be a determinant of technology investment (Souitaris, 2001), as the latter is often too costly to be undertaken by organizations. After all public policy measures aim to improve access to funding. We used a 1–7 scale to gauge the availability of external financial resources.

4. Data analysis and results

The means, standard deviations and correlations of the variables are presented in Table A.2 of . Correlation coefficients are quite low, indicating that multicollinearity problems may not arise. Moreover for the regression model without the interaction terms the tolerance statistics are well above 0.50.

Table 1 presents the regression results for the effectiveness of technology investment indicating statistically significant coefficients (Models 1–6). Models 1 and 2 use contribution on achievement of objectives, models 3 and 4 use improvement of productivity and models 5 and 6 use overall satisfaction as dependent variables respectively. Models 1, 3 and 5 depict the baseline models including the control variables and all the independent variables. In models 2, 4 and 6 we have added the interaction term of internal capability with networking as well as the interaction terms of strategic importance with both internal capability and networking. Variables were standardized before the estimation of the interaction terms to avoid multicollinearity and to enhance the interpretation of the results (Cohen et al., 2003). As can be seen from Table 1 the predictive validity of the six models is reasonable.

In model 1 regressing contribution on achievement of objectives on internal capability, networking, strategic importance of the technology investment and contextual controls explains 30.4 percent ($p < 0.01$) of the variance in investment effectiveness. Model 2, in which the three interaction terms are added explains 37.2 percent ($p < 0.01$) of the variance in effectiveness. In model 3 regressing productivity improvement on the "main effects" variables explains 12.5 percent ($p < 0.05$) of the variance in effectiveness. Model 4, that comprises also the three interaction terms explains 17.7 percent ($p < 0.05$) of the variance in effectiveness. Finally, in model 5 regressing overall satisfaction on the "main effects" variables explains 19.6 ($p < 0.01$) percent of the variance in effectiveness as measured by satisfaction, whereas model 6 that includes also the interaction terms explains 23.9 percent ($p < 0.05$) of the variance. In all cases we examined the changes in R^2 (Cohen et al., 2003) between the restricted models 1, 3 and 5 and the full models 2, 4 and 6 respectively. The interaction terms added in models 2, 4 and 6 present a statistically significant improvement over the restricted models containing only the main effects (ΔR^2 0.068, $p < 0.01$ in model 2; ΔR^2 0.052, $p < 0.05$ in model 4; ΔR^2 0.044, $p < 0.05$ in model 6).

In models 1, 3, and 5, several controls appear to be statistically significant. More specifically, the size of technology investment bears a significant positive contribution on technology investment effectiveness as measured by achievement of objectives (0.986, $p < 0.05$ in model 1) although it is not significantly related neither to improvement of productivity nor to overall satisfaction. Firm's size appears to play a significant negative role in both

Table 1
Results of models explaining effectiveness of technology investment.

Variables	Contribution on objectives achievement		Productivity improvement		Overall satisfaction	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	−0.936**	−1.312***	4.451***	3.593***	5.458***	5.203***
Controls						
Size of technology investment	0.985**	0.992**	0.865	1.142	−0.243	−0.170
Firm's size	−0.286***	−0.284***	−0.477*	−0.472*	0.132	0.128
Technological dynamism	0.163**	0.091	0.306*	0.169	−0.104	−0.105
External financial resources	0.109*	0.125*	0.006	0.019	−0.102	−0.103
Independent variables						
Internal capability	0.203***	0.191**	0.545**	0.561**	0.294***	0.292***
Networking	0.104	0.165*	0.042	0.096	0.042	0.083
Strategic importance of technology investment	0.156**	0.171**	0.381**	0.404*	0.186*	0.090
Interaction terms						
Internal capability * networking		0.218***		0.297*		0.124**
Strategic importance * internal capability		0.137		0.005		0.063
Strategic importance * networking		0.178*		0.304*		0.048
R^2	0.304***	0.372***	0.125**	0.177**	0.196***	0.239**
ΔR^2		0.068		0.052		0.044
ΔF		3.686***		1.918**		1.683**

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.08$.

objectives achievement and productivity improvement (−0.286, $p<0.01$ in model 1; and −0.477 in model 3). Technological dynamism seems to have a positive impact on effectiveness of technology investment as measured by both contribution on achievement of objectives and productivity improvement (0.163, $p<0.05$ in model 1; and 0.306, $p<0.01$ in model 3). Finally, the availability of financial resources external to the firm seems to bear a significant positive effect on contribution on achievement of objectives (0.109, $p<0.08$ in model 1).

Hypothesis 1 stated that the higher the level of a firm's internal technological capability the higher the effectiveness of technology investment made by the firm. Results in Table 1 strongly support this hypothesis. Internal capability is found to be positively and significantly associated with all three measures of technology investment effectiveness (0.203, $p<0.01$ in model 1; 0.545, $p<0.01$ in model 3; and 0.294, $p<0.01$ in model 5).

Hypothesis 2 predicted that higher level of networking would increase the level of effectiveness of technology investment. The variable expressing networking does not support this hypothesis. The respective coefficients in all three models 1, 3 and 5 are statistically insignificant showing that there is no relationship between networking and effectiveness. It appears that networking does not produce direct contribution in the achievement of the objectives of the investment nor in improvement of productivity. Again the overall satisfaction with the technology investment does not appear to be affected by the level of networking.

Hypothesis 3 stated that networking in the presence of strong internal technological capability will have an important influence on technology investment effectiveness. Results in Table 1 do support this hypothesis. The interaction of networking with internal capability is positively related to effectiveness with statistically significant coefficients in all three models 2, 4 and 6 (0.218, $p<0.01$ in model 2; 0.297, $p<0.08$ in model 4; and 0.124, $p<0.05$ in model 6).

Hypothesis 4 predicted that strategic importance of technology investment is positively related to its effectiveness. Results support the hypothesis for all measures of effectiveness. Strategic importance is found to have a positive influence on effectiveness of technology investment in all three models 1, 3 and 5 (0.156, $p<0.05$ in model 1; 0.381, $p<0.05$ in model 3; and 0.186, $p<0.08$ in model 5).

Hypothesis 5a and 5b stated that strategic importance in the presence of strong internal capability as well as in the occurrence of intense networking will have a greater impact on technology investment effectiveness. With respect to internal capability, results in Table 1 do not support this hypothesis. No significant relationship was found between the interaction term of strategic importance—internal capability and effectiveness, although the signs of all coefficients are positive, in line with expectations. However, with respect to networking, results support the hypothesis. The interaction of strategic importance with networking is positively related to effectiveness with statistically significant coefficients in models 2 and 4 (0.178, $p<0.08$ in model 2; and 0.304, $p<0.08$ in model 4).

In order to confirm the effects of the interaction terms on technology investment effectiveness we conducted an additional analysis. We entered each interaction term one at a time following the baseline models (Brouthers et al., 2000). Results of the regression analyses for singular interactions are presented in Table A.3 of . The introduction of the interaction between internal capability and networking bears a significant change in R^2, in all three models regressing technology effectiveness, corroborating the validity of our results. Moreover, as expected, the introduction of the interaction between strategic importance of the technology investment and networking bears a significant change in R^2 in the models using contribution on achievement of objectives and productivity improvement to measure effectiveness.

5. Discussion of results

Overall, the results confirm the important role of internal technological capability on technology investment effectiveness and the moderating role of networking.

The significant impact of internal capability on technology investment effectiveness is in line with results from previous studies (Grimpe and Kaiser, 2010; Lin et al., 2009; Nicholls-Nixon and Woo, 2003; Schilling, 1998). It suggests that an organization's effort to embody technology in its processes and to introduce functional modifications and innovations in processes and products depends on prior technological knowledge, which has been accumulated from previous investments in broader technological activities and innovations. Our findings suggest that such knowledge build the necessary internal capability to recognize, understand, appraise and apply both existing tacit knowledge (Rosenberg, 1990) and knowledge generated externally (Cohen and Levinthal, 1990) so as to effectively select and deploy technologies. Internal capability seems to provide the basis for a successful technology investment, being necessary for the accomplishment of technological change. On the contrary, firms with a limited internal capability appear to have inferior technology investment outcomes. Probably these firms enact a narrower set of technological options and innovation thus having fewer chances to utilize the potential posed by advanced technologies and exploit the associated benefits.

As regards networking the findings seem to be inconsistent with some previous research (e.g. Yam et al., 2011; Freel and De Jing, 2009; Nicholls-Nixon and Woo, 2003), as they suggest that investing in networking linkages has no direct effect on effectiveness of technology investment. For networking to work, however, there may be certain preconditions. Of critical importance would be prior knowledge accumulation (Grimpe and Kaiser, 2010; Lin et al., 2009). In this respect, it is particularly interesting to interpret these results in the specific context of Greek manufacturing. Greek firms, mainly characterized by small size and family ownership, are going through a transition phase towards technological modernization. Simple logic and empirical evidence suggest that small and medium-sized firms of a small country in the European periphery with very few, if any, technological leaders cannot accelerate on issues of technological development (see for example Spanos et al., 2004; Spanos and Voudouris, 2009). This is also supported by a recent report on technological innovation indicators (European Innovation Scoreboard, 2009) that shows clearly that Greek firms stay behind their counterparts in other member-states. For Greek firms, starting from a state of comparatively low technological and innovation level, an attempt to catch up in the accumulation of technological capabilities mainly through networking may be inadequate. Faced with limited experience from prior technology investments, limited financial and, more importantly, managerial resources, Greek firms may see the development of technological capabilities and technological innovation as a constrained optimization problem. In this sense a firm attempting to innovate by heavily investing in network linkages may neglect to invest in internal technological capability. As investments in internal capability tend to be path dependent (Dierickx and Cool, 1989) and firms that lack such capability are more likely to never invest in it (Cuervo-Cazurra and Annique Un, 2010). Greek firms may deprive themselves from the benefits of internal technological capability accumulation. This internal capability, beyond being necessary for the successful assimilation of new technology, is also necessary for absorbing effectively knowledge through networks. Under these circumstances, it is very difficult for the average Greek firm that invests in intense networking linkages without emphasizing at the same time the link between internal capability and networks, to leverage unique network resource combinations, which would enhance the effectiveness of technology investment.

In order for firms to be able to capitalize on network benefits they have to develop their internal capability. As the findings suggest network resources may complement and activate an organization's capability under the condition that the organization has developed sufficient skills and knowledge to manage their integration and produce innovative adaptations. Firms that have already made substantial investments in internal technological accumulation are in a better position to interact with e.g. technology suppliers and also to look to other organizations that have made technology commitments in the past and seek to learn from their accumulated competence. Such firms can 'learn-by-interacting' (Lundvall, 1992), and are more likely to effectively utilize linkages to obtain access to supplementary valuable assets and complement their internal capability, creating "interactive dynamic capabilities" (Von Tunzelmann and Wang, 2007). This finding is in the same line with other findings originating out of the literature dealing with the role of absorptive capacity of the firm in the innovation process (Schmidt, 2005) and strengthens previous results emphasizing the complementarity of internal and external knowledge sources for innovative performance (Lin et al., 2009, 2012; Cassiman and Veugelers, 2006; Caloghirou et al., 2004). It reveals that the extent to which an organization relies on internal capability affects the use and effective application of external sources of knowledge.

The results of this study also reveal that the strategic importance of technology investment plays a crucial role on its effectiveness. It seems that strong managers' perceptions about the strategic value of technology investment for an organization's competitiveness lead to increased managerial attention (Ocasio, 1997) and concentrated efforts towards technology incorporation and adaptation in order for technology to realize expected outcomes. Perceived strategic importance may be seen as a subordinate expression of desired end-states that exerts a causal influence as antecedent to the implementation of technology investment. Managers direct their actions toward those desired-end-states (Van de Ven and Poole, 1995) supporting technology investment in multiple ways, such as training, incentives to use, dedication of resources and capabilities unfoldment. As a result the organization's implementation climate is strengthened, which augments technology acceptance by organizational members (Davis et al., 1989). This predisposition, whether subjective or objective, seems to have an impact on managerial effort and commitment to appropriately use the technology, positively affecting effectiveness of technology investment.

Of interest is the finding of an insignificant moderating impact of strategic importance on internal capability, seen in combination with a positive moderating impact on networking, which have to be explained from a capabilities and attention based perspective. Internal technological capability and knowledge are essential elements for mastering new technology and may be used for any technology investment regardless of its importance. Managerial attention may focus on extending the capabilities of the firm, through networking so as to bring more external sources of knowledge to bear in the case of technology investments with strategic importance. This finding corroborates previous contentions about the role of managerial attention to manage external relations (e.g. Grimpe and Kaiser, 2010). It is interesting especially when interpreted in the case of acquired technology and technological modernization of firms in developing and catching-up economies such as Greece. Such firms typically develop technological capabilities, through networking, in a stepwise progression moving along trajectories in their technology investments in which past learning facilitates future augmentation of capabilities that feeds back and reinforces existing stocks of knowledge and expertise (Spanos and Voudouris, 2009). In this context it is logical to expect that the use of internal capability will be at maximum in any new technology investment, in order to nourish the process of internal capability accumulation. But when it comes to consider strategically technology important investments managerial actions are likely to be directed to external knowledge resources. It is in such a circumstance that network capabilities need to be channelled so as to produce new solutions for the organization. Stronger networking connections are likely to contribute more to technology investment success.

Finally, as regards the impact of the controls the positive effect of the size of technology investment on achievement of objectives falls in with previous findings indicating that the size of technology investment may contribute to an increase of its innovative output (Caloghirou et al., 2004). In addition, the insignificant impact on both productivity improvement and overall satisfaction strengthens previous results suggesting the possibility of different effects of technology investment on different measures of performance (Barua et al., 1995; Hitt and Brynjolfsson, 1996; Aral and Weill, 2007).

Contrary to our expectations firm's size appears to play a negative role. This suggests that smaller firms may be more sensitive and flexible in selecting and incorporating technologies, despite–or perhaps precisely because- of their relatively limited resources. It may be that size brings with it bureaucracy, fixed views and limits flexibility, thus making the expected benefits from resource availability difficult to materialize. This may be particularly relevant to the specific Greek context, where smaller firms representing the great majority of the local economy seem to be ahead of their larger counterparts in terms of technological modernization (e.g. Spanos and Voudouris, 2009).

Technological dynamism in the business environment positively affects effectiveness of technology investment. As the frequency, boldness and aggressiveness of the technological changes become higher; firms may become more motivated and open to investing in technologies. Continuous efforts to remain competitive through a sequence of moves, comprising investment and deployment of technologies, may serve firms to gradually increase their skills and knowledge required for further successful technology assimilation (Damanpour, 1996).

Finally, the positive impact of the availability of financial resources external to the firm strengthens our expectations that the existence of external financial resources for the technology investment may act as a driving force, a "catalyst" motivating firms to invest in and effectively incorporate technologies in order to enhance their competitiveness. This is especially true for Greece, where the existence of external financial resources has in the past been considered as limited.

6. Conclusion

Firms are increasingly endeavouring to enhance the value of their technology investments in order to increase their competitive advantage and performance. To deepen our understanding of that issue, this study attempted to examine questions pertaining to technology investment effectiveness. Technology investment effectiveness is measured as: (a) the degree to which technology investment contributes to the achievement of business objectives, (b) the degree of improvement of productivity due to technology investment and (c) overall satisfaction by the technology investment reached.

We were mainly interested in examining: (a) the individual and interaction effects of an organization's internal technological capability and networking as well as (b) the direct and moderating effects of strategic importance of technology investment on its effectiveness. We developed hypotheses based on the extant literature and the idiosyncrasies of the Greek economic environment, which provides the specific context for this research.

The results of this study yield two major contributions to the research and management of technology. First, they provide evidence that technology investment effectiveness, independently of how it is measured, is mainly driven by an organization's internal capability. Networking complements internal capability only in case that an adequate level of internal capability is already developed by the firm. These findings appear to confirm the importance of internal capability for technology investment effectiveness, strengthening the arguments of prior researches (Grimpe and Kaiser, 2010; Lin et al., 2009; Nicholls-Nixon and Woo, 2003; Schilling, 1998). Most importantly, they seem to illuminate the mixed findings of limited previous studies investigating whether the effects of internal capability and networking are complementary or substitutive for effective technology investments (e.g. Nicholls-Nixon and Woo, 2003; Cassiman and Veugelers, 2006; Lin et al., 2009; Rothaermel and Alexandre, 2009; Grimpe and Kaiser, 2010). Specifically, the findings of the present study suggest that networking can enhance technology investment effectiveness only when it is combined with increased internal capability. Networking may complement and increase internal capability, creating synergistic effects, but it cannot act as a substitute of it. The extent to which an organization relies on internal capability enhances also the contribution of networking. Internal capability seems to be a prerequisite for the utilization of concomitant external sources of knowledge.

Second, the findings show that effectiveness of technology investment depends upon the perceived strategic importance of the investment, which seems to guide managerial attention and behaviour. They also suggest that the extent to which the technology investment is important directs managerial attention towards extending capabilities through networking and collaboration with external sources. The interplay between external sources and internal capability and knowledge is a *sine qua non* for technological development. When it comes to consider technologies of strategic importance, initiatives are more likely to turn to network knowledge in order to facilitate technology success.

Taken together, results point towards a model of effective technological change based on "interactive dynamic capabilities" (Von Tunzelmann and Wang, 2007). Internal technological capability is important in itself and in addition it is augmented through network interactions. The level of perceived strategic importance of technology investment – reflecting the degree of its strategic intent – exerts a causal influence on technology implementation and capabilities used for the effective technology investment. Such capabilities need to be developed internally but most likely success will call for interaction with different networks creating interactive knowledge flows and "learning by interacting" (Lundvall, 1992). It is in this sense that interactive dynamic capabilities, representing a synergistic hybrid between the resource based view and the strategic management theory (Von Tunzelmann and Wang, 2007), drive successful technological change.

The findings of this study may have important implications for managers and decision makers. The main implication is that a firm in an effort towards technological modernization needs to take into serious consideration the strategic value of the technologies in which it intents to invest. It also needs to build upon the accumulation of its internal technological capability in order to create the necessary knowledge for successful technological change. This internal capability needs however to be complemented by capabilities through networking, which are necessary especially for strategically important investments.

This is of particular interest for Greece, where local industrial R&D spending is very limited, representing a small percentage of the respective spending in other European countries (Souitaris, 2001; European Innovation Scoreboard, 2009). Greek firms should not have expectations that investing, even at a rapid rate, high amounts of money in technologies and learning of the basic skills to operate them suffices to increase performance. On the contrary, firms should strive against technological inertia by investing in strategically important for them technologies and more importantly by investing in the accumulation of their own technological capability, augmented by capabilities acquired through networking. This combination will allow Greek firms to maximize the benefits from technology investments. However, for Greek firms being dislocated from the main international centres of technology generation, and having limited access to resources that are widely available to firms operating within the realms of elaborated and advanced National Innovation Systems (e.g. effective linkages among suppliers and users of advanced technology, scientific and technological infrastructure), investments in technological knowledge accumulation may be difficult and time-consuming, thus discouraging firms to that direction. That is why policy intervention may be necessary.

Governmental policy aiming at encouraging private investment (e.g. state aid incentives, financial grants, etc.) is essential but not enough. More focused efforts are needed that should take into consideration not only the technology investment proposal per se but also to provide incentives for integration of technology and firm—“self”-production of innovations. In this respect, an important role for policy makers would be to combine various enterprise policy initiatives aiming at the technological upgrading of manufacturing firms with public funding of industrial training, skills development and building of R&D activities. Furthermore, an opportunity would be to link the local development of technological capabilities with the creation of technological networks that would serve as a channel for the transfer of knowledge and capabilities necessary for successful technology investments.

In this research we attempted to shed some light on the issue of success of technology investment. Our results should however be evaluated against the study’s limitations. First, even though we have included some very important factors influencing the value of technology investment, our model is far from exhaustive. The omission of potential determinants such as decision-makers’ personal characteristics, different networks and other organization—and industry-specific factors is noteworthy. This was, however, beyond the scope of the present study, which mainly attempted to investigate the direct and interaction effects of internal technological capability, networking and strategic importance of technology investment for its effectiveness. Another limitation may stem from the specific environment from which the sample data was collected, i.e. Greece. Evidence from other national contexts would be required to qualify on the results and enhance the generalizations of our findings. Furthermore, our investigation is necessarily bounded by the constraints imposed from an essentially cross section analytical framework with limited time span, based on memory recalls. Had we used longitudinal data, we would have been able to examine the cycle between the organization’s decisions to invest in a technology till the evaluation of the technology effectiveness by following the events, internal and external to the firm, that have an impact to it. Finally, if we had detailed data about various technology investment projects in the same organization we would have been able to conduct a multi-level analysis in order to increase the robustness of our results. These, however were beyond the scope of the present analysis. Future studies, employing a different research design and studying technology investment and its effectiveness over time, could remedy these limitations.

Appendix A

A.1. Sample size determination

To determine the size of the random sample, this study uses the following equation (Newbold, 1995):

$$n = \frac{Np(1-p)}{(N-1)\sigma^2_{\hat{p}_x} + p(1-p)}$$

where n is the sample, N is the population, p is the proportion of firms in a population possessing a certain attribute, $\hat{p}_x$ is the random variable representing the sample proportion and $\sigma^2_{\hat{p}_x}$ is the desired variance of the sample proportion.

The objective is to determine a random sample from the population (i.e., 1173 firms). The attribute determining the random sample is the proportion that the technology investment under analysis is effective. Given that the proportion of firms in the population possessing this particular attribute (p) is not known, this study follows a more conservative approach of

Table A1

Internal technological capability	
Please rate your company’s skills in the following areas relative to your major competitors. In rating please focus on the period the decision for technology investment was made (1: very low …0.7: very high)	
Measures	First order loadings[a]
Capability of modification or improvement of the equipment independently of the supplier	0.523
Capability of modification or improvement of the production process	0.818
Ability to upgrade technology related to your main products	0.900
Skills in conducting R&D and developing innovative solutions	0.795
Overall self-generating technological skills and capabilities	0.521
Model summary statistics: $X^2(5)=9.368$, $p=0.095$, CFI=0.938, Robust CFI=0.977, Cronbach’s alpha=0.8	
Networking	
Please rate the extent of your company’s collaborations with the following linkages (1: very low …0.7: very high)	
Measures	First order loadings[a]
Suppliers	0.845
Customers	0.511
Infrastructure and service providers	0.926
Other firms, for technology development	0.630
Universities or research institutions	0.528
Model summary statistics: $X^2(4)=13.104$, $p=0.094$, CFI=0.953, Robust CFI=0.977, Cronbach’s alpha=0.79	
Strategic technology importance	
How would you evaluate the importance of the technology investment at the time the decision was made with respect to the following statements (1: very low …0.7: very high)	
Measures	First order loadings[a]
The technology investment would determine the future technological development of the firm	0.709
The technology investment would determine the overall development of the firm	0.897
The technology investment would determine the competitiveness of the firm	0.616
Model summary statistics: $X^2(2)=0.817$, $p=0.66$, CFI=0.992, Robust CFI=1, Cronbach’s alpha=0.78.	

All first order loadings significant at $p<0.05$.

[a] Loadings standardized for identification purposes.

Table A2

Variables	1	2	3	4	5	6	7	8	9	10
1.Contribution on achievement of objectives	1	0.581[a]	0.246[a]	−0.22[b]	0.25[a]	0.13	0.12	0.32[a]	0.26[a]	0.29[a]
2. Improvement of productivity		1	0.39[a]	−0.14	0.13	0.08	0.03	0.21[b]	0.09	0.22[b]
3. Overall satisfaction			1	0.04	0.08	0.08	0.06	0.14[b]	0.19[b]	0.29[a]
4. Size				1	−0.14	0.14	0.08	−0.22[a]	0.07	0.16
5. External financial resources					1	−0.12	−0.01	0.24[a]	−0.01	0.08
6. Technological dynamism						1	−0.09	0.06	0.21[b]	0.20[b]
7. Size of technology investment							1	−0.01	−0.03	0.10
8. Strategic technology importance								1	0.15	0.14
9. Networking									1	0.43[a]
10. Internal capability										1
Mean	8.6	4.71	5.2	2,4	3.83	4.5	4.97	5.1	4.52	4.99
Standard deviation	3.5	2.09	1.13	0.38	1.98	0.93	6.10	1.25	0.92	0.85
N	124	137	105	137	139	138	136	138	139	132

[a] Correlation significant at the 0.01 level.
[b] Correlation significant at the 0.05 level.

Table A3

	Contribution on objectives achievement			
	Main effects	Internal capability∗networking	Technology importance∗internal capability	Technology importance∗networking
	Model 1	Model 2	Model 3	Model 4
R^2	0.304***	0.357***	0.304	0.327*
ΔR^2		0.053	0.000	0.023
ΔF		8.548***	0.074	1.985*
	Productivity improvement			
	Main effects	Internal capability∗networking	Technology importance∗internal capability	Technology importance∗networking
	Model 5	Model 6	Model 7	Model 8
R^2	0.125**	0.152**	0.132	0.150**
ΔR^2		0.028	0.007	0.026
ΔF		3.753**	0.929	3.488**
	Overall satisfaction			
	Main effects	Internal capability∗networking	Technology importance∗internal capability	Technology importance∗networking
	Model 9	Model 10	Model 11	Model 12
R^2	0.196**	0.224**	0.196	0.202
ΔR^2		0.028	0.000	0.006
ΔF		4.308**	0.02	0.860

substituting the $p(1-p)$ with the largest possible value, which is 0.25. This approach ensures that whatever the true proportion, a 95% confidence interval extends no further than 0.08 on each side of the sample proportion. Hence, according to the following equation, a random sample of 138 firms suffices.

$$96\sigma_{\hat{p}_x} = 0.08$$
$$\sigma_{\hat{p}_x} = 0.04$$
$$n = \frac{(1173)(0.25)}{(1172)(0.04)^2 + 0.25} = 138$$

A.2. Measures and construct validation (CFA) results

See Table A.1.

A.3. Means, standard deviations and Pearson correlations

See Table A.2.

A.4. Models of regression analyses for singular interactions

See Table A.3.

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