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TECHNOLOGICAL STRATEGIC ALLIANCES: FORMATION UNDER THE REAL OPTIONS APPROACH

Isabel Estrada Vaquero
Natalia Martín Cruz
Gabriel de la Fuente
Universidad de Valladolid

Abstract: Technological strategic alliance (TSA) formation represents an important competitive mechanism for firms, and it can be considered as a real option on future technological opportunities. Our objective is to analyse, under a real options reasoning, how firms decide between forming TSAs or adopting alternatives one-step technology strategies. Using a panel of 29376 observations from 4050 manufacturing firms operating in Spain - covering the 1998-2005 period -, we find that the greater the firm's absorptive capacity and the greater the degree of technological risk, the more likely is the firm to form a TSA rather than adopting other technology strategies. Our results also show that the greater the risk of pre-emption by rivals and the greater the opportunity costs associated with TSA formation, the less likely is the firm to form a TSA.

Keywords: Real options, alliance formation, technology, flexibility-commitment trade-off.

Departamento de Organización de Empresas y C.I.M
Facultad de Ciencias Económicas y Empresariales
Avda. Valle Esgueva, 6, E47140
Valladolid-Spain
Tlfn. (+34) 983 423951
Fax (+34) 983423299
isabel_estradavaquero@hotmail.com
ambiela@eco.uva.es
gfuente@eco.uva.es

1. Introduction

Firms are resorting increasingly to interfirm collaboration to deal with the current complex environment, characterized, among others, by markets globalization and continuous technological change. Academic interest in strategic alliances has also been arisen, proliferating the number of theoretical and empirical papers on the topic, specially from the 80's. In this regard, two broad streams can be recognized (Aulakh and Madhok, 2002): the first stream focuses on the motives behind alliance formation, and the second one is based on the governance of the collaboration process. This paper is primary concerned with the formation research stream. Specifically, we focus on the formation of *technological strategic alliances* (henceforth TSAs).

Given the current strategic importance of learning, TSAs constitute an important source of competitive advantage (Garcia-Canal, Valdes-Llaneza and Sanchez-Lorda, 2008), as this kind of collaboration is more often oriented towards inter-organizational learning than those that do not have technological scope (Colombo, 2003). We define a TSA as a formalized long-term agreement between two o more organizations, which engage in interdependent value chain activities, such as R&D activities, to transfer existing technological capabilities from one partner to another and/or to generate jointly new ones (Khanna, Gulati and Nohria, 1998; Feller, Parhankangas and Smeds, 2006; Lavie, 2007; Lavie, Lechner and Singh, 2007; Faems, Janssens, Madhok and Van Looy, 2008).

TSAs are one of the possible strategies that firms can adopt to acquire technological capabilities, thus, to capture value from technology (Inkpen, 2005). But firms can also resort to alternative technology strategies like acquisition of other firms, which have already the pursued technological capabilities, or also arm's length transactions. One of the main differences between these technology strategies and TSAs is the nature of the embedded investment process. While both acquisitions and arm's length transactions represent one-step or full investment strategies, TSA formation represents a sequential or incremental investment strategy. Hence, TSAs provides the firm with the option to access to certain technological capabilities, acting as a platform to capture future technological opportunities while avoiding full resources commitment, i.e. maintaining flexibility.

The central question that emerges and motives our research is: *How do firms decide between forming TSAs or adopting alternatives one-step technology strategies?* To answer this question, explicit valuation of the value generated by TSA formation –relative to the value generated by other alternatives strategies- is needed. In line with this, our objective is to extend the current state of understanding into TSA formation by using the real options approach (henceforth ROA). We do not deny the worth of the insights offer by other approaches, but we emphasize the usefulness of the ROA, for several reasons. First, the concept of value creation offered by ROA is particularly suitable, through superior reflection of the technological opportunities as value drivers

(Kester, 1984; Myers, 1984; Pape and Schmidt-Tank, 2004). According to the ROA, the value created by any investment can be broken into the cash flows stemming from the assets-in-place and those stemming from future opportunities (Myers, 1984). Concerning TSAs, we identify as the main source of value the ability of the partners to earn sustained rents and, specially, to capture future strategic opportunities from their technological capabilities, (Madhok, 2004). Secondly, the ROA literature has specifically addressed the differences between incremental and one-step investment strategies, as well as having pointed out the advantages of the first ones under uncertainty. Thus, the ROA not only can be considered as a valuation mechanism for the TSA formation, but also it offers valuable theoretical arguments, recognizing the importance of the trade-off between commitment and flexibility in decision-making.

The rest of the paper is organised as follows. First, we explain TSA formation under the real options reasoning. Next, we present our valuation model and develop our theoretical hypotheses. The subsequent sections are devoted to the presentation of the methodological issues, the empirical findings, and their implications for research. The paper concludes by pointing out our main contributions and limitations, as well as some directions for further empirical work.

2. Putting TSA formation into a real options reasoning

The question of why firms engage in interfirm collaboration has been broadly addressed from different theoretical frameworks. Scholars researching alliance formation have been particularly inspired by transactions cost theory (Williamson, 1975) and the resource-based view (Barney, 1991; Peteraf, 1993). The first theory suggests that firms should engage in TSAs (hybrid forms), instead of resorting to pure market or hierarchy, when collaboration represents the form that minimizes the transaction costs associated with the development of technological capabilities (Kogut, 1988; Hill, 1990; Dyer, 1997; Hennart and Reddy, 1997; Barney, 1999; Madhok, 2000; Madhok, 2004). On the other hand, the resource-based view claims that TSAs allow firms to create more value than what could have been created through either market transaction or acquisitions, due to the synergies that arise when two bundles of complementary technological capabilities are properly combined (Teece, 1986; Kogut, 1988; Eisenhardt and Schoonhoven, 1996; Barney and Hesterly, 1999; Barney, 1999; Hitt, Dacin, Levitas, Arregle and Borza, 2000).

ROA goes beyond transaction costs and synergies and offers new useful insights into the issue, by considering TSAs as real options and recognizing the interdependences associated with strategic decisions (Miller and Folta, 2002). As Kogut and Kulatilaka (2001) stress “a real option is the investment in physical assets, human competence, and organizational capabilities that provide the opportunity to respond to future contingent events” (p. 745). In his pioneering work, Kogut (1991) considers that joint ventures “are created as real options to expand in response to future technological and market developments" (p.19) and, in this regard, he suggests that investments in joint ventures "serve as platforms" (p. 32). In line with this, Kogut and Kulatilaka (1994) establish that platform investments, like joint ventures, represent investing in opportunity and, thus, should be recognized as real options. More recently, many works inspired by the ROA (Folta, 1998; Folta and Miller, 2002; Colombo, 2003; McGrath and Nerkar, 2004; Pape and Schmidt-Tank, 2004; Vassolo, Anand and Folta, 2004; Savva and Scholtes, 2005) have drown the analogy between the strategic alliance and an American call option[1]. The outcome of a TSA is a portfolio of technological capabilities previously unavailable, which provides its owners (TSA partners) the right (but not the obligation) to invest in future opportunities. In other words, TSAs represent compound real options- i.e. real options that involve complex series of nested investments or represent multistage investments. In particular, we consider that forming a TSA provides two linked options: the option to defer full commitment to the technology that underlies the TSA, and the growth option to capture future technological opportunities. When a firm forms a TSA it gains the access to a growth option for future technological expansion, while retaining the option to defer full commitment to this technology (Vassolo et al., 2004; Fisch, 2006). Thereby, ROA proposes to consider the trade-off between commitment and flexibility in evaluating the convenience of TSAs versus one-step technology strategies.

Delaying the decision of full commitment- waiting for more information- represents a source of flexibility for firms, which has value insofar as the investment is irreversible and risky (Mcdonald and Siegel, 1986; Dixit and Pindyck, 1995). This source of flexibility arises from the incremental nature of the TSA investment process. Once the opportunity to form a TSA is recognised and the firm decides to engage in the collaboration process, it could delay full commitment to the underlying technology. Thus, the firm may preserve flexibility by waiting for more information from the environment, about whether it is convenient to capture effectively future opportunities upon larger commitment or not. This incremental nature can be represent by the following four-step option chain regarding TSA formation (Hurry, Miller and Bowman, 1992; Bowman and Hurry, 1993), as shown in Figure 1.

Step 1. Recognition of the shadow option: Shadow options represent latent opportunities for firms. In this case, the firm's base of contacts and prior interfirm ties may create the latent opportunity to form TSAs. However, this opportunity come into being only once the firm recognises it.

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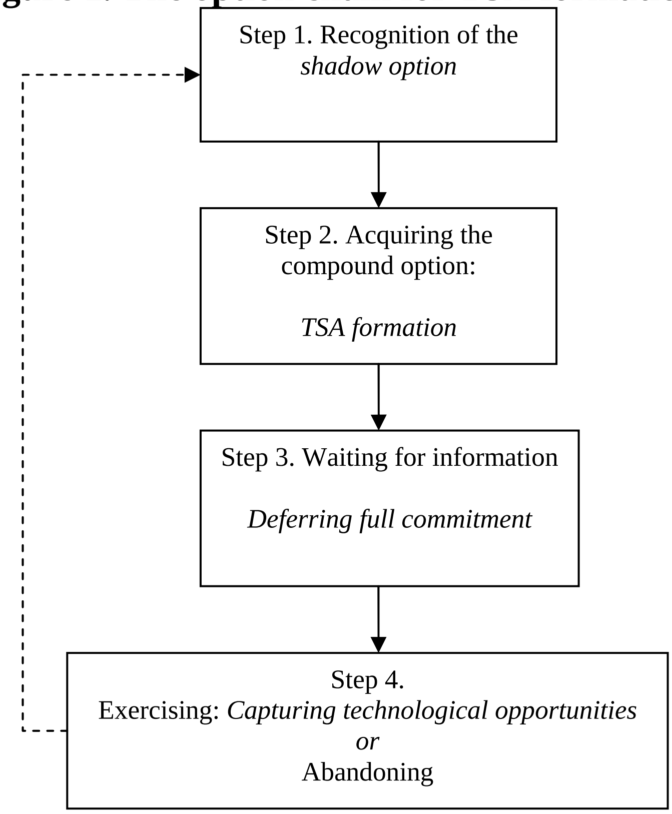
[1]A call option conveys the right, but not the obligation, on the holder to buy and underlying asset (a stock, a stock index, a commodity future) at a given price and at some point in the future. Unlike European options, American call options can be exercised anytime during its life.

Step 2. Acquisition of the option: As in the case of financial options, the cost of acquiring a call option on technology (through TSA formation) is small, relative to the cost of directly purchasing the technology. In this step, the firm's objective is to guarantee the access for certain technological capabilities at some point in the future, while keeping only a small amount of resources at risk, thus, *putting the foot at the door*.

Figure 1. The option chain for TSA formation



Step 3. Waiting for information: During this exploratory period, the firm holds this option 'open', waiting for a signal from the environment which allows it to decide. In other words, upon this holding period, the firm has exercised the middle option to defer full commitment to the underlying technology. Enjoying this period to evaluate the technology for the larger investment in next step, thus, deferring full commitment, allows the firm to maintain flexibility[2].

Step 4. Option exercise/abandon: If a positive signal arises from the environment, the firm will exercise its final call option on technology upon a larger investment. Thereby, the firm will commit fully to the underlying technology in order to capture technological opportunities. On the contrary, if the signals emerged from the environment seem to discourage the full

[2] However, as we explain in the third section, there may be some factors (e.g. the risk of pre-emption by rivals), which may lead to make early full commitments.

commitment, the firm will abandon its option, thus, ruling out the capture of these opportunities.

Whatever the result of step 4 is, as a consequence of its involvement in the TSA, the firm has acquired shared experiences with the partner and other business contacts, and it has attained a new bundle of capabilities in this regard. Thus, the firm has formed the background for, among others, engaging in new interfirm collaborative process (i.e. for new shadow options).

3. Model and Hypothesis

The firm's decision between forming a TSA or adopting an alternative one-step technology strategy, need to be based on the explicit valuation of each strategy. Thus, it is required to analyse if the ability of the partners to earn sustained economic rents and, specially, to capture value from future strategic opportunities, is greater than what could have been attained in the absence of technological collaboration- i.e. if the firm had engaged in alternative one-step technology strategies. In this regard, ROA "offers a perspective from which to develop ideas that are relevant to the problems facing decision-makers in established firms" (McGrath and Nerkar, 2004: 19).

Thus, to deal with this valuation task, we resort to the analogy between TSAs and American call options. This analogy allows us to identify some explanatory variables from the option pricing theory (OPT)[3], which are pertinent to value TSA formation. OPT models (Black and Scholes, 1973; Merton, 1973) suggest the following variables affecting the value of a call option: the underlying asset value (*S*), the exercise price (*X*), the asset price volatility (σ), the option life (*T*), the risk-free interest rate (*r*), and the dividends (δ).

Accordingly, the value of a call option is given by the following expression (above specified the expected signs):

$$Call = f\left(\overset{+}{S}, \overset{-}{X}, \overset{+}{\sigma}, \overset{+}{T}, \overset{-}{r}, \overset{-}{\delta},\right)$$

However, to offer a more comprehensive valuation model on TSA formation, it may be convenient to adapt the OPT variables for the particular case of TSA formation. Thus, in Table 1, we explain briefly the analogy between the variables affecting the call value (financial option) and the variables we consider specifically affect to the value of TSA formation (as a real option).

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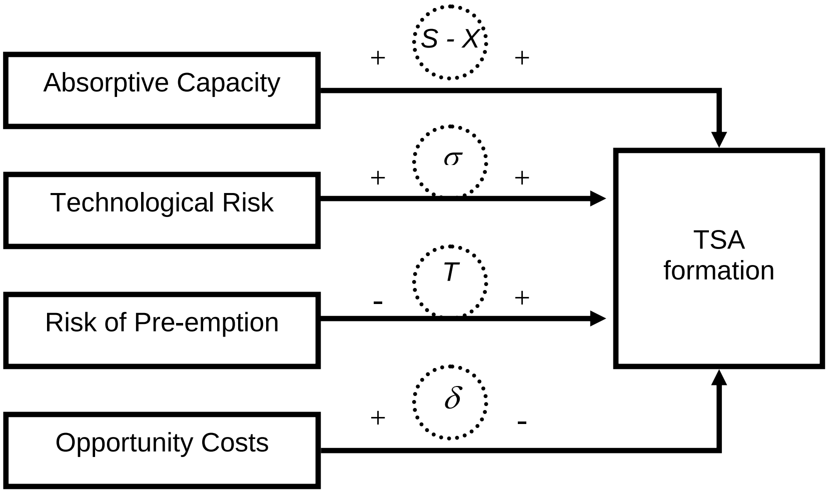
[3] For a more detailed application of the option-based valuation techniques see Myers (1977), Kester (1984), Dixit and Pindyck (1994), Trigeorgis (1991; 1996), and Copeland and Antikarov (2001).

Table 1. Analogy between the variables affecting call and TSA formation values

	Call	TSA Formation
S	Underlying asset value	Underlying technology value: Represents the technology/capabilities that the firm want to have access in future through the TSA formation. Underlying technological capabilities are likely to be more valuable as the future opportunities they allow to capture are greater.
X	Exercise price	Expenditures in terms of organizational an economic resources, needed to capture effectively future technological opportunities, thus, to make full commitment.
σ	Price asset volatility	Underlying technology risk: The extent in which the environment is likely to take a sudden turn regarding the underlying technology, making it become obsolete.
T	Option life	Underlying technology expiration: The period of time during which the decision of commit fully to the underlying technology may be deferred.
δ	Dividends	Opportunity costs represent a loss of value in terms of cash flows or learning opportunities, coming from having adopted TSA instead of other one-step technology strategies.

All these variables proposed by OPT can be easily identified and quantified for a call on a financial asset. Concerning real options, however, these variables represent abstract and intangible concepts, thus, are difficult to determine. For instance, it is easy to identify the period which represents the life of an American call option but for a TSA there may be not an explicit expiration date for capturing future opportunities (not even if partners agree in advance an expiration date for their collaboration). Another example is represented by the intangible nature of the technological capabilities that form the underlying technology value of a TSA. Thereby, despite the clear relationship between the OPT variables and the relative value of TSA formation, we face such a problem of 'inobservability'. As McGrath, Ferrier and Mendelow (2004) stress "In the field of management, however, application of real options theory is preparadigmatic. Scholars have not yet been freed from the need constantly to re-examine its first principles". In the same thread of thought, Kogut and Kulatilaka (2004) point out that "In contradiction to the idea of 'domain extension', we propose a 'translation'. […] A good domain translation understands not only the original language and the targeted language but also their correspondence […] (p. 103). Thus, in order to propose testable hypotheses grounded in ROA and to count on data that can be used to test them, we 'translate' the concepts underlying OPT variables, drawing the correspondences between them and other more operative variables, which are unequivocally related to the first ones.

Figure 2. Option-based valuation model for TSA formation.



In particular, as Figure 2 shows, we consider the relationship between the firm's *absorptive capacity* (Cohen and Levinthal, 1990) and the difference between the underlying technology value and the exercise price (*S*-*X*); the relationship between the *exogenous technological risk* or *environmental technological risk* (Folta, 1998; Vassolo et. al, 2004; Yin and Shanley, 2008)[4] and the underlying technology risk *(σ);* the relationship between the *risk of pre-emption by rivals* and the option life (*T*); finally, we consider the relationship between the *opportunity costs* and the dividends (δ).

The effects of each one of these observable variables on firms' propensity for TSA formation (relative to the propensity for other one-step strategies) are explained in the following sections.

Absorptive Capacity

To capture future technological opportunities, firms need to develop in advance the needed capabilities. Concerning TSA, such technological capabilities may be built through learning about the partner's existing technology or else co-developing innovations among partners. In other words, firms need to succeed in developing interfirm technological learning to capture future opportunities. Following our previous definition of TSA, TSA formation may offer such possibility, but it is not a sufficient condition. In explaining that, the theory of

[4] Folta (1998) and Vassolo et al. (2004) consider that *exogenous technological risk* is usually specific to the industry and implies that the technological trajectory is not already established or it is likely to change, and it is predominantely resolved over time rather than through firm actions. In a similar vein, Yin and Shanley proposes that *environmental risk* refers to the clarity or predictability of the technological premises of the industry.They stress that this risk "is multidimensional: technologies and products may change, market acceptance of a product line may be unclear, and new products may have an impact on future industry operations" (2008: 480). We consider both concepts as interchangeable.

absorptive capacity (Cohen and Levinthal, 1990) suggests that a firm's capacity of learning from the TSA is greater when the new technological knowledge to be assimilated is related to the firm's existing technological capabilities (Lane and Lubatkin, 1998). Absorptive capacity may be defined as the firm's dynamic capability to acquire, value, assimilate and exploit new technological knowledge from the TSA (Lane and Lubatkin, 1998; Zahra and George, 2002). In this regard, it has been pointed out that if firms have complementary knowledge bases, their capacity to absorb partners' technological knowledge from collaboration is greater (Colombo, 2003; Sakakibara, 2003) and, thus, mutual inter-firm learning is easier to arise (Dyer and Singh, 1998; Lane and Lubatkin, 1998). The reason stems from the fact that a firm's absorptive capacity tends to develop cumulatively, be path dependent and builds on prior capabilities (Cohen and Levinthal, 1990).

The concept of absorptive capacity allows to draw two implications for the firm's propensity for TSA formation under a real options reasoning. First, the greater the firm's ability to acquire, value, assimilate an exploit the technological capabilities that underlie the TSA, the greater these capabilities' value (*S*) for the firm, due to the firm's ability to take advantage of future opportunities through exploiting the underlying technology as well as the value generated by that, are likely to be greater. Secondly, the greater the firm's absorptive capacity, the less the expenditures of organizational resources required to make full commitment to the underlying technology (i.e. the lower the price for exercising the final TSA option, *X*).

In short, absorptive capacity encourages TSA formation rather than other one-step strategies, by increasing the underlying technology value (*S*) and simultaneously reducing the exercise price (*X*) for capturing future opportunities.

These ideas are captured in our first hypothesis:

Hypothesis 1. *The greater the firms' absorptive capacity, the more likely is the firm to form a TSA instead of engaging in alternative one-step technology strategies.*

Technological Risk

TSA formation is considered as a platform for taking advantage of technological future opportunities (Kogut, 1991; Kogut and Kulatilaka, 1994; Kogut and Kulatilaka, 2001), and, thus, provides the firm with the right to defer the decision of committing to a certain technology until the exercise is optimum. Following the OPT insights, we consider that high *exogenous technological risk* (i.e. *technological environmental risk*) implies the possibility that the basic technological assumptions of the TSA may be challenged or rendered obsolete (Yin and Shanley, 2008). Thus, the ROA suggest that firms should prefer to engage in sequential technology strategies, such as TSAs, when the technological risk is high rather than alternative one-step strategies. What is more, through TSA formation, firms not only protect themselves from the technological risk, but also may benefit from it (Kogut, 1991). Unlike other approaches, the ROA considers specifically the firm's ability to manage with and benefit from technological risk by *putting the foot on the door*.

The option to defer full commitments represents a valuable source of flexibility (Folta, 1998). That is particularly worth for firms operating in highly risky environments (Dixit and Pindyck, 1995). As Yin and Shanley (2008) proposes, alliances will be more likely than other alternative strategies, like acquisitions, in industries where technological risk is high. In line with this, there is much empirical evidence supporting the argument that firms facing with high degree of *exogenous technological risk* are more likely to form TSA rather than those firms facing with lower degrees of risk. For instance, Hurry et al., (1992) reveal that Japanese firms, unlike American firms, follow real options logic to make high-technology investments in the U.S. In a similar vein, McGrath and Nerkar (2004) prove that American pharmaceutical firms prefer sequential investment R&D strategies to one-step strategies. It has been also empirically found that those Spanish firms which belong to industries with high technological risk have a greater propensity to establish cooperative R&D agreements (Bayona, Garcia-Marco and Huerta, 2001). Folta (1998) shows that equity alliances are preferred to acquisitions in the U.S. biotechnology industry, due to the less resources commitment required. Similarly, Vassolo et al. (2004) show how technological risk influences whether firms in that industry exercise their real options.

On the basis of these arguments relative to the *exogenous technological risk* (i.e. *environmental technological risk*), which act as the underlying technology risk (σ), we propose our second hypotheses:

Hypothesis 2. *The greater the exogenous technological risk (i.e. environmental technological risk), the more likely is the firm to form a TSA instead of engaging in alternative one-step technology strategies.*

The risk of pre-emption by rivals

While delaying the decision of making full resources commitment to a certain technology is valuable in terms of protecting and profiting from the technological risk, it may involve the risk of pre-emption by rivals (Trigeorgis, 1991; Folta, 1998; Miller and Folta, 2002). High levels of this risk may favour early strikes of the option or even may foster that firms engage in one-step technology strategies rather than TSAs. Thus, in practice, the risk of pre-emption reduces the available time to postpone the full commitment to the underlying technology. (Folta and Miller, 2002)- i.e. reduces the option life (T). Forming TSA, instead of engaging in a one-step technology strategy, may increase the risk of pre-emption firms have to cope with, due to, unlike financial options, the option to take advantage of future technological opportunities is generally not exclusive but collective (Kester, 1984). This option is not exclusive for the firm that has engaged in the TSA but it may be available for many other firms. As Miller and Folta (2002) point out "strategic alliances may produce shared growth options. Technologies generated by the alliance provide the bases for future business opportunities" (p.661). It means that the option to capture future technological opportunities may be exercised by other rivals during this period as well. Thus, the risk of pre-emption stems from the possibility that rivals exercise the option pre-emptively. Obviously, firms that have made small commitments to a certain technology (e.g. through TSA formation) will be better positioned than those that have not made any previous commitment, but only supposing that this technology remains dominant. In this regard, the option may also be not exclusive in the sense that a rival may attain a radical technological innovation and this new technology may be able to dominate the market, making the rest of technologies obsolete. In both cases, while the degree of protection from technological risk offered by TSA formation is high, the degree of protection from the risk of pre-emption by rivals is low, relative to that offered by other alternative one-step strategies, specially, acquisition (Folta, 1998). Therefore, early investment commitment or even following a one-step technology strategy from the beginning may be justified when the risk of pre-emption by rivals is high, to avoid losing value (Trigeorgis, 1991; Miller and Folta, 2002).

These arguments give rise to the following hypothesis:

Hypothesis 3. *The greater the risk of pre-emption by rivals, the less likely is the firm to form a TSA instead of engaging in alternative one-step technology strategies.*

Opportunity Costs

Considering the TSA as a call option allow us to understand how firms may also fall into opportunity costs when they engage in TSA formation (Colombo, 2003; Folta and Miller, 2002; Miller and Folta, 2002). A holder of an American call option on a financial asset, such as a share, which is giving out dividends, does not receive such dividend payment unless he/she strikes the option and, thus, buys effectively the share. Although the holder has protected himself/herself from the share price volatility through the call acquisition, he/she is falling into opportunity costs: the dividends. Thus, opportunity costs concerning real options act as the dividends (δ) in the financial options case (Merton, 1973; Trigeorgis, 1991; Miller and Folta, 2002).

When opportunity costs exist, the TSA formation value is decreased (Miller and Folta, 2002), relative to the value of alternative one-step strategies which do not involve such costs. In particular, opportunity costs derived from TSA formation may take the form of sacrificed cash flows or learning possibilities (Folta and Miller, 2002). If the firm engages in a one-step technology strategy like acquisition, it will be able to use the underlying technology immediately and that is likely to provide economic rents. These rents or cash flows which the firm could have earned by exploiting these technological capabilities represent opportunity costs. Regarding learning opportunity costs, for instance, when TSAs involve the co-development of a new technology, partners usually concentrate a great part of their R&D efforts on it. However, it could be possible that the collaborative research activities do not result effectively in innovation. Although it may be partially considered as an investment to acquire some technological capabilities through interfirm learning (Lane and Lubatkin, 1998), it may be considered as a loss of other technological learning opportunities, which may exist beyond the TSA.

Hence, if the firm had invested in other one-step technology strategy like acquisition, it would have been able to prevent these types of losses. Thus, the existence of opportunity costs discourage TSA formation (Folta and Miller, 2002; Miller and Folta, 2002), fostering one-step technology strategies.

We capture this set of opportunity cost-related arguments in our last hypothesis:

Hypothesis 4. *The greater the opportunity costs associated with TSA formation, the less likely is the firm to form a TSA instead of engaging in alternative one-step technology strategies.*

4. Methodology, Sample and Variables

4.1. Sample

We test our hypotheses on a sample of manufacturing firms with more than 10 employees operating in Spain. Data comes from the Survey of Entrepreneurial Strategies (henceforth ESEE) which has been carried out by the 'Public Enterprise Foundation' (*Fundación SEPI*) in collaboration with the Spanish Ministry of Industry, Tourism and Commerce. The ESEE database's objective is to gather information about firms' strategies. The sample is stratified by industry, province, and firm size to guarantee the reliance of the data, and new firms substitute for nonresponding ones within each stratum every year[5].

Moreover, the ESEE database matches our research requests basically for two reasons. First, the ESEE was conceived specially to provide an adequate source for the implementation of the econometric models, being one of the best Spanish data source available for making firm-level estimations (Merino and Rodríguez, 1997; Delgado, Martín and Jaumandreu, 1999; Alvarez and Molero, 2005; López and Martín, 2008). Secondly, the ESEE database provides longitudinal information, among others, about the sequential and one-step technology strategies followed by firms. In turn, the ESEE allows us to connect over time

[5] For broader information about the ESEE database, see www.funep.es/esee. Information about publicated papers using this database is available in www.funep.es/esee/esee_articulos.asp.

such firms' strategic decisions with a wide range of features of its environment (e.g. information about the degree of technological risk or of the thread of pre-emption by rivals).

Table 2. Sample's description.

Year	1998	1999	2000	2001	2002	2003	2004	2005	Total
No. of Observations	3676	3662	3618	3659	3654	3743	3738	3628	29376
Total No. of TSAs	168	155	162	137	132	91	101	114	1060
Joint Ventures	89	82	87	72	69	50	55	61	565
Other TSAs	79	73	75	65	63	41	46	53	495

In particular, the panel used in this paper covers the eight-year period from 1998 to 2005 and is composed of 29376 observations (within the total period), coming from 4050 firms. Table 2 provides information on the sample detailed by years. In addition to its longitudinal nature, our sample is comparable with those used in previous research (e.g. Vassolo et *al.*, 2004; Folta y Miller, 2002; Colombo, 2003). Moreover, unlike most of prior research, our sample provides information from a range of manufacturing industries[6].

4.2. Specification of the econometric model

In order to test our hypotheses and identify what factors influence firms' propensity to form TSAs instead of engaging in alternative one-step technology strategies, we use a binomial logit model, using the data analysis and statistical software Stata 9. The dummy dependent variable equals 1 if the firm has engaged in a joint venture with technological scope (henceforth, JV), taking null value otherwise[7]. Due to the dichotomous nature of the JV variable, a logit analysis is the most suitable method. Moreover, sample has a panel data structure because we identify the observations from each individual (firm) at every time, and, thereby, fixed effects or specific features of each firm may exist. Thus, in fixed-effects logit for panel data, observations are grouped by firms, and the likelihood function is calculated for each firm, providing more efficient estimations. We test the existence of fixed or random effects by conducting the Hausman test, which follows a χ^2 distribution, under the null hypothesis of lack of systematic differences in coefficients from fixed-effects and random-effects estimates. In sum, this is the model to be tested:

$$\text{Prob. }(TSA_{it}=1) = \beta_0 + \beta_1\cdot\text{Absorptive\_Capacity} + \beta_2\cdot\text{Technological\_Risk} + \beta_3\cdot\text{Risk\_Preemption} + \beta_4\cdot\text{Opportunity\_Costs} + \beta_5\cdot\text{Firm's Size} + \beta_6\cdot\text{Firm's Age} + \beta_7\cdot\text{Belonging\_Group} + \eta_i + \varepsilon_{it}$$

[6] The ESEE database collects information of firms operating in the 18 Spanish manufacturing industries, according to the classification of the National Statistic Institute of Spain (INE). The industry list is displayed in the appendix.

[7] In order to guarantee the reliability of the analysis, we consider two exclusive categories of firms: those that engage in JV, and those that neither engage in JV nor in any other kind of technological collaboration.

Where *i* represents each individual (i.e. each firm) and *t* represents time; η_i is the fixed-effects term for each individual, and ε_{it} is the random error for each observation). A brief explanation on explanatory and control variables is offered below.

4.3. Variables and Measures

This section describes the measures we use from the ESEE for the explanatory and control variables in the model and, when necessary, which other sources are used to construct the variables. The measures we use, whenever it is possible, are based on prior empirical research.

Absorptive Capacity
Traditionally, the literature has suggested that the firm's absorptive capacity is represented by systematic R&D efforts, both internally developed and externally contracted (Cohen and Levinthal, 1990; Sakakibara, 1993; Lane and Lubatkin, 1998; Bayona et al., 2001; Zahra and George, 2002; Arbussà and Coenders, 2007). Accordingly, we measure the firm's absorptive capacity using, first, the ratio total (internal and contracted) amount of R&D expenses to the firm's annual sales- ACAP1. In line with this, we use the annual number of product innovations- ACAP2-, as we consider this measure represents the outcomes of the firm's R&D systematic efforts.
In addition, we use the number of R&D employees /the total number of firm's employees ratio–ACAP3. We consider that the greater the number of R&D employees, the greater the firm's ability to learn and absorb new technological knowledge from a TSA.
All these measures are directly provided by the ESEE.

Technological risk
Following prior empirical research (Folta, 1998; Folta and Miller, 2002; Vassolo et al. 2004), technological risk is meant to capture the exogenous or environmental risk specific to the main industry in which the firm operates. We use two different measures for technological risk. First, the recognition of the managerial capacity of evaluating the environment is one of the most important assumptions from the ROA, that has highly contributed to the ROA be considered as superior, compared to traditional project valuation methods- i.e. discounted cash flow techniques. (Kester, 1984; Myers, 1984; Trigeorgis and Mason, 1987; Kulatilaka and Marcus, 1992; Dixit and Pindyck, 1995; Pape and Schmidt-Tank, 2004; De Andrés, Azofra and De La Fuente, 2006). Thus, as Yin and Shanley (2008) propose and in line with Bayona et al. (2001), we use a dummy variable provided by the ESEE- TECHRISK1-, which equals 1 if the firm's manager has considered technological change is likely to occur and has considered the potential use of technologies alternative to the currently one used by the firm (zero otherwise).

Second, as a more objective measure, we have created a categorical variable-TECHRISK2-, using the Spanish National Institute of Statistics (INE) classification for industry technological intensity. TECHRISK2 takes the values 1, 2, and 3, depending on the degree of the technological intensity of the industry (medium, medium-high, and high).

The risk of pre-emption by rivals

Regarding the risk of pre-emption by rivals, the value of deferring the option exercise is expected to decrease with an increasing number of technological rivals. Thus, the risk of pre-emption has usually been measure by the number of rivals of the industry (Folta and Miller, 2002; Folta, 1998; McGrath and Nerkar, 2004). In a similar vein, we measure this risk of pre-emption using a market concentration index -PREEMPT1- provided by the ESEE, which adds up the market shares of the four main rival firms, as long as there are rivals with significant market share (it takes null value otherwise). Additionally, we consider the effects of industry lifecycle. In particular, the necessity of innovation for firms' survival (i.e. degree of technological rivalry) increases as the industry approaches maturity and, specially, decline stage. Thus, we use a related categorical variable from the ESEE- PREEMPT2-, which equals 1 if the industry is in its early stages (introduction and growth stages), 2 if the industry is in the maturity stage, and 3 if the industry is in the decline stage.

Opportunity Costs

As far as we know, opportunity costs have not been measured in prior empirical research in a pertinent manner to our study. The reason may stem from the fact that many authors consider the risk of pre-emption by rivals as an opportunity cost (Folta, 1998; Colombo, 2003; McGrath and Nerkar, 2004), while we address the differences between these two variables. We have approximated the underlying technology's expiration (T) by the number of rivals, so we choose a different measure for opportunity costs, which is related to the cash flows generated by the current firm investments. In particular, we use the ratio operating income minus investments to assets, as a proxy for those opportunity costs that takes the form of cash flows- OPPORT.

Control Variables

In order to take account of other factors, which may have a bearing on firms' propensity to TSA versus one-step technology strategies, we include several control variables following prior empirical research (Bayona et al., 2001; Folta and Miller, 2002; Colombo, 2003; López and Martín, 2008). First, the size of the firm is measure as the log of the firm's annual sales-SIZE. Second, the firm's age is captured by the number of years since the firm's founding –AGE. Finally, we use a dummy variable –GROUP- which equals 1 if the firm belongs to a group of companies (i.e the firm is a parent or subsidiary company), and zero otherwise.

5. Empirical Findings

Table 3 provides information on descriptive statistics (relative frequencies are provided instead of the mean for categorical variables, indicating values in parentheses), and Table 4 on simple correlation matrix, both of explanatory and control variables.

Table 3. Descriptive statistics of explanatory and control variables

	N	Min.	Max.	Mean/%	S.D.
ACAP1	4445	0	26	0.07	0.709
ACAP2	10308	0	500	1.56	13.192
ACAP3	6251	0	35	0.09	0.679
TECHRISK1	10474	0	1	6.3%(1) 29.4%(0)	
TECHRISK2	18903	0	3	76.2% (1) 17.7% (2) 6% (3)	
PREEMPT1	5285	0	100	6.12	22.021
PREEMPT2	18752	0	3	29.3%(1) 56% (2) 14.7%(3)	
OPPORT1	4352	-352	12190	47.20	330.905
SIZE	12278	0	23	15.92	2.059
AGE	28888	0	275	25.35	21.688
GROUP	16630	0	1	35.4%(1) 20.2%(0)	

Table 4. Simple correlation matrix of explanatory and control variables

	ACAP1	ACAP2	ACAP 3	TECHRISK1	TECHRISK2	PREEMPT1	PREEMPT 2
ACAP1	1						
ACAP2	0.004	1					
ACAP 3	**0.628****	0.17	1				
TECHRISK1	**0.082****	**0.031****	**0.093****	1			
TECHRISK2	**0.103****	0.003	**0.116****	**0.85****	1		
PREEMPT1	-.014	-0.10	0.014	**0.042****	-0.005	1	
PREEMPT2	**-0.038***	-0.001	-0.013	**-0.068****	**-0.054****	**-0.042****	1
OPPORT1	-0.014	-0.007	-0.024	**-0.031***	-0.015	-0.026	0.026
SIZE	**-0.104****	**0.037***	**-0.100****	**0.069****	0.016	-0.002	0.013
AGE	**0.105****	**0.050****	**0.122****	**0.124****	**0.056****	0.016	**0.068****
GROUP	**0.060****	0	**0.068****	**0.053****	-0.004	0.377	0.012
	OPPORT1	SIZE	AGE	GROUP			
OPPORT1	1						
OPPORT2	-0.024						
SIZE	**0.209****	1					
AGE	**-0.081****	**-0.047****	1				
GROUP	**-0.134****	**-0.066****	**0.042****	1			

Results of the econometric estimates of the binomial logit models are illustrated in Table 5 to 7. The estimated values of the coefficients of the independent variables, their standard errors, and the individual significant levels are provided. Tables also show the results of Hausman χ^2 tests. The goodness of fit of each model to the data is assessed by the Loglikelihood-ratio (LR) test, which follows a χ^2 distribution and can be considered as an analogous test to F statistic (Aldrich and Nelson, 1989). LR test compares the fit of the *null* model and the fit of the estimated model. Thus, it tests the null hypothesis that all coefficients except the intercept are zero.

Specifically, Table 5 provides information on the estimates of simple models- from (1) to (8)-, which are conducted just to verify the individual effects of explanatory variables on the probability of forming JV. The results of these estimates are in accordance with our theoretical arguments.

Table 5. Estimates of binomial logit models (I)

Variable Name	Simple Models							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ACAP1	**0.5772***** (0.1111)							
ACAP2		**0.1865***** (0.0570)						
ACAP3			**1.8967***** (0.2696)					
TECHRISK1				**2.0503***** (0.2813)				
TECHRISK2					**1.4383***** (0.1269)			
PREEMPT1						**0.0082**** (0.0038)		
PREEMPT2							**-0.4870***** (0.1090)	
OPPORT1								**-0.0608***** (0.0436)
Log-likelihood	-595.73	-186.80	-580.27	-172.15	1341.11	-817.80	-205.13	-593.61
No. Of Observations	4445	531	4443	546	10474	1636	546	4352
LR Test (d.f)	165.98*** (1)	22.05*** (1)	66.13*** (1)	490.40*** (1)	298.10*** (1)	525.02*** (1)	145.06*** (1)	152.18*** (1)
Hausman χ^2 Test	2.66 (1)	2.30 (1)	9.19** (1)	20.18*** (1)	0.12 (1)	0.09 (1)	0.14 (1)	1.91 (1)

Table 6 provide information on the estimates of reduced models-from (9) to (20). Unlike full models, reduced ones do not include control variables. Finally, information about the estimates of full models- from (21) to (32)- are displayed in Table 7.

Table 6. Estimates of binomial logit models (II)[i]

	Reduced Models											
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
ACAP1	**3.1458****	**0.4332*****	**0.4506*****	**0.3312*****								
	(1.4476)	(0.1018)	(0.0970)	(0.1020)								
ACAP2					**0.3320****	**0.0361*****	**0.2384****	**0.0678*****				
					(0.1688)	(0.0093)	(0.1021)	(0.0192)				
ACAP3									**1.1632*****	**1.4360*****	**1.4391*****	**1.1686*****
									(0.3157)	(0.2649)	(0.2810)	(0.1899)
TECHRISK1	**2.0804*****		**2.8102*****		**2.5461*****		**2.5167*****		**2.9085*****		**2.7897*****	
	(0.7286)		(0.2459)		(0.8025)		(0.1021)		(0.3264)		(0.2485)	
TECHRISK2		**1.0289*****		**0.9202*****		**1.1566*****		**1.0184*****		**1.0263*****		**0.8915*****
		(0.1872)		(0.2375)		(0.1861)		(0.2347)		(0.1899)		(0.1899)
PREEMPT1	0.0408			0.0061	0.0022			0.0053	0.0041			0.0047
	(0.0315)			(0.0055)	(0.0139)			(0.0055)	(0.0060)			(0.1899)
PREEMPT2		**-0.6558*****	**-0.6389*****			**-0.6785****	**-0.6354***			**-0.6672*****	**-0.6613*****	
		(0.1710)	(0.1840)			(0.1723)	(0.1688)			(0.1744)	(0.1899)	
OPPORT	**1.3828****	**-0.0570*****	**-0.0526*****	**-0.0587*****	**1.3348***	**-0.0651*****	-0.0041	**-0.0690*****	**-0.0466****	**-0.0479*****	**-0.0441*****	**-0.0509****
	(0.7194)	(0.0169)	(0.0171)	(0.0226)	(0.7804)	(0.0175)	(0.0437)	(0.0234)	(0.0218)	(0.4463)	(0.0162)	(0.0215)
Log-likelihood	-18.09	-547.69	-492.30	-324.17	-18.97	-545.85	-43.55	-324.57	-280.59	-533.96	-480.65	-317.81
No. of Observations	86	4326	4326	2160	85	177	4272	2142	2160	4324	4324	2160
LR test	27.73***	132.28***	110.52***	66.72***	25.52***	120.38***	40.55***	64.24***	49.26***	121.86***	102.10***	63.70***
(d.f)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Hausman test	13.26**	4.05	5.87	7.83*	12.00**	9.57*	0.01	4.90	8.23*	4.21	3.66	4.80
(d.f.)	(4)	(3)	(4)	(4)	(4)	(4)	(3)	(3)	(4)	(3)	(4)	(3)

[i] *** 99% confidence level, ** 95% confidence level, * 90% confidence level.

Table 7. Estimates of binomial logit models (III)[i]

	Full Models											
	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
ACAP1	0.4011***	0.5274***	0.5408***	0.3795***								
	(0.1025)	(0.1089)	(0.1029)	(0.1037)								
ACAP2					0.05175**	0.0371***	0.2554**	0.0611***				
					(0.0199)	(0.0093)	(0.1086)	(0.0185)				
ACAP3									1.3576***	1.6198***	1.6468***	1.3128***
									(0.3429)	(0.2784)	(0.2981)	(0.3029)
TECHRISK1	2.7838***		2.6478***		2.8736***		2.5374***		2.7291***		2.6101***	
	(0.3283)		(0.2509)		(0.3308)		(0.5948)		(0.3301)		(0.2545)	
TECHRISK2		1.0108***		0.9395***		1.1882***		1.0821***		1.0215***		0.9115***
		(0.1931)		(0.2346)		(0.1903)		(0.2322)		(0.1946)		(0.2375)
PREEMPT1	0.0062			0.0066	0.0054			0.0060	0.0048			0.0051
	(0.0059)			(0.0055)	(0.0059)			(0.0055)	(0.0062)			(0.0057)
PREEMPT2		-0.7474***	-0.7151***			-0.7980***	-0.5516			-0.7655***	-0.7425***	
		(0.1797)	(0.1907)			(0.1811)	(0.4262)			(0.1830)	(0.1037)	
OPPORT	-0.0549**	-0.0668***	-0.0624***	-0.0588**	-0.0572**	-0.0682***	-0.04217	-0.0612**	-0.0494**	-0.0595***	-0.0556**	-0.0533**
	(1.4476)	(0.0182)	(0.0186)	(0.0226)	(0.0237)	(0.0183)	(0.0481)	(0.1037)	(0.0224)	(0.1742)	(0.0178)	(0.0216)
SIZE	0.2569**	0.3732***	0.3685***	0.2378**	0.1420*	0.2650**	0.4691	0.1441*	0.2673**	0.3993***	0.3861***	0.2559**
	(1.4476)	(0.0899)	(0.0941)	(0.1133)	(0.1235)	(0.0880)	(1.1901)	(0.1123)	(0.1239)	(0.0896)	(0.0943)	(0.1132)
AGE	0.0274***	0.0278***	0.0242***	0.0309***	0.0297***	0.0319***	-0.2403	0.0336***	0.0249**	0.0257***	0.0215**	0.0293***
	(0.0086)	(0.0065)	(0.0068)	(0.0079)	(0.0086)	(0.0064)	(0.1426)	(0.0079)	(0.0088)	(0.0066)	(0.1037)	(0.0081)
GROUP	-0.4020	-0.4003	-0.2388	-0.6850	-0.5177	-0.5930*	-0.8818	-0.8135*	-0.4757	-0.4525	-0.2844	-0.7576*
	(0.4642)	(0.3432)	(0.3603)	(0.4307)	(0.4688)	(0.3450)	(1.2541)	(0.4344)	(0.4634)	(0.3451)	(0.3621)	(0.4321)
Log-likelihood	-272.18	-513.35	-466.30	-306.71	-271.08	-510.34	-40.76	-305.25	-267.01	-498.10	-454.55	-299.79
No. of Observations	2141	4286	4286	2141	2120	4229	174	2120	2142	4285	4285	2142
LR test	48.08***	114.60***	101.30***	52.74***	48.32***	105.08***	43.93***	51.88***	44.76***	101.24***	89.48***	47.22***
(d.f)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)
Hausman test	12.79*	5.81	8.50	8.24	12.61*	2.23	14.17**	6.85	8.14	6.65	9.00	5.85
(d.f.)	(7)	(6)	(7)	(6)	(7)	(7)	(7)	(6)	(7)	(6)	(7)	(6)

[i] *** 99% confidence level, ** 95% confidence level , * 90% confidence level.

The main objective of this study is to analyse how firms decide between forming TSAs or adopting alternatives one-step technology strategies. In general terms, the findings of both sets of regressions (reduced and full models) support the hypotheses inspired by the ROA. The only exception is the positive coefficient of the variable OPPORT in models (9) and (13), contrary to what we have hypothesized. Notice that, for both models, Hausman test indicates the existence of fixed effects and, thus, the poor number of observations taken into account may be the reason for these contradictory results. Despite that, given the similarity of the results revealed by both sets of regressions, we only describe the findings on the basis of the full models.

Regarding full models, the results are similar across models. However, results of the estimate from model (27) are contradictory to what we have hypothesized and to the results of the rest of the models. As in the case of models (9) and (13), this may be caused by the low number of observations considered by the fixed-effects estimate. Other than that, the estimates from the full models tell a quite consistent story, as the signs of the coefficients are the same across models, and, in general terms, the same variables are statistically significant in each model (Wooldrige, 2002). The exception for this last condition is represented by the coefficient of GROUP, which remains insignificant except in models (26), (28), and (32).

Detailed description of results is provided in the following.

First, we have hypothesized that the greater the firms' absorptive capacity the greater the propensity for TSA formation rather than for engaging in one-step technology strategies. This first hypothesis is clearly confirmed. The coefficients of all measures used for absorptive capacity-ACAP1, ACAP2 and ACAP3- are positive and significant across models. On the one hand, the results indicate the necessity of make systematic R&D efforts and, specially, to count on a great amount of technicians employees, in order to support the innovation learning process- see (21) to (24), and (29) to (32). On the other, as estimates (25) to (28) show, the positive relationship between the outcomes of these firm's systematic R&D efforts (i.e. number of product innovations) and its propensity for engaging in TSAs is also proved, although the influence is relatively lower.

Second, results support our argument that firms resort to technological collaboration as a way to maintain flexibility, thus, to protect themselves from technological risk. We find that firms which perceived the technological risk they have to face is higher -TECHRISK1 are more likely to form TSAs rather than engaging in other one-step technology strategies –see, for instance, (25). Similarly, results show that those firms which belong to industries with a higher technological intensity-TECHRISK2-, have a greater propensity to establish TSAs rather than adopting one-step strategies –see, for instance, (26). More specifically, the perceived degree of technological risk seems to be more relevant in decision-making. In sum, our second hypothesis is clearly confirmed.

Third, the results provide partial support for our third hypothesis that the greater the risk of pre-emption by rivals, the less likely is the firm to form TSA instead of engaging in alternative one-step technology strategies. The negative coefficient of the variable related to the industry lifecycle-PREEMPT2- is significant in each model it is considered. However, the same cannot be said with respect to the market concentration- PREEMPT1-, unlike what have been found in prior research- see (21), (24), (25), (28), (29), (32). Thus, we can just state that as the industry approaches latest stages of its lifecycle, the firm's propensity for forming TSAs decreases, increasing the likelihood of engaging in other one-step technology strategies, which provide a quick-response capacity to the increasingly higher degree of technological rivalry. In fact, interfirm collaboration is more usual in the introduction and growth stages in practice, when the technological trajectory of the industry remains unestablished.

Moreover, we clearly find that the greater the opportunity costs associated with TSA formation, the less likely is the firm to form TSA instead of engaging in alternative one-step technology strategies. Thus, our fourth hypothesis is also confirmed.

Finally, with regard to the control variables, we find that both the firm's size-SIZE- and the firm's age-AGE- affect positively the likelihood of forming TSAs, although the influence of the firm's age is quite small. These positive relationships may be founded in the necessity of certain dimension, a wide profile of business contacts, and a well-established firm's image and legitimacy to be able to take part in such kinds of collaborative projects like JV. The propensity for choosing TSAs rather than other one-step strategies, however, does not be specially affected by the firm's belonging to a group of companies-GROUP. However, when estimates show a significant coefficient for GROUP-see (26), (28), and (32)- the likelihood of forming a TSA rather than resorting to market transactions or acquisitions, is negatively affected by the firm's belonging to a group of companies.

6. Conclusion

The main objective of the paper is to analyse how firms decide between forming TSAs or adopting alternatives one-step technology strategies, under real options logic.

Our results provide empirical support for the four hypotheses grounded in ROA. Thus, we find that decision-makers implicitly follow ROA premises when choosing the technology strategy. Specifically, our findings show that the greater the firms' absorptive capacity and the greater the technological risk the firm need to face, the greater the propensity for TSA formation instead of engaging in one-step technology strategies. Furthermore, we find that as the risk of pre-emption by rivals and the opportunity costs associated with TSA formation increase, the less likely is the firm to form a TSA rather than adopting other one-step technology strategies, like arm's length transactions or acquisitions.

In sum, the contribution of the paper into the alliance formation research is insight into how firms decide between forming TSAs or adopting alternatives one-step technology strategies, on the basis on certain internal factors (the degree of firm's absorptive capacity, the firm's age, its size, and the firm's belonging to a group of companies), alliance-level factors (opportunity costs associated with the TSA formation), and, finally, on the basis of some exogenous factors (the degree of technological exogenous risk that managers perceived the firm needs to deal with, the degree of technological intensity of the industry, and the thread of pre-emption by rivals). Other than this contribution, we expand prior ROA literature. Our paper takes a step further in the development of an investment theory for the field of strategic management, by 'translating' the concepts from the original OPT language to the concern of a particular kind of strategy: technological interfirm collaboration.

In line with this, our paper may have also implications for management. First, our theoretical development may allow decision-makers to put explicitly TSA formation under a real options reasoning, in accordance with their necessity to capture the strategic value of future opportunities, taking into account the flexibility-commitment trade-off. In fact, the four-step option chain we have presented seems to reflect the observed incremental-investment behavior of firms operating under uncertainty. Furthermore, our research represents an example for how managers may be able to better evaluate comparatively the convenience of forming a TSA or engaging in other one-step strategies, depending on such internal, alliance-level, and exogenous factors.

Our paper has also limitations. Among others, we consider the main one is that we analyse the likelihood of forming a particular type of TSAs: technological joint ventures. Further work analysing whether our model is suitable for other types of technological collaborative arrangements is needed. Moreover, our sample just provide information on manufacturing firms operating in Spain, without including information neither about firms belonging to high-tech industries (e.g. biotechnology), nor about firms belonging to the services sector (e.g. technology consultancy), and nor about other kind of organizations (e.g. research centers, universities, non-profits). Thus, a second set of future lines of research needs to be aimed to analyse whether results could vary when these other features are taken into account.

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Appendix.

Industry list

Industry ESEE	CNAE93	Industry ESEE	CNAE93
1. Meat	151	11. Mineral Proudcts	261, 268
2. Foodstuffs and Tobacco	152, 158, 160	12.Metallurgic Products (ferrous and non-ferrous)	271, 275
3. Beverage	159	13. Metallic Products	281, 287
4. Textil	171, 177, 181, 183	14. Agriculture and Industrial Machinery	291, 297
5. Furs and Footwear	191, 193	15. Computation and Office Machinery	300, 331, 335
6. Wood	201, 205	16. Electrical Machinery and Equipment	311, 316, 321, 323
7. Paper	211, 212	17. Motor Vehicles	341, 343
8. Printing and Graphic Arts	221, 223	18. Other transport modes	351, 355
9. Chemicals	251, 247	19. Furniture	361
10.Plastic and Rubber	251, 252	20. Other Manufactures	362, 355, 371, 372