TECHNOLOGICAL JOINT VENTURE

FORMATION UNDER THE REAL OPTIONS APPROACH

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TECHNOLOGICAL JOINT VENTURE FORMATION UNDER THE REAL OPTIONS APPROACH

Abstract: Drawing on the real options approach, we analyse which factors motivate firms to choose technological joint venture formation as their technology strategy. Scholars researching joint ventures through the real options lens have usually focused on the ending stage of the alliance rather than on its formation. Using a panel of 29 376 observations from 4050 manufacturing firms operating in Spain between 1998 and 2005, our results are consistent with real options approach predictions. We find that the greater the firm's absorptive capacity and the higher the degree of technological risk, the more likely the firm is to form a technological joint venture. Results also suggest that the greater the risk of pre-emption by rivals and the higher the opportunity costs associated with technological joint venture formation, the less likely the firm is to choose such a technology strategy. A further step towards bridging the gap between finance theory and strategic analysis is thus taken.

Keywords: Technological joint ventures, absorptive capacity, technological risk, technology strategy, real options.

1. Introduction

The growing technological complexity prevailing in many sectors makes competition be best regarded as a learning and innovation race (Powell, 1998). In order to seek innovation there are two basic strategies for firms: *make* and *buy*. Developing a new technology in isolation requires a wide set of competences to be already in place and, when possible, usually involves expensive and long-term commitment. Acquiring another firm which already possesses the desired technological capabilities usually proves a faster yet more inflexible and riskier strategy, as occurs with arm's length transactions.

A middle strategy between *make* and *buy* is technological collaboration, which is becoming increasingly important. Managers seem to realize that in order to bring about technological innovation, it is critical to develop interorganizational links (Powell, 1998), due to the interactive nature of the process (Bayona, García, and Huerta, 2002). For example, over 60% of innovative European firms resort to technological collaboration with other firms or institutions (such as universities or research centres)[1], a trend which does not seem to be confined to Europe (e.g. Link and Scott, 2005). One of the most complex and important phenomena of technological collaboration is the formation of technological joint ventures[2] (henceforth, TJVs). In fact, the importance of this kind of collaboration has been dealt with in previous literature (e.g. García-Canal, Valdés-LLaneza, and Sánchez-Llordá, 2008; Hagedoorn, Link and Vonortas, 2000;

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[1] Source: *Fourth Community Innovation Survey*, http://epp.eurostat.ec.europa.eu. Data for firms active in innovation in the EU27 area, Iceland and Norway in the 2002-2004 period.

[2] TJVs are formalized long-term agreements (involving the creation of a new jointly-owned firm) between two or more organizations, which usually engage in interdependent value chain activities, such as R&D, to transfer existing technological capabilities from one partner to another and/or to generate new ones jointly. (Khanna, Gulati and Nohria, 1998; Kogut, 1988).

Link, Patton, and Siegel, 2002; Link and Scott, 2005; Marín and Siotis, 2008; Oxley and Sampson, 2004). Scholars researching TJVs have been particularly inspired by transaction cost economics (Williamson, 1975), and also by the resource-based-view (Barney, 1991). The former theory focuses on the choice of TJV as a form of governance for technological alliances, arguing that such high-commitment collaboration structure ensures that hazards arising from opportunism associated to technology transfer and development are avoided (e.g. García-Canal et al., 2008). From the resource-based view, scholars claim that TJVs allow firms to create value by means of the synergies that emerge when two bundles of complementary technological capabilities are suitably merged and allowed to interact closely (e.g. Oxley and Sampson, 2004).

From a different perspective, the real options approach (henceforth, ROA) provides a complementary explanation of TJVs that highlights their value as a flexible learning strategy in high-tech contexts (Chi and McGuire, 1996). TJVs also represent transitional modes towards complete acquisition that have been interpreted as an alternative to buying strategies. The difference between them lies in the nature of the embedded investment process, since acquisitions represent one-step or full investment strategies, and TJVs imply a sequential or incremental investment strategy. According to the ROA, TJVs are analogous to financial call options in the sense that they provide their partners the right (not the obligation) to buy the developed technology (underlying asset) at a specific price (exercise price) at or before a specific date (expiration date). As call options, TJVs enable partners to reduce downside risk, while maintaining access to upside opportunities by expanding sequentially. Hence, TJVs provide the firm with the option to access certain technological capabilities, acting as a platform to profit from future technological opportunities while avoiding full resources commitment, i.e. maintaining flexibility. The more uncertain the future regarding the technology to be acquired, the more valuable the TJV (flexibility) relative to other kinds of investment.

Since Kogut (1991) proposed the analogy between joint ventures and options to expand sequentially, a number of papers have contributed to the development of this line of research. According to Cuypers and Martin (2007), one advantage of ROA is that it provides a dynamic perspective which can explain each of the joint venture's stages, from formation to exercise (acquisition of partner/dissolution). However, most papers exploring joint ventures from ROA have focused on the analysis of its ending stage. This is the case of Chi (2000); Kogut (1991), Kumar (2005), Li, James, Madhavan, and Mahohey (2007), or Vassolo Anand and Folta, (2004), among others, who developed models to predict the conditions under which firms exercise the growth/abandon option embedded in joint ventures. Less attention has been paid to the initial stage of forming the joint venture as a result of a strategic decision taken under uncertainty. Exceptions are Chi and McGuire (1996) and Folta (1998), who analyse how the downside risk limiting feature of postponing the outright acquisition affects the decision to undertake a joint venture.

We contribute to the understanding of this second strategic decision problem, addressing calls for empirical research on the drivers underlying firms' motivation to choose this technology strategy (Marín and Siotis, 2008). The dynamic perspective offered by ROA and the role played by flexibility and uncertainty in the valuation of corporate resource commitments offer an appropriate framework to understand how learning advantages and risk exposure can impact strategic choice. We use the basic analogy between TJVs and financial call options to derive testable hypotheses that link the relative value of TJV to a number of factors that unambiguously approximate the variables of the difference between the underlying asset value and strike price (a), the underlying asset risk (b), expiration date (c), and the opportunity cost (d). We hypothesize that the likelihood of forming a TJV depends positively on absorptive capacity and technological risk, and negatively on risk of pre-emption by rivals and opportunity costs. These hypotheses are tested on a panel of 4050 Spanish manufacturing firms from 1998 to 2005. Our results indicate that the decision to form a TJV has much to do with its option-like characteristics. We thus take a step further towards developing an investment model for the field of strategic management.

The rest of the paper is organised as follows. First, we review recent literature on the application of ROA to strategic management and offer an overview of TJVs as real options chains. Focusing on one of the initial stages of these chains (TJVs formation), section 3 presents the model and derives the hypotheses to be tested. Section 4 shows the methodological issues. The main empirical findings are described in the fifth section. The paper concludes by discussing the findings, contributions, implications, and limitations, as well as suggesting some directions for further work.

2. ROA, strategic management and TJVs

The ROA states that a firm's asset portfolio comprises two differing components: assets-in-place, and real options (Kester, 1984; Myers, 1977, 1984). Assets-in-place refers to allocation of resources which a firm has already undertaken and not abandoned. The value of this component emerges from the cash-flows which are expected to be generated over time. Yet, a firm's market value is determined not only by the expected cash-flow of a specific allocation of resources, but by the resources themselves and, therefore, the cash-flows as generated by any other allocation the firm might make (Andrés, Azofra, and de la Fuente, 2006). The rights or real options to decide over various allocations of resources and capabilities have value in so far as exercising them will impact the firm's future cash-flows. The ROA exploits the analogy between financial options and real options to translate valuation models and insights from the option pricing theory (henceforth, OPT) to corporate investments and strategies[3].

The ROA is a powerful tool for explaining many entrepreneurial and managerial decisions, shaping incremental and sequential investments of resources in response to uncertainty evolution (Bowman and Hurry, 1987, 1993). For example, Hartmann and Hassan (2006) explore the managerial application of real options analysis for R&D projects in the pharmaceutical industry, and state the potential of this emerging valuation method as an auxiliary tool. Cassimon, Engelen, Thomassen, and VanWouwe (2004) propose compound-option models to value new drug applications and R&D investments of pharmaceutical firms. The multiple-case study conducted by Gil (2007) examines how safeguard decisions are taken regarding embedded real options in the context of an airport expansion programme (growth-options, stage-options, and switch options). Baldwin, Hienerth, and Hippel (2006) explore the process that user innovations usually follow, from when they are created to when they become commercial products, resorting to the analogy between a new design and a call option. They argue that "every new design is an option", and stress that technological uncertainty "justifies investment in multiple design searches." (Baldwin et al., 2006: 1296-1297).

[3] For a deeper analysis of ROA see Dixit and Pindyck (1994), Trigeorgis (1996), or Copeland and Antikarov (2001).

Real options reasoning applied to strategic resource commitment under uncertainty is straightforward: the optimal investment policy allows the firm to maximize the value of its portfolio of present and future risk opportunities.[4] To access these opportunities (acquire these options), the firm must invest in developing the appropriate bundle of resources and capabilities. After all, "a real option is the investment in physical assets, human competence, and organizational capabilities that provide the opportunity to respond to future contingent events" (Kogut and Kulatilaka, 2001: 745). Hence, TJV formation belongs to the category of strategic investments for whose valuation the ROA can be applied to (McGrath, Ferrier and Mendelow, 2004; Reuer and Tong, 2005). 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" (Kogut, 1991: 19) and suggests that investments in joint ventures "serve as platforms" (Kogut, 1991: 32). In line with this, Kogut and Kulatilaka (1994) establish that platform investments, like joint ventures, represent opportunity investments and should therefore be recognized as options. Several papers inspired by the ROA (Colombo, 2003; Folta, 1998; Folta and Miller, 2002; McGrath and Nerkar, 2004; Pape and Schmidt-Tank, 2004; Savva and Scholtes, 2005; Vassolo et al., 2004) have drawn the analogy between different sorts of strategic alliances and call options. A call option conveys on the holder the right, but not the obligation, to buy an underlying asset (e.g., a stock, an index, another derivative) at a given price (strike price) and at some point in the future (time to expiration). Similarly, a joint venture provides its partners with the opportunity, but not

[4] When applying the value maximization criteria, the ROA focuses on the portfolio of the whole opportunities (already exercised and postponed), which is wider than the portfolio of assets defined by the traditional financial models (discounted cash-flows models). Depending on the level of uncertainty, the optimal investment policy may not be the acquisition of the most valuable assets, but the sequential commitment of resources in a broad range of unrelated options.

the obligation, to invest in the acquisition of the bundle of assets developed or gained through the collaboration process, at or before the agreement expiration.

In the case of TJVs, the underlying asset is a portfolio of previously unavailable technological capabilities (underlying technology) which endow its owners (TJV partners) with the right to invest in their acquisition and application. In many cases, TJVs represent compound real options that involve complex series of nested investments or represent multistage investments. Forming a TJV allows its partners to defer full commitment to the underlying technology while preserving the growth option to profit from future technological opportunities. When a firm forms a TJV it accesses a growth option for future technological expansion, while retaining the option to defer full commitment to this technology (Fisch, 2006; Vassolo et al., 2004). The ROA thus enables firms to consider the trade-off between commitment and flexibility when evaluating the choice of TJV formation as a technology strategy.

Delaying the decision to full commitment represents a source of flexibility for firms, which has value insofar as technology investments are irreversible and risky (Dixit and Pindyck, 1995; McDonald and Siegel, 1986). This source of flexibility derives from the incremental nature of the TJV investment process. In the words of Tong and Reuer (2007), TJVs are transitional investments by design: they enable firms to reduce downside risk while accessing upside opportunities. The firm may preserve flexibility by waiting for more information from the environment about whether it is convenient to effectively capture future opportunities by making a larger commitment or not. As long as the firm maintains the right to exercise the option (by terminating the alliance and investing on its own in acquiring the whole underlying technology), it preserves all the potential upside profits, while limiting downside losses to the initial investment. This asymmetry in potential outcomes of TJVs is particularly valuable as the level of uncertainty increases.

The transitional nature of TJVs can be represented by the following four-step option chain (Bowman and Hurry, 1993; Hurry, Miller and Bowman, 1992), shown in Figure 1. The process starts with the recognition of the shadow options (step 1), which represent latent opportunities for firms. In the case of TJVs, the firm's base of contacts, prior links and technological experience make up the latent opportunities. In Step 2, the firm acquires the option through TJV formation. As in financial options, the cost of acquiring a call option on technology is small, compared to the cost of directly purchasing the technology. In this step, the firm's objective is to ensure access to certain technological capabilities at some point in the future, while exposing only a small amount of resources to risk (*getting a foot in the door*).

Figure 1 about here

In Step 3, the firm keeps the option alive while obtaining information about its optimal exercise. During this stage, the firm holds this option 'open', waiting for a signal from the environment to decide whether to exercise or abandon. In other words, through this holding period, the firm exercises the intermediate option to defer full commitment to the underlying technology to a later stage when both the necessary knowledge and the suitable scenario emerge. Taking advantage of this stage to evaluate the environment surrounding the underlying technology allows the firm to limit downside losses to initial sunk costs while preserving the upside potential (Chi and McGuire, 1996). However, waiting costs (opportunity costs and those arising from the risk of pre-emption by rivals) may encourage outright adoption rather than TJV formation. The final stage (Step 4) implies either the exercise or abandonment of the option embedded in the TJV.

If a positive signal emerges from the environment, the firm will exercise its final call option on the underlying technology by making a larger investment[5]. The firm will thereby commit itself fully to the underlying technology in order to benefit from technological opportunities. By contrast, if the signals from the environment discourage full commitment, the firm will abandon its option, thus ruling out the capture of these opportunities (Kogut, 1991; Kumar, 2005; Vasolo et al., 2004). Whatever the outcome of Step 4, as a consequence of its involvement in the TJV, the firm will gain shared experiences with the partner and other business contacts, and will have enhanced its alliance capability (Kale and Singh, 2007), reinforcing the background for, amongst other things, engaging in future interfirm collaborative processes (i.e. new shadow options).

Figure 1 highlights TJVs as option chains from a dynamic perspective. As noted earlier, most previous research into joint ventures under the ROA (e.g. Kogut, 1991; Vassolo et al., 2004) has focused on the circumstances triggering the exercise or the abandonment of the embedded option (Steps 3 and 4), while research into conditions under which the shadow option is acquired (Step 2) remains scarce. We will henceforth focus on TJV formation.

3. Model and Hypothesis

A firm's decision to choose TJV as a technology strategy should be founded on the value-creation criteria (Madhok, 2004). Given the above-mentioned option-like characteristics of TJVs, factors impacting TJV value should correlate with the variables affecting the value of an American call option.

[5] One particular form of TJV exercise extensively studied (e.g., Chi, 2000; Chi and McGuire, 1996; Kogut, 1991; Reuer and Tong, 2005) is the buyout of the partner stake in the TJV. However, this is not the only possible ending of a fruitful TJV. Another is the full development and adoption of the underlying technology.

According to OPT, the variables affecting the value of a call option are (Hull, 2002): underlying asset value (*S*), exercise price (*X*), underlying price volatility (σ), option life (*T*), the risk-free interest rate (*r*), and dividends (δ). Particularly, the value of an American call option depends positively on its life span, the risk-free return, and the underlying asset's value and risk, and negatively on the strike price, and dividends. That is:

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

In the case of a TJV, the underlying asset is represented by the technology to be adopted. Its value and risk are akin to the price and volatility of the underlying asset in financial derivatives, so that the higher they are the more valuable the TJV (real option) proves. The life span of the option in a TJV corresponds to the time during which the opportunity to adopt the underlying technology remains available. The greater the time span, the more valuable the TJV. The exercise price is akin to the amount of resources required by outright acquisition of the underlying technology. The higher the exercise price, the lower the value of the TJV. Finally, dividends from the underlying asset in financial derivatives are analogous to the benefits to be secured from the one-step adoption of the underlying technology, and that are lost due to postponement of the option exercise. Logically, the higher the opportunity costs, the lower the value of the TJV. Table 1 summarizes the analogy between the variables affecting the call value (financial option) and the corresponding variables affecting the value of a TJV (real option).

Table 1 about here

The variables affecting the value of a call option can easily be identified and quantified for a financial derivative. As regards TJVs, however, these variables represent non-observable concepts and thus prove difficult to measure. For instance, it is easy to identify the life of an American call option. Yet for a TJV there may not be an explicit expiration date for the underlying technology (not even if partners agree in advance an expiration date for their collaboration), insofar as competitors can anticipate making the underlying technology obsolete. Another example is the value and volatility of the underlying technology. As the underlying technology is not usually publicly traded, we have no observable prices from which to estimate current values and volatility, and therefore these must be subjectively approximated. Likewise occurs with the exercise price and opportunity costs of a TJV, which are not only different for each firm but also always uncertain. Despite the clear relationship between OPT variables and the relative value of TJV formation, there is a problem of 'unobservability'. Thus, in order to propose testable ROA hypotheses, we 'translate' the concepts underlying OPT variables, drawing the correspondences between them and other observable variables, which are unambiguously related to the former. As Figure 2 shows, we particularly consider the relationship between the firm's *absorptive capacity* and the difference between the underlying technology value and the exercise price (S-X); the relationship between the *exogenous technological risk* and the underlying technology risk (σ); the relationship between the *risk of pre-emption by rivals* and the option life (T); and finally, the relationship between *opportunity costs* and the underlying technology's dividends (δ). Each of these observable variables has an unequivocal effect on the variables on which TJV value depends, and can therefore be used to establish testable propositions on a firms' propensity to form a TJV as explained below.

Figure 2 about here

Absorptive Capacity

To take advantage of the technological knowledge generated through the collaboration, firms need to develop the required capabilities in advance. In the case of TJVs, such technological capabilities may be built by learning about the partner's existing technology or co-developing innovations among partners. In other words, firms need to successfully develop interfirm technological learning so as to make the most of TJV output. Regarding this strayegy, absorptive capacity may be defined as the firm's dynamic ability to acquire, value, assimilate and exploit the new technological knowledge to emerge from the TJV (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Zahra and George, 2002). Li et al (2007) find that the value of the growth option embedded in a collaborative venture as estimated by each partner depends on its learning capabilities. 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 emerges more easily (Dyer and Singh, 1998; Lane and Lubatkin, 1998). This is because a firm's absorptive capacity tends to develop cumulatively, be path dependent and to build on previous capabilities (Cohen and Levinthal, 1990).

The concept of absorptive capacity allows us to draw two implications for firms' propensity for TJV formation under a real options reasoning. First, the greater the firm's ability to acquire, value, assimilate and exploit the technological capabilities underlying the TJV, the greater the value these capabilities will have (*S*) for the firm, due to its ability to take advantage of future opportunities by exploiting the underlying technology and the value it generates. Secondly, the greater the firm's absorptive capacity, the less the expenditure on organizational resources required to make a full commitment to the underlying technology (i.e. the lower the price for exercising the final TJV option, *X*). In short, absorptive capacity increases the difference between the underlying technology value (S) and the option's exercise price, which in turn positively impacts the value of the TJV (option). These ideas are reflected in our first hypothesis:

Hypothesis 1. *The greater the firm's absorptive capacity, the more likely the firm is to form a TJV.*

Technological Risk

TJV formation is considered a platform for taking advantage of future technological opportunities while containing downside losses (Kogut, 1991; Kogut and Kulatilaka, 1994; 2001), thus providing the firm with the right to defer the decision to commit itself to a certain technology until exercise is optimum. We consider that higher exogenous technological risk[6] implies that the basic technological assumptions of the underlying technology may be challenged or rendered obsolete (Yin and Shanley, 2008), therefore,

[6] 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 yet established or is likely to change, and is predominantly resolved over time rather than through firms' actions. In a similar vein, Yin and Shanley (2008) propose 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" (Yin and Shanley, 2008: 480).

the volatility of the underlying asset is higher. Thus, ROA suggests that the higher the exogenous technological risk, the higher the value of forming a TJV.

Firms should prefer to engage in sequential technology strategies, such as TJVs, when the technological risk is high rather than in alternative one-step strategies. What is more, firms may not only shield themselves from technological risk through TJVs but also benefit from them (Kogut, 1991). Thus, unlike other approaches, ROA specifically considers not only the firm's ability to tackle but also to profit from technological risk by *getting a foot in the door*.

The option to defer full commitment is a valuable source of flexibility (Folta, 1998), which proves particularly valuable for firms operating in high risk environments (Dixit and Pindyck, 1995). As Yin and Shanley (2008) propose, alliances will be more likely than other alternative strategies, such as acquisitions, in industries where technological risk is high. In line with this, there is much empirical evidence to support the argument that firms facing a high degree of exogenous technological risk are more likely to form a TJV than firms facing less risk. For instance, Hurry et al., (1992) find that, unlike American firms, Japanese firms follow real options logic to make high-technology investments in the U.S. In a similar vein, McGrath and Nerkar (2004) evidence that American pharmaceutical firms prefer sequential investment R&D strategies to one-step strategies. It has also been shown empirically that Spanish firms involved in 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 lower number of resources firms need to commit themselves to. 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 relating to exogenous technological risk, which act as the underlying technology risk (σ), we propose our second hypothesis:

Hypothesis 2. *The greater the exogenous technological risk, the more likely the firm is to form a TJV.*

The risk of pre-emption by rivals

While delaying the decision to make a full resource commitment to a certain technology may prove valuable in terms of reducing downside risk and may help to profit from technological risk, it may involve the risk of pre-emption by rivals (Folta, 1998; Miller and Folta, 2002; Trigeorgis, 1991). High levels of this risk may favour early strikes of the option or even encourage firms to engage in one-step technology strategies rather than TJVs. Thus, in practice, the risk of pre-emption reduces the available time to postpone full commitment to the underlying technology (Folta and Miller, 2002), that is, it reduces the option life (T), which in turn reduces the value of the TJV.

Forming a TJV, instead of engaging in a one-step technology strategy, may increase the pre-emption risk firms have to cope with since, unlike financial options, the real option to take advantage of future technological opportunities is generally collective rather than exclusive (Kester, 1984). This option is not exclusive for the firm that has engaged in the TJV and may be available to many other firms in the industry. 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" (Miller and Folta, 2002: 661). It means that the option to exploit future technological opportunities may also be exercised by other rivals during this period. Thus, the risk of pre-emption stems from the possibility that rivals exercise the option pre-emptively. In short, the time to maturity increases the option value, but the option embedded in a TJV is likely to expire sooner, the higher the rivalry (Kumar, 2005). These arguments give rise to the following hypothesis:

Hypothesis 3. *The greater the risk of pre-emption by rivals, the less likely the firm is to form a TJV.*

Opportunity Costs

Considering the TJV as a call option allows us to understand how firms may also incur in opportunity costs when engaging in TJV formation (Colombo, 2003; Folta and Miller, 2002; Miller and Folta, 2002). A holder of an American call option on a share which is giving out dividends, receives no such dividend payment unless striking the option and actually buying the share. Although holders safeguard themselves against share price volatility through the call acquisition, they incur in opportunity costs: dividends. Thus, opportunity costs concerning real options act as the dividends (δ) in the financial options case (Merton, 1973; Miller and Folta, 2002; Trigeorgis, 1991). When opportunity costs exist, TJV value falls (Miller and Folta, 2002) relative to the value of those alternative strategies which do not involve such costs. In particular, opportunity costs derived from TJV formation may take the form of sacrificed cash flows (Folta and Miller, 2002). If the firm engages in a one-step technology strategy such as acquisition, it will be able to use the underlying technology immediately, which is likely to yield financial returns. These returns or cash flows which the firm could have earned by exploiting these technological capabilities represent opportunity costs.

Hence, if the firm had invested in another one-step technology strategy such as acquisition, it would have been able to prevent this kind of loss. Thus, the existence of opportunity costs discourages TJV formation (Folta and Miller, 2002; Miller and Folta, 2002).

We reflect this set of opportunity cost-related arguments in our final hypothesis:

Hypothesis 4. *The greater the opportunity costs associated with TJV formation, the less likely the firm is to form a TJV.*

4. Methodology, Sample and Variables

4.1. Sample

We test our hypotheses on firm-level data taken from the *Survey of Entrepreneurial Strategies* (In Spanish, *Encuesta sobre Estrategias Empresariales*, henceforth ESEE). The ESEE database is conducted yearly by the 'Public Enterprise Foundation' (*Fundación SEPI*) in collaboration with the Spanish Ministry of Industry, Tourism and Commerce. The ESEE is aimed above all at gathering information about firms' strategies, with the explicit goal of generating a panel data. The sample is stratified by industry, region, and firm size to guarantee data reliability, and new firms replace non-responding ones in each stratum every year. Moreover, all the information is subject to validation and logical consistency controls[7].

The ESEE database matches our research requirements basically for two reasons. First, the ESEE was primarily conceived to provide an adequate source for the implementation of econometric models and is one of the best Spanish data sources available for making firm-level estimations (Álvarez and Molero, 2005; López and

[7] For further information on the ESEE database, see www.funep.es/esee. Information on published papers which use this database is available at www.funep.es/esee/esee_articulos.asp.

Martín, 2008; Merino and Rodríguez, 1997). Secondly, the ESEE database provides longitudinal information, amongst other data, concerning firm's choices on technology strategies. In turn, the ESEE allows us to connect over time such firms' strategic decisions with a wide range of features regarding their environment (e.g. information about the degree of technological risk or the risk of pre-emption by rivals).

The ESEE's population of reference is made up of Spanish firms with more than ten employees belonging to the manufacturing industry, according to the classification of the Spanish National Statistics Institute (INE). Specifically, the panel used in this paper covers the eight-year period from 1998 to 2005 and comprises 29 376 observations (within the total period), from 4050 firms. Table 2 provides information on the sample detailed by years.

Table 2 about here

In addition to its longitudinal nature, our sample is comparable in size with those used in previous research (e.g Colombo, 2003; Folta and Miller, 2002; Vassolo et al., 2004). Moreover, unlike most previous research, our sample provides information from a range of manufacturing industries.

4.2. Specification of the econometric model

In order to test our hypotheses and identify which factors influence firms' propensity to choose TJV formation as their technology strategy, we apply a binomial logit model, using *Stata 9* data analysis and statistical software. The dummy dependent variable equals 1 if the firm has formed a TJV, taking null value otherwise. Due to the dichotomous nature of the dependent variable, a logit analysis is one of the most suitable methods. Moreover, the sample has a panel data structure and we identify the observations from each individual (firm), thereby, fixed effects or specific features of each firm may exist. In fixed-effects logit regression for panel data observations are grouped by firms, and the likelihood function is calculated for each firm, thus 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. 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). The 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.

In sum, this is the model to be tested:

$$\begin{aligned} Prob.\ (TJV_{it}=1) = {} & \beta_0 + \beta_1 \cdot Absorptive\_Capacity + \beta_2 \cdot Technological\_Risk + \beta_3 \cdot Risk\_Preemption \\ & + \beta_4 \cdot Opportunity\_Costs + \beta_5 \cdot Firm\ Size + \beta_6 \cdot Firm\ Age + \beta_7 \cdot Group + \eta_i + \varepsilon_{it} \end{aligned}$$

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 (see Table 3), when necessary, which other sources are used to construct the variables. The measures we use, whenever possible, are based on prior empirical research.

Table 3 about here

Absorptive Capacity

Traditionally, the literature has suggested that firm's absorptive capacity is represented by systematic R&D efforts (R&D intensity), both internally developed and externally contracted (Arbussà and Coenders, 2007; Bayona et al., 2001; Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Sakakibara, 1993; Zahra and George, 2002;). Accordingly, we measure firm's absorptive capacity using first the total (internal and contracted) amount of annual R&D expenditure/the firm's annual sales ratio- ACAP1 (R&D intensity). In line with this, we use the annual number of product innovations- ACAP2-, as we consider this measure represents the outcomes of firms' systematic R&D efforts. In addition, we use the number of R&D employees/the total number of firm employees' ratio–ACAP3 (R&D staff). We consider that the greater the number of R&D employees, the greater the firm's ability to learn and absorb new technological knowledge (Xia and Roper, 2008). All these measures are built using data directly provided by the ESEE and capture all dimensions of firms' absorptive capacity. The use of R&D intensity and R&D staff is intended to capture the firm's ability to value, acquire, and assimilate new technological knowledge, while the ability to apply it is reflected by the firm's number of innovations.

Technological risk

Following prior empirical research (Folta, 1998; Folta and Miller, 2002; Vassolo et al. 2004), the variable of technological risk aims to reflect the exogenous risk specific to the main industry in which the firm operates. We use two different measures for technological risk. First, as proposed by Bayona et al. (2001) and Yin and Shanley (2008) we use a dummy variable provided by the ESEE- TECHRISK1-, which equals 1 if the firm's manager feels technological change is likely to occur and has considered the possible use of alternative technologies to that currently 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 technological intensity in an industry (medium, medium-high, and high).

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 measured by the number of rivals in the industry (Folta, 1998; Folta and Miller, 2002; 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, provided there are rivals with significant market share (it takes null value otherwise). Additionally, we consider the effects of industry lifecycle (Katila and Mang, 2003), since the need to innovate for firms to survive (i.e. degree of technological rivalry) increases as the industry approaches maturity and, particularly, the 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 manner pertinent to our study. This may be because many authors consider the risk of pre-emption by rivals as an opportunity cost (Colombo, 2003; Folta, 1998; McGrath and Nerkar, 2004), whereas we address the differences between these two kind of ‘waiting costs’. We have approximated underlying technology expiration (*T*) by the number of rivals, and so, we choose a different measure for opportunity costs, which is related to the cash flows generated by current firm investments. In particular, we use the ratio operating income minus investments to assets as a proxy for those opportunity costs that take 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 form TJVs, we include several control variables following prior empirical research (Bayona et al., 2001; Colombo, 2003; Folta and Miller, 2002; López and Martín, 2008). First, the size of the firm is measured as the log of the firm’s annual sales-SIZE. Second, the firm’s age is reflected by the number of years since the firm was founded –AGE. Finally, we use a dummy variable –GROUP- which equals 1 if the firm belongs to a corporate group (i.e. the firm is a parent or subsidiary company), and zero otherwise.

5. Empirical findings

Table 4 provides statistical information for explanatory and control variables and Table 5 shows a simple correlation matrix.

Table 4 about here

Table 5 about here

The results of the econometric estimates of the binomial logit models are illustrated in Tables 6 to 8. Specifically, Table 6 provides information on the estimates of *simple models*- from (1) to (8)-, which are calculated merely to verify the individual effects of explanatory variables on the probability of TJV formation. Table 7 provides information on the estimates of *reduced models*-from (9) to (17) - and the estimates of *full models* (control variables included) - from (18) to (28) - are displayed in Table 8.

Table 6 about here

Table 7 about here

Table 8 about here

Results concur with our theoretical arguments. Estimates are fairly consistent, as the signs of the coefficients are the same across models, and, in general terms, the same variables are statistically significant in each model (Wooldridge, 2002). First, we have hypothesized that the greater the firms' absorptive capacity the greater the propensity for TJV formation. This first hypothesis is clearly confirmed. The three measures used for absorptive capacity (ACAP1, ACAP2, and ACAP3) are positive and significant across models. Thus, results reveal the need to make systematic R&D efforts and, particularly, to employ a high number of technical staff in order to support the learning process. Findings also reveal the positive relationship between the ability to apply new technological knowledge (i.e. number of product innovations) and the likelihood of adopting TJV formation as the technology strategy, although the influence is relatively lower than that of the ability to value, acquire, and assimilate new technological knowledge.

Second, results support our argument that firms resort to technological collaboration to maintain flexibility in high-risk contexts. We find that firms which perceived the technological risk they face to be higher (TECHRISK1) are more likely to form TJVs. Similarly, results show that those firms which belong to industries with a higher technological intensity (TECHRISK2) have a greater propensity to establish TJVs. 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, results provide partial support for our third hypothesis that the greater the risk of pre-emption by rivals, the less likely the firm is to form TJVs. The variable related to the industry lifecycle- PREEMPT2- is significant in each model for which it is considered. However, the same cannot be said of market concentration- PREEMPT1-, contrary to what has been stated in prior research. Thus, we can simply state that as the firm approaches the latter stages of its lifecycle, its propensity to form TJVs decreases, due to the increasingly higher degree of technological rivalry. In fact, interfirm collaboration is more common in the introduction and growth stages in practice, when the technological trajectory of the industry is yet to be established.

With regard to the last hypothesis, we clearly find that the greater the opportunity costs associated with TJV formation, the less likely the firm is to form a TJV. Thus, our fourth hypothesis is also confirmed.

Finally, with respect to the control variables, we find that both the firm's size -SIZE- and the firm's age -AGE- positively impact the likelihood of forming TJVs, although the influence of the firm's age is quite small. The tendency to choose TJV formation as the technology strategy, however, is not so affected by the firm's belonging to a corporate group -GROUP. In the few cases that estimates show a significant coefficient for GROUP the likelihood of forming a TJV is negatively affected by the firm's belonging to a corporate group.

To sum up, findings reveal that that the greater the firm's absorptive capacity, the higher the degree of technological risk, and the greater size and firm's age, the more likely the firm is to form a TJV. On the contrary, results also suggest that the greater the risk of pre-emption by rivals and the higher the opportunity costs associated with TJV formation, the less likely the firm is to choose such a technology strategy. The firm's belonging to a corporate group also seems to discourage TJV formation. A discussion of the findings is offered below.

6. Discussion and conclusion

Drawing on the ROA, we have examined which factors motivate firms to choose TJV formation as a technology strategy. Scholars researching joint ventures through the real options lens have usually focused on the ending stage of the alliance rather than on its formation. This gap in the literature has motivated the current research. Our hypotheses have been tested using a panel of 29 376 observations from 4050 manufacturing firms operating in Spain between 1998 and 2005.

Our findings provide strong support for the four hypotheses grounded on ROA assumptions. First, we found that the greater the firm's absorptive capacity, the more likely the firm is to form a TJV. This finding is in consonance with the idea that absorptive capacity increases the value of TJV formation by increasing the difference between the underlying technology value and the option's exercise price. It also supports the basic premise suggested by Cohen and Levinthal (1990). Many empirical studies have also found firms' absorptive capacity to be an antecedent of technological alliance formation (e.g. Bayona et al., 2001; Cantwell and Colombo, 2000; Fritsch and Lukas, 2001; Xia and Roper, 2008). For example, the research by Bayona et al. (2001) shows that those Spanish firms which systematically develop their R&D capacity have a greater propensity to cooperate since they possess the ability to absorb technological knowledge and thus learn from collaboration. Other interpretations have also been made. Xia and Roper (2008) find that those firms which engage in R&D only occasionally find fewer partners to ally with.

Second, we found that the greater the exogenous technological risk the firm has to face, the more likely the firm is to form a TJV. This finding is consistent with the ROA prediction that firms resort to TJV formation as a flexible technology strategy in high-risk contexts. Prior literature is in full agreement on the issue (e.g. Coronado, Acosta and Fernández, 2008; Folta, 1998; Vassolo et al., 2004). The research by Coronado et al. (2008), in consonance with ROA, links the technological dynamism of the sector to the existence of technological opportunities, and finds a positive relationship between it and the firm's innovative efforts. Nevertheless, Nieto and Quevedo (2005) find that the intensity of the innovative effort of those Spanish firms with high absorptive capacity is independent of the level of technological opportunities. Further work clarifying the cross-effects of absorptive capacity and technological risk on the choice of TJV formation as technology strategy is required.

With regard to our third hypothesis only partial support was found. It may be worth explaining this result detailing the two measures used for the risk of pre-emption by rivals. On the one hand, the expected effect of market concentration on firms' propensity to form TJVs has not been evidenced. Such a finding may prove somewhat surprising since it totally contradicts prior research. For example, Folta (1998) finds that fewer rivals in a technological subfield in the biotechnology industry led to a preference for joint venture formation over acquisition. Miller and Folta (2002) find that firms tend to exercise those growth options underlying equity partnerships in biotechnology that are exposed to the risk of pre-emption by rivals (which depends on the number of rivals). What is clear is that the intensity of firms' efforts to innovate and thus also cooperate for this purpose is shaped by industry structure. The studies by Folta (1998) and Folta and Miller (2002) particularly address high-tech environments as research contexts (biotechnology industry). Hence, deeper analysis linking market concentration, degree of technological rivalry, and technology strategy choices taking into account inter-industry differences is needed.

Moreover, Raider (1998) posits the need to replace market concentration as an indicator of industry structure when analysing the impact on the innovative behaviour of firms. In fact, in this paper, the significance of the risk of pre-emption is corroborated when it is evidenced in connection with the industry life cycle rather than concentration. We have argued that as the industry approaches the maturity and particularly the decline stages, the degree of technological rivalry (i.e. the risk of pre-emption by rivals) intensifies, thereby decreasing the incentives to defer commitment. From a different perspective, Katila and Mang (2003) found that the more mature the biopharmaceutical industry the earlier the timing of technological collaboration in the product development life cycle. They argue that there is a gradual strengthening of institutional support infrastructure (e.g. intellectual property protection), which speeds up collaboration. We suggest that the underlying driver of such a strengthening of institutional support should be the increasing competitive pressure in the industry. In other words, the strengthening of institutional support may be another indicator of increased risk of pre-emption by rivals, evidence such as that of Katila and Mang (2003) thus proving consistent with ROA predictions. A challenge for further research is to investigate alternative operationalizations of the risk of pre-emption by rivals.

Results also reveal that opportunity costs associated to TJV formation discourage firms from adopting such a technology strategy. The last hypothesis is also confirmed. However, public policies are increasingly promoting alliance formation, technological collaboration thus being carried out in many cases under co-financed programmes. Taking this into account, the negative effects of opportunity costs on TJV formation may be weakened due to the existence of government grants, exploration of which may prove an interesting avenue of future research. Whether this is true or not, we expand the view of prior real options literature regarding opportunity costs through our operationalization of the concept. Opportunity costs and the risk of pre-emption by rivals have traditionally been treated as interchangeable concepts. Nevertheless, the notion of opportunity costs is broader and, by analogy with financial options, should refer to those which the firm has not earned because it has adopted the formation of TJV as a technology strategy rather than other alternative strategies.

Our results also prove the positive relationship between firm size and age and their propensity to form TJVs, in consonance with prior literature. For example, Bayona et al. (2001) found that in Spain cooperative R&D is far more common for large firms than for small or medium ones. Several interpretations of similar results have also been made. Coronado et al. (2008) study internal and external factors affecting the attitudes towards innovation of firms located in a peripheral region of Spain. They found that favourable attitudes by firms towards innovation (amongst others, represented by participation in R&D cooperative projects), increases with the size of the firm, due to enhanced access to financial resources. Fristsch and Lukas (2001) find that cooperative firms tend to be relatively larger, arguing that the propensity for cooperation is positively related to a firm's economic activity. We suggest a different view, which can also be applied to understand the relevance of the firm's age. Mora-Valentín, Montoro-Sánchez, and Guerras-Martín (2004) identify the partners' reputation as a determining factor in the success of cooperative agreements. In line with this, we suggest that firms need to achieve a certain size, a wide profile of business contacts, and a well-established corporate image and market reputation to be recognized as an attractive partner to ally with, and thus be able to form a TJV. A potential line for further work may be to examine whether a partner's reputation increases the likelihood of TJV formation, by increasing the value of the underlying technology (S).

Results suggest that TJV formation is less common amongst firms which belong to a corporate group. This finding may be interpreted using transaction cost economics arguments. García-Canal et al. (2008) found that Spanish firms tend to adopt the form of joint venture for the agreement when it involves unilateral technology transfer or when partners pursue technological innovation in order to prevent partners' opportunism. Colombo (2003) argues that when partners have similar technological capabilities, given the great absorptive capacity, "the need to cope with greater appropriability hazards make the use of *low-flexibility* forms more likely" (Colombo, 2003: 1214). However, when partners have developed inter-organizational trust the need for controlling opportunism is reduced (Faems, Janssens, Madhok, and Van Looy, 2008). That may be the case of firms belonging to the same corporate group. It seems logical to think that their primary inter-firm relationships are carried out with other firms in the same group, and that they resort to contractual forms when collaborating together. As a field for future research, this issue may be analysed under a real options lens, since choice of governance form involves choice between flexibility and commitment.

In sum, the contribution of the paper towards alliance formation research is to provide an insight into how firms decide either to form TJVs, based on certain internal factors (the firm's absorptive capacity, age, size, and belonging to a corporate group), strategic choice-factors (the opportunity costs linked to TJV formation), and, finally, on the basis of some exogenous factors (managerial risk perception, technological intensity of the industry, and risk of pre-emption by rivals).

By way of a further contribution, this paper addresses calls for empirical research applying OPT to strategic decision analysis. Although as far back as 1984 Myers encouraged scholars to make a conscious effort to bridge the gap between finance theory and strategic analysis Myers (1984), this question still remains unresolved. As Mc Grath et al. (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 vein, 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 […] (Kogut and Kulatilaka, 2004: 103). We take a step further towards developing an investment theory for the field of strategic management, by ‘translating’ the concepts from the original OPT language into a particular kind of strategic decision: formation of TJVs.

Moreover, according to Kogut and Kulatilaka (2001) a firm’s capabilities represent its platform to respond to future opportunities. The difference between viewing the firm as a portfolio of options rather than a bundle of resources and capabilities is mainly perspective: while the latter focuses on the performance of previous strategic decisions (investments) the former highlights the future possibilities to emerge from core competences of the firm. Both portfolios are the same, although the former is easier to value than the latter since it is easier to value an asset in terms of what it may allow to be done rather than the asset itself. Therefore, the link between options (opportunities) and the resource-based strategic approach of the firm is straightforward, thereby providing the basis to apply real options valuation to strategic decision making. By doing this, a wide range of strategic choices (e.g. the creation of corporate spin-offs), traditionally addressed from a resource-based view, may be consistently analysed from the ROA. As a consecuence, a wide range of promising lines of future research emerge. However, application of ROA to the strategic management field should go beyond academic interest and seek to solve practical strategic decision problems in real-life contexts. Although it may prove complex (Myers, 1984), 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). Hence, a primary scholarly task should be to provide comprehensive proofs of ROA potential for practitioners. We believe this paper may constitute one such attempt and we hope to encourage further empirical work. We have presented TJVs as option chains, based on their option-like properties. In other words, TJV formation generates future choices and enables preferential access to future opportunities (McGrath et al., 2004). Nevertheless, not all strategic decisions necessarily fit a real options perspective (Hartman and Hassan, 2006), otherwise real options logic would be overextended and the advantages of its applications undermined (Adner and Levintal, 2004). Thus, the true challenge for research is to clarify not only how to apply ROA to strategic decision analysis but also when to do so.

Finally, we draw attention to the limitations of this paper. Despite the quality of the data, some data constraints may be identified. First, the database employed only provides information about technology strategy adoption of manufacturing firms operating in Spain and does not include information about firms that belong to other sectors, such as the high-tech (e.g. biotechnology), or the service sector (e.g. technology consultancy). Moreover, specific country factors may hinder full generalization of results. Other important characteristics of TJVs are missing. The database does not allow us to identify either the geographical scope of the collaboration (domestic versus international TJVs), or the number of the partners involved (dyadic versus multi-party TJVs) and their organizational nature (e.g. firm-firm collaboration versus firm-university collaboration). The dynamics of alliance formation may prove different in each case (García-Canal et al., 2008; Lavie, Lechner, and Singh, 2007; Mora-Valentín et al., 2004). Examining TJV formation taking into account these peculiarities may be an important issue for future research.

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