TECHNOLOGY ACQUISITION AND THE CHOICE OF GOVERNANCE BY ESTABLISHED FIRMS: INSIGHTS FROM OPTION THEORY IN A MULTINOMIAL LOGIT MODEL

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ABSTRACT

This paper examines the governance decisions of established firms seeking technological know-how. Option theory is used to supplement the traditional transaction cost approach. Empirical results from a multinomial logit model indicate that the combined transaction cost and option theory model provides a richer description of governance choice.

Technological change that weakens or destroys established firms' advantages in research and development (R&D) and production may have little effect on their relative advantage in distribution and marketing. This situation creates opportunities for cooperation, rather than competition, between established firms and smaller, more innovative firms having technical expertise, but lacking downstream capabilities. This study addresses how established firms access the technological know-how, techniques, and procedures relevant prior to product commercialization. Traditionally, industry incumbents have used three means to obtain new technology from smaller innovators: (1) non-equity forms of collaboration such as research contracts, licensing agreements, or non-equity joint ventures; (2) equity forms of collaboration such as equity joint ventures or minority equity investments; or (3) acquisition (integration) of the innovating firm(s) and its technology. This paper studies how established firms choose between these three governance mechanisms in their attempts to access new technology. It is proposed in this paper that transaction costs and option value jointly determine the choice of governance among established firms.

THEORETICAL MODEL

The choice between governance modes is critically determined by two factors: transaction costs and option value. Thus, firms interested in accessing technology are assumed to maximize utility (U) with respect to alternative modes of governance.

$$U(NE, E, A) = f(\text{Transaction costs, Option value}) \quad (1)$$

where NE represents non-equity forms of collaboration, E represents equity forms of collaboration, and A represents acquisition. Since governance selection is made at the project level, all non-equity forms of collaboration which are accompanied by minority investments are considered equity forms.

Transaction cost theory highlights the importance of the costs associated with governing and monitoring transactions. It advocates selecting an governance form which minimizes the sum of production and transaction costs, and suggests that transaction costs are often determinant. Generally, integrative modes, such as acquisition, are thought to minimize transaction costs by aligning the incentives of parties. Equity collaborations are believed to have similar alignment properties. Transaction costs increase as firms move from internal governance modes to equity collaborations to non-equity collaboration and market governance (Williamson, 1985).

The costs of governing outside of hierarchies are accentuated in uncertain environments because it is harder to specify *ex ante* all possible contingencies and the contractual adaptations to be made in each case. Previous work has found support for the influence of transaction costs on the preference for integration over collaboration, and on the preference for equity collaborations over non-equity collaborations (Pisano, 1988). To date, the relationship between integration and equity collaborations has not been addressed in the transaction cost literature. Nor has empirical analysis distinguished between the factors affecting the choice among these three governance modes.

A growing number of scholars have recognized the potential of option theory where environments are embedded in uncertainty (Kogut, 1991; Bowman & Hurry, 1987; Sanchez, 1993). The real option literature in the field of managerial finance examines the value of waiting before irreversibly committing resources (McDonald & Siegel, 1986). Since acquisition of a firm and its technology generally entails sunk costs, or commitment, it exposes the acquiring firm to the risk of owning a technology which may turn out to have little value. Recent studies have found that collaborations often precede integration of a valuable technology (Mitchell & Singh, 1992) or acquisition of a trading partner (Kogut, 1991). This evidence may suggest that established firms use certain forms of collaboration as options to acquire technology.

Equity and non-equity collaborations which provide a right, but not an obligation to purchase, allow established firms to wait until the technology's value is more certain

and positive before committing to the acquisition of the technology-holder. This option to wait becomes valuable when the value of the underlying technology is volatile. Acquisitions are not options to wait since the firm fully realizes the hazards of a devaluation. Thus, the relevant issue is the choice between acquisition of the innovator versus purchase of a call option to acquire the innovator.

While having the ability to delay investment is important, it is not the only element necessary for characterizing investments as options. Options must provide firms with a claim on future investments. If no claim exists, then the investment opportunity may potentially be bid away by rivals. Two such "claims" are likely to exist in collaborative modes of governance. First, certain forms of collaboration provide a partner a "right to buy and sell equity" or a "right of first refusal". In other words, the investor (the established firm) has a stated contractual right to acquire part, or all, of the other firm or the joint venture pre-empting other potential investors. For example in the biotechnology industry, Rhone-Poulenc Rorer had an option to buy a majority stake of Applied Immune Sciences after an initial 37% stake taken in 1993.

A second claim on technology involves the opportunity for the partner to recognize value in the technology before other potential bidders. This claim arises because of private information shared through close interaction of the partners, and perhaps through involvement on the board of directors of the target firm. Since this argument hinges on private information of the value of a technology, and not the technology itself, it can be distinguised from the transaction cost argument addressing weak appropriability regimes.

These claims highlight an important difference between equity and non-equity collaborations. Potentially, equity collaborations can involve both types of residual claims (Kogut, 1991). However, non-equity collaborations can incorporate only the claim on private information. As a result, equity collaborations are likely to show significantly stronger option characteristics than non-equity collaborations and should be preferred during uncertain times because of the combination of high option value and low transaction costs.

HYPOTHESES

A model incorporating both transaction costs and option perspectives should be preferred to the traditional transaction cost model. This leads to the first hypothesis.

Hypothesis 1: A combined Transaction Cost - Option Theory model will provide a richer description of governance choice than the Transaction Cost only model.

Hypotheses 2A through 2C reflect traditional relationships which have been empirically supported in the transaction cost literature. Two key behavioral assumption in the transaction cost paradigm are bounded rationality and opportunism. Bounded rationality is exploited when relationships are expected to involve multiple projects. A relationship with a larger scope increases the number of contingencies that must be written into the initial contract, thus adding complexity and increasing the difficulties of executing the contract. The incentives for opportunism should be related to the competitiveness of the contracting environment. A more competitive contracting environment will have relatively more rivals or fewer potential partners. The presence of many rivals is likely to lead to more opportunistic behavior and fewer potential partners is expected to increase the firm's exposure to small numbers bargaining.

Internal organization facilitates vertical information flow and, thereby, minimizes the problem of bounded rationality and the likelihood of opportunistic behavior. As a result, increased scope of relationships, many rivals, and few potential partners will lead to a preference for acquisition and equity collaborations over non-equity collaborations. It should also lead to a preference for acquisitions over equity collaborations.

Hypotheses 2A-C: (A) Increased scope of relationships, (B) more rivals, and, (C) fewer potential partners are expected to lead to a preference for integrative forms of governance. (Acquisition preferred to equity collaborations preferred to non-equity collaborations).

The value of an option is predominantly influenced by volatility in the value of the underlying asset. In the case of technology options, the greater the volatility in the value of the underlying technology, the more valuable is the call option relative to ownership of the technology, all else being equal. As a result, technological volatility will lead to collaborative modes of governance.

In addition to volatility, option pricing models in finance, such as the Black-Scholes model (Black & Scholes, 1973), offer additional variables relating to the value of options. Three of these relationships (the value of technology, the option duration, and the interest rate) are expected to directly influence the choice of governance. Thus, greater technology value leads to a higher value for a call-option on that technology. This is synonymous with the stock (bond) price for a financial option.

The development of a new technology requires a period of time for completion. Longer project duration implies higher uncertainty; an outcome similar to that associated with higher volatility. Over a long period of time, a number of unforseeable contingencies may arise even when technology value is relatively stable. Since downside risk is limited, options are more valuable the

more time remaining before project completion. This is synonymous with time to maturity of the financial option.

As with financial options, the higher the interest rate, the lower the present value of the exercise price (remaining cost of the innovative firm) as contracted upon in the technology option. A higher interest rate will have the same effect of lowering the remaining cost. Thus, higher interest rates tend to imply higher call values. This effect assumes that the exercise price has been determined at the initiation of the option. It is unclear if this effect will remain significant for non-equity collaborations.

Hypotheses 3A-D: (A) Volatility, (B) higher technological value, (C) longer project duration, and (D) higher interest rates are expected to lead to a preference for equity agreements over alternative forms of governance. (Equity collaborations preferred to non-equity collaborations preferred to acquisition).

RESEARCH DESIGN

The biotechnology industry was chosen as a context for this study because of its recognized importance and the rich mixture of institutional arrangements for organization of the innovation process. The sample contains 947 acquisitions and collaborations involving small biotechnology companies and established firms for the time period between October 1984 and December 1992. The main data source for developing this sample is the North Carolina Biotechnology Actions Database. BioScan and the Predicast F&S Index of Corporate Change were used to verify and supplement the primary source. The CRSP (Center for Research in Security Prices) files were used to accumulate the measures of volatility and technology in the biotechnology industry between 1984-1992.

The dependent variable, defined in Table 1, identifies the form of governance alternatives. The independent variables, also defined in Table 1, relate to transaction cost or option theory. The scope of the relationship, the number of potential partners, and the number of rivals are derived from the transaction cost literature. Technological volatility, technology value, project duration, and interest rate are linked to option theory. The relative importance of the volatility variable indicates that further discussion of its specification is warranted. Technology volatility is designed to capture the nature of the volatility surrounding the technology in question, where technology is characterized broadly as the biotechnology segment in which the transaction takes place (Pisano, 1988). Stock indices were created from the top four biotechnology segments: human therapeutic, human diagnostic, agriculture, and supplier. Each index was created from weekly returns of nine biotechnology firms specializing in the respective markets. While 47% of all transactions occurred across international boundaries, this index should be representative of global industrial activity, due to prominence of US biotechnology research. Technology volatility is measured as the 26-week standard deviation of the log of weekly returns for each segment.

TABLE 1
Variable Definitions and Descriptive Statistics

Variable	Definition	Ratios	Mean
Choice Variables			
1. Acquisition	Purchase of greater than 50% of a biotechnology firm.	0.1140	n/a
2. Equity	Initiation of minority direct investment, equity joint ventures, or other type of collaboration simultaneous to equity ownership.	0.2967	n/a
3. Non Equity	Collaborations initiated with no equity ownership.	0.5892	n/a
Independent Variables			
1. Scope	Scope = 1 if partners were involved in more than one project, else 0.	n/a	0.4245
2. Potential Partners	The number of biotechnology firms in the segment involving project j.	n/a	267.65
3. Rivals	The number of established firms in the segment involving project j.	n/a	28.39
4. Volatility	The 26-week standard deviation of the log of weekly returns for the appropriate biotechnology index.	n/a	0.3396
5. Technology Value	The value of the biotechnology index corresponding to project j.	n/a	339.35
6. Project Duration	Project duration = 1 if project j is in the therapeutic segment, else 0.	n/a	0.5576
7. Interest Rate	The 2 year Treasury note average monthly rate.	n/a	8.0624

947 cases

METHODOLOGY

The multinomial logit methodology is appropriate for testing models where utility differences determine the probability of selection amongst a series of discrete choices, and is employed in this paper. The fundamental assumption underlying discrete choice modeling is the independence of irrelevant alternatives (IIA). Essentially, the IIA assumption requires that the ratio of the choice probabilities of any two alternatives be unaffected by the systematic utilities of any other alternatives. The most widely accepted test of the validity of the IIA assumption has been developed by Hausman and McFadden (1984). Initiation of this test reveals a Hausman statistic of 1.625. This statistic falls below the critical value at the 0.001 level indicating that the estimated coefficients are stable across the choice set thus providing statistical support for our trinomial specification.

RESULTS

The parameters were estimated using the LIMDEP version 6.0 software package. Table 2 illustrates the results from the transaction cost model (column 1), the option theory model (column 2), and the combined model (column 3). In this study, the estimated coefficients were normalized to the choice of acquisition (normalization is required for logit estimation).

Formal log-likelihood ratio tests were conducted to test the null hypothesis that the estimated coefficients were jointly zero. They are reported at the bottom of Table 2. These tests compare the incremental improvement in fit obtained in the theoretical model with respect to a null model [£(0)]. The test statistic is χ^2 distributed with degrees of freedom equal to the difference in the number of parameters in the models being compared. All three models are found to be significant at the 0.001 level. A more rigorous test of the significance of the explanatory coefficients is one that compares the fit of the theoretical models with a constant only model [£(c)]. This test was also conducted and is reported at the bottom of Table 2. Again all three models are shown to be significant at the 0.001 level, providing support for the substantive coefficients in each of the theoretical models.

The main hypothesis (H1) argues that option variables provide explanatory power that significantly complements the traditional transaction cost analysis. Since the management and economics literature has widely recognized transaction costs as a determinant of governance choice, at the exclusion of option value, the null hypothesis is that transaction costs fully specify the choice model. A log-likelihood ratio test was performed. This test reveals a chi-squared test statistic of 43.14 with 8 degrees of freedom. Thus, we can reject the null hypothesis at a 0.001 level of significance and conclude that the option variables significantly improve model fit.

While not reported here, the sample was segmented along both high and low volatility and foreign and domestic transactions to test for the robustness of these findings. In all but the high volatility segment, option variables significantly contributed to improved model fit. Thus, the importance of option theory in explaining choice of governance seems robust to a number of environmental contingencies.

TABLE 2
Multinomial Logit Parameter Estimates on Choice of Govenance Mode

Independent Variables (normalized to acquisition choice)	Parameter Estimates		
	Transaction Cost (1)	Option Value (2)	Combined (3)
Constant-Equity	-0.5201	-1.6914	-2.5596†
Constant-Non Equity	1.2212***	-0.8428	0.2416
Scope-Equity	1.8135***		1.7402***
Scope-Non Equity	0.2740		0.0977
Potential Partners-Equity	0.0019*		-0.0040†
Potential Partners-Non Equity	0.0015†		-0.0024
Competitors-Equity	0.0044		-0.0008
Competitors-Non Equity	-0.0010		-0.0215*
Interest Rate-Equity		0.1355	0.2135†
Interest Rate-Non Equity		0.1797†	0.1609
Technology Value-Equity		0.0007	0.0022*
Technology Value-Non Equity		0.0001	0.0008
Volatility-Equity		2.5832*	2.7005*
Volatility-Non Equity		1.5425	1.0972

Duration-Equity		1.0389***	0.9277**
Duration-Non Equity		1.1078***	1.4840***
Log-Likelihood Fit Statistic; L(β)	-809.43 (8df)	-848.44 (10 df)	-786.86 (16df)
-2[L(0) - L(β)]	461.94***	383.92***	501.08***
-2[L(c) - L(β)]	123.2***	45.18***	162.34***

† p < .10, * p < .05, ** p < .01, *** p < .001 number of transactions = 947

Results for the tests of the remaining hypotheses are provided in column 3 of Table 2. The transaction cost coefficients provide tests of hypotheses 2A-C. The positive and significant coefficient for the scope-equity variable indicates that when the scope of a relationship involves multiple projects equity collaborations are preferred to acquisition. No significant relationship was found between scope and the preference for non-equity collaboration over acquisition.

A comparison of the estimated coefficients normalized to acquisition allowed the construction of a test to determine the relative preferences between equity and non-equity collaborations. This test revealed that as scope of the relationship increased there was a significant preference for equity forms of collaboration over non-equity forms. The positive equity to acquisition relationship is not consistent with our expectations. However, our finding that equity collaborations are preferred to non-equity collaborations when relationships involve multiple projects is consistent with our expectations and the earlier work of Pisano (1988). Thus, there is only mixed support for hypothesis 2A.

Following previous work, hypothesis 2B indicated that an increase in the number of potential partners would be related to a preference for less integrated forms of governance. This hypothesis was strongly supported by the transaction cost (only) model (column 1). However, the inclusion of the option theory variables reversed the sign of the preference between equity collaborations and acquisition and eliminated the significance of the relationship between non-equity collaboration and acquisition. Thus, the failure to include concepts from option theory may yield misleading findings.

The final transaction cost hypothesis indicated that increasing the number of competitors would lead to a preference for more integrated forms of governance. While no significant preference was found between equity and acquisition, the significant negative coefficient on the non-equity variable does indicate that as the number of competitors increases acquisition is preferred to non-equity forms of collaboration .

The theoretical discussion in this paper hypothesizes that increases in the option variables will lead to higher option value and thus, an increase in the probability of buying a call option through either equity or non-equity forms of collaboration. Examination of coefficients in the full model (column 3) provide support for hypotheses 3A through 3D. T-tests on coefficients specific to the choice of equity collaborations reveal positive and significant relationships for volatility, technology value, project duration, and interest rates. Thus, higher values of these variables are associated with increased preference for equity collaborations over acquisition. Additional tests verify that as technology value and volatility increase equity collaborations are preferred to non-equity collaborations. These findings strongly support the option theory argument with respect to equity collaborations. The characterization of non-equity collaborations as options is less strongly supported. T-tests on coefficients specific to the choice of non-equity collaborations reveal only one significant relationship - project duration. Interestingly, non-equity collaborations are preferred over other governance forms when duration is high.

Our results strongly support the contribution of option theory to the choice of governance. The option coefficients were found to be largely significant and in the hypothesized direction. Particular support was garnished for the characterization of equity collaborations as options. Evidently, established firms use equity collaborations to hedge downside risk while maintaining the potential to capitalize on a budding technology. As expected, less support is provided for the non-equity collaborations as options. Thus, we have illustrated that transaction costs and option value jointly determine governance choice.

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