Entering and exiting collaborative purchasing relationships

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Many companies establish collaborative relationships (CRs) with suppliers either alongside or in preference to purchasing parts through a process of competitive bidding (CB). CRs offer flexibilities and options arising mainly from the "looseness" of the contractual relationship. One significant decision element confronting a firm intending to engage in a CR is when to enter such a relationship and when to abandon it. This paper develops a model that focuses on such timing issues. It provides an optimal timing valuation approach to establishing/abandoning a CR that incorporates differential learning rate payoffs. To achieve this, a real options' frame of reference is adopted that enables a formal analysis of the contingencies embedded in a CR. A standard illustration of the application of the model is provided.

Keywords: collaborative purchasing relationships; real options; timing issues.

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1 Introduction

Traditionally, the costs and benefits accruing to a firm producing required parts or subcomponents internally have had to be weighed against those of outsourcing via competitive bidding (CB) for the products (Quinn and Hilmer, 1994). Recently, alterations to buyer-supplier links have been regarded as presenting a mid-way option: the collaborative relationship (CR), which represents a "quasi-vertical" form of integration (Richardson, 1993). Such purchasing linkages are finding increasing appeal among many companies (Handfield et al, 2000; Helper and Sako, 1995; Lambert and Cooper, 2000; Liker and Choi, 2004; Trent and Monczka, 1998). Indeed, Sheth and Sharma (1997, p.91) have noted that "organizational buying is dramatically shifting from the transaction oriented to the relational oriented philosophy and will shift from a buying process to a supplier relationship process".

Such a shift is clearly in evidence in contemporary business-to-business relationships whereby factors such as product development input, price rebates, after sales warranties, supplier inspection policies and information systems integration, play increasingly important roles. Strategic and contractual issues between buyers and sellers continue to gain relevance, particularly in new product development contexts (Arnold, 2000; Axelson et al, 2000; Cousins, 1999; Gadde and Snehota, 2000; Narayanan and Raman, 2004; Pierick and Wynstra, 2000; Reniers and Tapiero, 1995). Supplier selection decisions generally entail a variety of dimensions requiring evaluation (Dalmin and Mininno, 2003; Weber et al., 1991). The development of relationships-based or collaboration-oriented purchasing behaviour can be influenced by many factors including similarities between the industry and technologies of buyer and suppliers (Burik and Halskan, 2001; Gadde and Häkansson, 2001; Womack and Jones, 1994), prior experiences of change among suppliers (Frey and Schlosser, 1993, Hahn et al, 1990), effective communications between buyer and suppliers (Hoberman and Mailick, 1992; Lascelles and Dale, 1989; Mohrman and Mohrman, 1993; Van Weele, 2000), the creation of cost information exchange relationships (Ellram, 1996), and the consideration of purchase leverage factors and volume of initial business (Billington and Ellram, 2001; Kulmala, 2004). The importance of experiential learning is also characteristic of customer supplier links (Bessant et al., 2003; Dyer and Singh, 1998; Krapfel et al, 1991; Langfield-Smith and Greenwood, 1998; Stjernstrom and Bengtsson, 2004).

Ultimately, the decision to engage in a collaborative relationship with a supplier as opposed to engaging in transaction focused competitive bidding for required products by a buying firm entails a variety of cost-benefit implications that stem from the various options available only in the subcontracting link. For instance, a CR could offer the opportunity to alter product specifications mid-stream as dictated by the volatility of market demands. Likewise, it may be possible to earn superior returns through learning rate differentials between CR and CB suppliers. Unplanned purchase volume changes, including temporary suspension of purchases, could also be effected in the buying relationship. Further, the relationship could lead to growth opportunities contingent upon entering the initial contract but not specified at the time. These features of CRs require an economic assessment of the flexibilities offered vis-à-vis the cost implications of establishing CRs. By contrast, it is clear that establishing a CR can be time consuming with resources being required to set up an appropriate trading infrastructure. Moreover, there has to be a willingness to share operational information (Dyer and Singh, 1998; Handfield et al., 2002).

One specific issue concerns the point in time when the economic benefits accruing from a CR can be regarded as exceeding those under CB. An important purchasing decision issue is thus when to shift out of CB and establish a CR and when to abandon the CR and switch back to CB. This timing issue has not been addressed in the prior literature and provides the primary motivation for the present study. This concern is addressed here by appealing to a real options perspective which lends itself to considering timing issues in purchase choice decisions. More generally, a real options approach, although prevalent in many facets of managerial decision-making, has not been adequately considered in guiding purchase decisions in the literature. This void provides a further source of motivation for the paper.

The real options perspective enables a dynamic assessment of CR variables which may be subject to uncertainty and provides an approach to the economic valuation of the contingencies embedded in CRs. Some scholars have suggested that timing issues affecting managerial decisions should be considered using a real options frame of reference (Amran and Kulatilaka, 1998; Copeland and Tufano, 2004; Dixit and Pindyck,1994; Luehrman, 1998a;1998b; Trigeorgis, 1996). Within emerging business-to-business supply situations, a number of scholars have applied real options based analyses although timing issues have not been the central concern (Amran and Kulatilaka, 1999; Copeland, 2001; Means and Schneider, 2000; Van Putten and MacMillan, 2004). In this paper we extend the real options approach to take into account the time implications of learning rate effects in supplier switch decisions.

The paper is structured as follows: we first discuss the characteristic differences between collaborative subcontracting relationships and competitive bidding. This is followed by the development of a formal CR valuation model, which draws on an options valuation perspective. An example of the application and results of the model are discussed with special reference to entry and exit timing decisions over time-bound maturities. We conclude with a discussion of the contributions and limitations of our analysis and comment on research possibilities for applying our approach to other CR issues not tackled here.

2 Purchase Options

Two options exist for a company wishing to purchase a subcomponent or a service-based product from an external supplier. On the one hand, the buyer can put out a bid tender and choose the most competitive quote for a certain number of parts over a period of time. Benefits from past performance are limited, exchanges tend to be at arm's length and product specifications and prices are well defined. In contrast to this transaction-based competitive bidding approach, the buyer can establish a collaborative relationship with a supplier. Such a relationship would entail sharing of technical and financial information, managerial interaction and liaison and a more flexible buyer-supplier link as to time/volume variables and product specification. The costs involved in identifying the right supplier for a collaborative relationship and operationalising such a link differ from those in a bidding situation.

Competitive bidding involves a specific set of economic transactions whose terms are made explicit prior to the commencement of trading. An attempt is made to cover recourse options for departures from the terms of the contract and the buyer-supplier link is characterised by a concern which minimizes each party's dependence on the other. By contrast, collaborative subcontracting relationships are founded on trust and transactional dependence with specific supply undertakings (often made orally) extending over only part of the overall trading relationship. The obligations of long-term CRs are diffuse and guide the resolution of specific transaction problems on a case-by-case basis. The CR exhibits mutual indebtedness which can span over long periods with a loose principle of give and take. A CB situation is characterised by narrow and formal channels of communication between the buyer's purchasing department and the supplier's sales department whereas a CR tends to have extensive and multiple channels of communication between a variety of functional managers and departments within the two companies. The most significant difference between CB and CR for the purposes of this paper is that CR sets very loose terms of trade as to supply quantity, timing of supply, product specifications and product price at the time of establishing the trading relationship. Conversely, CB formally and narrowly stipulates how much is to be traded, at what price and time. This enables the economic exposure to be calculated with a high degree of accuracy prior to the commencement of trading. Table 1 identifies some contrasting characteristics of CB and CR.

The absence of contractualised specificity as to quantity, price and timing of supply makes it difficult to assess the economic value of a CR trading link. The buyer's ability to alter quantities purchased from the supplier and to change product specifications confers operational flexibility. There is also a timing choice embedded in a CR that enhances managerial flexibility. A company may, for instance, decide to enter a market either as an innovator or as a follower. This will dictate when it will purchase required subcomponents from a supplier. The timing decision is conditioned by product life cycle considerations that place strategically desirable time frames relating to market entry (Dunk, 2004). A firm may choose to delay entry into a market for the sale of its final product and thus also delay the purchase of subcomponents from a supplier. Here, the firm faces a timing decision. Should it invest in the product and allocate resources to the new business opportunity sooner rather than later whereby it might enhance the likelihood that it will dominate the market in the long run by virtue of an early lead. Issues of volume strategies and low cost positioning will form part of the decision process. This type of timing issue is amenable to analysis using a "real" options perspective (see below).

What makes the analysis real is that the heuristics relate to investments in physical and human assets rather than to financial instruments. This form of timing decision is however not the focus of the present analysis. Rather, we focus on the situation whereby the decision to produce the product has already been taken by a firm. It may then choose to deal with the supplier offering the lowest bid. Conversely, it may opt to form a closer alliance with a subcomponent supplier and develop a collaborative relationship. Here, the buying firm would be making a "platform investment" (Dixit and Pindyck, 1994; Kogut and Kulatilaka, 1994; Luehrman, 1998). As such, it would be enabling operating flexibility by for instance, altering purchase volumes in line with changing sales of the final product. Moreover, it would create the possibility of rapid expansion and growth in ways not anticipated at the outset. There is also a timing element in that the CR will put into effect a transfer of benefits accruing from the lower cost of producing subcomponents over time alongside the accumulation of experience by the supplier (Child, 2005).

The initial subcomponent or service offering cost of a supplier able to engage in a CR may supercede that of a CB value supplier but the higher cost needs to be considered in the light of foregoing the payoffs from a CR. In particular, the transfer of knowledge and the availability of flexibilities say between a supplier and assembler may over time contribute to value advantages exceeding those of pure initial subcomponent price differentials between CB and CR. Ultimately, not engaging in a CR will cost the buyer the benefit of cost reduction learning. The longer the buyer holds off entering into a CR in favour of entertaining a CB link, the lower the experience-related cost minimization it can tap into. It is this timing issue which is delineated within the real options lens and which provides the focus of the arguments developed below.

The incentive to establish or abandon a CR is considered here to depend on the extent to which learning effects are available.[1] Naturally, some firms will opt for both CR and CB depending on their purchasing portfolio mix (Axelson et al., 2000). The existence of learning (or experience) curves has been established in a variety of industries (Dutton and Thomas, 1984; Dyer, 1996). In the presence of learning effects, marginal costs decrease in cumulative output. In part, this is because of the aggregate result of labour learning, process improvement, product standardisation, and economies of scale. The extent to which economies of learning are available varies across and within industries and is explained by differences in R&D expenditure and capital intensity as well as team effects (Dyer, 1997; Dutton and Thomas, 1984; Gruber, 1992; Lieberman, 1984). In practice, learning effects are higher under CR links than in CB links and so the resulting costs mount with delays in establishing CR links. The earlier the establishment of a CR, the earlier it is possible to establish and achieve precise learning curve parameters on

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[1] As might be expected, in the case of a CR, X is an amount net of any premium applied by the subcontractor to allow for irreversible equipment or tooling investments made.

the basis of quantifiable effects between volume and cost reductions. The CB option does not provide equivalent incentives for supplier or customer related investments.

It is likely that forestalling a CR, will create delays representing learning curve losses to the buyer. But just as there is an entry timing issue with economic value implications, the option to temporarily or permanently abandon the CR entails an evaluation of time-affected economic factors. Our approach is to use a real options perspective to place an aggregate value on the operational and managerial flexibilities offered by a CR-based buyer-supplier link such that the optimal contract entry and abandonment time may be determined. For this, a formal assessment of the uncertain elements of the CR subcontracting link is undertaken. The analytical model is developed below. This is followed by an illustrative example.

3 Timing options to adopting collaborative relationships

Consider an assembler with an investment opportunity consisting in the launch of a new product. The assembler may establish a CR within the time horizon [0,T] and purchase some or all of the subcomponent part requirements. Alternatively, the assembler can purchase the subcomponents from a supplier following a competitive bidding process.

What determines decisions towards a CR approach is the hidden gains from the arrangement under conditions of uncertainty. The value of the gains from a CR can be characterised as contingent-claims or real options (Dixit and Pindyck, 1994; Luehrman, 1998a;1998b; Trigeorgis, 1996). By embarking on a CR linkage, the buying company which assembles the final product after purchasing a subcomponent from a supplier is in fact making an investment as it believes there is a pay-off that will translate into contingent profits. In formal terms, the value of the pay-off depends on the present value S of the expected cash flows, the present value X of the cost of the subcomponent[2] , the time-horizon T for the CR, the volatility rate of S, and the discount rate, r.Thus the value of the profit expected from a CR arrangement can be represented as $C(S, X, T, \sigma, r)$ - which in financial terms is equivalent to a “call” option.

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[2] It is well known that $dC(.)/d\sigma > 0$ and $dC(.)/db < 0$, which can be shown from the Black-Scholes formula with dividend payments.

The present value S of the cash flows from revenues of the new product to be launched less all material and operating costs, except for the incremental cost of the subcomponent associated with the CR, is stochastic and generated by a geometric Brownian motion. Over the interval $[t, t + dt]$, it can hence be represented by:

$$dS/S = \mu dt + \sigma dz \tag{1}$$

where:

μ = the instantaneous expected rate of the present value of cash flow stream S;

σ = the volatility rate of S;

z = a factor generated by a Wiener process;

The value of the pay-off from a CR that is exercised immediately is:

$$C_0 = Max\,(S - X, 0) \tag{2}$$

Where zero profits reflect profits above those to be derived from CB.

Effectively, the assembler can be consiered to be holding a timing option on the opportunity to collaborate with the supplier. One can then define the value of the timing-option V as:

$$V = C\,(S, X, T, \sigma, r) - C_0 \tag{3}$$

The value of the timing option represents the excess value of the deferrable undertaking over the currently achievable profits.

To derive the value of the CR pay-off, C(.), we use the options value derivation which is well-determined in the literature and can be characterised by the Black-Scholes formula (Black and Scholes,1973; Merton,1973), which is presented in Appendix A. In this analysis, we have assumed that X is constant. It could however be argued that X might in reality be stochastic1. This would be the case for instance when the uncertainty surrounding the demand for the final product affects the demand for the subcomponent. When both S and X are stochastic, we can value the CR payoff embedded in our analysis using the approach developed by Magrabe(1978).

3.1 The Implication of Cost Reduction Events

Suppose, that early establishment of a collaborative relationship yields a deterministic payoff D derived for instance from a one-time technological breakthrough or learning event after the start of production by the supplier. This may render earlier implementation of the project advantageous. If the payoff D occurs at time t^*, then the present value of profits initially is $S_0 + De^{-rt} - rt * -X$ and at time t^*, the value of the project is $S_{t*} + D - X$. It is to be noted that t^* represents some optimal time, which lies between t and T. This designation is consistent with the Black-Scholes model approximation procedure for valuing American call options.

Given that the value of the timing option must be equal to zero at a time when delaying implementation becomes no longer worthwhile, we can posit that there is a "threshold" present value of the project $\hat{S}_{t^*}$ when this will occur. Thus at time t^*, from equation (2):

$$V(t^*, T) = C\left(\hat{S}_{t^*}, X, t^*, T, \sigma, r\right) - \left(\hat{S}_{t^*}, +D - X\right) = 0 \tag{4}$$

where C(.) is given by a Black-Scholes option value formula.

Equation (4) captures the point at which both the present value of profits from the undertaking and the cost of further delaying are sufficiently large as to make the option of delaying any longer unattractive. This gives two possibilities for timing choices: either $S_{t^*} > \hat{S}_{t^*}$ and implementation should proceed at time t^* or $S_{t^*} < \hat{S}_{t^*}$ and waiting for time T is preferable.

Suppose the assembler decides that it would, in strategic terms, be sensible to assume a longer time period over which the product can be produced and marketed and hence to expand the time frame over which the CR could be established. This will increase the time to maturity of the option and hence increase the threshold $\hat{S}_{t^*}$ value. The company will then find it is desirable to delay establishing the CR link. Conversely, an increase in the value of the bonus D from early entry into the CR will proportionately decrease the value of the timing option and therefore lower the threshold present value. The company will then be induced to opt for earlier CR entry. Likewise, as the cost of purchasing the subcomponent via a CR increases, the company will feel less pressed to enter the relationship and will prefer to delay (the threshold value will be higher). In this case, the problem of valuing the CR gains with an explicit benefit from learning D, or technological change occurring at time t^*, we value C(.) in equation 4 using the usual Black-Scholes formula with S replaced by $Se^{-b(T-t^*)}$ where $b = D/S$. This approach was proposed by Black (1975) for valuing American type options that pay dividends. The Black approach preserves simplicity. It is a closed-form model for which a comparative static analysis can be performed. (Alternatively, numerical procedures based on binomial trees may be appropriate but the ability to perform simple comparative static analysis becomes more constrained.)

3.2 Learning Curve Effects

Typically, supplier learning will be ongoing and will lead to not one singular event but to a stream of cost reduction improvements. Effectively, it is likely that there is a learning curve effect afforded by the subcontractor if the CR is established. This could stem from production of the subcomponent which yields known (deterministic) cost reductions as a function of volume output. Although CRs entails loose terms of trade as to supply quantity, timing of supply, product specification and product price, it is possible to establish more precise learning curve parameters on the basis of quantifiable effects between volume and cost reductions. It is anticipated that delaying the establishment of the CR will cause the loss of bonuses accruing from learning curve effects. What therefore is essential is to adjust Equation (4) to enable threshold values to be obtained at each present value decline caused by the bonus paid out such that:

$$C\left(S_{k^*}, X, t_h, t_{k^*}, T, \sigma, r\right) = \hat{S}_h - X \tag{5}$$

Here h represents a time point just before a known present value decline caused by D_h, t_{k^*} is the optimal time point when the option value is maximised. The term t_h represents times before the dividend payment. This gives a value for $\hat{S}_h$ which makes the timing option worthless at time t_h so that the CR link is established when $S_h > \hat{S}_h$ .If $S_h < \hat{S}_h$ then the company awaits time t_{k^*}. We can express D received continuously as a percentage of S, giving us a yield rate b. In our scenario, b is taken to be a dividend yield that is enjoyed continuously as a surrogate for learning curve effects. It will be referred to as the learning rate. A numerical application of the model developed above follows.

4 The optimal timing for CR entry: A numerical example

Suppose that S, the present value of total revenues from the sale of the new products less the material and operating costs net of the price of the subcomponent, follows the process analysed in the previous section over five years ($T = 5$) and that $S_0 = \$100m$. The market risk-free rate of return is assumed to be equal to 10%. We utilized the valuation approach developed by Black (1975) for American type options with a dividend yield. Table 2 shows the value of the deferrable subcontracting collaborative relationship opportunity for different degrees of uncertainty (represented by different values of volatility rates s of the CR link ranging from 0.05 to 0.4) and for a range of different learning rates b (from a lower bound of 0% to an upper bound of 15%). Table 3 shows the value of the timing option and Table 4 indicates threshold measures $\hat{S}_t$ for these values of σ and b.

Table 2 indicates the value of the deferrable undertaking whose opportunity cost of postponement is reflected by the foregone benefits implied by the learning rate. For a given learning rate, increased uncertainty increases the value of the deferrable contract though as the learning rate increases for a given degree of uncertainty, the deferrable contract value decreases. The value of the deferrable CR option is monotonically increasing in volatility and decreasing in the learning rate2.

Table 3 suggests that for a given learning rate, increases in uncertainty increase the value of the timing option for lower learning rates (0 to 3%). This is in line with the established result that the value of an American option is an increasing function of uncertainty (volatility rate). An increase in the volatility rate makes the option more likely to be profitable. This increases the intrinsic value of the option. As the cash flows to be derived from higher learning rates (5% and above) increase, a high degree of uncertainty militates against postponing the establishment of the CR link.

Table 4 indicates that for low learning rates, the threshold point for establishing the contract is high. As learning rates increase, the desirability of early contract adoption increases. In this example, a learning rate at or above 3% yields a present value of profits that compares favourably with the alternative outsourcing option (competitive bidding) which offers lower returns (that is, below 3%,$\hat{S}_{t^*} > \$100m$).

5 The decision to abandon a collaborative relationship

Once a collaborative relationship is entered into, altered circumstances may make it necessary to abandon the relationship earlier than anticipated. This could be justified for instance if the supplier is believed to be facing financial difficulties and may close down, or if the assembler expects a superior rival product to be launched by a competitor making the continued production and marketing of the existing product unviable, or if the need for the subcomponent part is diminished or its costs are rising due to exogenous factors. The supplier in such cases would have to give up anticipated future cash flows. Expectations about future cash flows from the collaborative relationship will be revised by the assembler as new information arises, such that the value of the link wanders randomly. Uncertainty about future cash flows is related to uncertainty about the value of CR as an option. A stochastic process for the value of the CR may be viewed as reflective of the underlying process for the cash flows. Suppose now that the assembler has an ongoing collaborative relationship with the supplier and is assessing the option to abandon the relationship. Any associated costs to ending the CR would be seen as a lower limit of the project's value. That is the abandonment alternative becomes an insurance against further losses. The payoff is referred to as a "put" and can be represented as $P(S, X, T, \sigma, r) = Max(X - S, 0)$. So one abandons the contract if $S \le \hat{S}^*$. The value of the threshold $\hat{S}^*$ decreases as the learning rate b increases. The gains from abandoning are partially offset by the loss from learning effects. Therefore, the firm requires a lower $\hat{S}^*$ to abandon, as learning gains increase.

Tables 5, 6 and 7 provide the relevant data for the numerical example developed above.

Table 5 indicates that as the volatility rate of $ increases, the option to abandon increases the potential loss from taking this action. In effect, the learning rate is a monotonically increasing function of this loss of value. Table 6 indicates that volatility increases enhance the value of the timing option. Likewise, increases in the learning rate would be expected to be matched by rises in the value of the timing option. Table 7 confirms that increases in the volatility rate reduce the abandonment threshold points as do learning rate increases. This is reflective of the diminished likelihood of exiting from the CR at high b or volatility values.

In the case of a CR being entered into without limits being placed on the number of subcomponents to be supplied or as to the duration of the relationship, it is possible to construct a real options analytical model which uses an infinite time horizon perspective. This point is not pursued further in this paper.

6 Conclusion

Placing an economic value on collaborative subcontracting relationships present difficulties tied to the flexibility and open-endedness of such buyer-supplier links. One decision element involves the timing option as to when such a link should be formed and when it should be abandoned. Our concern has been to provide an approach to entry and abandonment timing decisions by using a real options perspective. In assessing when to enter or abandon a contractual relationship the real options-based perspective provides a reference point directly reflective of the managerial flexibility embedded in CRs.

Our approach has been to model the standard situation of the learning curve versus the wait-time as a cost-benefit trade off. This scenario can readily be extended to consider the implications of infinite time contracts and definable product profitability distributions for our model. As shown, possibilities exist for the real options perspective to be extended by altering assumptions concerning stochasticity of the learning rate and subcomponent costs in both entry and exit situations. The approach enables an analysis of when it is optimal to enter a product market in the presence of sales uncertainty. It is thus possible also to view a CR as a strip of options whereby the object is to value the CR as a sequence of opportunities. It may be that the buyer may want to temporarily halt the purchase of subcomponents. This would imply the need to develop a multiple entry/exit heuristics model. The approach presented here readily lends itself to this. In practice, a CR can enable the assembler to benefit from the knowledge acquired by the supplier and to use this knowledge to alter subcomponent features which can lead to unanticipated opportunities to redesign the product. This flexibility can be analysed by viewing the relationship as a compound option, i.e. an option with other options nested inside. Such more specific elements of buyer-supplier linkages and the decision to enter CR's will likely become important as organizations ponder over issues of costs, efficiency and strategic advantages in their purchasing activities (Kapoor and Gupta, 1997; Sheth and Sharma, 1997). This is so particularly in the light of outsourcing thinking coming to be seen as a “paradigm” (Kakabadse and Kakabadse, 2000).

What is clear from the results of this investigation is that a buying firm which recognises the differential impacts of learning effects accruing at the supplier end establishes a platform for assessing when to enter or exit a CR. Moreover, our illustration impresses the worth of uncertainty and volatility - in increasingly uncertain global products and services markets across most categories, such a perspective can be of core relevance to purchase-focused decision making. Additionally, in situations where innovations build on the learning of past profitable products thereby enabling subcontractors to produce “nested” subcomponent supply opportunities, it would be incumbent on assemblers to develop and build on the heuristic approach we have delineated. Further, in modern competitive industrial environments where the ability of firms to manage knowledge is regarded as a core competitive strength, the approach we have outlined in this paper to considering purchase options across the CR-CB spectrum indicates that purchasing choice is itself an investment in learning that can be portrayed in managerially simple terms (Copeland and Tufano, 2004) and which can produce high potential pay-offs.

7 Appendix

7.1 The Black Scholes option valuation model and Black (1975) Model

Asume S follows Geometric Brownian process in equation 1 below. The Black and Scholes (1973) formula, for value a call option with maturity period T-t, is given by

$$C(.) = SN(d1) - XN(d2) \tag{6}$$

where
$d1 = (ln(S/X) + (r + \sigma^2/2)(T - t))/\sigma\surd(T - t)$
$d2 = d1 - \sigma\surd(T - t).$

Black (1975) proposed an approximate formula for valuing American options. Black’s approach, in valuing American options which pays a divided D continuously, and giving a dividend yield b, we replace S with Sexp(-b(T-t)) the Black-Scholes formula above.

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Table 1:Constrasting characteristics of competitive bidding (CB) versus collaborative relationships (CR)

Buyer-Supplier Link Characteristics	Competitive Bidding (CB)	Collaborative Relationship (CR)
Knowledge	Proprietary	Operational knowledge flows between each party and there is "forced sharing" of information between competing suppliers.
Price	Lowest bidder usually Obtains contract	Immediate price competitiveness is often secondary
Timing terms	Strictly stipulated penalties for deviations from contractual terms. Commitments tend to be short-term.	Option exists to delay and even abandon purchases either temporarily or permanently without relinquishing buyer-supplier link over long term.
Contract specificity	Product specifications usually predetermined	Limitless product specification changes may be made
Communication channels	Narrow and formal	Multiple channels, information exchange is less formal and more frequent

Table 2: Value of deferrable subcontracting collaborative relationship opportunity (C(.))

S = \$100m, X = \$30m, r = 10%, T = 5 yrs

Learning Rate b(%)	Volatility Rate of S (σ)				
	0.05	**0.1**	**0.2**	**0.3**	**0.4**
0	81.8041	81.8041	81.8043	81.8436	82.1501
1	76.927	76.927	76.936	77.0468	77.5123
2	72.3412	72.4364	72.7964	73.2657	74.0755
3	70	70.0597	70.4045	70.9581	71.8519
5	70	70	70	70	70
7	70	70	70	70	70
10	70	70	70	70	70
15	70	70	70	70	70

Table 3: Value of timing option V(.)

Learning Rate b(%)	Volatility Rate of S (σ)				
	0.05	0.1	0.2	0.3	0.4
0	11.8041	11.8041	11.9043	11.8436	12.1501
1	6.927	6.927	6.936	7.0468	7.5183
2	2.3412	2.4364	2.7964	3.2657	4.0755
3	0	0.0597	0.4045	0.9581	1.8519
5	0	0	0	0	0
7	0	0	0	0	0
10	0	0	0	0	0
15	0	0	0	0	0

Table 4: Threshold Point Project Values ($\hat{S}_{t^*}$)

Learning Rate b(%)	**Volatility Rate of S (σ)**				
	0.05	0.1	0.2	0.3	0.4
0	111.8041	111.8041	111.8043	111.8436	112.1501
1	105.8683	105.8683	105.8686	105.9168	106.2562
2	100.2822	100.2822	100.2825	100.3415	100.7159
3	95.02417	95.02417	95.02417	95.09631	95.5077
5	85.41352	85.41352	85.41495	85.5181	86.00952
7	76.89056	76.89056	76.89355	77.03888	77.6171
10	65.87009	65.87009	66.87891	66.11164	66.82918
15	51.33974	51.33974	51.38887	51.83548	52.79157

Table 5: Value of Abandonment Option P(.)

S = \$100m, X = \$30m, r = 10%, T = 5yrs

Learning Rate b(%)	**Volatility Rate of S (σ)**				
	0.05	**0.1**	**0.2**	**0.3**	**0.4**
0	0	0	0.0002	0.0518	0.4363
1	0	0	0.0003	0.0626	0.4845
2	0	0	0.0005	0.0753	0.5373
3	0	0	0.0008	0.0901	0.5945
5	0	0	0.0018	0.1272	0.7241
7	0	0	0.0036	0.1769	0.8745
10	0	0	0.0099	0.2818	1.1432
15	0	0	0.0465	0.5787	1.7363

Table 6: Value of Timing Option V (.)

S = $100m, X = £30m, r = 10%, T = 5 yrs

Learning Rate b(%)	**Volatility Rate of S (σ)**				
	0.05	**0.10**	**0.20**	**0.30**	**0.40**
0	0	0	0	0.0123	0.0904
1	0	0	0	0.0136	0.0927
2	0	0	0.0001	0.0148	0.0949
3	0	0	0.0002	0.0159	0.0969
5	0	0	0.0002	0.0175	0.0983
7	0	0	0.0003	0.0182	0.0971
10	0	0	0.0002	0.0162	0.0882
15	0	0	0	0.0086	0.0667

Table 7: Threshold Abandonment Values $\hat{S}t^*$

$S = \$100m$, $X = \$30m$, $r = 10\%$, $T = 5yrs$

Learning Rate b(%)	Volatility Rate of S (σ)				
	0.05	**0.1**	**0.2**	**0.3**	**0.4**
0	30.	30.	29.9998	29.9482	29.5637
1	29.7030	29.7030	29.7027	29.6411	29.2233
2	29.4118	29.4118	29.4113	29.3379	28.885
3	29.1262	29.1262	29.1254	29.0387	28.5490
5	28.5714	28.5714	28.845	28.7430	28.2145
7	28.0374	28.0374	28.0340	27.8721	27.2201
10	27.2727	27.2727	27.2637	27.0166	26.2335
15	26.0870	26.0870	26.0465	25.5837	24.5751