Asymmetric Buyer-Seller Relationships and Real Switching Options

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Abstract

Industrial buyer-seller relationships are frequently characterized by the fact that the seller and/or the buyer have to dedicate specific up-front investments to the relationship. Marketing research analyzes these relationships on the basis of Transaction Cost Economics (TCE). TCE highlights the risk of hold-up which arises after specific investments are dedicated. However, exogenous uncertainties are largely neglected in TCE. Therefore, the aim of this paper is to analyze the effects of both hold-up and exogenous uncertainty on the value of customers in buyer-seller relationships. From the perspective of a supplier, the value of her customers is modeled by a dynamic programming approach. It is shown how different contracting scenarios affect hold-up and the value of an option to switch customers. A numerical analysis illustrates the analytical findings.

JEL classification: L14, D23, O33

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I. Introduction

If a firm intends to dedicate specific assets to a relationship, it will take two types of uncertainty into account. First, it has to consider the risk of hold-up, i.e. the hazards of ex post exploitation by the partner caused by renegotiations on prices. Second, the firm has to encounter potential exogenous uncertainties, as e.g. fluctuations in demand, shifts in technology, etc. The first type of uncertainty is largely discussed in Transaction Cost Economics (TCE). Oliver E. Williamson's (1985, 1996) argues that in the presence of specific assets, the risk of hold-up will lead to underinvestment or, more generally, to a failure of market contracting, because contracts (must) remain incomplete. Based on Williamson's idea, the hold-up problem and potential remedies have been formally discussed in incomplete contracts literature (e.g. Grossman and Hart, 1986; Hart and Moore, 1990).[1] Frequently, investments into buyer-seller relationship are unevenly distributed between the partners. As a result, asymmetric relationships characterized by an asymmetric distribution of the risk of hold-up occur.

Real options approaches account for the second type of uncertainty. Exogenous uncertain variables like fluctuations in prices and demand or arrival of technological innovations can be represented by stochastic processes. Real option models assess the value of different kinds of options. However, traditional real options rarely apply directly to buyer-seller relationships. For example, a seller might not be able to defer an investment to produce a specialized good to a future period, if the customer needs the product immediately. Or, the option to abandon or switch to a different partner can be extremely costly since cancellation fees have to be paid. Conversely, the behavioral option to exploit the partner in relationships ex post has not been considered in real options literature so far. At this point, it becomes clear that an integration of hold-up considerations into real options analysis is still at an early stage of development. And,

[1] For an overview and a critical discussion, see Maskin and Tirole (1999).

neither TCE nor real options analysis account for hold-up and exogenous uncertainty jointly.

Therefore, the aim of this paper is to analyze hold-up in asymmetric buyer-seller relationships and its effect on real options. More precisely, I investigate the option of a supplier operating in an existing relationship to switch to a new customer. It can be shown that the value of the switching option is affected by hold-up potentials, institutional safeguards and cancellation fees as well as exogenous uncertainty.

The paper is organized as follows. Section II lays out the origin of hold-up and its asymmetric distribution in buyer-seller relationships by a simple bargaining scheme between a buyer and a seller. Potential solutions to hold-up are discussed. Section III explores a stable relationship in a dynamic setting where seller and buyer are exposed to environmental uncertainty. From the perspective of a supplier the value of the flexibility in different contracting scenarios is modeled by a dynamic programming approach. In section IV, a numerical analysis demonstrates how the different contracting scenarios affect the value of the switching option. I summarize the main results in section VI and indicate avenues for future research.

II. Asymmetric Relationships and Hold-up

Real-world examples of asymmetric relationships and hold-up are prominent in the automobile industry. A famous example may help clarify the hold-up problem (Klein, Crawford, and Alchian, 1978). In the 1920's, General Motors purchased their automobile bodies from a supplier called Fisher Body. With a shift from open, wooden bodies to closed, metal bodies, specific stamping machines were needed to produce the bodies. To encourage Fisher to make the investment, General Motors and Fisher concluded a contract with an exclusive dealing clause. This clause should reduce Fisher's risk of being exploited by unattractive price renegotiations by General Motors after having made the investment. To prevent monopoly pricing by Fisher, they agreed to fix prices by concluding a long-term contract. Over the years, demand for automobiles and bodies increased substantially. General Motors was unsatisfied with the price being too high compared to the dramatic increase in output. Apparently, the long-term contract was inappropriate to deal with hold-up and exogenous uncertainty. Further, necessary for efficiency reasons General Motors found it that Fisher located the body plant adjacent to GM's assembly plants. Fisher refused to built the new plant since it feared exploitation after having made the new specific investment. Eventually, the problem was resolved: General Motors acquired Fisher Body in 1926.[2]

From a theoretical perspective, the specificity of assets is the main cause of the risk of hold-up. Asset specificity relates both to physical and human investments that cannot be redeployed without valuable sacrifice if contracts are prematurely broken (Williamson, 1985). The degree of specificity is indicated by quasi-rents. Klein et al. (1978, p. 298) forward a basic definition: "The quasi-rent value of the asset is the excess of its value over its salvage value, that is, its value in its next best *use* to another renter". The degree of asset specificity and the amount that can be appropriated by the other party depends on the existence and level of salvage values. An economic agent compares the asset's present value from the first best use with a potential value when used with a second best *user*. If a second best user cannot be found, the asset may be transferred to a second best *use* and may realize a value in this second best use while adaptation costs have to be considered. Finally, in case the asset cannot be relegated to a second best use(r), it may be possible to resell the investment.

As soon as one party has dedicated specific assets to a relationship, quasi-rents are created. The risk of hold-up arises because the non-owner may seek possibilities for expropriation of the quasi-rent by renegotiating on prices. The party having specifically invested in a relationship is exposed to hold-up because the option to 'exit' the relationship would result in the loss of the quasi-rent since the asset has relatively little or no value outside the relationship. Here, the interrelation between the notion of asset specificity and irreversibility which is stressed in real options literature (e.g. Pindyck, 1991) becomes clear: While asset specificity analyzes different alternatives to use the asset apart from its original designation, irreversibility refers to the asset's salvage value when resold to a secondary market. Other users or uses are not considered, so that irreversibility is a special case of asset specificity. Consequently,

[2] Although the Fisher Body example may appear somewhat antiquated, hold-up is still an important problem in the automobile industry nowadays (see e.g. Dyer, 1997).

hold-up considerations have not been part of real options analysis so far. I subsequently discuss the hold-up problem in more detail.

Consider a seller S (the upstream party) and a buyer B (the downstream party) who want to start up a relationship in the sense that the upstream party employs an asset to produce a good that is used in the downstream party's production process. To establish this relationship the seller S must dedicate a specific investment I, i.e. she has to buy a machine in order to fabricate the product for the buyer. The investment is contingent to start up the relationship, i.e. without the investment no trade can occur. Moreover, the investment costs are fixed and cannot be varied. If the investment is made at date 0, the input will be supplied and benefits will be received from date 1 onwards. The seller incurs operating costs of c per unit, while the product's value to the buyer is v per unit. Both v and c are common knowledge at date 0. The parties will bargain on price p and they will trade if S makes the investment and if $v \geq c$. At date 0, the parties lack knowledge on their own and their partner's second best alternatives so that the degree of asset specificity and the risk of hold-up can only be observed ex post. Further, assume the traded amount q which is determined exogenously e.g. by the market condition, to be constant in future periods. Both parties do not restrict the number of periods they want to trade. Both parties are risk-neutral and share the risk-free discount rate r per period. At date 0, the bargaining power is equally distributed between the parties and both partners have outside trading partners (large numbers exchange condition).

Then, the supplier's net present value (NPV) is $\Pi_S = [(p-c)q]/r - I$. The future net cash flows have to surmount the investment expenditures to make the investment attractive to the supplier. The buyer's profits amount to $\Pi_B = [(v-p)q]/r$. At date 0, the input price p_0 has to satisfy the following condition to equalize the NPV earned by each party

$$(p_0 - c)q/r - I = (v - p_0)q/r . \qquad (1)$$

The partners would thus agree on the following price p_0^* to carry out exchange from an ex ante perspective:

$$p_0^* = (v + c + I\,r/q)/2\,. \tag{2}$$

The seller S's (as well as buyer B's) profit amounts to

$$\Pi_S = [(v - c)\,q/r - I]/2 = \Pi_B\,. \tag{3}$$

Obviously, the partners split up their total surplus equally 50:50 from an ex ante perspective, which is the Nash bargaining solution. In this way, the buyer finances half of the amount *I* to be invested. This solution results from an equal ex ante distribution of bargaining power.

Without any contract specifying the trading price p_0^* in advance, the parties to the exchange have to fear deviations from the original agreement as soon as their outside options are revealed at date 1. Depending on the value of second best alternatives the risk of hold-up arises at date 1. On the one hand, supplier S has dedicated the physical specific investment to customer B, so that S is only able to sell the (specific) products to B. On the other hand, B has invested time and needs the product at date 1, so that from customer B's perspective, A is the only supplier being able to provide the product. The former large numbers situation turns into a small numbers situation. An ex ante competitive situation turns into a bilateral monopoly ex post (Williamson 1985). Although this relationship turns out to be symmetric ex post, since neither parties have second best alternatives, it will be unfavorable for the seller. In a bilateral monopoly the parties will again end up in a (symmetric) Nash bargaining solution ex post, if they renegotiate on prices. But, the seller has already invested and the investment is sunk at date 1. Therefore, the price p_1 bargained ex post will satisfy $(p_1 - c)\,q/r = (v - p_1)\,q/r$. This price then amounts to $p_1^* = (v + c)/2$, which is obviously lower than the price bargained ex ante (p_0^*) and the supplier's gains are affected accordingly. In this situation, the buyer does not co-finance the seller's investment. In this respect, ex post bargaining is inefficient for the party having specifically invested, as the initial investment is not taken into account in price bargaining. In asymmetric investment situations with symmetric ex post bargaining positions, partial hold-up arises for the party with the higher input level. To safeguard the party dedicating the higher investment and to induce the investment, Williamson (1983) proposes to post a hostage equal to the specific investment (or the difference of investment expenditures in case of asymmetric investment) that has to be transferred by the opposite party in advance.

If we deviate from the abstract bilateral monopoly assumption, we can discuss the risk of hold-up in the following situations. If both parties to a transaction discover outside alternatives which deliver the same values as the current partner, the risk of hold-up does not occur because price renegotiations become inefficient. The price will be preserved at $p_1^* = p_0$.

Reality has shown, however, that an abstract assumption of a purely symmetric relationship ex post is improbable to hold. Each party may have different outside opportunities ex post. From the buyer's perspective, there may be other suppliers willing and able to invest specifically and to start up a relationship with buyer B. In contrast, seller S may be bound to the buyer, if her investment turns out to be highly specific. Then, the absence of second best alternatives may put her in an inferior bargaining position. Even if a large numbers situation prevailed ex ante and the parties agreed to split up total surplus evenly, asymmetries in bargaining power may come into being and affect price renegotiations ex post.

Therefore, renegotiation causes inefficiencies due to the fact that asymmetric distributions of bargaining power are discovered after specific investments are made. Consider γ as the degree of the buyer's bargaining power and α as the supplier's bargaining power, where $\alpha = 1 - \gamma$. Bargaining power depends on the existence and the value of second best alternatives which are discovered ex post. With asymmetric bargaining positions ex post, the price p_1 bargained ex post has to satisfy

$(v-p_1)/\gamma=(p_1-c)/(1-\gamma)$, so that $p_1^*=v+\gamma(c-v)$ at date 1. Two extreme cases can be considered: (1) Second best alternatives are discovered by the buyer in contrast to the seller at date 1. B's outside option is a seller who delivers exactly the same quality and demands the same price as S. In this situation, B can exploit S's quasi-rent, so that $\gamma = 1$ and $p_1 = c$. S is exposed to hold-up and is only able to cover operating costs. She will not gain any surplus to amortize the specific investment made at date 0. (2) Seller S may have outside alternatives in contrast to the buyer. If we assume that the second customer pays the same prices as B, $\gamma = 0$, so that $p_1 = v$. In this situation, S exploits B's quasi-rent and B is exposed to hold-up.[3] Table 1 summarizes the discussion.

Seller S \ Buyer B	Buyer B: lacks alternatives	Buyer B: has alternatives
Seller S: lacks alternatives	Investor risks partial hold-up $p_1^*=\frac{v+c}{2}$	Seller risks hold-up $p_1^*=c$
Seller S: has alternatives	Buyer risks hold-up $p_1^*=v$	Hold-up is inefficient $p_1^*=p_0$

Table 1: Hold-up in Buyer-Seller Relationships

Anticipating inefficiencies from renegotiation, especially the seller S will abstain from the deal, since she has to fear an adverse ex post bargaining position and exploitation by the partner. She risks to suffer a loss at the level of the specific investment made at date 0 and a loss of quasi-rents, if $p_1 = c$, so that the investment yields a negative net present value (NPV).[4]

[3] Then the investment turns out to be completely unspecific.
[4] The hold-up problem can as well be modeled as a Prisoner's Dilemma.

Different ways to resolve to the hold-up problem have been discussed to prevent underinvestment and market failure. Among others, vertical integration (Williamson, 1975; Klein et al., 1978; Williamson, 1985), long-term contracts (Joskow, 1987), the distribution of property rights (Grossman and Hart, 1986; Hart and Moore, 1990), exchange of hostages (Williamson, 1983), etc. have been proposed to safeguard the partners against hold-up potentials.

Consequently, seller S and buyer B agree to establish safeguards to reduce the risk of hold-up and ex post bargaining on the part of the supplier. A simple assumption to make in a stable market is that they conclude a long-term contract specifying the input price p_0^* in advance. Both parties will adhere to the contract if they fear potential losses in case of defection, i.e. if they attempt to exploit the other party by altering the initial price. If a third party, e.g. a court, can observe all monetary transactions between the partners, the parties can write a contract so that the third party can impose penalties on the reneging party. A court could, of course, simply enforce the price in the contract to be adhered to. Even more important than pure enforcement is the mechanism behind a contract, i.e. the expected loss from a breach of contract making the partners adhere to the initial price agreement.

First, imagine that buyer B discovers alternative trading partners and deviates from p_0^* from date 1 onwards. Then, the extreme case $p_1 = c$ occurs. If B had to make up for the loss the seller will suffer due to exploitation, putting the seller in the same position as without exploitation (i.e. the difference between p_0^* and $p_1 = c$), the expected loss would deter ex post appropriation of the seller's quasi rent. Such an expected penalty may be $K_B = [(v-c)q/r + I]/2$ to corroborate the initial price agreement and to assure the seller's expected payoffs.

In the opposite case, i.e. the seller deviates from the initial price, the price will go to $p_1 = v$ in the extreme. To determine the amount putting the buyer in the same position as without exploitation we have to consider the difference between p_0^* and $p_1 = v$. The expected penalty has to be identical to the seller's, so that $K_S = [(v-c)q/r + I]/2$.

The parties will adhere to the initial price agreement fixed in the contract if they have to expect future punishment. But the contract discussed above would be efficient only in stable markets without any environmental uncertainty. All variables are common knowledge and can be observed by all parties. In reality though, uncertainty of environmental factors prevails and more flexible or incomplete contracts are needed to cause efficiency as the Fisher Body case has shown. Moreover, not all variables may be common knowledge in reality, so that additionally asymmetric information between the exchange parties and a third party can be assumed.[5] TCE literature has concisely focused on the hazards of hold-up thereby neglecting external uncertainties. The following argument addresses the hold-up problem in (a)symmetric buyer-seller relationships. The next section discusses the value derived from a rigid long-term contract arising from protection against hold-up as well as its failure in the presence of market dynamics.

III. Hold-up and Real Switching Options

In a stable environment, long-term contracts may be appropriate to reduce the risk of hold-up. What will happen if the firm's environment was first thought to be stable but then becomes dynamic? Especially hazardous are shifts in technology. A famous example put forward by Porter (1980, p. 310) may demonstrate the fatality of unexpected technological change with regard to vertical integration: "Imasco, a leading Canadian cigarette producer, backward integrated into the packaging material used in its manufacturing process. However, technological change made this form of packaging inferior to other varieties, which the captive supplier could not produce. The supplier was eventually divested after many difficulties."

In this case, technological change made vertical integration obsolete. The same may hold for long-term contracts, so that the costs of dissolving such arrangements cause inefficiencies. The main reason is that hold-up considerations only refer to second best alternatives. In the presence of market dynamics and technological

[5] I do not intend to consider such extensions and refer to the large body of literature treating the problem of incomplete contracts (e.g. Grossman and Hart 1986, Hart and Moore 1985, for some recent criticism see Maskin and Tirole 1999.).

innovation, in fact *better* outside alternatives may emerge in the course of time. Then switching to the new and more attractive alternative becomes relevant (cf. the cigarette producer example). In markets where technological innovation is probable to generate more attractive alternatives less safeguarding and higher degrees of flexibility seem appropriate to the firm. A trade-off between the aim to deter hold-up and the desire to profit from attractive outside opportunities appears.

I investigate this trade-off from a seller's perspective in a buyer-seller-relationship. Further, I demonstrate by a real options model how rigid contracts affect switching from one state to another (see e.g. Brennan and Schwartz 1985, Dixit 1989). In this paper, I focus on just *one* single switching point and I analyze a seller's option to switch from a stable and current customer B to a 'new' outside opportunity, i.e. customer C who offers more attractive exchange conditions due to technological innovation. We can assume that switching back to customer B after having switched to customer C is not possible, on account of a loss of confidence on the side of the initial customer. The supplier S can thus decide whether to stay with the 'old' buyer B or to switch to the 'new' and uncertain customer C. A very simple solution to determine the optimal switching rule is to apply a perpetual American call option with dividends (Sick 1995). In this context, I use a dynamic programming approach to solve the seller's switching problem. I investigate the effect of the arrival of an uncertain outside alternative on the supplier's (switching) policy and show that the rigidity raises the trigger point because of the costs of dissolving the contract.[6]

Seller S can either be in a relationship with buyer B (denoted as state B) or in a relationship with customer C (denoted as state C). Assume that the supplier S is at first in state B after date 0, i.e. she carries out transactions with buyer B. The investment of I has already been dedicated (I is sunk) and a long-term contract has been concluded specifying the bargained price p_0^* as well as the penalty payments K_S in case of breach of contract at date 0, because the arrival of better outside opportunities cannot be anticipated. Demand q_B (the index distinguishes between the different states) is still

[6] The arrival of the new customer is deterministic in this paper. Further extensions could model customer C's arrival by a jump process.

stable in this market, so that this relationship is not affected by uncertainty. The value $V_B = (p_0^* - c)q_B$ provided by customer B per period is constant and non-stochastic.

Because of technological innovation after date 0, the supplier gets the chance to switch to state C, i.e. customer C operating in a dynamic market. To establish this new relationship with C, the supplier S has to dedicate a new specific (and irreversible) investment *J*. With this customer C, she can fix a contract stating the bargaining price (for simplicity assume the same price as in state B: p_0^*). She incurs the same operating costs *c*. Buyer C is also risk-neutral and shares the discount rate *r* per period. The time horizon for this relationship is infinite. Exogenous uncertainty is caused by fluctuations of the quantities to be exchanged with customer C (state C). Demand quantities q_C can be described to evolve over time as a geometric Brownian motion with drift. Because of fixed prices and stable operating costs per unit, customer C's value ($V_C = (p_0^*$ - c) q_C) evolves accordingly and can therefore be formulated as a geometric Brownian motion with drift:

$$dV_C = \mu V_C \, dt + \sigma V_C \, dz , \qquad (4)$$

where μ is the drift parameter and $\mu \in [0, r)$ denotes the expected growth rate of V_C. With a constant dividend yield δ, we can substitute $\mu = r - \delta$.[7] σ is the expected volatility and *dz* is the increment of a standard Wiener process with $dz \sim N(0, dt)$. C's current customer value V_C is known today, but future values are lognormally distributed with variance of the logarithm growing linearly with time.

The supplier's optimal decision depends on just one single state variable, i.e. the current (stochastic) value of customer C (V_C). A very simple way to determine an optimal investment rule is to model the value derived from customer C as a perpetual American call option with dividends. As an alternative interpretation to the conventional option model we can conceive the present case as an option to switch from one asset to another (Sick, 1995): From one asset, the owner of an American call

[7] The dividend or convenience yield can be described as the benefits from holding an asset or as an incentive to exercise an American call option early (see e.g. Brennan and Schwartz, 1985).

(the seller) receives a constant dividend that is his/her minimum payoff (net payoffs from customer B); from the other asset, the owner receives a stochastic net payoff (net payoffs from customer C). We can interpret this model from the seller's perspective as that she has to abandon customer B and therewith the certain payoff with the present value V_B/r in order to benefit from the risky asset (customer C).

I denote $F(V_C)$ as the expected net present value when we start with a value V_C and the supplier S is in state B, i.e. in a relationship with customer B. Therefore, the solution consists of this function and the optimal rule to switch to customer C, i.e. we are looking for a value V_C^* that triggers the supplier's switching from customer B to customer C: For $V_C < V_C^*$ supplier stays with customer B and receives V_B; for $V_C > V_C^*$ supplier switches to the new customer C.

For the seller S, there is a continuation payoff V_B with customer B. She has a binary choice: Either to stay with customer B or to switch to customer C. She will switch to customer C, if $V_C^* - J - K_S > V_B/r$, i.e.

$$F(V_C^*) = \max\left\{V_B / r,\, V_C^* - J - K_S\right\}, \tag{5}$$

with $V_C^* - J - K_S$ as the net payoff from customer C to be maximized when switching to customer C. She chooses the larger of the two values. Until the investment J is made and penalty payments (K_S) are paid, the supplier S cannot benefit from customer C, i.e. before the switch she earns V_B per period. In the continuation region, i.e. the values of V_B where it is not optimal to invest into C, but to stay with customer B (state B), the Bellman equation becomes:

$$r\,F\,dt = E\,(dF) + V_B\,dt, \tag{6}$$

i.e. the total expected return from customer C over a time interval dt ($r\,F\,dt$) equals the expected rate of capital appreciation plus the stable value V_B from customer B over time. Using Itô's Lemma, we get

$$dF = F'(V_C)\,dV_C + \tfrac{1}{2}F''(V_C)(dV_C)^2 . \qquad (7)$$

By substituting dV_C and $(dV_C)^2$ from (4) and because $E(dz) = 0$, $E(dz)^2 = dt$ and dt^2 goes faster to zero than dt in the limit, the expected value of dF is

$$E(dF) = F'(V_C)(r-\delta)\,V_C\,dt + \tfrac{1}{2}F''(V_C)\sigma^2 V_C^2\,dt . \qquad (8)$$

Substituting into the Bellman equation (6), dividing by dt and rearranging, we receive the asset equilibrium condition as a second-order ordinary differential equation, which is non-homogenous

$$\tfrac{1}{2}F''(V_C)\sigma^2 V_C^2 + F'(V_C)(r-\delta)\,V_C - rF + V_B = 0 . \qquad (9)$$

The solution to (9) and the threshold value V_C^*, where S switches from B to C, can be found by solving (9) to the following three boundary conditions (10) – (12): First of all, an *end-point condition* for $V_C = 0$ is

$$F(0) = V_B / r . \qquad (10)$$

If $V_C = 0$, the option to switch to customer C does not have any value – the only value is derived from customer B. This boundary is known in contrast to the free boundary V_C^*. Therefore, we need the two following boundaries: V_C^* has to satisfy the value matching condition

$$F(V_C^*) = V_C^* - J - K_S \ , \qquad (11)$$

which means, when V reaches V_C^*, the supplier can invest and receive V_C^* - J - K_S. We can reinterpret equation (11) when we rewrite it as $V_C^* - F(V_C^*) = J + K_S$. If the supplier invests, she will receive the value V_C from customer C, but she will lose the option to switch $F(V_C)$. The threshold V_C^* is where this net gain equals the investment costs J plus the penalty payment K_S. Here, we see that the costs of dissolving the institutional arrangement of a long-term contract raises the trigger point V_C^* not only by the investment J but also by the amount of the penalty K_S.

Finally, V_C^* has to satisfy the *high contact condition* (or smooth pasting condition)

$$F^{'}(V_C^*) = 1\ , \tag{12}$$

which assures a smooth transition between the two different states. The function has to be a tangent to the boundary, so that the slope of the function has to match the slope of the boundary. This first order condition represents the optimal selection of the trigger value (Sick, 1995).

As a way to find a general solution of the homogenous part of equation (9), we can try a functional form and determine by substitution if the form works. Since a particular solution to equation (9) is $F = V_B/r$, the solution must take the functional form

$$F(V_C) = A V_C^{\beta} + V_B / r\ , \tag{13}$$

with A being a constant that has to be determined and β found by σ, r and δ. Since the homogenous part of (9) is linear in F and its derivatives, the general solution can be determined as a linear combination of two independent solutions. When trying a form of (13), it can be shown by substitution that it will satisfy the equation, if β is a root of the fundamental quadratic equation

$$\tfrac{1}{2}\sigma^2 \beta(\beta - 1) + (r - \delta)\beta - r = 0\ , \tag{14}$$

which has roots

$$\beta_+ = \tfrac{1}{2} - (r-\delta)/\sigma^2 + \sqrt{[(r-\delta)/\sigma^2 - \tfrac{1}{2}]^2 + 2r/\sigma^2} > 1 \tag{15}$$

and

$$\beta_{-} = \tfrac{1}{2} - (r-\delta)/\sigma^2 - \sqrt{[(r-\delta)/\sigma^2 - \tfrac{1}{2}]^2 + 2r/\sigma^2} < 0 . \qquad (16)$$

Consequently, we can write the general solution of the whole (non-homogenous) equation (9)

$$F(V_C) = A_{+} V_C^{\beta_{+}} + A_{-} V_C^{\beta_{-}} + V_B / r . \qquad (17)$$

Now, the constants A_{+} and A_{-} have to be determined. They can be determined by using technical boundary conditions, which assert a meaningful solution to differential equations. Therefore, we analyze the limiting behavior of equation (17), if V_C becomes very small (as the boundary condition (10) implies). As V_C becomes very small, the term $A_{-} V_C^{\beta_{-}}$ and therewith the whole function $F(V_C)$ goes to $\pm\infty$, since $\beta_{-} < 0$. Thus, we have to set $A_{-} = 0$ to avoid unreasonable results. We can simplify equation (17), which then yields

$$F(V_C) = A_{+} V_C^{\beta_{+}} + V_B / r . \qquad (18)$$

Seller S will only convert her switching option when V_C reaches V_C^* from below. Now, we can use the boundary conditions (11) and (12) to solve for the unknown constant A_{+} and the trigger point V_C^*. Substituting (18) into the value matching condition (11), we get

$$A_{+} V_C^{*\beta_{+}} + V_B / r = V_C^* - J - K_S \ , \qquad (19)$$

which yields

$$A_{+} = \frac{V_C^* - (J + K_S + V_B / r)}{V_C^{*\beta_{+}}} . \qquad (20)$$

The seller thus chooses V_C^* to maximize A_{+}. Deriving (18), substituting into the high-contact condition (12) and rearranging yields

$$V_C^* = \frac{\beta_+}{\beta_+ - 1}(J + K_S + V_B / r) . \qquad (21)$$

Substituting this into the numerator of equation (20) and rearranging yields

$$A_+ = \frac{\frac{1}{\beta_+ - 1}(J + K_S + V_B / r)}{V_C^{*\beta_+}} . \qquad (22)$$

Using (22) in equation (18), we receive

$$F(V_C) = \frac{1}{\beta_+ - 1}(J + K_S + V_B / r)\left(\frac{V_C}{V_C^*}\right)^{\beta_+} + V_B / r . \qquad (23)$$

This is the value of customer B including the option to switch to customer C. Supplier S will only switch to customer C, if his value surmounts the investment costs J, the penalty payments K_S and of course the value of customer B (V_B/r) which can be clearly seen in equation (21). Another important aspect in equation (21) is the factor $\beta_+/(\beta_+ - 1)$. It shows that the simple NPV rule is incorrect, because it raises the switching point by this factor, since $\beta_+ > 1$ and therefore $\beta_+/(\beta_+ - 1) > 1$. On account of uncertainty the critical value V_C^* has to be higher than just $J + K_S + V_B/r$.

Three effects have to be distinguished when hold-up considerations are introduced in real switching options. (1) The penalty fee K_S to be paid, if the contract with B is (prematurely) cancelled raises the hurdle and delays switching to the profitable outside option C. For this reason, the value of the real switching option decreases. (2) Without any safeguards, i.e. neither the seller nor the buyer B have secured prices by contracts so that neither party has to fear penalties in case of offence ($K_S = 0$, $K_B = 0$), the supplier may risk hold-up as long as the value of the outside option C remains at a low level, if the buyer has alternative suppliers. Then, in case the buyer B can exploit the supplier, V_B/r converges to zero. Although the seller does not have to pay any penalty anymore in order to switch to customer C, she is exposed to the risk of hold-up. Because $K_S = 0$, the hurdle falls and the value of the switching option increases. But then $V_B/r = 0$ which has two ambiguous effects: It lowers the hurdle and thereby raises the option value, while the "missing dividend" $V_B/r = 0$ again reduces the value from the switching option. Figure 2 illustrates these two effects on the value of the real option.

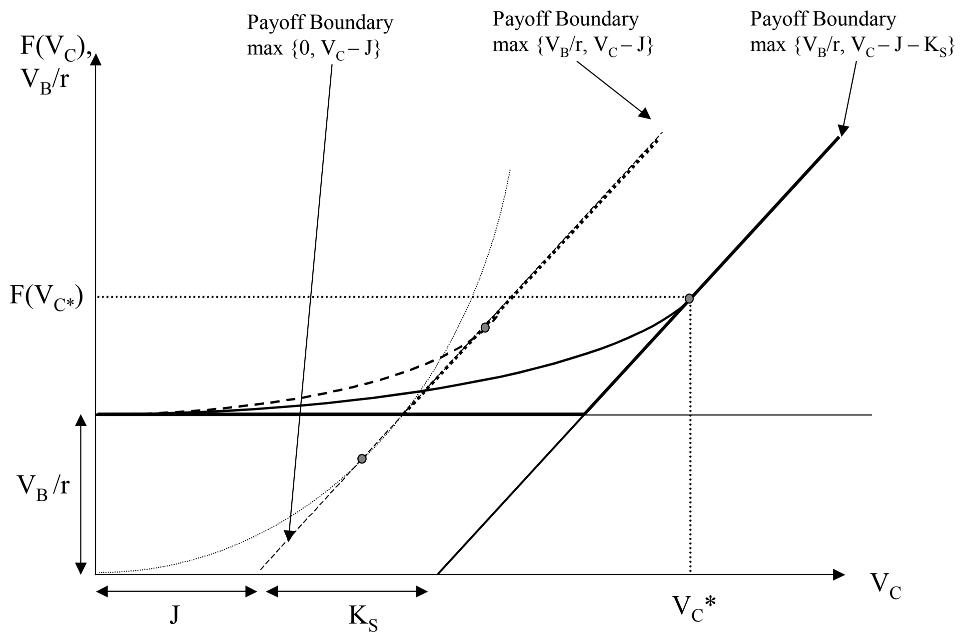

Figure 1: Hold-up and Real Switching Options

Here, the three boundary conditions given by equations (10) – (12) can be clearly identified. As well, we can observe how the trigger point rises on account of the penalty costs K_S which supplier S has to pay to buyer B in order to benefit from customer C. On the other hand, without K_S (and K_B) the seller is exposed to hold-up. The hurdle falls, but the value of the option is reduced before the option is exercised.[8]

(3) A third effect is important concerning the volatility σ of customer C's values. An increasing σ affects β_+ in a way that β_+ decreases and the hurdle rises. In case the seller is safeguarded against exploitation, the value of the option to switch to customer C increases since V_B/r cannot be reduced by customer B. In the opposite case, if V_B/r can be exploited, the value of the switching option rises for very low values of V_C with a rising σ and declines in the long-run after the switching option has been exercised.

[8] Similarly, we can discuss asymmetric cases where only one party is secured against hold-up.

The riskier the customer C, the less valuable the option to switch because of hold-up by customer B in the long-run.

These findings have remarkable influence on the construction of contracts. As I have shown, a long-term contract is efficient in stable markets, because it prevents the risk of hold-up by imposing sanctions. In contrast, in the case of unstable markets with new outside opportunities appearing rigid contracts become suboptimal due to the high costs of dissolution and adaptation (K_S). In dynamic environments, where the arrival of new opportunities is probable and future states cannot be clearly conceived before signing a contract, the parties would abstain from rigid arrangements and set up more flexible contracts, e.g. short-term contracts. Here, the trade-off between the desire to reduce the risk of hold-up (to increase K_S) and the ability to profit from new opportunities (to reduce K_S) becomes obvious.

IV. Numerical Analysis

A numerical example may help illustrate the previous analytical findings. The results partly confirm the traditional findings from option pricing methods, but they also provide new insight concerning hold-up. Assume that a seller has already concluded a long-term contract with a customer B in the past because she did not expect any environmental turbulence. Let the perceived value v of the product by the customer B be \$12.90 per unit, while the supplier incurs operating costs c of \$3.00. The initial investment I amounted to \$10,000, customer B demands 1,000 units per period. Both, S and B share a discount rate of r = 10%. Therefore, they agreed on a price of \$8.00 per unit at date 0. As well, they agreed on a penalty payment for the party deviating from the initial price or quitting the relationship. The payment K_S that supplier S would have to pay equals \$50,000. The perpetual value V_B/r by customer B is as well worth \$50,000.

After having concluded the contract, a new business opportunity (customer C) becomes available to supplier S ex post. Then, the hurdle, V_C^*, that induces S to switch to the new customer C can be determined. Assuming the same price conditions as with customer B, but at an annual volatility of demand volumes of 20% (starting with the amount of 1,000), a dividend yield of 4% and a start-up investment J of \$10,000, the switching point is at \$354,722. The switching point is this high since it has to surmount the initial investment J, the value of the current value of customer B V_B/r and of course the penalty payment K_S. Moreover, uncertainty raises the factor $\beta_+/(\beta_+ - 1)$ and therewith the switching point V_C^*.

To demonstrate the effects of a binding contract with customer B and the risk of hold-up, I investigate the value of the switching option without any penalty payments, i.e. $K_S = 0$. In this case, it may appear that switching to a new customer becomes even more attractive, since the seller no longer has to pay a penalty fee for switching to customer C. The switching point V_C^* drops to \$32,247. But, if neither the seller S nor the buyer B have to fear sanctions from ex post expropriation ($K_S = 0$, $K_B = 0$), the supplier S will be exposed to exploitation by customer B, if she lacks outside options ex post in contrast to B, so that $V_B/r = 0$. Figure 2 illustrates the value of the real switching option in the two different contracting scenarios.

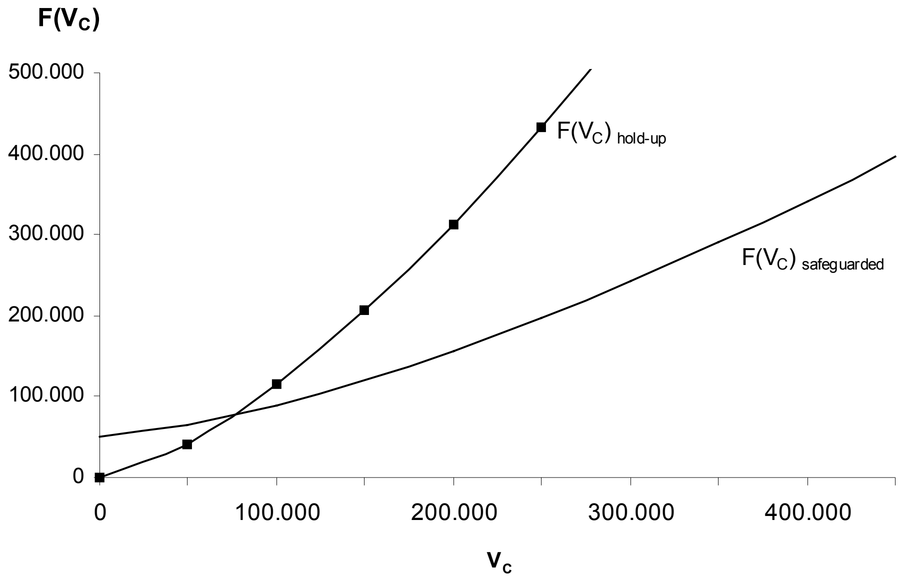

Figure 2: Option Values from Different Contracting Scenarios

For very low values provided by customer C, the symmetric arrangement where both parties are safeguarded against hold-up delivers higher values in comparison to the hold-up case. For higher values, the option to switch becomes more attractive since S can escape from the hold-up position and can switch to customer C.

Further, if the volatility of customer C's values rises from 20% to 40%, the value of the option to switch increases for low values of V_C, and falls for very high values. With increasing uncertainty in a safeguarded relationship, the value of the option to switch first rises, but with higher value of V_C decreases again. The same effect appears at much lower values in the hold-up case. Increasing volatility affects the situation where the supplier is exposed to expropriation relatively more because hold-up erodes the dividend V_B/r. The following figure demonstrates the impact of a rise in volatility on the value of the switching option in the two different contracting scenarios.

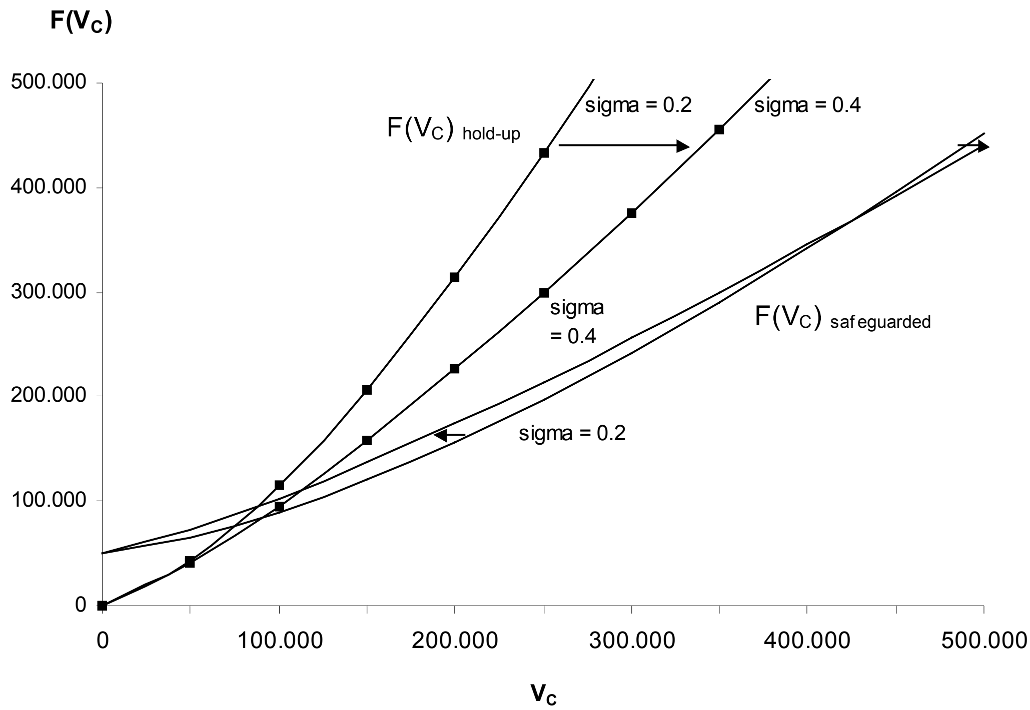

Figure 3: The Impact of Uncertainty

Assuming a positive linear relationship between K_S and V_B/r, the following effect on the value of the switching option can be observed. For very low values of the outside option (V_C) K_S and $F(V_C)$ are positively correlated. This is the safeguarding effect: The higher the expected penalty for customer B to exploit A's quasi-rents, the higher the dividend and thereby the option value. If the outside option becomes more attractive with increasing V_C (and exercising the switching option becomes optimal) the relationship between K_S and $F(V_C)$ reverses: The trade-off between the desire to safeguard investments and the desire to profit from outside opportunities appears. Whereas K_S (and K_B) reduces the risk of hold-up, it prevents switching to better trading partners as they become more attractive. The desire to reduce hold-up and to increase K_S automatically reduces the benefit from outside opportunities, i.e. the value of customer C. For different values of K_S, V_C and $F(V_C)$ we receive the following diagram (figure 4).

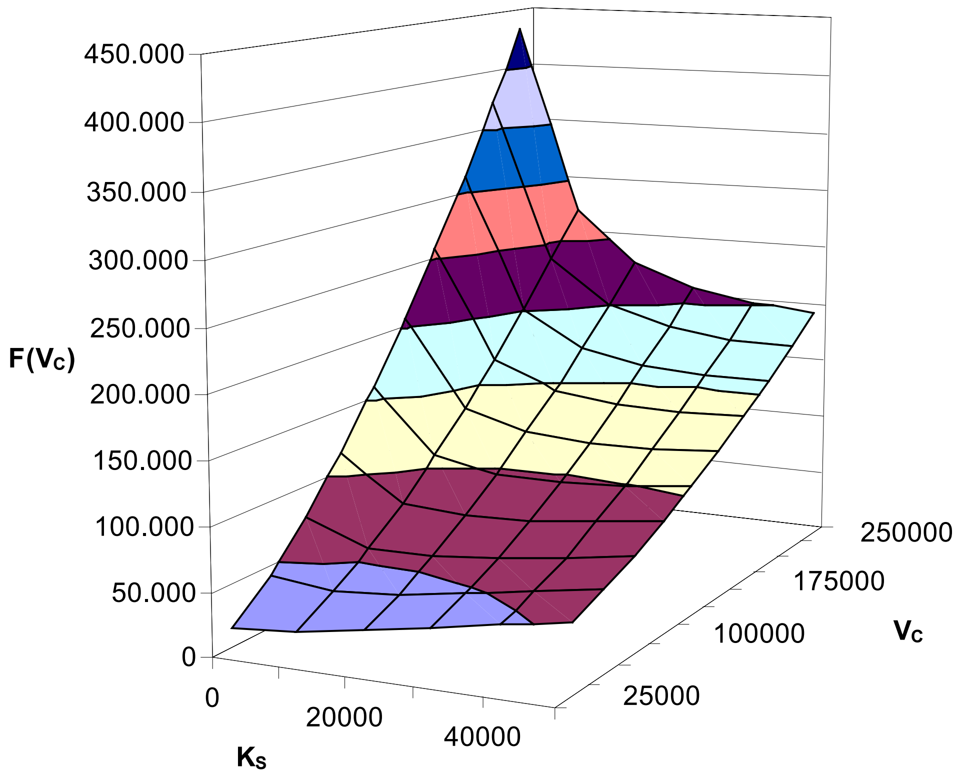

Figure 4: Relationship between K_S and $F(V_C)$

Combining different degrees of K_S and V_C , we see that the trade-off between K_S and $F(V_C)$ emerges with an increasing value of customer C (V_C). The safeguarding effect for low outside values positively affects the option value.

V. Conclusion

In this paper, I have shown how contracting scenarios influence the value of a switching option in buyer-seller relationships. I have integrated hold-up considerations into real options analysis. The effect of hold-up in buyer-seller relationships can be modeled by an erosion of the dividend, while cancellation fees can be represented by an additional variable in a perpetual American call with dividends. The value of the dividend and the cancellation fee are interdependent. The existence of real options can have considerable influence on the construction of contracts. On the one hand, contracts reduce hold-up potential, thereby making outside opportunities unattractive; but on the other hand, the parties bound to a contract cannot profit from more attractive upcoming outside opportunities. In highly dynamic markets with high probability of innovation and more attractive alternatives in the future, the parties to an exchange would therefore request more flexibility in contract design in order to maintain the option to take advantage of new developments. Hold-up potentials become inefficient in dynamic markets, because of the probability that more profitable outside options emerge. Moreover, with rising uncertainty of outside switching options, contracts positively affect the value of the customer switching option.

With this paper I hope to contribute to an integration of ideas from TCE, contract theory and real options analysis. And, I feel that fruitful new insight can be derived from further interdisciplinary research. This paper should be understood as a first step towards more research on the integration of real options into the design of contracts, and vice versa. This seems to be a promising future research area.

In addition to the application of the simple model presented in the paper, several extensions can be elaborated to make the model more realistic. For example, the value of the initial customer B may as well be affected by uncertainty. Besides, the arrival of the new customer C can be modeled by a jump process. So far, I have exclusively investigated the seller's perspective. The customer's perspective could be introduced by game-theoretic analysis. Finally, future research has to submit more detailed hypotheses that follow from a positive use of the model to full-fledged empirical tests.

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