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NEGOTIATION OF INVESTMENT SHARES IN INTERORGANIZATIONAL SUPPLY CHAINS: A GAME-THEORETIC APPROACH

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Abstract

In this paper, we analyze negotiations of investment shares in interorganizational supply chains. To formulate the research issue more precisely, we develop a taxonomy of enterprise networks in general. We propose an investment sharing model that makes use of Shapley values as indicators of relative negotiation power in a network. It turns out that a focal buyer (supplier) in a supply chain can reduce investment shares and by that increase profits from the network if the number of non-focal suppliers (buyers) increases. However, this effect is connected with distortions of investment incentives and makes investment decisions difficult to implement. In the presence of additional coordination costs to support a certain supplier (buyer) base, an optimal number of suppliers (buyers) exists. As a large part of investments for interorganizational supply chains often concerns information and communication systems and technologies, these results are particularly important in the field of information management.

Keywords: Investment sharing, interorganizational network, supply chain, cooperative game theory, Shapley values

Introduction

One of the important investment decisions in supply chains concerns interorganizational information and communication systems. In the presence of power differences between the participants in the chain, the question arises: Who pays for the installation and operation of these systems—suppliers, buyers, or both, and if both, in what proportions? The solution to this question is of theoretical as well as of practical interest, because it has an impact on investment incentives of the partners in the supply chain and on the stability of the cooperation.

Today, with the advent of open, Internet-based technologies, proprietary information systems in supply chains increasingly are being replaced by standardized systems with easy connectivity for suppliers and buyers. On the one hand, standardized web-based systems are less costly to develop, install, and operate; on the other hand they become a common resource to everyone and no longer constitute a significant competitive advantage. Tightly coupled and highly integrated investment strategies into interorganizational information systems, as we could observe in the past, and still can observe in strategically important situations today, are expected to play a lesser role in the future. As a consequence, contributions of the network members to these investments are no longer planned long beforehand but negotiated on the spot. Within the negotiation process, relative negotiation power plays an important role. Because of lower network integration, one can expect that supply chains involve an increasing number of partners, as can be observed in the automobile industry with the introduction of global sourcing and web-based procurement platforms. Hence, the question arises: How is investment sharing influenced by the size of the supply chain?

We propose a model for negotiating investment shares in interorganizational supply chains. It is based on cooperative game theory with transferable utilities and specifically on the application of Shapley values as measures of negotiation power. Of course, negotiation of investment shares is not limited to interorganizational information systems but applies to any kind of interorganizational resource. Therefore, we will treat the case generally, but with information systems as a major interorganizational resource in mind. In the next section, we state our research objective and methodology more precisely. A negotiation model for general network structures is then developed and applied to supply chains and with a numerical example presented. The findings from the model analysis are further discussed. The paper concludes with a brief summary and the identification of areas for future research. The results presented in this paper extend previous work (Schober 1999; Schober and Raupp 2003) to negotiation of investment shares in more general networks with emphasis on two-level supply chains with one buyer (or supplier) and several suppliers (or buyers).

Problem Statement and Research Methodology

The term *interorganizational network* refers to a coordination mechanism that is located between coordination by markets and by hierarchies (Williamson 1991). A single firm may be a member of several interorganizational networks depending on the specific task of each network. Interorganizational supply chains are a special subclass of these networks. To characterize supply chains more precisely, the following taxonomy for general networks is proposed:

Network topology: Interorganizational networks are either symmetric, asymmetric or mixed. In symmetric networks all network members are mutually interconnected. Interfirm alliances in research and development or standardization committees are examples for symmetric networks. In asymmetric networks, one *focal* member exists who cooperates with all other *non-focal* members, whereas the non-focal members do not maintain direct relationships between themselves. A two-level supply chain, where several suppliers cooperate with one buyer, is an example for an asymmetric network. Mixed network topologies involve more than one focal member and several non-focal members. They are located between the two extreme topologies. Examples for mixed topologies include consulting networks with some consultants acting as gatekeepers into the network or supply chains with more than one focal member.

Network size: Interorganizational networks are either quite small or they are large. Interfirm alliances or supply chains are mostly small. Professional societies are examples of large networks. The network size can also be fixed, for instance in a network of actors in a theater production, where the network size depends on the number of roles in the play.

Network value: The total value of a network can either be fixed or variable. For a given product or part, such as tires purchased by an automobile manufacturer, the total periodical contract volume is fixed and results from a given forecast for car sales. In a consulting network, the value may be variable depending on the size and the expertise of the network members.

Network strategy: A network strategy can either be highly integrated or loosely coupled. In the following we refer to a *strategic network* if its strategy is highly integrated, otherwise to a *nonstrategic network*. A strategic network involves products or services that are of essential strategic importance to all network members. In the automobile industry, fuel injection pumps or complex electronic devices are typical examples of products that are strategically important for the automobile manufacturer as well as for the respective suppliers. Strategic networks rely on common strategies at the network level and particularly in the case of supply chains on highly integrated interorganizational business processes including specialized and often proprietary information systems. Strategic networks are primarily long-term oriented. Trust between network members plays an important role. A nonstrategic network involves products or services that are of no essential strategic importance to some of the network members such as general purchase goods. Nonstrategic networks are usually not based on jointly formulated strategies on the network level nor do they employ integrated business processes, but connect individual processes and information systems via open and standardized interfaces, such as general purchase platforms and product catalogs. Nonstrategic networks are often more short-term oriented. A typical characteristic of nonstrategic networks is that the financial contribution to common resources, for instance to system interfaces, is negotiated between the network members rather than jointly agreed beforehand in the form of long-term strategies and contracts.

This network taxonomy is certainly far from complete. For instance, it does not cover differences in the legal form of the cooperation. However, it serves well for the characterization of the type of supply chain we are considering in this paper. We concentrate on *asymmetric* and *nonstrategic networks* with *small size* and *fixed network value*. The typical example that we use for the remainder of the paper is a buyer, who employs one or more suppliers for a fixed total volume contract of general purchase goods. The key issue of our analysis is how investments into common, network-specific resources are shared between all network members. Connected with this issue is the question of how many suppliers should be contracted by the buyer.

Negotiation processes in interorganizational networks are part of a network's strategy. A rich body of research exists on network strategy in general (e.g., Astley 1984; Astley and Fombrun 1983; Bresser 1988; Bresser and Harl 1986; Carney 1987; Oliver

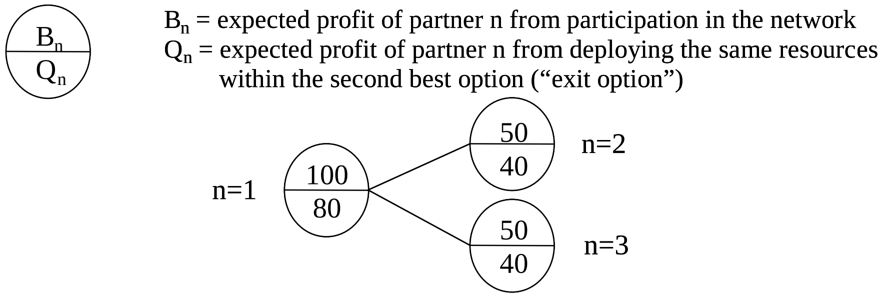
1988). One important part of network strategy concerns financing of shared resources. This issue is strongly influenced by the distribution of negotiation power in a network (Adler 2001; Carney 1998; Contractor and Lorange 1988). Resource sharing in interorganizational supply chains with particular emphasis on the resource "information" has found much attention in the recent literature (e.g., Cachon and Fisher 2000; Lee et al. 2000; Lee and Whang 2000; Li 2002; Samaddar and Kadiyala 2004). A major part of the work on negotiation in supply chains is based on noncooperative game theory, often on sequential games with leaders and followers in the negotiation process. For example, Li (2002) and Samaddar and Kadiyala (2004) have modeled the information sharing problem as a Stackelberg game with a focal manufacturer as the leader and retailers as followers. Cooperative game theory and particularly the Shapley value approach have been applied far less to negotiation problems in supply chains (Cachon and Netessine 2004). Unlike competitive games, cooperative games concentrate less on specific decisions of the network members and more on sharing the outcome of a network between its members as a function of relative bargaining power. One major root of cooperative game theory goes back to the Nash bargaining problem (Nash 1950). The concept of Shapley values is an extension of Nash's two-persons game to n persons (Shapley 1953). Shapley values have since then been interpreted as measures of bargaining power in networks (Aumann and Dreze 1974; Aumann and Myerson 1988; Harsanyi 1963; Myerson 1977).

We propose a static negotiation model based on Shapley values. The attractive feature of the Shapley values approach is that the results of the negotiation process do not depend on the absolute profits of each network member, but only on the differences to the best options outside of the network. This property is appealing both from a theoretical and a practical point of view, because the precise sources of profits for each network member are irrelevant for the negotiation results. Since we have the analysis of major one-time investment decisions in mind, rather than more continuous decisions (e.g., on inventory levels), a static model seems appropriate.

A Model for Negotiating Investment Shares in Interorganizational Networks

Under rational behavior it can be assumed that each member of an interorganizational network entering the network remains in the network if it expects a higher profit than it would achieve in another arrangement employing the same resources (second best option). The expected profit from the second best option, therefore, defines the "exit option" of each network member. The individual difference between the expected profit from the network participation and the exit option is a measure of bargaining power of a network member. The smaller this difference, the larger the potential threat that the network member might exit. These differences play a major role in the classical Nash bargaining problem and also for Shapley values. The basic concept of Shapley values is illustrated in Figure 1. Assume that a buyer (n = 1) cooperates with two suppliers (n = 2, 3). The buyer expects a profit of $B_1 = 100$ from participating in the network. The exit option is $Q_1 = 80$ (the buyer, for instance, can threaten to produce the supply internally via backward integration). The corresponding profit values for the two suppliers are $B_2 = 50$, $Q_2 = 40$, $B_3 = 50$, and $Q_3 = 40$.

Let $C_n(H) = V(H) – V(H\text{-}\{n\})$ denote the contribution of network member n to the total value of a sub-coalition H of the network, whereby V(H) is the value of sub-coalition H including member n and V(H-{n}) is the value excluding member n. The Shapley value B_n^* is defined as the average contribution of member n taking all possible sub-coalitions H into account where n is member of H. These sub-coalitions can be enumerated by considering all permutations of sequential network build-up (see the first column in Figure 1). For instance, in the permutation 3 – 1 – 2, first member 3 enters the network forming the trivial sub-coalition H = {3}, then member 1 enters forming H = {3,1} and finally member 2 enters forming the full network H = {3,1,2}. Columns 2 to 4 in Figure 1 contain the corresponding contributions $C_n(H)$. The last row contains the Shapley Values B_n^* as the average over all coalitions where n is member (i.e., the average over all rows above). They express the average contribution of each network member to the total network value. If we interpret the sequence of "entering" a sub-coalition as the sequence of taking up negotiations for profit sharing, then the Shapley values constitute a measure of relative negotiation power. Shapley values higher than the original profit expectations, in our case for member 1, indicate a strong power position while Shapley values less than the original profit expectations, for members 2 and 3, indicate weak power positions. Member 1 could collect "side payments" in the size of the power difference of 3.33 profit units from members 2 and 3, each paying 1.67 profit units to member 1. After negotiation, the profits of members 2 and 3, $B_2^* = B_3^* = 48.33$, are still above their exit options $Q_2 = Q_3 = 40$, hence members 2 and 3 still profit from the network participation. The reason why suppliers 2 and 3 possess less bargaining power is that within sub-coalitions H = {2,3} and H = {3,2} both members cannot negotiate because they can cooperate only with the buyer n = 1. The Shapley values constitute a redistribution of the individual profit expectations, that is, the sum of all profits before negotiation (*ex ante* profits) equals the sum of all profits after negotiation (*ex post* profits). Under the conditions of symmetry (all permutations have the same probability), linearity (values of different coalitions can be added) and carrier (inessential players are rewarded by their exit option), which hold in our case, the Shapley values exist and are unique (Myerson 1991, p. 436, Shapley 1953).



$C_n(H) = V(H) - V(H-\{n\})$ = contribution of partner n to the value V(H) of a coalition H that includes n

Negotiation sequence (H)	$C_1(H)$	$C_2(H)$	$C_3(H)$
1 - 2 - 3	Q_1=80	$B_1+B_2-Q_1$=70	$B_1+B_2+B_3-B_1-B_2$=50
1 - 3 - 2	Q_1=80	$B_1+B_3+B_2-B_1-B_3$=50	$B_1+B_3-Q_1$=70
2 - 1 - 3	$B_2+B_1-Q_2$=110	Q_2=40	$B_2+B_1+B_3-B_2-B_1$=50
2 - 3 - 1	$B_2+B_3+B_1-Q_2-Q_3$=120	Q_2=40	$Q_2+Q_3-Q_2$=40
3 - 1 - 2	$B_3+B_1-Q_3$=110	$B_3+B_1+B_2-B_3-B_1$=50	Q_3=40
3 - 2 - 1	$B_3+B_2+B_1-Q_3-Q_2$=120	$Q_3+Q_2-Q_3$=40	Q_3=40
Average = Shapley value B_n*	103.33	48.33	48.33

Figure 1. Shapley Values as a Measure of Negotiation Power

Next we extend the example to more general network topologies and to more flexible profit functions. We also provide a closed formulation for the Shapley values, so that enumeration as in the example above is no longer required. Furthermore, we introduce investments into joint network resources. Let us assume that the expected profit $B_n(X)$ of network member n, after a joint investment of size X and an individual investment share $w_n(X)$, is given by

$$B_n(X) = R_n(X) + s_n\, \beta_n(X) - w_n(X)\, X \qquad (1)$$

for all n = 1, 2, .., N

$R_n(X)$ expresses the profit portion that is independent of the network's topology. The term $s_n\, \beta_n(X)$ measures the profit contribution that depends on the network's topology. The factor s_n denotes the number of partners with whom member n employs direct economic links and β_n denotes the profit contribution per link; for example, for the network in Figure 2 with mixed topology, $s_1 = 2$, $s_2 = 3$, $s_3 = 2$, $s_4 = 3$ and $s_5 = 2$. The parameters $\beta_n(X)$ can be either positive or negative, expressing positive or negative network externalities.

If the exit option of network member n is denoted by $Q_n(X)$ then the Shapley values $B_n(X)^*$ corresponding with profits (1) are calculated in the following closed form:

$$B_n(X)^* = B_n(X) - [\,(1/(s_n+1))\,(R_n(X) - w_n(X)\,X - Q_n(X))\,] + [\,\Sigma_m\,(1/(s_m\,(s_m+1)))\,(R_m(X) - w_m(X)\,X - Q_m(X))\,] - [\,0.5\,(s_n\,\beta_n(X) - (\Sigma_m\,\beta_m(X)))\,] \qquad (2)$$

for all n = 1, 2, .., N

Thereby the summation Σ_m in the second and the third [ ]-term is applied over all network members m that maintain direct economic links with member n, for instance $m \in \{2,3\}$ for member n = 1 or $m \in \{2,3,5\}$ for member n = 4 in Figure 2. Note also that the exit options generally depend on the investment level X (e.g., if additional switching costs are incurred by the investment). Equation (2) is a straightforward extension of the results given by Schober and Raupp (2003, p. 30 and 65 for the proof) for the case of constant $\beta_n = \beta$.

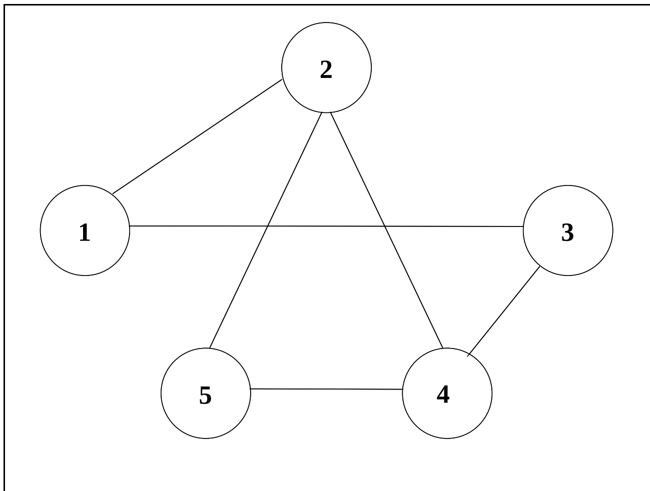


Figure 2. Network with Mixed Topology

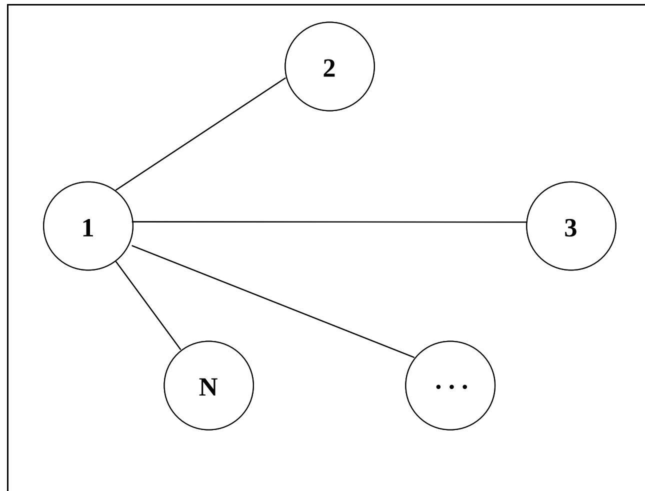


Figure 3. Two-Level Supply Chain

We observe from equation (2) that member n loses $1/(s_n+1)$ of its own threat potential $R_n(X) - w_n(X)\ X - Q_n(X)$ within the negotiation process (first [ ]-term in (2)) and gains $1/(s_m\ (s_m+1))$ of the threat potential $R_m(X) - w_m(X)\ X - Q_m(X)$ of each neighboring member m (second [ ]-term in (2)). In addition, member n loses half of its own structure-dependent profits and gains half of the corresponding profits of its direct neighbors (third [ ]-term in (2)). Concerning negotiation power, it is advantageous for member n to possess many neighbors (large s_n) while each neighbor maintains only few links to its neighbors (small s_m). The extreme case of negotiation power imbalance from a structural point of view is the asymmetric two-level supply chain where $s_1 = N - 1$ for the focal member (e.g., buyer) and $s_m = 1$ for each non-focal member $m \neq 1$ (e.g., supplier; see Figure 3). In such supply chains, the negotiation power of buyer 1 increases with the number of suppliers, as will be explored in more detail in the next chapter. On the other hand, in symmetric networks, where all network members mutually cooperate, negotiation power imbalances diminish with increasing number of network participants (Schober and Raupp 2003, p. 32). Hence, different network topologies exhibit quite different patterns of power distribution.

In order to calculate the investment shares, we use the Shapley values (2) as indicators for relative negotiation power. We choose investment shares $w_n(X)$ in such a way that the differences between $B_n(X)$ in (1) and the corresponding Shapley values $B_n(X)^*$ in (2) become as small as possible, under the additional constraints that $w_n(X) \geq 0$ and $\Sigma_n\ w_n(X) = 1$. Hence, we solve the following quadratic optimization problem for the decision variables $w_1(X), w_2(X), \ldots, w_N(X)$:

$$\text{Minimize } \Sigma_n \{ B_n(X) - B_n(X)^* \}^2 \tag{3}$$

$$\text{subject to } w_n(X) \geq 0;\ \Sigma_n\ w_n(X) = 1;\ B_n(X) \geq Q_n(X) \qquad \text{for all } n = 1, 2, .., N$$

Note that the negotiation model (3) uses the Shapley values only for the calculation of the investment shares and restricts side payments to these shares (unlike in the example of Figure 1, (3) does not necessarily consider full side payments). Substituting (2) into (3), the optimization problem (3) becomes equivalent to

$$\begin{aligned}\text{Minimize } \Sigma_n \{ & [\ (1/(s_n+1))\ (R_n(X) - w_n(X)\ X - Q_n(X))\ ] - [\ \Sigma_m\ (1/(s_m\ (s_m+1)))\ (R_m(X) - \\ & w_m(X)\ X - Q_m(X))\ ] + [\ 0.5\ (s_n\ \beta_n(X) - (\Sigma_m\ \beta_m(X)))\ ]\ \}^2\end{aligned} \tag{4}$$

$$\text{subject to } w_n(X) \geq 0;\ \Sigma_n\ w_n(X) = 1;\ B_n(X) \geq Q_n(X) \qquad \text{for all } n = 1, 2, .., N$$

The objective function in (4) is convex, because the part of the objective function that relates to the quadratic forms in $w_n(X)$ (i.e., $\Sigma_n \{ \Sigma_m\ (1/(s_m\ (s_m+1)))\ w_m(X)\ X - (1/(s_n+1))\ w_n(X)\ X \}^2$), is always nonnegative. Therefore, a unique minimum exists.

Application of the Negotiation Model to Supply Chains

We now consider a two-level supply chain with one buyer and N - 1 suppliers (of course, the results apply equally to the reverse case of one supplier and several buyers). This means that we have to set in (4) $s_1 = N – 1$ and $s_n = 1$ for n = 2, 3, …, N, if n = 1 denotes the buyer. In a first step, we assume that the buyer makes decisions on the total purchase volume, on the number of suppliers, and on the split of the purchase volume between the various suppliers. In a second step, the decisions on the investment level X and on the shares $w_n(X)$ are made. For any given X, the shares are calculated by using optimization model (4). Step 1 is an important assumption because otherwise suppliers could improve their profits by building smaller sub-coalitions with the buyer and by sharing the total purchase volume within these sub-coalitions. In this case, the profit allocations for the full supply chain are no longer in the core of the game and the Shapley value approach is not meaningful. We explicitly specify the impact of the joint investment X on $R_n(X)$ in (4) by the function

$$R_n(X) = r_n\,(1 + \alpha \ln(1+\sigma X)) \qquad (5)$$

$$\text{for all } n = 1, 2, .., N$$

with $r_1 = 100$, $r_n = 100/(N-1)$ for n > 1, $\alpha = 0.135$ and $\sigma = 0.5$. The parameter r_n measures the base profit expectation of each network member before investment, α and σ the profit increase due to investment X. Hence, we assume that the total network value before investment adds up to 200 monetary units and is equally split between the buyer (100) and all suppliers (100), that is, we consider a supply chain with fixed total network value. Note, however, that it is not essential whether the network value comprises one or several purchase products, as long as the total value is fixed. Next we assume that the exit options are given by constant values $Q_1(X) = 80$ and $Q_n(X) = 80/(N-1)$, neglecting a potential impact of investment X on switching costs. Furthermore, we set $\beta_n(X) = 0$ for all network members n and all investment levels X. Note that this assumption is not very restrictive, because setting $\beta_n(X) = \beta(X)$, which implies the same network externalities for all members n, would yield the same results as the β-terms and, in this case, cancel out in (2) and (4). Later in the paper we will deviate from this assumption and introduce coordination costs for the buyer $\beta_1(X) < 0$. As a consequence of the parameter settings, if the buyer collaborates with only one supplier, both parties expect the same profits and have the same exit options so that the Shapley values are identical and indicate equal negotiation power. Hence, from (4) it follows that investments are equally shared for all levels of X (i.e., $w_1(X) = w_2(X) = 0.5$). We have chosen this equal starting position on purpose in order to concentrate solely on the impact of the number of suppliers on investment sharing and to isolate this impact from the other model parameters.

The profit function $R_n(X)$ fulfills the condition of decreasing marginal returns (i.e., $dR_n(X)/dX > 0$ and $d^2R(X)/dX^2 < 0$). Having investments into interorganizational information systems specifically in mind, we assume that potential system applications can be ordered by productivity impact and that most productive applications are implemented first, leading to decreasing marginal returns from the investment. One could argue that in special cases the profit function should be S-shaped because a substantial information base is needed before the system becomes productive. However, this assumption does not change the essential conclusions from the model. The value for the total supply chain is $V(X) = \Sigma_n R_n(X) – X$. Setting the first derivative of V(X) equal to zero, we find that the optimal investment level for the total supply chain is given by $X^{opt} = \alpha\,(\Sigma_n r_n) – 1/\sigma = 25$, yielding a total network value after investment of V(25) = 245 (see Figure 4). V(x) declines beyond this investment level and for large X > 108 becomes even less than the network value V(0) = 200 before investment. The optimal investment level and the resulting optimal total network value are obviously independent of the number of suppliers involved.

Now we turn to the computation of the individual investment shares for more than one supplier by applying the negotiation model (4). To solve (4), we used the optimization system LINGO (LINGO 2003). Figure 5 exhibits the investment shares allocated to the buyer depending on the number of suppliers involved. With only one supplier, the share is 50 percent, as shown earlier. However, by collaborating with two suppliers instead of one for the same fixed contract volume, the investment share of the buyer decreases substantially. For small investment levels less than X = 20 it is zero. This effect becomes even more pronounced if the supplier base increases further. With 10 suppliers, the buyer does not carry any investment share below an investment level of about X = 50.

What is the impact of this investment sharing pattern on the buyer's and the suppliers' profits? The left part of Figure 6 contains the results for the buyer. Due to the declining investment shares, the buyer's profit increases with the number of suppliers involved. Also, the optimal investment level from the buyer's point of view shifts to the right, for instance, with 5 suppliers to about X = 40 and with 10 suppliers to about X = 50, as compared to $X^{opt} = 25$ for the network as a whole. Vice versa the profit left for all suppliers declines with an increasing number of suppliers (see the right-hand part of Figure 6). Accordingly, their joint (and individual) optimal investment level declines to about X = 10. For higher investment levels, the profit impact is negative, compared to the profit line of 100 without investments.

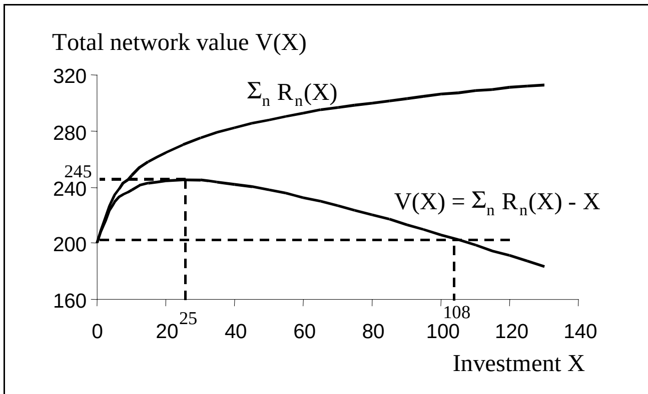


Figure 4. Total Network Value

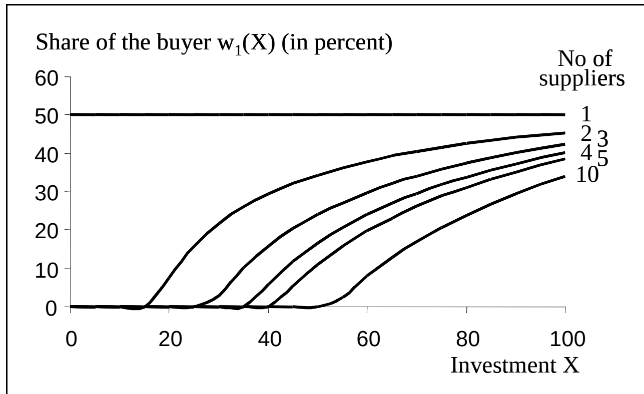


Figure 5. Investment Shares of the Buyer

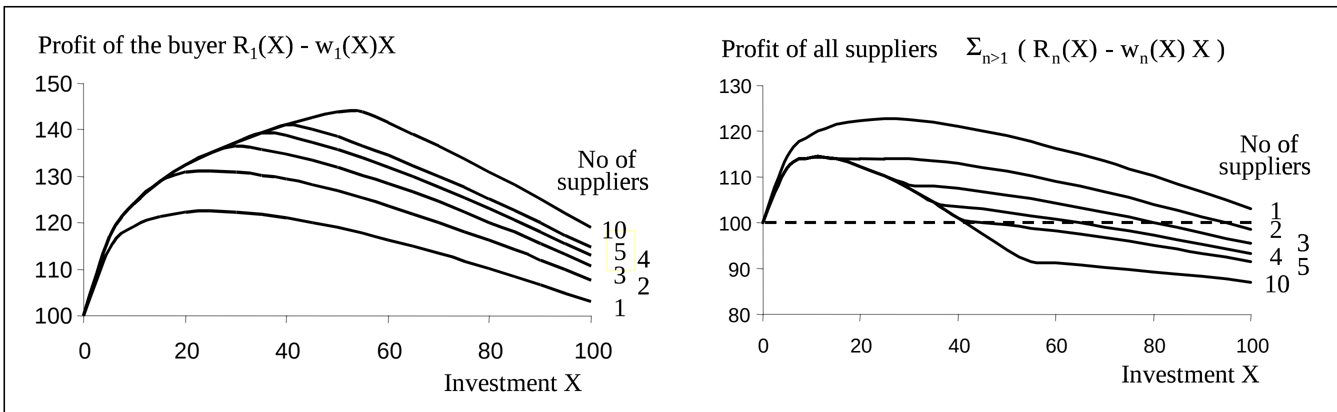


Figure 6. Profit of the Buyer (Left) and All Suppliers (Right)

Obviously, we observe a conflict concerning optimal investment levels. While the buyer's investment propensity increases with a growing number of suppliers, the reverse happens to the suppliers. A joint negotiation result at the optimal investment level of $X^{opt} = 25$ for the network as a whole becomes quite unlikely. As a consequence, the network becomes unstable with respect to joint investment decisions.

In our scenarios so far, the buyer can increase profits by increasing the supplier base. But one can argue that a buyer has to carry higher coordination costs along with a larger supplier base. To evaluate this effect within our numerical example, we set $\beta_1(X) = -3$ for all levels of X. This implies that the buyer has to carry coordination costs of three monetary units for each supplier added to the network. Figure 7 exhibits the model results. We now see that adding suppliers does no longer increases the profits of the buyer automatically. Instead, we get an optimal number of four suppliers.

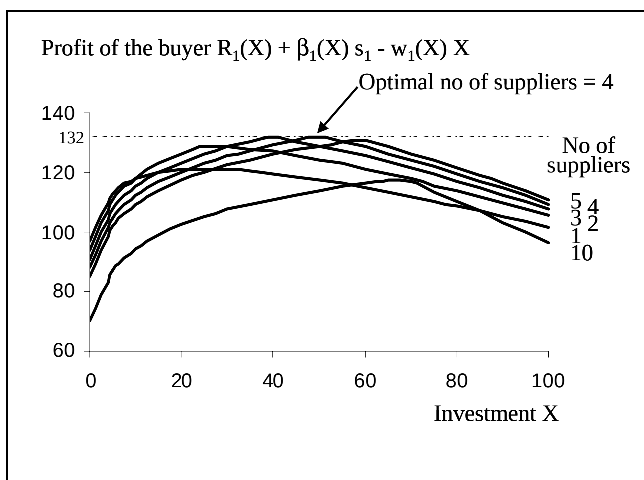


Figure 7. Optimal Number of Suppliers in the Presence of Coordination Costs

Discussion

As a result of the underlying asymmetric network topology, supply chains are particularly prone to imbalances of negotiation power. These imbalances, if exercised, have a strong impact on investment sharing. The focal partner, in our case the buyer, is able to reduce its share by increasing the number of suppliers for a fixed purchase volume, at least to a certain point, until coordination costs become too large for the buyer or the volume splits are no longer attractive for the suppliers. In practice, negotiation power is most often imposed indirectly, for instance, if the buyer tries to make the suppliers mainly or solely responsible for adding resources to the network. Such instances were reported for European networks (Bjørn-Andersen and Krcmar 1995) and for Canadian networks (Bergeron and Raymond 1997). Other scholars have come to comparable conclusions using either empirical investigations or theoretical concepts different from the one proposed here (e.g., Bakos and Treacy 1986; Choudhury 1997; Helper 1991; Iacovou et al. 1995; Johnston and Vitale 1988; Seidmann and Sundararajan 1998).

Our numerical exploration shows that adding suppliers goes along with increased distortion of investment incentives. While the buyer in a supply chain is interested in high investment levels to increase profit, the reverse is true for the suppliers. In the end, it may become difficult to implement any investment strategy because of diverse interests. The failure of EDI can partly be attributed to investment sharing problems (Hart and Saunders 1997; Riggins et al. 1994; Wang and Seidmann 1995). On the other hand, the non-focal partners can regain negotiation power if they cooperate and act opposite the focal partner as one entity. Suppliers' cooperatives and common intermediaries are typical strategies of such power bundling.

Negotiation is only one specific rule for arriving at investment shares. In fact, other rules can be superior. As we have seen in our numerical example, negotiation in general does not automatically lead to optimal investment levels for the total network because of distortion of propensities to invest. If optimal investment levels count, especially in strategic networks with long-term orientation and highly integrated business processes, other sharing rules may be more adequate. Optimal investment levels can be ensured if each partner in the network collects the same marginal return from its investment share (Bakos and Brynjolfsson 1993, 1998; Schober 1999). Such optimal investment sharing rules have been advocated by various scholars (Clemons and Row 1993; Hart and Saunders 1997; Moore 1998; Ring and Van de Ven 1994). Another way of arriving at better sharing rules with respect to total network value are voluntary constraints of negotiation power by the focal partner, for instance by reducing the number of non-focal partners in the network (Bakos and Brynjolfsson 1993; Clemons et al. 1993; Choudhury 1997; Helper 1991) or by relying on joint ownership agreements (Bakos and Nault 1997). These rules are based on strong mutual trust as opposed to negotiation practices (Bensaou 1997; Zaheer and Venkatraman 1994). A focal partner can, of course, use different sharing rules at the same time, depending on the strategic character of the various products and services purchased. Moreover, different cultures may apply different rules, as has been reported from Japanese firms that rely much more on strategic network formations (Ahmadjian and Lincoln 2001; Bensaou 1997; Bensaou and Venkatraman 1995; Helper and Sako 1995).

Interorganizational information systems are a major source of joint investments in supply chains. Today, we observe a trend away from proprietary systems to open, standardized, and web-based systems. These systems are cheaper to procure, to install, and to operate. Hence, investment intensities should play a lesser role in the area of interorganizational information systems. The impact of these investments on profitability might diminish as well. Whether this trend makes the problem of investment sharing for information systems less important is an interesting open question. Yet, even with the declining strategic importance of information systems, there are many other potentials for imposing negotiation power in supply chains, which were not explicitly addressed in this paper, such as investments into inventory levels or enforcement of price reductions. Hence the problem of investment, cost, and profit sharing stays alive, or even becomes more urgent with the increasing presence of enterprise networks.

Conclusion

In this paper, we have analyzed the problem of investment sharing in interorganizational supply chains. Basically we concentrated on networks where investment shares are negotiated rather than defined by integrated network strategies (i.e., on nonstrategic supply chains). It turned out that a focal partner in such a supply chain can profit from the asymmetric network topology and reduce its own investment share by adding non-focal partners. In the presence of additional coordination costs, the success of this strategy is limited and an optimal number of non-focal partners exists. In our analysis, we concentrated on two-level supply chains. However, our methodology can be directly extended to n-level supply chains, with second-level suppliers and so on. Interestingly, in such chains intermediate-level suppliers may gain bargaining power, according to our model, if they can pass negotiation pressures to upstream members in the chain. However, it is doubtful that investment sharing is done simultaneously in such complex chains. Here, sequential models seem more appropriate.

Our results complement other theoretical and empirical work with similar findings. Much of the empirical work reflects on case studies. More comprehensive field surveys are still missing. Another important research issue concerns the relative evolution of strategic versus nonstrategic supply chains. Connected with this issue is the future architecture of interorganizational information systems in supply chains (i.e., proprietary versus standardized and open systems). Finally, the endogenous formation of supply chains in defense of negotiation power imbalances, for instance the endogenous formation of cooperatives or intermediaries, constitutes a topic of interesting and important research into supply chains and enterprise networks in general.

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Appendix. List of Symbols Used in the Investment Sharing Model

X	=	joint investment into a network resource
n	=	individual network member ($n = 1, 2, \ldots, N$)
$w_n(X)$	=	investment share of network member n
$B_n(X)$	=	expected profit of network member n
$R_n(X)$	=	part of $B_n(X)$ that is independent of the network topology
$\beta_n(X)$	=	part of $B_n(X)$ that is dependent on the network topology (profit per direct link)
s_n	=	number of direct links of network member n with other network members
$Q_n(X)$	=	best option of network member n outside of the network (second best option)
$B_n(X)^*$	=	Shapley value of network member n
r_n, α, σ	=	parameters of the detailed specification of $R_n(X)$