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The Relational Advantages of Intermediation

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This paper provides a novel explanation for the use of supply chain intermediaries. We find that even in the absence of the well-known transactional and informational advantages of mediation, intermediaries improve supply chain performance. In particular, intermediaries facilitate responsive adaptation of the buyers' supplier base to their changing needs while *simultaneously* ensuring that suppliers behave as if they had long-term sourcing commitments from buying firms. In the face of changing buyer needs, an intermediary that sources on behalf of multiple buyers can responsively change the *composition* of future business committed to a supplier such that a sufficient level of business comes from the buyer(s) that most prefer this supplier. On the other hand, direct buyers that source only for themselves must provide all their committed business to a supplier from their own sourcing needs, even if they no longer prefer this supplier. Unlike existing theories of intermediation, our theory better explains the observed phenomenon that although transactional barriers and information asymmetries have steadily decreased, the use of intermediaries has soared, even among large companies such as Walmart.

Key words: global sourcing; intermediaries; supply chain relationships; relational contracts; flexibility; Li & Fung; repeated games
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1. Introduction

This paper is inspired by the phenomenal growth of supply chain intermediaries that source products or services on behalf of other firms. These often completely take over the sourcing function—they select, verify, and approve suppliers; they allocate business between different suppliers; and they manage the relationship with each supplier, including provision of incentives for investments, performance, and compliance.

A notable sourcing intermediary is Li & Fung Ltd., which provides sourcing services to major brands and retailers worldwide, including Walmart, Target, Zara, and Levis. Li & Fung has grown at a compounded annual rate of 23% for the last 14 years to achieve annual sales of over HK$120 billion. Best known for sourcing apparel and toys from the low-cost economies of Asia, the group today operates in an expanding range of categories. It is present in more than 40 economies across North America, Europe, and Asia, with a global sourcing network of nearly 15,000 international suppliers, as well as thousands of buyers. It has the ability to provide both low-cost and quick, responsive sourcing. Yet Li & Fung does not own any means of production or transport, nor is it in the business of directly retailing the vast majority of the products it sources. It provides only an interface between multiple buyers and suppliers (McFarlan et al. 2007).

The benefits and costs that intermediaries bring to supply chains have long been studied by scholars in finance, economics, and supply chain management (see Wu 2004 for a comprehensive summary). Two main benefits are identified to justify the existence of intermediaries: transactional and informational benefits. Transactional benefits include the ability of intermediaries to provide immediacy by holding inventory or reserving capacity, plus the benefits that arise out of the reduced costs of trade. Intermediaries that aggregate demand can use their scale to better use facilities, amortize fixed costs, and reduce the costs of searching and matching. Transactional benefits are most salient for smaller firms that do not individually have the scale to justify fixed investments, and when the institutional barriers to trade are high.

A second class of benefits arises from the informational role that intermediaries play. An intermediary's exposure to and better ability to synthesize dispersed information allows it to reduce information asymmetries, ensure better price discovery, and provide superior administration of contractual coordination mechanisms. Both these gains increase the efficiency of a supply chain, and the intermediary can appropriate some of these gains while sharing the rest with its supply chain partners. On the other hand, an additional tier in a supply chain is known to increase incentive misalignment, which can lead to insufficient stocking levels, poor information sharing, and insufficient investments (Cachon and Lariviere 2005).

Interestingly, with advancements in communication technologies and reductions in barriers to trade, many scholars have predicted a "flat world," in which global economic integration and democratizing technologies would diminish both the informational and transactional roles of intermediaries. In particular, scholars have long hypothesized that one of the major business impacts of the Internet would be the dis-intermediation of traditional entities (Wigand and Benjamin 1995, Friedman 2007). Online platforms such as Alibaba.com have indeed rendered the traditional price discovery and matching roles of intermediaries irrelevant. The growth of intermediaries in the face of changes brought about by the Internet and economic integration suggests that the conventional view on the advantages of intermediation may be incomplete.

Furthermore, it is instructive to examine the firms that have decided to move away from direct sourcing to mediated sourcing. In January 2010, Walmart Inc. decided to enter into an open-ended sourcing arrangement with Li & Fung Ltd. (Cheng 2010). The agreement delegated the sourcing of certain Walmart products to Li & Fung; this was expected to bring revenues in excess of US$2 billion to Li & Fung. Many of Li & Fung's clients are similar large firms, such as Target, Gap, Benetton, etc. Existing theory on the role of intermediaries based on scale and informational advantages seems less credible in explaining the move of big firms to adopt mediated sourcing. In particular, firms such as Walmart arguably have more scale, similar market access, and local information than the intermediaries that they hire.[1] An anecdotal analysis of the reasons provided by firms for employing sourcing intermediaries highlights two key themes. First, the ability of firms like Li & Fung to ensure better supplier collaboration, investments, and compliance with quality, social, and environmental norms is highlighted. Supplier investments in capacity and in ensuring compliance are cited as major business risks that are alleviated by intermediation. Second, mediated sourcing may allow firms to be more responsive in adapting their supplier base in the face of changes in the business environment such as supply chain disruptions brought about by adverse natural events, political upheaval, and volatility in the trade environment (energy costs, exchange rates, tariffs, etc.) (Fung et al. 2007, Loveman and O'Connell 1995, McFarlan et al. 2007).

This paper provides a new, previously unidentified advantage of sourcing through intermediaries. We develop a stylized model to compare direct and mediated sourcing. Our model captures two key features of the sourcing environment: the fact that buyers preferences regarding suppliers change over time as the business environment changes, and the presence of incomplete contracts caused by nonverifiability/noncontractability of supplier investments in capacity, quality, or compliance with social, environmental norms, limited legal liabilities, etc. (Aghion and Holden 2011).

Our analysis illustrates that an intermediary that pools the sourcing needs of different buyers can better incentivize beneficial supplier behavior than individual direct buyers can *and* responsively adjust the buyers' supplier base. With incomplete contracts that typify the sourcing of all but the simplest commodities, suppliers are typically incentivized by committing to provide future business contingent on performance. However, with changing preferences over suppliers, meeting these commitments may require sourcing from less-preferred suppliers. An intermediary that sources on behalf of multiple buyers breaks this trade-off by exploiting differences between different buyers' preferences over suppliers. An intermediary can responsively change the *composition* of the committed business such that the level of business required to ensure desired supplier behavior comes as much as possible from the buyer(s) that most prefer this supplier. On the other hand, direct buyers, which source only for themselves, must provision all the committed business from their own sourcing needs, irrespective of what their preferences over suppliers may be. Sourcing for multiple buyers gives intermediaries a certain flexibility in meeting the commitment to provide future business to a supplier—the flexibility of choosing which buyer to match to which supplier.

We demonstrate the existence and operation of this effect in a model with two buyers, two suppliers, and an intermediary that allows for any generic game-theoretic interactions among buyers, suppliers, and intermediaries that contribute to contractual incompleteness. We allow buyer preferences over suppliers to vary in an arbitrary, stochastic, nonstationary, heterogeneous fashion. Our analysis illustrates that the key to the existence of the highlighted advantage is a difference in buyer preferences over suppliers, at any given time. This difference could arise out of stochastic preferences over suppliers of ex ante

[1] In 2011, Walmart's annual revenues were US$421.85 billion, compared to Li & Fung's US$15.96 billion. Walmart also operates more than 189 super centers in China and employs more than 50,000 local workers, making it one of the larger organized hypermarket chains in China (Li & Fung 2010, Walmart 2011).

identical buyers or deterministic but nonstationary preferences of heterogeneous buyers.

Our analysis of mediated sourcing makes three key contributions. First, we provide a new explanation for the existence of intermediaries and their rapid growth. Second, to the best of our knowledge, this is the first paper in the supply chain literature that provides a generic, rigorous, and highly adaptable foundation for analyzing incomplete contracts in a three-tier, multibuyer, multisupplier repeated-sourcing setting. Third, it contributes to the sourcing and procurement literature by bringing together the largely parallel literatures on operational flexibility (see Goyal and Netessine 2011) and relational contracts (see Taylor and Plambeck 2007a). Our analysis captures the changing preferences over suppliers, central to the operational flexibility literature and the incomplete contractability that drives results in the relational contracting literature. It illustrates the trade-off between the opposite sourcing strategies prescribed in the two streams and demonstrates how mediated sourcing breaks the trade-off.

2. Literature Review

Strategies for sourcing have been a central focus of recent research in supply chain management. Work on flexible sourcing to manage changing sourcing needs and relational contracts to deal with contractual incompleteness are most relevant to our study.

2.1. Studies on Flexible Sourcing

Flexible sourcing or responsively sourcing from multiple suppliers has been suggested as a strategy to deal with the changing business environment. Kouvelis et al. (2004) demonstrate the exposure of global sourcing firms to risks arising from subsidized financing, tariffs, regional trade rules, and taxation. Allon and Van Mieghem (2010) and Lu and Van Mieghem (2009) study the choice between sole and dual sourcing strategies and consider the influence of changing logistics costs and trade barriers. Finally, Tomlin (2006) and Chod et al. (2010) examine the value of these flexible sourcing strategies under different contingencies. In line with this literature, our model allows for buyers to have changing preferences over suppliers and is agnostic regarding the source of these changing preferences, thus allowing us to address each of the reasons highlighted above.

2.2. Studies on Relational Contracting

The literature addresses the inefficiencies that arise due to the profit-relevant noncontractible actions of sourcing partners. This has been a central focus of microeconomics research for more than three decades (see Aghion and Holden 2011 for a summary), and there is a growing body of operations literature that highlights the use of relational contracts as a remedy to these inefficiencies. Taylor and Plambeck (2007a, b) study settings in which price and capacity are noncontractible. Debo and Sun (2004) study a setup where inventory levels are noncontractible. Plambeck and Taylor (2006) study joint production with unobservable utility-relevant actions. Ren et al. (2010) consider forecast sharing by a buyer in a setup where he has an incentive to inflate the forecasts. In each of these studies, building long-term relationships is presented as a mechanism for providing intertemporal incentives that mitigate myopic opportunistic behavior. In line with this literature, the transaction step game of our model (introduced in §3.1) captures these noncontractible aspects of sourcing interactions. As in our treatment of changing buyer preferences over suppliers, rather than model any of the specific noncontractible actions studied in this literature, we consider a generic game that captures the key elements of each of the above settings.

2.3. Trade-Off Between Flexible Sourcing and Relational Contracting

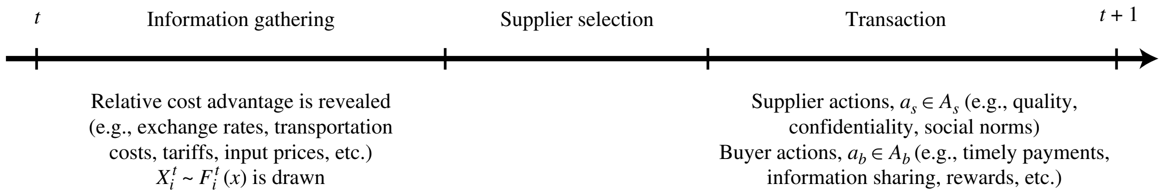
Flexible sourcing and relational contracting are competing strategies. Tunca and Zenios (2006) consider the trade-off between relational contracts and flexible procurement auctions in a setting with multiple buyers and sellers. Swinney and Netessine (2009) look at the same trade-off when there is a possibility of supplier bankruptcy or default. Li and Debo (2005, 2009) illustrate the long-term shortcomings and benefits of committing to a single supplier when future sourcing options may change. Our study continues in the tradition of examining the trade-off between relational contracts and flexible sourcing, and we demonstrate the utility of mediated sourcing in relieving this trade-off. Sourcing intermediaries have never before been studied in this context.

3. Model Setup, Direct and Mediated Sourcing

3.1. Model Preliminaries

Consider two buyers, b_1 and b_2, that repeatedly source products or services from two potential suppliers, s_1 and s_2. Each supplier has ample capacity to meet the sourcing needs of one or both buyers. We model the repeated trade between these buyers and suppliers as an infinitely repeated game—in each stage of the game, both buyers source the product. Buyers and suppliers discount future profits with a discount factor δ, which captures the time value of money and the probability of exit from the market. The sourcing exercise itself proceeds in three steps (Figure 1). First is the *information-gathering step*, where the differences in the costs of sourcing from the two suppliers are revealed. Second is the *supplier-selection step*, where

Figure 1 **Stage Game at Time** t



each buyer's business is distributed among the two suppliers. Finally, the product or service is actually sourced in the *transaction step.* These three steps constitute the stage game that is repeated in every period $t \in \{0, 1, 2, \ldots\}$.

3.1.1. The Information-Gathering Step. In this step, buyers acquire information about the prices, capabilities, and performance of different suppliers to ascertain the advantage of one supplier over another. This advantage could arise out of a match between the buyers' product specifications and the suppliers' idiosyncratic capabilities, or differences in exchange rates, transportation or telecommunication costs, cross-border tariffs, pass-through input costs, etc. To capture the dynamic business environment and the evolution of the buyers' business, we allow this relative advantage to change stochasticaly from one sourcing period to another. In particular, at time t, the per unit profit of buyer i, $i \in \{1, 2\}$ if he sources from supplier 1, includes an additive component, X_i^t, the relative advantage of supplier 1 in supplying buyer i, that is publicly drawn from a probability distribution function that has both positive and negative support and can be asymmetric. $F^t(X_1^t, X_2^t)$ denotes this joint bivariate distribution of the relative advantage that supplier 1 has in supplying buyer 1 and 2. F_1^t and F_2^t are the partial densities. All else being equal, if the realization of X_i^t is positive, buyer i's profits will be higher if he sources from supplier 1 than from supplier 2, and supplier 1 is the current *preferred* or, taking a total cost of ownership view, the "lower-cost" supplier. Note here that we make no assumptions on the stationarity of the buyers' preferences over suppliers, nor do we assume that the buyers are symmetric. Our setup allows heterogeneous buyers' preferences regarding suppliers to randomly and systematically vary over time, in both their direction and intensity, in an arbitrary fashion.

3.1.2. The Supplier-Selection Step. In this stage, the sourcing business is allocated between the two suppliers. To facilitate clear illustration, we assume that the two buyers' sourcing needs are comparable in dollar value, and without loss of generality, we normalize that value to one unit.[2]

[2] A simple extension allows us to consider buyers with different sourcing budgets. All effects presented below continue to hold.

3.1.3. The Transaction Step. The actual sourcing of the product or service takes place in this step. Both the buyer and supplier can now undertake some actions that influence the profits of their sourcing partner. On the supplier side, these could include operational actions such as efforts in ensuring quality or timely delivery, conforming to technical and labor standards, following environmental and social norms, maintaining confidentiality of proprietary information, providing prompt after-sales service and support, etc. On the buyer's side, these could include accurate sharing of demand information, timely payments, access to new business opportunities and capital, cross-investments, access to capital, training, technology transfer, recommendations, rewards, sanctions, etc.

We model all buyer–supplier interactions in the transaction step as a completely general finite two-player game that can capture any economic interactions during the sourcing stage between the buyer and supplier, including those mentioned. We denote the extensive form of this generic game by Γ. In game Γ, the set of buyer and supplier feasible actions is denoted as $A_b, A_s \subset \mathbb{R}^n$. The set of feasible action profiles is then given by $A \equiv A_s \times A_b$. Each element of set A, a, describes the actions undertaken by the two players in this game. On completion of game Γ, the action profile a is perfectly and publicly observable. Buyer and supplier profits are given by general profit functions $u_b, u_s\colon A \to \mathbb{R}$. We denote the Nash equilibrium of game Γ as $a^N \in A$, associated with actions corresponding to *opportunistic behavior*, and we assume that it is unique and the payoff associated with it is *inefficient*. In particular, there exists a more efficient outcome $a^C \in A$, associated with *cooperative behavior*, that makes each player better off than the Nash equilibrium outcome: $u_s(a^C) > u_s(a^N)$ and $u_b(a^C) > u_b(a^N)$.

This setup allows any number of sequential or simultaneous buyer or supplier actions, and the profits can be any arbitrary function of these actions. We consider situations where self-interested behavior and the consequent Nash equilibrium outcome are inefficient. The classic prisoner's dilemma type game is a simple example of this game. In the sourcing context, game Γ captures situations where incomplete contracts and incentive misalignment lead to a departure from first-best behavior. This departure could arise on account of poor performance on unobservable quality dimensions and the accompanying low prices (Tunca and Zenios 2006), insufficient investments in unverifiable capacity (Taylor and Plambeck 2007b), inefficiencies arising from limited information sharing (Ren et al. 2010), etc. Additionally, our setup also captures some key decentralization issues from the service outsourcing literature related to service quality, capacity building, utilization, etc. (Ren and Zhang 2009, Roels et al. 2010).

3.1.4. Alternate Supply Chain Structures. We model and compare two alternate sourcing structures:

1. *Direct Sourcing*: Each buyer sources directly from the suppliers. The buyers allocate business between suppliers, and each buyer acts independently in the transaction step.
2. *Mediated Sourcing*: Both buyers source through a third party, the *intermediary*. The intermediary allocates business and acts for both buyers in the transaction step.

Finally, note that in our setup there are no fixed investments, fixed order costs, or other scale advantages, nor are there any information asymmetries or any benefits from information aggregation. Thus, the previously documented transactional and informational advantages of mediation do not exist in our setup. Based on existing theory, mediated sourcing should offer no advantage over direct sourcing. In fact, in the presence of incentive misalignment, one would a priori expect vertical integration and reduction of the number of tiers to be superior because of limited incentive misalignment. In the next sections, we describe the game in each of the two setups and compare the equilibrium outcomes in §4. A formal, technical description of the games and the equilibria is provided in Appendices B–D.

3.2. Direct Sourcing

In direct sourcing, the buyers act independently, and their choices can be analyzed in two identical but distinct games. We analyze buyer i's game next.

3.2.1. The Stage Game at Time t. Figure 2 illustrates the stage game played between buyer i and suppliers 1 and 2. First, the random cost advantage of supplier 1 in supplying buyer i, $X_i^t \sim F_i^t(x)$, is drawn. Next, buyer i sources a fraction $\theta_i^t\colon \{X_i^t\} \to [0,1]$ from supplier 1 and $1-\theta_i^t(X_i^t)$ from supplier 2. Finally, buyer i and each of the suppliers play the transaction step subgame Γ. We denote the game involving buyer i and supplier j as Γ^{ij}, and the actions in this game are denoted as $a_{ij}^t \in A$. The stage game payoffs are

$$u_{b_i}^t = \theta_i^t(X_i^t)\cdot(u_b(a_{i1}^t)+X_i^t) + (1-\theta_i^t(X_i^t))\cdot u_b(a_{i2}^t),$$
$$u_{s_1}^t = \theta_i^t(X_i^t)\cdot u_s(a_{i1}^t), \quad u_{s_2}^t = (1-\theta_i^t(X_i^t))\cdot u_s(a_{i2}^t).$$

The action profile $\alpha_{d_i}^*$, which prescribes setting $\theta_i^t(X_i^t)$ as $\tilde{\theta}_i^t \equiv I\ (X_i^t \geq 0)$ followed by actions $a_{i1}^t = a_{i2}^t = a^N$, is a subgame-perfect equilibrium of the direct sourcing stage game, where $I(\cdot)$, the indicator function, is 1 when the condition is satisfied (Appendix C, Lemma 3).

3.2.2. The Repeated Game. In the repeated game, the stage game is played in each period $t \in \{0,1,2,\ldots\}$.

3.2.3. Potential Equilibrium Strategies. In each of the two transaction step games, the players may play the cooperative or the Nash actions. Specifically, three kinds of behavior may arise in equilibrium: (1) the buyer and *both suppliers* always play the *Nash actions*; (2) the buyer and *one supplier* (supplier 1 or supplier 2) play the *cooperative actions* in the transaction games that involve them, and the buyer and the other supplier play Nash actions in the transaction step game; or (3) the buyer and *both suppliers* always play the *cooperative action*. We call these *the direct transactional* (d_iT), *the direct single relationship* (d_is_1 or d_is_2), and *the direct dual relationship* (d_id) *sourcing strategies*, respectively. Note that in all three of these strategies, at any time, the buyer can choose to source from *both* the suppliers or just *one* of them. The difference lies in the choice of suppliers with which the buyer decides to play the cooperative outcome, or the supplier(s) with whom the buyer enters into a so-called long-term relationship (Taylor and Plambeck 2007b).

Formally, $\forall\, k \in \{T, s_1, s_2, d\}$, strategy $\sigma^{d_ik}(\boldsymbol{\theta}_i)$, where $\boldsymbol{\theta}_i$ is the sequence of the allocation functions, $\boldsymbol{\theta}_i \equiv \{\theta_i^t(X_i^t), t \geq 0\}$, prescribes the following play: if in all past play, the outcomes of the selection

Figure 2 **Direct Sourcing Stage Game for Buyer i**

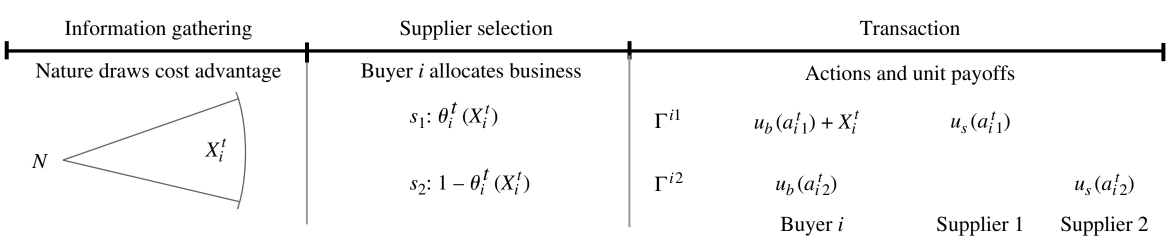


Table 1 Equilibrium Outcomes of the Direct Sourcing Game (Lemma 1)

Strategy	Buyer i	Supplier 1	Supplier 2
$\sigma^{d_i s_1}(\boldsymbol{\theta}_i)$	$\frac{1-\delta}{\delta}\max\{\bar{\theta}_i^t G_b, (\tilde{\theta}_i^{\,t}-\theta_i^t(X_i^t))X_i^t-\eta_b\theta_i^t(X_i^t)\}$	$\frac{1-\delta}{\delta}G_s\bar{\theta}_i^t$	
$\sigma^{d_i s_2}(\boldsymbol{\theta}_i)$	$\frac{1-\delta}{\delta}\max\{(1-\underline{\theta}_i^t)G_b, (\tilde{\theta}_i^{\,t}-\theta_i^t(X_i^t))X_i^t-\eta_b(1-\theta_i^t(X_i^t))\}$		$\frac{1-\delta}{\delta}G_s(1-\underline{\theta}_i^t)$
$\sigma^{d_i d}(\boldsymbol{\theta}_i)$	$\frac{1-\delta}{\delta}\max\{G_b, (\tilde{\theta}_i^{\,t}-\theta_i^t(X_i^t))X_i^t-\eta_b\}$	$\frac{1-\delta}{\delta}G_s\bar{\theta}_i^t$	$\frac{1-\delta}{\delta}G_s(1-\underline{\theta}_i^t)$

Notes. $\bar{\theta}_i^t \equiv \max_{X_i^t}\theta_i^t(X_i^t)$ and $\underline{\theta}_i^t \equiv \min_{X_j^t}\theta_i^t(X_i^t)$ are the maximum and minimum amount of business allocated to supplier 1 in any state; G_s and G_b denote the gain from the most profitable deviations of the supplier and buyer in the subgame Γ. This is the difference between the profit of the best-response action to the cooperative actions of the other player in game Γ and the profit of the cooperative action. $\eta_b \equiv u_b(a^C)-u_b(a^N)$, $\eta_s \equiv u_s(a^C)-u_s(a^N)$ are the buyer's and supplier's gain from cooperation, respectively.

and transaction step actions prescribed below were observed, continue to play the corresponding selection and transaction step actions; otherwise, play action $\alpha_{d_i}^*$ (the stage game equilibrium) forever.[3]

Selection Step Actions: At time t, the amount sourced from supplier 1 (the sourcing fraction) is given by the tth element of the sequence $\boldsymbol{\theta}_i$, $\theta_i^t(X_i^t)$.

Transaction Step Actions: The prescribed actions are (a^N, a^N) for strategy d_iT, (a^C, a^N) for strategy d_is_1, (a^N, a^C) for strategy d_is_2, and (a^C, a^C) for strategy d_id, where the first element denotes the actions in the transaction game with supplier 1 and the second with supplier 2.

The present value of the expected normalized profit of player n, $n\in\{s_1, s_2, b_i\}$, under strategy σ is given by

$$U_n(\sigma)=(1-\delta)\sum_{t=0}^{\infty}\delta^t E\big[u_n^t(X_i^t, \theta_i^t(\sigma), a_{i1}^t(\sigma), a_{i2}^t(\sigma))\big]. \quad (1)$$

Further, define operator $\mathcal{E}^t(\mathbf{u}_n)\equiv(1-\delta)\sum_{\tau=t}^{\infty}\delta^{\tau-t}E[u_n^\tau]$, where $\mathbf{u}_n\equiv\{u_n^t, t\ge 0\}$ and the expectation is taken over each X_1^t and X_2^t using F^t. Given a payoff stream, $\mathbf{u}_n$, the operator, $\mathcal{E}^t(\mathbf{u}_n)$, denotes the normalized expected present value of this payoff stream starting from period t. Applying Equation (1) to the four potential equilibrium strategies described above gives us the expected normalized discounted profits earned by following each of the strategies.

The buyers' profits from any strategy depend on the degree of relational sourcing and the allocation of business among suppliers. In particular, all else being equal, the strategies with more relationships (dual $\succ$ single $\succ$ transactional) and strategies in which $\boldsymbol{\theta}_i$ is chosen "responsively"—i.e., after observing each X_i^t, element $\theta_i^t(X_i^t)$ is chosen to maximize the current period payoff—provide the highest profit. For dual relationships, this responsive $\boldsymbol{\theta}_i$ is $\tilde{\boldsymbol{\theta}}_i\equiv\{\tilde{\theta}_i^{\,t}, t\ge 0\}$, which dictates always sourcing everything from the lower-cost supplier. However, the ability to sustain the above strategy profiles as subgame-perfect equilibria of the repeated game depends on the incentives for the buyers and the suppliers to deviate from the strategy. The next lemma provides restrictions on $\boldsymbol{\theta}_i$ that ensure that the strategy is an equilibrium.

[3] These and all the other strategies proposed in this paper are Nash reversion trigger strategies; that is, on observation of a deviation from the equilibrium path, the Nash outcome is played in all future periods.

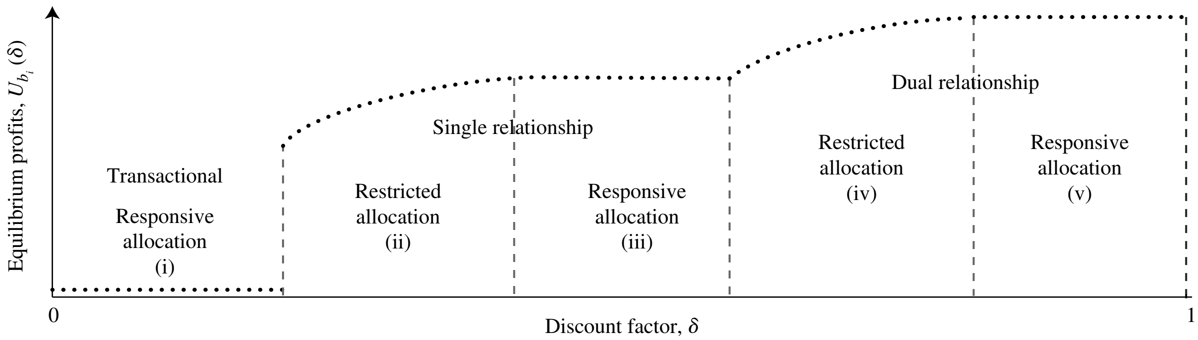
Lemma 1 (Equilibrium Outcomes of the Direct Sourcing Game)

(1) *The strategy profile $\sigma^{d_iT}(\tilde{\boldsymbol{\theta}}_i)$ is the only transactional subgame-perfect equilibrium of the repeated direct sourcing game.*

(2) *The strategy profile $\sigma^{d_ik}(\boldsymbol{\theta}_i)$ is a subgame-perfect equilibrium of the repeated direct sourcing game if and only if, for all $t\ge 0$ and all X_i^t, the difference between each player n's, $n\in\{s_1, s_2, b_i\}$, expected normalized continuation profit from this strategy, $U_n(\sigma^{d_ik}(\boldsymbol{\theta}_i))$, exceeds profit from the above transactional equilibrium, $U_n(\sigma^{d_iT}(\tilde{\boldsymbol{\theta}}_i))$, by at least the values provided in Table 1.*

Proof. The formal proof is provided in Appendix C, and the intuition follows. In direct transactional sourcing, player actions do not influence subsequent stages of the game. Thus, the stage game equilibrium, played in every period, is the subgame-perfect equilibrium of the repeated direct sourcing game. Sustaining the latter three relational strategy profiles as equilibrium outcomes requires that the immediate gains from the most profitable deviation be smaller than the loss in the continuation benefits. The loss in continuation benefits is given by the difference in the profits earned by following the relational strategy and the profits from the transactional sourcing strategy (recall that on observation of any deviation, all players resort to following the transactional strategy). The expressions in part 2 of the lemma capture the immediate gains from the most profitable deviation. The most profitable deviation arises when the maximum amount of business is transacted with cooperative behavior ($\bar{\theta}_i^t$ for supplier 1 and $1-\underline{\theta}_i^t$ for supplier 2). Further, for the buyer there is a deviation possible both in the selection step and in the transaction step. The more profitable deviation of these two defines the immediate gain of deviation for the buyer. $\square$

Figure 3 **Buyer *i*'s Achievable Payoff Region**



Note. The dotted line indicates the maximum profits achievable in equilibrium.

Recall that the buyer's profits are highest in the dual relationship strategy with responsive allocation, $\boldsymbol{\theta}_i = \tilde{\boldsymbol{\theta}}_i$. However, to sustain any relationship and allocation in equilibrium, the buyer must restrict the allocation as per the conditions in Lemma 1, departing from the responsive allocation. This tension between responsive allocation and the provision of the incentives to sustain relationships (cooperative outcomes) is a key characteristic of sourcing that our model is designed to capture.

This tension is captured in Figure 3. For any given discount factor, the figure illustrates the *highest equilibrium profits* that can be achieved.[4] Formally, as is typical in repeated game analysis and in statements of Folk Theorems (Mailath and Samuelson 2006), this figure illustrates the *achievable payoff region* of the buyer as a function of the discount factor. For any δ, this is

$$\max_{k\in\{T,s_1,s_2,d\}} \max_{\boldsymbol{\theta}_i} U_{b_i}(\sigma^{d_i k}(\boldsymbol{\theta}_i))$$
$$\text{s.t. strategy } \sigma^{d_i k}(\boldsymbol{\theta}_i) \text{ is an equilibrium},$$

where the optimization is over all equilibrium strategies. The first maximum refers to the kind of strategy and the second to the allocation function sequence in that strategy. Two characteristics of the equilibrium conditions in Lemma 1 help us understand this achievable payoff region. First, the equilibrium conditions for dual relationship strategies are more restrictive than the conditions for single relationship strategies (in dual relationship, sufficient incentives need to be provided to both suppliers, whereas in single relationship only to one). Second, for both dual and single relationships, the trade-off between responsive allocation and the provision of sufficient business to maintain relationship(s) is more restrictive, as the discount factor is smaller and the suppliers value future business less, thus requiring larger and larger departures from the responsive allocation to sustain relationships.

For the highest values of δ, region (v) in Figure 3, future business is valued highly by suppliers and the buyer can potentially maintain relationships with both suppliers while also allocating business responsively. Put differently, in this region, δ is high enough that the equilibrium conditions for even dual relationships are not binding. However, as δ gets smaller, the conditions become binding, and the buyer must now sacrifice the responsive allocation to maintain the two relationships; this decreases his profits (region (iv)). Next, at some point, the equilibrium conditions become so tight that no allocation can satisfy the dual relationship equilibria conditions, but single relationship equilibria may be sustained, first with responsive allocation and then potentially with a nonresponsive or restricted allocation (regions (iii) and (ii)).[5] Eventually, only transactional sourcing can be sustained as an equilibria (region (i)). In subsequent sections, we will illustrate how the trade-offs shown in Figure 3 change with mediated sourcing.

3.3. Mediated Sourcing

With mediated sourcing, both buyers delegate their supplier selection and their transaction step actions to a third party, the *intermediary*. The intermediary chooses the supplier for each buyer and acts on behalf of buyers in the transaction step. In lieu of the sourcing services provided by the intermediary, the buyers pay the intermediary an agreed upon commission. Specifically, the intermediary gets a fraction, β, of the total buyer-side profits. This fraction β could arise as a function of a bargaining process prior to signing up

[4] As is typical in repeated games, we express our equilibrium conditions in terms of the discount factor. However, these conditions can equally be interpreted as conditions on all exogenous parameters: the distribution, $F^t(x)$, the general profit functions, u_b and u_s, the gains from deviation G_b and G_s, and the benefits from cooperation η_b, η_s.

[5] Note here that in Figure 3, we show the single relationship equilibria with one supplier. With heterogeneous suppliers it is possible that we may have two single relationship regimes, one for each of the suppliers.

for the intermediary's services or by any other mechanism that divides the total profits generated.

In this setup, buyers do not have any profit-relevant actions after they have signed up for the intermediary's services. Thus, they are no longer relevant players in the mediated sourcing game. In essence, the mediated sourcing game follows exactly the same lines as the two direct sourcing games, except that the actions of the two individual buyers are now taken by one intermediary. In all other respects, the two described structures are identical.

3.3.1. The Stage Game at Time *t*. First, in the information gathering step, the differences in sourcing from different suppliers are revealed; i.e., X_1^t and X_2^t are drawn from joint distribution $F^t(X_1^t, X_2^t)$. Next, the intermediary allocates a fraction ν_i^t: $\{X_1^t, X_2^t\} \to [0,1]$ of buyer i's sourcing business to supplier 1, $i \in \{1,2\}$. Note that the allocations $\nu_i^t(X_1^t, X_2^t)$ correspond to the allocations $\theta_i^t(X_i^t)$ from direct sourcing, but now the allocations are a function of the relative cost advantage of supplier 1 in supplying both buyer 1 and 2, X_1^t and X_2^t. Put differently, the intermediary takes into account both buyers' preferences for a supplier in the sourcing decision, defined by $F^t(X_1^t, X_2^t)$. This is in contrast to direct sourcing, where buyer i takes into account only his own preferences, defined by the partial density $F_i^t(X_i^t)$. We denote the allocations of buyer 1 and buyer 2's business to supplier 1, (ν_1^t, ν_2^t) as ν^t, and the total business to supplier 1, $\nu_1^t + \nu_2^t$, is denoted by $\langle \nu^t \rangle$.[6] Finally, actual sourcing takes place in the transaction step, and the intermediary and the suppliers play transaction games Γ. The games are identical to the ones that buyers play in direct sourcing, except that buyers are replaced by the intermediary. We denote the game between the intermediary and supplier j as Γ^{Ij} and the actions in this game as a_{Ij}^t. Finally, the suppliers, the buyers, and the intermediary earn their profits. The profits are given as

$$u_I^t = \beta \sum_{i=1}^{2} \big[\nu_i^t(X_1^t, X_2^t) \cdot (u_b(a_{I1}^t) + X_i^t) + (1 - \nu_i^t(X_1^t, X_2^t)) \cdot u_b(a_{I2}^t)\big],$$
$$u_{s_1}^t = \langle \nu^t(X_1^t, X_2^t) \rangle \cdot u_s(a_{I1}^t),$$
$$u_{s_2}^t = (2 - \langle \nu^t(X_1^t, X_2^t) \rangle) \cdot u_s(a_{I2}^t).$$

The action profile α_m^*, that prescribes $\nu^t = \tilde{\nu}^t \equiv (\tilde{\theta}_1^t, \tilde{\theta}_2^t)$ followed by actions $a_{I1}^t = a_{I2}^t = a^N$ is a subgame-perfect equilibrium of the mediated sourcing stage game (Appendix D, Lemma 4).

3.3.2. The Repeated Game. In the repeated game, the stage game is played in each period $t \in \{0, 1, 2, \ldots\}$.

[6] $\nu_1^t, \nu_2^t, \langle \nu^t \rangle$, and ν^t are all functions of X_1^t and X_2^t, but we often suppress the arguments in subsequent discussion.

3.3.3. Potential Equilibrium Strategies. Supplier selection is now a function of the realization of both the relative cost advantages, X_1^t and X_2^t. With respect to transaction step actions, the choices follow along the same lines as those in direct sourcing. Specifically, the intermediary and the chosen supplier(s) may play Nash actions in all games, or the intermediary and one supplier may play cooperative actions in transaction games that involve them and Nash actions in the transaction games that involve the other supplier, or the intermediary and each supplier may always play the cooperative action. We call these *the mediated transactional* (mT), *single relationship* (ms_1 or ms_2), and *dual relationship* (md) sourcing strategies, respectively.

Formally, $\forall k \in \{T, s_1, s_2, d\}$, strategy $\boldsymbol{\sigma}^{mk}(\boldsymbol{\nu})$, $\boldsymbol{\nu} \equiv \{\nu^t(X_1^t, X_2^t), t \geq 0\}$ prescribes the following play: if in all past play only outcomes of selection and transaction step actions prescribed below were observed, continue to play the corresponding selection and transaction step actions, or else play action α_m^* (the stage game equilibrium) in all subsequent stage games.

Selection Step Actions: At time t, the amount sourced from supplier 1 for buyers 1 and 2 is given by the tth component of sequence $\boldsymbol{\nu}$, $\nu^t(X_1^t, X_2^t)$.

Transaction Step Actions: The prescribed actions are (a^N, a^N) for strategy mT; (a^C, a^N) for strategy ms_1; (a^N, a^C) for strategy ms_2; and (a^C, a^C) for strategy md. The first action denotes the actions in the game with supplier 1 and the second with supplier 2.

The present value of the expected normalized profit of player n, $n \in \{s_1, s_2, I\}$, under strategy σ is given by

$$U_n(\sigma) = (1-\delta) \sum_{t=0}^{\infty} \delta^t E[u_n^t(\sigma)]. \tag{2}$$

As before, the profits are highest with dual relationship strategies, when $\boldsymbol{\nu}$ is chosen responsively, $\boldsymbol{\nu} = \tilde{\boldsymbol{\nu}} \equiv \{\tilde{\nu}^t(X_1^t, X_2^t), t \geq 0\}$. Next we provide the necessary and sufficient conditions to sustain a strategy profile $\boldsymbol{\sigma}^{mk}(\boldsymbol{\nu})$ as an equilibrium.

Lemma 2 (Equilibrium Outcomes of the Mediated Sourcing Game)

(1) *The strategy profile $\boldsymbol{\sigma}^{mT}(\tilde{\boldsymbol{\nu}})$ is the only transactional subgame-perfect equilibrium of the mediated sourcing game.*

(2) *The strategy profile $\boldsymbol{\sigma}^{mk}(\boldsymbol{\nu})$ is a subgame-perfect equilibrium of the repeated mediated sourcing game if and only if, for all $t \geq 0$ and for all X_1^t and X_2^t, the difference between each player n's, $n \in \{s_1, s_2, I\}$, expected normalized continuation profit from this strategy, $U_n(\boldsymbol{\sigma}^{mk}(\boldsymbol{\nu}))$, exceeds profit from the above transactional equilibrium, $U_n(\boldsymbol{\sigma}^{mT}(\tilde{\boldsymbol{\nu}}))$, by at least the values provided in Table 2.*

Proof. A formal proof is provided in Appendix D. Note here that the equilibria that can be sustained in mediated sourcing (and all future results) do not depend on the specific split of profits, β. $\square$

Table 2 Equilibrium Outcomes of the Mediated Sourcing Game (Lemma 2)

Strategy	Intermediary	Supplier 1	Supplier 2
$\sigma^{ms_1}(\boldsymbol{\nu})$	$\frac{1-\delta}{\delta}\beta\max\left\{\langle\bar{\nu}^t\rangle G_b, \sum_{i=1}^{2}((\tilde{\theta}_i^{\,t}-\nu_i^t)X_i^t-\eta_b\nu_i^t)\right\}$	$\frac{1-\delta}{\delta}G_s\langle\bar{\nu}^t\rangle$	
$\sigma^{ms_2}(\boldsymbol{\nu})$	$\frac{1-\delta}{\delta}\beta\max\left\{(2-\langle\underline{\nu}^t\rangle)G_b, \sum_{i=1}^{2}((\tilde{\theta}_i^{\,t}-\nu_i^t)X_i^t-\eta_b(1-\nu_i^t))\right\}$		$\frac{1-\delta}{\delta}G_s(2-\langle\bar{\nu}^t\rangle)$
$\sigma^{md}(\boldsymbol{\nu})$	$\frac{1-\delta}{\delta}\beta, \max\left\{2G_b\sum_{i=1}^{2}((\tilde{\theta}_i^{\,t}-\nu_i^t)X_i^t-\eta_b)\right\}$	$\frac{1-\delta}{\delta}G_s\langle\bar{\nu}^t\rangle$	$\frac{1-\delta}{\delta}G_s(2-\langle\bar{\nu}^t\rangle)$

Notes. $\langle\bar{\nu}^t\rangle \equiv \max_{X_1^t, X_2^t}\langle\nu^t\rangle$ and $\langle\underline{\nu}^t\rangle \equiv \min_{X_1^t, X_2^t}\langle\nu^t\rangle$ are the maximum and minimum amounts of business allocated to supplier 1 in any state. G_s (G_b) denotes the gain from the most profitable deviation (defined as before).

Like the direct buyers, the intermediary acting on behalf of the two buyers in mediated sourcing faces a trade-off. Profits are increased by establishing relationships *and* by responsive allocation, but the intermediary may need to restrict his business allocation to sustain relationship(s) in equilibrium (Lemma 2). Further, as before, dual relationships are harder to sustain than single relationships, and all relationships are harder with lower values of the discount factor. Thus, the achievable payoff has a shape similar to the one illustrated for direct sourcing in Figure 3. However, there is one difference between this trade-off for mediated sourcing and direct sourcing. Rather than an individual buyer sourcing for himself, the intermediary is now sourcing on behalf of both buyers. This implies that the intermediary's allocation of business to the two suppliers is based on business accruing from the two buyers and his total costs are a function of both X_1^t and X_2^t, i.e., the relative cost difference between suppliers in supplying both buyers 1 and 2. In the next section, we will see how this drives the advantages and disadvantages of mediated sourcing.

4. The "Benefits" of Intermediation

Consider the total buyer-side surplus or the *sourcing profits*, π: in the case of direct sourcing, this is the sum of the two buyers' profits. In the case of mediated sourcing, it is the sum of the buyers' and the intermediary's profits. If the buyer-side surplus is higher for the mediated sourcing strategy, then there exists a surplus division factor β such that both buyers and the intermediary are better off under mediated sourcing. Thus, to compare direct and mediated sourcing, it is sufficient to compare the respective achievable sourcing profits. For each set of parameter values, the supply chain structure (direct or mediated sourcing) that achieves the higher sourcing profits is the preferred supply chain structure. Note that using sourcing profits for comparing strategies also brings scale parity between direct and mediated sourcing—in both cases, we are comparing the profits from sourcing two units from the suppliers.

Recall that the achievable sourcing profit regions were obtained by choosing the highest profit strategy that is also an equilibrium for a given set of parameter values. For both direct and mediated sourcing, the strategy space can be characterized by the type of relationship(s) (transactional, single, or dual relationship ($k \in \{T, s_1, s_2, d\}$)) and the allocation of business between suppliers (choice of $\boldsymbol{\theta}_i/\boldsymbol{\nu}$). Thus, to find the highest profit strategy that is an equilibrium, we need to consider the choice of relationship type and the choice of business allocation. To build our intuition, we first consider the highest equilibrium sourcing profit for a given type of relationship.

Definition. For all δ, i, and k, define $\pi^{d_i k}(\delta) = \max_{\boldsymbol{\theta}_i}\pi(\sigma^{d_i k}(\boldsymbol{\theta}_i))$, such that strategy $\sigma^{d_i k}(\boldsymbol{\theta}_i)$ is an equilibrium of the direct sourcing game for this δ. Similarly, define $\pi^{mk}(\delta) = \max_{\boldsymbol{\nu}}\pi(\sigma^{mk}(\boldsymbol{\nu}))$ such that strategy $\sigma^{mk}(\boldsymbol{\nu})$ is the equilibrium of the mediated sourcing game for this δ. For any given type of relationship k, $\pi^{d_i k}(\delta)$ and $\pi^{mk}(\delta)$ are the highest sourcing profits that are achievable as equilibria, considering all different possible allocations of business.

4.1. Ability to Sustain Relationships

The next theorem compares the ability of direct and mediated sourcing in sustaining a given type of relationship.

Theorem 1. *For each δ, and for each type of relationship, $k \in \{s_1, s_2, d\}$, sourcing through an intermediary earns higher sourcing profits than* both *buyers sourcing directly with the same relationship*:

$$\forall\,\delta, k \quad \pi^{mk}(\delta) \geq \pi^{d_1 k}(\delta) + \pi^{d_2 k}(\delta),$$

with strict inequality for some δ.[7]

Proof. A formal proof is provided in Appendix E. □

[7] The inequality is strict for $\delta < \bar{\delta}^k$; $\bar{\delta}^k$ is the smallest δ such that strategy k with responsive allocation is an equilibrium.

Table 3 **Constraints for Supplier 1**

Direct, $\mathcal{D}(\boldsymbol{\theta}_1, \boldsymbol{\theta}_2)$	Mediated, $\mathcal{M}(\boldsymbol{\nu}_1, \boldsymbol{\nu}_2)$
(D.1) $\mathcal{E}^{t+1}(\boldsymbol{\theta}_1) - d\bar{\theta}_1^t \geq \gamma_1^t$	(M) $\mathcal{E}^{t+1}(\boldsymbol{\nu}_1 + \boldsymbol{\nu}_2) - d(\nu_1^t + \nu_2^t) \geq \gamma_1^t + \gamma_2^t$
(D.2) $\mathcal{E}^{t+1}(\boldsymbol{\theta}_1) - d\bar{\theta}_2^t \geq \gamma_2^t$	

Note. $\gamma_i^t \equiv \mathcal{E}^{t+1}(\mathbf{1} - \mathbf{F}_i(0))(u_s(a^N)/u_s(a^C))$, $d \equiv ((1-\delta)/\delta)(G_s/u_s(a^C))$, $\mathbf{1} - \mathbf{F}_i(x) \equiv \{1 - F_i^t(x), t \geq 0\}$.

Sketch of the Proof. For any given type of relationship k, we can write the best sourcing profit for direct sourcing as

$$\pi^{d_1 k}(\delta) + \pi^{d_2 k}(\delta) = \max_{\boldsymbol{\theta}_1, \boldsymbol{\theta}_2} \mathcal{E}^0(\boldsymbol{\Pi}^k(\boldsymbol{\theta}_1, \boldsymbol{\theta}_2))$$
$$\text{s.t.} \quad \boldsymbol{\theta}_1, \boldsymbol{\theta}_2 \in \mathcal{D}^k(\boldsymbol{\theta}_1, \boldsymbol{\theta}_2),$$

where the set $\mathcal{D}^k$ denotes the feasible set defined by the equilibrium conditions for direct sourcing strategy k and, as before, the optimization is over a sequence of functions $\boldsymbol{\theta}_i \equiv \{\theta_i^t(X_i^t), t \geq 0\}$.[8] Interestingly, the mediated sourcing profit, π^{mk}, can be written with exactly the same objective function, but with a different feasible set, $\mathcal{M}^k$:

$$\pi^{mk}(\delta) = \max_{\boldsymbol{\nu}_1, \boldsymbol{\nu}_2} \mathcal{E}^0(\boldsymbol{\Pi}^k(\boldsymbol{\nu}_1, \boldsymbol{\nu}_2))$$
$$\text{s.t.} \quad \boldsymbol{\nu}_1, \boldsymbol{\nu}_2 \in \mathcal{M}^k(\boldsymbol{\nu}_1, \boldsymbol{\nu}_2).$$

This suggests that the difference between mediated and direct sourcing can be understood by examining the set of equilibrium conditions, $\mathcal{D}^k(\boldsymbol{\theta}_1, \boldsymbol{\theta}_2)$ and $\mathcal{M}^k(\boldsymbol{\nu}_1, \boldsymbol{\nu}_2)$. It is most instructive to compare the conditions that come from the incentives for suppliers; for example, consider supplier 1's incentives[9] (Table 3).

Sourcing directly, buyers 1 and 2 must *each individually* ensure that their stream of orders, $\boldsymbol{\theta}_1$ or $\boldsymbol{\theta}_2$, is such that the supplier has an incentive to continue the relationship. Conditions (D.1) and (D.2) reflect this. In mediated sourcing, in contrast, the intermediary must only ensure that the combined stream of orders on behalf of buyers 1 and 2, $\boldsymbol{\nu}_1 + \boldsymbol{\nu}_2$, is such that the supplier has an incentive to continue the relationship. Condition (M) reflects this. Essentially, the condition for maintaining a mediated relationship is the sum of the conditions for maintaining equivalent direct relationships. Thus, the equilibrium conditions for direct relationships are a subset of the conditions for mediated relationships, and mediated sourcing always (weakly) outperforms direct sourcing for a given relationship. Also, note by looking at the right-hand side of the above equations that the combined stream of orders, although potentially larger than any single buyer's order stream, must also cross a higher threshold. Put differently, the intermediary does indeed have more scale than any individual buyer, but this scale cuts both ways, providing more incentives to stay in the relationship, but also proportionally more gains from cheating or deviating from the relationship. Thus, the advantage of mediated sourcing that drives the above result is *not* simply arising from the greater scale of an intermediary.

To better understand the above effect, consider the following three cases:

Case I. The discount factor is high enough that neither of the constraints, (D.1) or (D.2), is binding. Direct buyers can choose the responsive allocation stream and achieve the highest profits. In such a setup, we also show that constraint (M) will not be binding, and mediated sourcing will earn the same profits. Thus, direct and mediated sourcing perform equally well.

Case II. Next, consider the case where the discount factor is a bit lower, and one of the two constraints, (D.1) or (D.2), becomes binding while the other has some slack. This happens when the buyers are heterogeneous in their *long-run preferences* over suppliers, i.e., $\gamma_1^t \neq \gamma_2^t$ or equivalently $\mathcal{E}^{t+1}(\tilde{\boldsymbol{\theta}}_1) \neq \mathcal{E}^{t+1}(\tilde{\boldsymbol{\theta}}_2)$. That is, the discounted probability that buyer 1 prefers supplier 1 is not equal to the discounted probability that buyer 2 prefers supplier 1. For example, when buyer 1 in the long run prefers supplier 1 more than buyer 2, $\exists\, \delta$, where constraint (D.1) is not binding and constraint (D.2) is binding. Now although one order stream, $\boldsymbol{\theta}_2$, is constrained in a specific fashion, the other, $\boldsymbol{\theta}_1$, is not constrained and can be set to the responsive order stream—the unconstrained optimal. In the case of mediated sourcing, the only constraint, (M), is the sum of constraints (D.1) and (D.2); as a result, it is not binding and the order streams on behalf of buyer 1 and the order stream on behalf of buyer 2 *both* can be set to their responsive or unconstrained maximization values. Essentially, if one buyer prefers a supplier more than the other buyer in the long run, mediated sourcing makes it possible to use this buyer's bias to compensate for the other buyer's weaker interest. In direct sourcing, the buyer that prefers the particular supplier would find it in its interest to provide more business than is strictly necessary, whereas the other buyer would be forced to provide more business than it wants to just to sustain the relationship. Pooling the order streams eliminates this inefficient situation, and the level of business accruing to the supplier on behalf of both buyers can be adjusted to *the minimum level sufficient for sustaining the relationship*, achieving a responsive allocation. In this fashion, an intermediary can *exploit*

[8] $\boldsymbol{\Pi}^k(\mathbf{x}, \mathbf{y}) = \{\Pi^{k,t}(x^t, y^t), t \geq 0\}$, $\Pi^{k,t}(x^t, y^t) \equiv (x^t + y^t)u_b(a_1^{tk}) + x^t X_1^t + y^t X_2^t + (2 - (x^t + y^t))u_b(a_2^{tk})$, a_j^{tk} denotes $a_{1j}^t(\sigma^k)$ or $a_{2j}^t(\sigma^k)$ or $a_{Ij}^t(\sigma^k)$, depending on the context.

[9] Supplier 2's incentives, if applicable (i.e., if $k = d$ or s_2), follow along the same lines.

the differences between buyers in their long-run preferences over suppliers to outperform direct sourcing.

Case III. Finally, consider a case where the discount factor is such that both constraints, (D.1) and (D.2), are binding. This arises for low enough δ or when the buyers are symmetric. Now, constraint (M) will also be binding, but the order streams in mediated sourcing will still earn higher profits by being more responsive. Say in direct sourcing, the constrained optimal order streams are $\boldsymbol{\theta}_1^*$ and $\boldsymbol{\theta}_2^*$. Now construct order streams $\boldsymbol{\nu}_1$ and $\boldsymbol{\nu}_2$ as follows: when $X_i^t \geq X_{\bar{i}}^t$,[10] set $\nu_i^t(X_1^t, X_2^t) = \min\{1, \theta_1^{*t}(X_1^t) + \theta_2^{*t}(X_2^t)\}$ and $\nu_{\bar{i}}^t(X_1^t, X_2^t) = \theta_1^{*t}(X_1^t) + \theta_2^{*t}(X_2^t) - \min\{1, \theta_1^{*t}(X_1^t) + \theta_2^{*t}(X_2^t)\}$. Hence, by construction, $\forall X_1^t, X_2^t$ $\nu_1^t + \nu_2^t = \theta_1^{*t} + \theta_2^{*t}$. This order stream is constructed such that from the supplier's point of view, the orders coming from the two separate buyers or from the intermediary are identical. However, the intermediary can better adapt the composition of the orders to the *current realization* of the relative cost advantages. In particular, the intermediary ensures that whatever quantity of orders must be sent to the supplier, its composition is such that to the maximum possible degree, it is composed of orders on behalf of the buyer who has a cost advantage of sourcing from this supplier in this sourcing period. Again, the intermediary uses one buyer's stronger preference for a supplier, $X_i^t \geq X_{\bar{i}}^t$, to compensate for the other buyer's weaker preference. However, this time the difference in preference arises out of the random draws of the relative cost advantage, $X_1^t \neq X_2^t$, or what we call *myopic* preferences. Thus, an intermediary can exploit the *myopic* bias of one buyer for a supplier to ensure that *the allocation of business* is such that the composition of the business allocated to the suppliers is the most advantageous. In contrast, direct buyers do not have the flexibility to change the composition of the orders going to a suppliers, so they often end up with a suboptimal composition of orders.

To summarize, mediated sourcing performs better than direct sourcing by adjusting the level of sourcing business allocated to a supplier when the buyers have heterogeneous long-run preferences over suppliers, or by responsively adjusting the composition of sourcing business allocated to a supplier when the buyers have different myopic preferences over suppliers. Essentially, with heterogeneous long-run preferences over suppliers, one buyer wants to allocate more business than necessary to ensure cooperative behavior, whereas the other may want to allocate less business than necessary. An intermediary that pools the order streams from both buyers can use one buyer's above-requirement allocation to compensate for the other buyer's below-requirement business. Similarly, with different myopic preferences, the supplier can be provided the same incentives for cooperative behavior as in direct sourcing, but the composition of that business can be adjusted responsively.

Corollary (Relationship Between Buyers' Preferences over Suppliers)

(1) Perfectly Correlated Preferences: *Suppose* $\forall t$, $X_1^t = \alpha X_2^t$.

(a) *If* $\alpha = 1$, $\forall \delta$, *k mediated sourcing has no advantage over direct sourcing*: $\pi^{mk}(\delta) = \pi^{d_1 k}(\delta) + \pi^{d_2 k}(\delta)$.

(b) *If* $\alpha \neq 1$, $\forall \delta$, *k mediated sourcing is better at maintaining a given relationship than the direct buyers*: $\pi^{mk}(\delta) \geq \pi^{d_1 k}(\delta) + \pi^{d_2 k}(\delta)$, *with strict inequality for some* δ.

(2) Identically Distributed Preferences: *If* $X_1^t, X_2^t \sim F^t(x)$, $\forall \delta, k$ *mediated sourcing is better at maintaining a given relationship than the direct buyers*: $\pi^{mk}(\delta) \geq \pi^{d_1 k}(\delta) + \pi^{d_2 k}(\delta)$, *with strict inequality for some* δ.

(3) Deterministic Preferences: *Suppose* $X_i^t = x_i$, *when* $t = 2\mathcal{T}$, *and* $X_i^t = -x_i$, *when* $t = 2\mathcal{T} + 1$, *where* $\mathcal{T} \in \{0, 1, 2, \ldots\}$,

(a) *If* $x_1 = x_2$, $\forall \delta, k$ *mediated sourcing has no advantage over direct sourcing*: $\pi^{mk}(\delta) = \pi^{d_1 k}(\delta) + \pi^{d_2 k}(\delta)$.

(b) *If* $x_1 \neq x_2$, $\forall \delta, k$ *mediated sourcing is better at maintaining a given relationship than the direct buyers*: $\pi^{mk}(\delta) \geq \pi^{d_1 k}(\delta) + \pi^{d_2 k}(\delta)$, *with strict inequality for some* δ.

If $\alpha = 1$, the realizations of each buyer's preferences regarding suppliers will always be identical and there are no benefits from changing the level or composition of orders to a supplier. However, even if the draws are perfectly correlated, with $\alpha \neq 1$, the two draws will be different and the intermediary can exploit the difference. Further, if buyer preferences are identically distributed, or if on average both buyers prefer the same supplier, there are no long-run differences between buyer preferences, $\forall t$, $\gamma_1^t = \gamma_2^t$, but in each period there is still a chance that the realizations of each buyer's preferences over suppliers will be different, $\Pr\{X_1^t \neq X_2^t\} > 0$, and the intermediary can exploit myopic differences, as described above. Finally, if there is no risk involved, i.e., the shocks are deterministic, but there is still a difference in the buyers' preferences about suppliers in every period $x_1 \neq x_2$, the intermediary can continue to exploit the resultant differences in myopic and long-run preferences, as described above. The corollary starkly demonstrates that the effects highlighted accrue from differences in buyer preferences regarding suppliers. These could arise from myopic differences in preferences of suppliers and/or from systematic or long-run heterogeneity in preferences of suppliers—but as long as there is a possibility that the *realized* preferences of buyers about suppliers are different at some point

[10] For $i \in \{1, 2\}$, $\bar{i} = 3 - i$ (the other buyer).

in time, mediated sourcing can better maintain relationships. This illustrates that our argument extends beyond the pooling of randomness in preferences to the pooling of *random*, *systematic*, and *temporal differences* in preferences.

4.2. The Preferred Supply Chain Structure

In the above section, we illustrated how intermediaries are better at maintaining any given relationship. However, the choice of the preferred supply chain structure depends on the achievable sourcing profits that take into account *both* the ability to maintain a given relationship and the choice of which relationship to maintain. In this section, we consider both of these effects and identify the preferred supply chain structures.

For any δ, the best achievable sourcing profit in direct sourcing, $\pi^d(\delta)$, is $\max_k \pi^{d_1 k}(\delta) + \max_k \pi^{d_2 k}(\delta)$; in mediated sourcing it is $\pi^m(\delta) = \max_k \pi^{mk}(\delta)$, where $k \in \{T, s_1, s_2, d\}$.

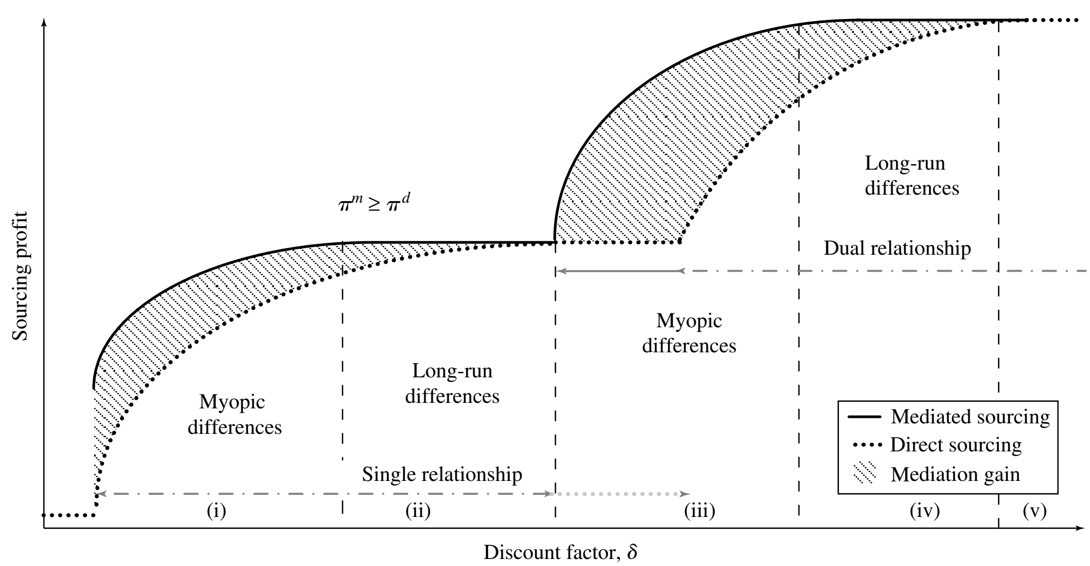
Theorem 2. *Mediated sourcing outperforms direct sourcing, i.e.,* $\forall\, \delta\ \pi^m(\delta) \geq \pi^d(\delta)$, *with strict inequality for some* δ, *if the same strategy* k *is the solution to both* $\max_k \pi^{d_1 k}(\delta)$ *and* $\max_k \pi^{d_2 k}(\delta)$. *This condition always holds when the buyers are ex ante symmetric in their preferences over suppliers i.e.,* $\forall\, t$, $F_1^t = F_2^t$.

Proof. The formal proof is provided in the appendix. □

Figure 4 illustrates the comparison between direct and mediated sourcing, as described in Theorem 2. For the highest values of the discount factor (region (v)) in both direct and mediated sourcing, the firms can achieve first-best profit, because the responsive allocation stream satisfies the dual relationship equilibrium conditions. For lower values (region (iv)), one of the buyers' responsive allocation streams is no longer sufficient for sustaining the dual relationship. In direct sourcing, this buyer must now shift to a less-responsive allocation stream, but the intermediary can use the slack in the other buyer's responsive allocation to satisfy the supplier (long-run differences). Although, for even lower discount factors (region (iii)), both buyer's responsive allocation streams may now be insufficient for the supplier(s), mediated sourcing can still exploit the changing preferences that lead to myopic differences to earn higher sourcing profits. For even lower values of the discount factor, the same effects repeat for single relationships (region (ii), (i)).

The above result highlights that if the same relationship structure is used by the two direct buyers, the intermediary will be able to better maintain that relationship. However, it is possible that the two direct buyers prefer to maintain relationships with different sets of cooperative suppliers. In such cases, the intermediary will have to choose one of the two sets of cooperative suppliers or relationship structures, whereas the direct buyers can *each* choose their preferred relationship structure. Thus, direct sourcing may perform better, as direct buyers have more *selectivity* in choosing their relationships; in particular, they are not obliged to each have the same set of relationships, as is the case when an intermediary acts on their behalf. For example, in direct sourcing with a single relationship, each buyer must choose supplier 1 or 2 as the cooperative supplier. This can be the same supplier for both buyers or a different supplier for each buyer. If this is the same supplier for both, Theorem 2 applies and mediated sourcing outperforms direct sourcing. If the preferred supplier is different for the two buyers, in direct sourcing both

Figure 4 Mediated Sourcing Outperforms Direct Sourcing



buyers can choose their desired partner. But the intermediary, being constrained to choosing one supplier for both buyers, might find itself in a disadvantaged position. Thus, independent decisions on the type of relationship (k) of the two buyers in direct sourcing effectively gives the buyers more *selectivity* in choosing the preferred supplier, whereas the intermediary, being limited to choosing *one* type of relationship for both buyers, has lower selectivity. The next theorem formalizes this.

Theorem 3. *If all of the following conditions hold for all $t \geq 0$, then there exists $\hat{\delta} \in (0, 1)$ such that buyer $i \in \{1, 2\}$ prefers a single relationship with supplier 1 and buyer $\bar{i}$ with supplier 2. Consequently, direct sourcing outperforms mediated sourcing, $\pi^d(\hat{\delta}) > \pi^m(\hat{\delta})$:*

(1) $F_i^t(-\eta_b) = 0$, $F_i^t(\eta_b) = 1$;

(2) $\mu_i^t > 0$, $\mu_{\bar{i}}^t < 0$;

(3) $\mathcal{E}^{t+1}(\boldsymbol{\eta}_b + \boldsymbol{\mu}_{i-})$, $\mathcal{E}^{t+1}(\boldsymbol{\eta}_b - \boldsymbol{\mu}_{i+}) > (\eta_s G_b)/G_s$,

where $E[X_i^t] = \mu_i^t$ and $E[X_i^t \mid X_i^t \geq 0] = \mu_{i+}^t$, $E[X_i^t \mid X_i^t < 0] = \mu_{i-}^t$; $\boldsymbol{\eta}_b = \{\eta_b, t \geq 0\}$, $\boldsymbol{\mu}_{i\cdot} = \{\mu_{i\cdot}^t, t \geq 0\}$.

Proof. A more general statement of the theorem and its proof are provided in Appendix E. □

The conditions in Theorem 3 ensure that the two direct buyers wish to enter into relationships with different suppliers. Condition (1) implies that at time t, the expected discounted profit of buyer i from cooperation with supplier 1 amounts to $\mathcal{E}^t(\boldsymbol{\eta}_b + \boldsymbol{\mu}_i)$ and with supplier 2 to $\mathcal{E}^t(\boldsymbol{\eta}_b)$. Condition (2) ensures that for all t, buyer i prefers to source from supplier 1, $\mathcal{E}^t(\boldsymbol{\eta}_b + \boldsymbol{\mu}_i) > \mathcal{E}^t(\boldsymbol{\eta}_b)$, and buyer $\bar{i}$ from supplier 2, $\mathcal{E}^t(\boldsymbol{\eta}_b) > \mathcal{E}^t(\boldsymbol{\eta}_b + \boldsymbol{\mu}_{\bar{i}})$. Further, condition (3) ensures that there exist $\hat{\delta}$ for which these sourcing strategies are the most profitable equilibrium strategies. It is guaranteed by ensuring that the gain of single relationship over transactional sourcing for buyers i and $\bar{i}$, $\mathcal{E}^t(\boldsymbol{\eta}_b + \boldsymbol{\mu}_i) - \mathcal{E}^t(\boldsymbol{\mu}_{i+})$ and $\mathcal{E}^t(\boldsymbol{\eta}_b) - \mathcal{E}^t(\boldsymbol{\mu}_{i+})$, respectively, is high enough to make it compelling for the buyers to choose sourcing with a single relationship.

Note that the above effect arises only as the mediated single relationship is constrained to be either cooperative or noncooperative, but the intermediary can't choose to source part of the order cooperatively and the remaining part noncooperatively from the supplier it has a relationship with. If the intermediary could have such "partial cooperation" with one supplier, corresponding to different behavior when sourcing for the two client buyers, this disadvantage of intermediation would not arise and an intermediary would always outperform direct sourcing, as illustrated in Theorems 1 and 2. Taken together, our analyses demonstrate that mediated sourcing is better at maintaining relationships, whereas direct sourcing is better at letting buyers choose which supplier to get into a relationship with. In particular, there are three key phenomena that differentiate direct and mediated sourcing; the ability to use *long-run* and *myopic differences* that favor mediated sourcing and the better *selectivity* of direct sourcing.

These three phenomena are distinct from the transactional and informational advantages of intermediation. There are no information asymmetries or information aggregation effects in our setup. Further, the intermediary is not using the aggregated scale of buyer transactions to defray fixed transaction costs. The key drivers of our effects are incomplete contracting and the difference in buyer preferences over suppliers at any given point in time.

We conjecture that these effects may provide an explanation for the phenomenal recent growth in mediated sourcing. We believe that in the increasingly volatile business environment, there is increasing uncertainty in buyer preferences over suppliers, which leads to more changes and higher differences in buyer preferences. We also believe that as firms are outsourcing increasingly critical inputs and more complex parts of their businesses, sourcing is characterized more and more by incompleteness of contracts, which increases the value of maintaining relationships; per our analysis, this is a key advantage of intermediaries. Finally, our effects are agnostic regarding the scale of the sourcing company, which might also explain the adoption of mediated sourcing by companies more than predicted by existing theory.

Notice that our key effects are all driven by changing preferences of buyers regarding suppliers. Thus, one may conjecture that mediation is most useful in industries with a wide and diverse buyer/supplier base, like the apparel industry. On the other hand, industries such as aerospace or semiconductors, with a concentrated supplier base, perhaps derive fewer benefits.

5. Extensions

In our model of mediated sourcing, we assume that buyers transfer all their profit-relevant actions to the intermediary and thus have no control over buyer-side surplus or sourcing profits. Arguably, this assumption unfairly favors the mediated sourcing model—by assuming a perfect transfer of the actions from the buyers to the intermediary, we assume that the addition of the intermediary to the supply chain does not create any new incentive conflicts, or that the incentives of the buyer and the intermediary are perfectly aligned. However, it is possible for the buyer and intermediary to work at cross-purposes, and this incentive conflict would destroy some of the value created by mediation.

To address this concern, we developed and analyzed an alternate model of mediated sourcing that explicitly models the buyer-intermediary transaction as another generic extensive form game.[11] In this model, in addition to allowing inefficiency in the supplier-intermediary transaction, we allow for an additional inefficiency in the buyer-intermediary transaction. Specifically, we assume that the Nash behavior in the buyer-intermediary transaction decreases the sourcing surplus, as compared to the model presented in the paper. Only when the buyer and intermediary cooperative in their interaction is there no additional loss in efficiency.

Our analysis indicates that all the effects mentioned in this paper that drive the advantages of mediation continue to hold with this extension. However, when buyer-intermediary incentives are misaligned, as expected, there is an increased potential for opportunism in mediated sourcing compared to direct sourcing that lowers some of the gains from mediation; however, surprisingly, we find that there is also a "policing effect" that actually increases the gains from mediation. The increased potential for opportunism serves as a bigger deterrent against opportunism for some players. Specifically, intermediaries' opportunism can be punished by actions from both the buyers and suppliers.

In our model, we allowed buyer preferences regarding suppliers to change over time, but the suppliers are indifferent between buyers. Suppliers may also have preferred buyers, and these preferences may change over time. We also developed an extension to the model presented in the paper that allows both buyer and supplier preferences to change over time. Our analysis indicates that even in this setting, the effects described in the paper continue to operate, and mediated sourcing continues to outperform direct sourcing in establishing relationships. Note that although we have labeled one party as the supplier and the other as buyer, our model is agnostic regarding actual product flows. Thus, the results presented here are all equally valid if the roles are reversed.

Finally, note that we develop all the results in our paper for a cooperation outcome a^C. In the game Γ the firms could take various actions that correspond to different levels of cooperation. For example, there might exist another cooperative outcome a^c that is associated with a smaller gain from deviation by the buyer or the supplier, and it might be possible to sustain a^c when outcome a^C cannot be sustained. The results presented continue to hold true in such a case; our analysis is agnostic regarding the specific action that the players choose to cooperate on.

[11] The detailed models, their analyses, and the formal results discussed in all extensions described in §5 are available from the authors upon request.

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Appendix A. Summary of the Notation Used

Parameter	Definition
	Summary of model primitives
$F^t(X_1^t X_2^t)$, $t \geq 0$	Relative advantage that supplier 1 has in supplying buyers 1 and 2
$a \in A$	Describes the actions undertaken by the two players in the transaction game
$u_s(a)$, $u_b(a)$	Supplier and buyer profits are given by general profit functions: $A \to \mathbb{R}$
δ	Players discount future profits with a discount factor δ
β	A fraction of the total buyer-side profits received by the intermediary
	Summary of derived parameters of the model
a^N	Nash equilibrium of the buyer–supplier game
a^C	Cooperative action that Pareto improves the Nash outcomes
G_s, G_b	$\max_{a'_s,\xi}(u_s(a'_s, a_b^C \mid \xi) - u_s(a^C \mid \xi))$; $\max_{a'_b,\xi}(u_b(a'_b, a_s^C \mid \xi) - u_b(a^C \mid \xi))$
η_s, η_b	$u_b(a^C) - u_b(a^N)$, $u_s(a^C) - u_s(a^N)$
$\bar{\theta}_i^t$, $\underline{\theta}_i^t$	$\max_{X_i^t} \theta_i^t(X_i^t)$, $\min_{X_i^t} \theta_i^t(X_i^t)$
$\overline{\nu_1^t + \nu_2^t}$, $\underline{\nu_1^t + \nu_2^t}$	$\max_{X_1^t, X_2^t}(\nu_1^t + \nu_2^t)$, $\min_{X_1^t, X_2^t}(\nu_1^t + \nu_2^t)$
γ_i^t, d	$\mathcal{E}^{t+1}(\mathbf{1} - \mathbf{F}_i(0))\dfrac{u_s(a^N)}{u_s(a^C)}$, $\dfrac{1-\delta}{\delta}\dfrac{G_s}{u_s(a^C)}$
μ_i^t, μ_{i+}^t, μ_{i-}^t	$E[X_i^t]$, $E[X_i^t \mid X_i^t \geq 0]$, $E[X_i^t \mid X_i^t < 0]$

Appendix B. Formalization of §3.1

B.1. Notation for the Engagement Game Γ. Let Ξ be the collection of initial nodes of the subgames of game Γ, with ξ^0 being the initial node. The subgame of Γ with initial node $\xi \in \Xi$ is denoted by Γ_ξ, hence $\Gamma_{\xi^0} = \Gamma$. It is partially ordered by precedence relation, where $\xi < \xi'$ if ξ' is a node in Γ_ξ. A set of terminal nodes is denoted by Y, with typical element y. An action for player s (b) specifies a move for player s (b) at each information set owned by that player. At the end of the period, the players observe terminal node y reached. A unique terminal node is reached under a path of play implied by a. Given a node $\xi \in \Xi$, $u_{s(b)}(a \mid \xi)$ is player s's (b's) payoff from Γ_ξ, given the moves in Γ_ξ implied by a. The terminal node reached by a conditional on ξ is denoted by $y(a \mid \xi)$.

Appendix C. Formalization and Proofs for §3.2

C.1. Notation for the Direct Sourcing Stage Game at Time t, G^{it}

The collection of the initial nodes of the subgames of game G^{it} is $\Xi^{G^{it}} \equiv \{\xi^{\theta_i^t}\} \cup \{\Xi^{\Gamma^{i1}} \times \Xi^{\Gamma^{i2}}\}$, where $\xi^{\theta_i^t}$ is the sourcing fraction selection node and $\Xi^{\Gamma^{ij}}$ is the set of initial nodes of the subgames of game Γ played between buyer i and supplier j; i.e., we will add superscript ij to all nodes, so the initial node of game Γ, ξ^0, will become ξ^{0ij} and the initial node of the transaction step will be $\xi^{0_{i1}}\xi^{0_{i2}}$. The set of terminal nodes is $Y^{G^{it}} = Y^{\Gamma^{i1}} \times Y^{\Gamma^{i2}}$.

C.2. Notation for the Repeated Direct Sourcing Game $G^{i\infty}$

The set of period t, $t \geq 0$, ex ante histories is given by $\mathcal{H}^t = (\mathcal{X}_i \times \mathcal{A})^t$, identifying the state (X_i^t) and action profile ($\mathcal{A}$) in each previous period; $\mathcal{X}_i^t$ is the support of F_i^t, $\mathcal{A} \equiv \{\theta_i\} \times A \times A$. The set of period t, $t \geq 0$, ex post histories is given by $\tilde{\mathcal{H}}^t = (\mathcal{X}_i \times \mathcal{A})^t \times \mathcal{X}_i^{t+1}$, identifying the state and action profile in each previous period and identifying the current state. Let $\mathcal{H} = \bigcup_{t=0}^{\infty} \mathcal{H}^t$, $\tilde{\mathcal{H}} = \bigcup_{t=0}^{\infty} \tilde{\mathcal{H}}^t$; we set $\mathcal{H}^0 = \{\varnothing\}$, hence $\tilde{\mathcal{H}}^0 = \mathcal{X}_i^0$. The pure strategy for player n is a mapping $\sigma_n\colon \tilde{\mathcal{H}} \to \mathcal{A}_n$, associating an action with each ex post history.

C.3. Additional Lemmas

Lemma 3 (Direct Sourcing: The Stage Game Equilibrium). *A subgame-perfect Nash equilibrium of G^{it} is denoted by $\alpha_{d_i}^*$.*

Proof. By definition, an action profile $\alpha_{d_i}^*$ is a subgame-perfect equilibrium if for every node $\xi \in \Xi^{G^{it}}$, the profile $\alpha_{d_i}^* \mid \xi$ is a Nash equilibrium of subgames G_ξ^{it}. Stage game G^{it} starts with a choice of supply fractions—initial node $\xi^{\theta_i^t}$, i.e., $G^{it} = G^{it}_{\xi^{\theta_i^t}}$, and is followed by subgames of game Γ. We know that a^N is a subgame-perfect equilibrium of Γ. Hence, because of the additive separability of players' utilities, for every node $\xi \in \{\Xi^{\Gamma^{i1}} \times \Xi^{\Gamma^{i2}}\}$, $\alpha_{d_i}^* \mid \xi = (a^N, a^N) \mid \xi$, and so $\alpha_{d_i}^* \mid \xi^{0_{i1}}\xi^{0_{i2}}$ is a subgame-perfect equilibrium of the transaction step subgame. Hence, we only need to show that $\alpha_{d_i}^* \mid \xi^{\theta_i^t}$ is a Nash equilibrium of G^{it}; i.e., $\theta_i^t(X_i^t) \cdot (u_b(a^N) + X_i^t) + (1-\theta_i^t(X_i^t)) \cdot u_b(a^N) \geq \theta_i^{\prime t}(X_i^t) \cdot (u_b(a^N) + X_i^t) + (1-\theta_i^{\prime t}(X_i^t)) \cdot u_b(a^N)$. The prescribed choice, $\theta_i^t = \tilde{\theta}_i^{\,t} \equiv I(X_i^t \geq 0)$,[12] satisfies this inequality.[13] So $\alpha_{d_i}^*$ is a subgame-perfect equilibrium of G^{it}. □

C.4. Proof of Lemma 1

Part 1. $\alpha_{d_i}^*$, with $\theta_i^t = \tilde{\theta}_i^{\,t}$, is a subgame-perfect equilibrium of G^{it} (Lemma 3) and hence is a subgame-perfect equilibrium of $G^{i\infty}$. No other θ_i^t can be maintained, as, in any period, the buyer could deviate to $\theta_i^t = \tilde{\theta}_i^{\,t}$ and improve his profit.

Part 2. To establish this, we need to show that for all histories $(\tilde{h}^t, \xi)$, $t \geq 0$,

$$(1-\delta)u_n^t(\alpha^k \mid \xi) + \delta\mathcal{E}^{t+1}(\mathbf{u}_n(\sigma^k|_{(\tilde{h}^t,\, y(\alpha^k|\xi))}))$$
$$\geq (1-\delta)u_n^t(\alpha_n', \alpha_{-n}^k \mid \xi) + \delta\mathcal{E}^{t+1}(\mathbf{u}_n(\sigma^k|_{(\tilde{h}^t,\, y(\alpha_n', \alpha_{-n}^k|\xi))})) \quad \text{(L1)}$$

for all α_n' and all n, where α^k is an action profile prescribed by σ^k following the ex post history $\tilde{h}^t$.

We start with histories $\tilde{h}^t$ that include a deviation. Following such a history, the strategy σ^k is prescribing the stage game equilibrium to be played forever after, hence $\mathcal{E}^{t+1}(\mathbf{u}_n(\sigma^k|_{(\tilde{h}^t,\, y(\alpha^k|\xi))})) = \mathcal{E}^{t+1}(\mathbf{u}_n(\sigma^k|_{(\tilde{h}^t,\, y(\alpha_n', \alpha_{-n}^*|\xi))}))$. Further, from Lemma 3 we know $\forall\, \xi$: $u_n^t(\alpha_{d_i}^* \mid \xi) \geq u_n^t(\alpha_n', \alpha_{-n}^* \mid \xi)$. Taken together, these ensure that condition (L1) is satisfied. Further, for histories $\tilde{h}^t$ that do not include a deviation, the strategy is prescribing α^k to be played if no deviations are observed and the stage game equilibrium following any deviation. Next, we divide all initial nodes, $\xi \in \Xi^{G^{it}}$, into two classes: the ones on and the ones off the equilibrium path.

For all ξ that are off the equilibrium path, $\alpha^k \mid \xi = \alpha_{d_i}^* \mid \xi$; hence,

$$\mathcal{E}^{t+1}(u_n^\tau(\sigma^k|_{(\tilde{h}^t,\, y(\alpha^k|\xi))})) = \mathcal{E}^{t+1}(u_n^\tau(\sigma^k|_{(\tilde{h}^t,\, y(\alpha_n', \alpha_{-n}^k|\xi))})),$$

as the strategy prescribes the stage game equilibrium to be played forever after. Then we only need to show that $u_n^t(\alpha_{d_i}^* \mid \xi) \geq u_n^t(\alpha_n', \alpha_{-n}^* \mid \xi)$, which is established in Lemma 3. Taken together, these ensure that condition (L1) is satisfied.

Next, consider all ξ that belong to the equilibrium path. For the noncooperating supplier, denoted by s_N (in strategy $d_i s_1$ it is supplier 2, in $d_i s_2$ it is 1),

$$\mathcal{E}^{t+1}(\mathbf{u}_{s_N}(\sigma^k|_{(\tilde{h}^t,\, y(\alpha^k|\xi))})) = \mathcal{E}^{t+1}(\mathbf{u}_{s_N}(\sigma^k|_{(\tilde{h}^t,\, y(\alpha_{s_N}', \alpha_{-s_N}^*|\xi))}))$$

even if she deviates, this would not influence the continuation of cooperation among cooperating players. Thus we only need to ensure $(1-\delta)u_{s_N}(\alpha^k \mid \xi) \geq (1-\delta)u_{s_N}(\alpha_{s_N}', \alpha_{-s_N}^k \mid \xi)$. The latter holds as $\alpha_{s_N}^k \mid \xi$, prescribes a^N to be played with the noncooperative supplier which a subgame-perfect equilibrium of Γ. For the cooperative supplier(s), supplier j has deviations only inside Γ^{ij}, so we need to show that for all a_s', ξ the following holds: $\delta\mathcal{E}^{t+1}(\mathbf{u}_{s_j}(\sigma^k)) - \delta\mathcal{E}^{t+1}(\mathbf{u}_{s_j}(\sigma^{d_i T})) \geq (1-\delta)\vartheta_j(u_s(a_s', a_b^C \mid \xi) - u_s(a^C \mid \xi))$, where $\vartheta_1 = \theta_i^t(X_i^t)$ and $\vartheta_2 = 1 - \theta_i^t(X_i^t)$. Hence, $\delta\mathcal{E}^{t+1}(\mathbf{u}_{s_j}(\sigma^k)) - \delta\mathcal{E}^{t+1}(\mathbf{u}_{s_j}(\sigma^{d_i T})) \geq (1-\delta)\bar{\vartheta}_j G_s$, $G_s = \max_{a_s', \xi}(u_s(a_s', a_b^C \mid \xi) - u_s(a^C \mid \xi))$ and $\bar{\vartheta}_j = \max_{X_i^t} \vartheta_j$, ensures the above holds for all a_s', ξ.

In each period t, the buyer can deviate at the initial node $\xi^{\theta_i^t}$, which is immediately detectable: $\forall\, X_i^t$:

$$\begin{aligned}&\delta(\mathcal{E}^{t+1}(\mathbf{u}_{b_i}(\sigma^k)) - \mathcal{E}^{t+1}(\mathbf{u}_{b_i}(\sigma^{d_i T})))\\ &\quad\geq (1-\delta)[\theta_i^{\prime t}(u_b(a^N) + X_i^t) + (1-\theta_i^{\prime t})u_b(a^N)]\\ &\qquad - (1-\delta)[\theta_i^t(u_b(a_{i1}(\sigma^k)) + X_i^t) + (1-\theta_i^t)u_b(a_{i2}(\sigma^k))].\end{aligned}$$

The best deviation is $\theta_i^{\prime t} = \tilde{\theta}_i^{\,t}$, which is reflected in the statement of the lemma. If there are no deviations in the selection step,

$$\begin{aligned}&\delta(\mathcal{E}^{t+1}(\mathbf{u}_{b_i}(\sigma^k)) - \mathcal{E}^{t+1}(\mathbf{u}_{b_i}(\sigma^{d_i T})))\\ &\quad\geq (1-\delta)\vartheta_{b_i}(u_b(a_b', a_s^C \mid \xi) - u_b(a^C \mid \xi)),\end{aligned}$$

for all a_b', ξ, where by ϑ_{b_i}, we denote the amount of cooperation the buyer has; in $d_i d$ it is $\theta_i^t + 1 - \theta_i^t = 1$, in $d_i s_1$ it is θ_i^t and in $d_i s_2$ it is $1 - \theta_i^t$. It boils down to $\delta(\mathcal{E}^{t+1}(\mathbf{u}_{b_i}(\sigma^k)) - \mathcal{E}^{t+1}(\mathbf{u}_{b_i}(\sigma^{d_i T}))) \geq (1-\delta)\bar{\vartheta}_{b_i} G_b$, $G_b = \max_{a_b', \xi}(u_b(a_b', a_s^C \mid \xi) - u_b(a^C \mid \xi))$. This establishes all inequalities of Lemma 1.

[12] $I(W \geq w) = 1$, if $W \geq w$; $= 0$, if $W < w$.

[13] For concise representation, at times we suppress the argument of $\theta_i^t(X_i^t)$ and use θ_i^t.

Appendix D. Formalization and Proofs for §3.3

D.1. Notation for the Mediated Sourcing, the Stage Game, G^{It}

Denote the collection of the initial nodes of the subgames of G^{It} as $\Xi^{G^{It}} \equiv \{\xi^{\nu^t}\} \cup \{\Xi^{\Gamma^{I1}} \times \Xi^{\Gamma^{I2}}\}$, where ξ^{ν^t} is the sourcing fraction selection node and $\Xi^{\Gamma^{Ij}}$ is the set of the initial nodes of the subgames of games Γ played between the intermediary and supplier j; i.e., we add superscript Ij to all nodes. The set of terminal nodes is $Y^{G^{It}} = Y^{\Gamma^{I1}} \times Y^{\Gamma^{I2}}$. Each Γ^{Ij} is a merge of two transaction step games, as the intermediary now needs to source for two buyers from two possible suppliers. In Γ^{Ij} compared with the supplier that took the actions in game Γ, both suppliers j can now take the very same actions for each buyer's order, and whenever the buyers were to act, the intermediary now takes two such actions.

D.2. Notation for the Repeated Mediated Sourcing Game $G^{I\infty}$

The set of period $t \geq 0$ ex ante histories is given by $\mathcal{H}^t = (\mathcal{X} \times \mathcal{A})^t$, identifying the state (X_1^t, X_2^t) and the action profile $(\mathcal{A})$ in each previous period; $\mathcal{X}^t$ is the support of F^t, $\mathcal{A} \equiv \{\nu\} \times A \times A \times A \times A$. The set of period $t \geq 0$ ex post histories is given by $\tilde{\mathcal{H}}^t = (\mathcal{X} \times \mathcal{A})^t \times \mathcal{X}$. Let $\mathcal{H} = \bigcup_{t=0}^{\infty} \mathcal{H}^t$, $\tilde{\mathcal{H}} = \bigcup_{t=0}^{\infty} \tilde{\mathcal{H}}^t$; we set $\mathcal{H}^0 = \{\varnothing\}$, hence, $\tilde{\mathcal{H}}^0 = \mathcal{X}^0$.

D.3. Additional Lemmas

Lemma 4 (Mediated Sourcing: The Stage Game Equilibrium). *A subgame-perfect Nash equilibrium of G^{It} is denoted by α_m^*.*

Proof. From the additive separability of the utilities of the intermediary and the suppliers with respect to actions a_{I1} and a_{I2} in the merged games, and because a^N is a subgame-perfect equilibrium of Γ, it follows that $\alpha_m^* \mid \xi^{0\nu}$ is a subgame-perfect equilibrium of $G^{It}_{\xi^{0\nu}}$. Thus, we only need to show optimality in the supplier selection choice, or $\sum_{i=1}^{2}[\nu_i^t(u_b(a^N) + X_i^t) + (1-\nu_i^t)u_b(a^N)] \geq \sum_{i=1}^{2}[\nu_i'^t(u_b(a^N) + X_i^t) + (1-\nu_i'^t)u_b(a^N)]$. The prescribed choice satisfies this inequality. □

D.4. Proof of Lemma 2

The proof follows along the same lines as the proof of Lemma 1, noting that suppliers have $\vartheta_1 = \nu_1 + \nu_2$ and $\vartheta_2 = 2 - (\nu_1 + \nu_2)$ orders on hand on which they can deviate. In *md*, the intermediary is sourcing $\vartheta_1 + \vartheta_2 = 2$ orders cooperatively, in $ms_1 - \vartheta_1$, in $ms_2 - \vartheta_2$; the maximal possible deviations in transaction steps follow.

Appendix E. Proofs for §4

E.1. Proof of Theorem 1

1. For given strategy k, as $a_{1j}^t(\sigma^k) = a_{2j}^t(\sigma^k) = a_{Ij}^t(\sigma^k) \equiv a_j^k$, $j \in \{1, 2\}$, the sourcing profits for direct and mediated structures are given by $(\mathbf{X}_i \equiv \{X_i^t, t \geq 0\})$:

$$\pi^{d_1 k}(\delta) + \pi^{d_2 k}(\delta) = \max_{\boldsymbol{\theta}_1, \boldsymbol{\theta}_2} \mathcal{E}^0\big((\boldsymbol{\theta}_1 + \boldsymbol{\theta}_2)u_b(a_1^k) + \boldsymbol{\theta}_1\mathbf{X}_1 + \boldsymbol{\theta}_2\mathbf{X}_2 + (\mathbf{2} - (\boldsymbol{\theta}_1 + \boldsymbol{\theta}_2))u_b(a_2^k)\big),$$

$$\pi^{mk}(\delta) = \max_{\boldsymbol{\nu}_1, \boldsymbol{\nu}_2} \mathcal{E}^0\big((\boldsymbol{\nu}_1 + \boldsymbol{\nu}_2)u_b(a_1^k) + \boldsymbol{\nu}_1\mathbf{X}_1 + \boldsymbol{\nu}_2\mathbf{X}_2 + (\mathbf{2} - (\boldsymbol{\nu}_1 + \boldsymbol{\nu}_2))u_b(a_2^k)\big).$$

2. Further, we need to ensure that all cooperative players have sufficient incentives to maintain this strategy. For supplier s_j to cooperate in respective games with buyer i or the intermediary, as per Lemmas 1 and 2, the following constraints should be satisfied for all t $(\gamma \equiv u_s(a^N)/u_s(a^C)$, $d \equiv (1-\delta)/\delta)(G_s/u_s(a^C))$:

$$\begin{aligned}
s_1\colon\ &(\text{D.1})\quad \mathcal{E}^{t+1}(\boldsymbol{\theta}_1) - d\bar{\theta}_1^t \geq \gamma_1^t;\\
&(\text{D.2})\quad \mathcal{E}^{t+1}(\boldsymbol{\theta}_2) - d\bar{\theta}_2^t \geq \gamma_2^t;\\
&(\text{M})\quad \mathcal{E}^{t+1}(\boldsymbol{\nu}_1 + \boldsymbol{\nu}_2) - d(\overline{\nu_1^t + \nu_2^t}) \geq \gamma_1^t + \gamma_2^t;\\
s_2\colon\ &(\text{D.1})\quad \mathcal{E}^{t+1}(\mathbf{1} - \boldsymbol{\theta}_1) - d(1 - \underline{\theta}_1^t) \geq \gamma - \gamma_1^t;\\
&(\text{D.2})\quad \mathcal{E}^{t+1}(\mathbf{1} - \boldsymbol{\theta}_2) - d(1 - \underline{\theta}_2^t) \geq \gamma - \gamma_2^t;\\
&(\text{M})\quad 2 - \mathcal{E}^{t+1}(\boldsymbol{\nu}_1 + \boldsymbol{\nu}_2) - d(2 - \underline{\nu_1^t + \nu_2^t}) \geq 2\gamma - \gamma_1^t - \gamma_2^t,
\end{aligned}$$

where $\bar{\theta}_i^t \equiv \max_{X_i^t} \theta_1^t$, $\underline{\theta}_i^t \equiv \min_{X_i^t} \theta_1^t$; $\overline{\nu_1^t + \nu_2^t} \equiv \max_{X_1^t, X_2^t}(\nu_1^t + \nu_2^t)$, $\underline{\nu_1^t + \nu_2^t} \equiv \min_{X_1^t, X_2^t}(\nu_1^t + \nu_2^t)$.

3. We show that a mediated dual relationship performs better than a direct dual relationship, using the following strategy. Denote by θ_1^*, θ_2^* the solution to respective direct buyers' problems. Set ν_1^t, ν_2^t as follows: for i such that $X_i^t \geq X_{\bar{i}}^t$, set $\nu_i^t = \min\{1, \theta_1^{*t} + \theta_2^{*t}\}$ and $\nu_{\bar{i}}^t = \theta_1^{*t} + \theta_2^{*t} - \min\{1, \theta_1^{*t} + \theta_2^{*t}\}$. Doing so in every period t, the mediated system gains over direct:

$$\int_{-\underline{x}_1^t}^{\bar{x}_1^t} \int_{-\underline{x}_2^t}^{x_1^t} \min\{1 - \theta_1^{*t}, \theta_2^{*t}\}(x_1^t - x_2^t) f^t(x_1, x_2)\, dx_1^t\, dx_2^t + \int_{-\underline{x}_1^t}^{\bar{x}_1^t} \int_{x_1^t}^{\bar{x}_2^t} \min\{1 - \theta_2^{*t}, \theta_1^{*t}\}(x_2^t - x_1^t) f^t(x_1, x_2)\, dx_1^t\, dx_2^t.$$

By looking at the boundaries of the integral, one can see that this expression is always nonnegative.

4. Next, we need to ensure that in following the above described strategy, all the incentive constraints are satisfied. In direct sourcing, buyer i will choose θ_i^{*t}, to satisfy respective direct sourcing constraints. The supplier-side constraints in mediated sourcing, having $\nu_1^t + \nu_2^t = \theta_1^{*t} + \theta_2^{*t}$, are just the sum of the constraints that direct buyers have to satisfy. Hence, the supplier-side constraints, as defined in part 2, are satisfied. Further, the buyer-side constraints in direct sourcing can be expressed as $\pi^{d_i k}(\delta \mid t+1) - \pi^{d_i T}(\delta \mid t+1) \geq ((1-\delta)/\delta)G_{b_i}^{kt}$, where by $\pi^{d_i k}(\delta \mid t+1)$ we denote the expected normalized sourcing profit starting from period $t+1$ onward, and $G_{b_i}^{kt}$—is the highest gain buyer i can attain in period t from deviation, given that strategy k is played. Having $\nu_1^t + \nu_2^t = \theta_1^{*t} + \theta_2^{*t}$, the constraint of the intermediary can be written as $\pi^{mk}(\delta \mid t+1) - \pi^{mT}(\delta \mid t+1) \geq ((1-\delta)/\delta)(G_{b_1}^{kt} + G_{b_2}^{kt})$. In part 3 we established that $\pi^{mk}(\delta \mid t+1) \geq \pi^{d_1 k}(\delta \mid t+1) + \pi^{d_2 k}(\delta \mid t+1)$, further in transactional sourcing intermediary, and the buyers make the same sourcing profit, $\pi^{mT}(\delta \mid t+1) = \pi^{d_1 T}(\delta \mid t+1) + \pi^{d_2 T}(\delta \mid t+1)$ (transactional sourcing has no cooperation, hence none of the constraints specified in part 2 apply and both direct and mediated sourcing solve the same unconstrained optimization problem). Hence, the constraint of the intermediary is also satisfied.

5. We can show that the intermediary might be able to further improve profits. From expressions in part 4, the supplier-side constraints are just the sum of the constraints

Figure E.1 **Example: Optimal Order Allocation with Dual Relationships**

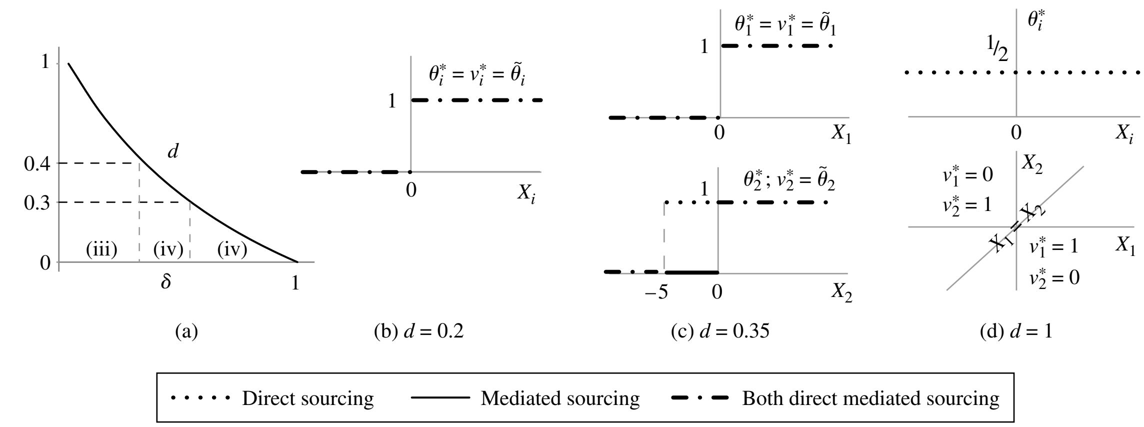

Table E.1 **Example: Supplier-Side Constraints That Ensure That a Dual Relationship Strategy Is Equilibrium for the Specified Allocation**

	Allocation θ_i		Responsive allocation, $\tilde{\theta}_i$	
	s_1	s_2	s_1	s_2
(D.1)	$E(\theta_1) \geq d\bar{\theta}_1$	$1 - E(\theta_1) \geq d(1 - \underline{\theta}_1)$	$0.5 \geq d$	$0.5 \geq d$
(D.2)	$E(\theta_2) \geq d\bar{\theta}_2$	$1 - E(\theta_2) \geq d(1 - \underline{\theta}_2)$	$0.3 \geq d$	$0.7 \geq d$
(M)	$E(\nu_1 + \nu_2) \geq d(\overline{\nu_1 + \nu_2})$	$2 - E(\nu_1 + \nu_2) \geq d(2 - \underline{\nu_1 + \nu_2})$	$0.8 \geq 2d$	$1.2 \geq 2d$

that direct buyers have to satisfy for this supplier. Hence, if for given δ, θ_1^{*t} is chosen so that the constraint of supplier 1 is binding, but θ_2^{*t} satisfies the respective constraint with slack, then the supplier-side constraint in mediated sourcing is satisfied with slack. Hence, the intermediary can further improve the sourcing profit by choosing $\boldsymbol{\nu}_1^*, \boldsymbol{\nu}_2^*$ to remove the undesired slack and improve the profit. To further illustrate the proof of the theorem we present a specific example in the next section.

E.2. Example

Consider the following example with stationary distributions: $F_i^t = F_i$, for all $t \geq 0$; further, set $F_1 \sim U[-50, 50]$, $F_2 \sim U[-70, 30]$. Finally, $u_s(a^N) = 0$. Hence, $\gamma = \gamma_1^t = \gamma_2^t = 0$, $\theta_i^t = \theta_i$ and $\mathcal{E}^{t+1}(\boldsymbol{\theta}_i) = E(\theta_i)$. For allocations, θ_i and ν_i, the constraints required to sustain a dual relationship are in columns 2 and 3 of Table E.1 (derived from part 2 of the proof of Theorem 1). In the last two columns of the table, the responsive allocation values—$\theta_i = \nu_i = \tilde{\theta}_i = I\ (X_i \geq 0)$—are used.

For $d \leq 0.3$ (δ corresponding to region (v)[14] in Figure E.1(a)), the responsive allocation itself ensures that all of the equilibrium constraints are satisfied, so $\theta_i^* = \nu_i^* = \tilde{\theta}_i$ (shown in Figure E.1(b)). Next, for $d \in (0.3, 0.4)$ (region (iv) (see Footnote 14) of Figure E.1(a)), direct buyer 2 cannot satisfy constraint of supplier 1 with responsive allocation, whereas buyer 1 still can do so. In fact, the constraint is satisfied with a slack. However, the intermediary can easily satisfy constraints for both suppliers with responsive allocation, $\nu_i^* = \tilde{\theta}_i$, for $d \in (0.3, 0.4)$. Effectively in this region, the intermediary is using the slack that buyer 1 has to subsidize buyer 2's weaker interest. We depict functions θ_i^*, ν_i^* in Figure E.1(c), where the dotted lines apply to direct sourcing, the solid to mediated, and the dash-dotted lines to both. This corresponds to §5 of the proof and case II of the sketch of the proof of Theorem 1. Last, for $d > 0.4$ (region (iii) (see Footnote 14) of Figure E.1(a)), the intermediary must also depart from responsive allocation to satisfy the constraints. In Figure E.1(d) we depict how θ_i^*, ν_i^* would look like for $d = 1$ if the buyers establish a dual relationship. To satisfy the constraints, direct buyers must in every period source half of their orders from each supplier, $\theta_i^* = \frac{1}{2}$, $\bar{\theta}_i = \underline{\theta}_i = \frac{1}{2}$ (top of Figure E.1(d)). In this case, the intermediary can source the same amount per period from each supplier (one unit from each), but if $X_1 > X_2$ (buyer 1 has higher preference for supplier 1) he will source buyer 1's order from supplier 1, and buyer 2's from supplier 2, $\nu_1^* = 1$, $\nu_2^* = 0$, and vice versa if $X_2 \geq X_1$ (Figure E.1(d), bottom). This achieves a more efficient allocation of orders, earning higher profits. This corresponds to part 3 of the proof and case III of the sketch of the proof of Theorem 1.

E.3. Proof of Corollary to Theorem 1

All statements of the corollary follow from the gain of mediation established in part 3 of the proof of Theorem 1.

E.4. Proof of Theorem 2

This follows from Theorem 1.

E.5. Proof of Theorem 3

In our setup we assume that whenever the intermediary enters into a relationship with the supplier it needs to always source cooperatively from this supplier (independent of the buyer it is sourcing for). This theorem allows us to demonstrate how restrictive this assumption can be. We will do so by constructing a specific set of conditions that lead to worse performance of mediated sourcing. Below we formulate more general version of Theorem 3. Theorem 3 follows if $F_i^t(-\eta_b) = 0$, $F_i^t(\eta_b) = 1$.

Theorem 4. *If all of the following conditions hold for all* $t \geq 0$, *there exist* $\hat{\delta} \in (0, 1)$ *such that buyer* $i \in \{1, 2\}$ *prefers*

[14] Labeling of the regions corresponds to labeling in Figure 4.

single relationship with supplier 1 *and buyer* $\bar{i}$ *with supplier* 2, $\pi^d(\hat{\delta}) = \pi^{d_i s_1}(\hat{\delta}) + \pi^{d_{\bar{i}} s_2}(\hat{\delta})$, *and direct sourcing outperforms mediated sourcing*, $\pi^d(\hat{\delta}) > \pi^m(\hat{\delta})$.

$$E[X_i^t \mid \eta_b \geq X_i^t \geq -\eta_b] + \eta_b \cdot (1 - F_i^t(-\eta_b) - F_i^t(\eta_b)) > 0,$$
$$E[X_{\bar{i}}^t \mid \eta_b \geq X_{\bar{i}}^t \geq -\eta_b] + \eta_b \cdot (1 - F_{\bar{i}}^t(-\eta_b) - F_{\bar{i}}^t(\eta_b)) < 0;$$
$$\mathcal{E}^{t+1}((\mathbf{1} - \mathbf{F}_i(0))(1-\gamma) + \mathbf{F}_i(0) - \mathbf{F}_i(-\eta_b)),$$
$$\mathcal{E}^{t+1}((\mathbf{F}_{\bar{i}}(0))(1-\gamma) - \mathbf{F}_{\bar{i}}(0) + \mathbf{F}_{\bar{i}}(\eta_b)) \geq 1-\gamma,$$
$$\text{where } \gamma \equiv \frac{u_s(a^N)}{u_s(a^C)};$$
$$\mathcal{E}^{t+1}(E[\mathbf{X}_i \mid \mathbf{0} \geq \mathbf{X}_i \geq -\boldsymbol{\eta}_b] + \boldsymbol{\eta}_b \cdot (1 - \mathbf{F}_i(-\eta_b))),$$
$$\mathcal{E}^{t+1}(\boldsymbol{\eta}_b \cdot \mathbf{F}_{\bar{i}}(\eta_b) - E[\mathbf{X}_{\bar{i}} \mid \boldsymbol{\eta}_b \geq \mathbf{X}_{\bar{i}} \geq \mathbf{0}]) > \frac{\eta_s G_b}{G_s}.$$

Proof. 1. Suppose that in single relationship sourcing with responsive allocation of orders between cooperative and noncooperative suppliers (we are going to refer to these profits as $\bar{\pi}^{d_i s_j}(t)$), buyers sourcing directly prefer to establish a relationship with different suppliers; i.e., for some $i \in \{1,2\}$ $\bar{\pi}^{d_i s_1}(t) > \bar{\pi}^{d_i s_2}(t)$ and $\bar{\pi}^{d_{\bar{i}} s_2}(t) > \bar{\pi}^{d_{\bar{i}} s_1}(t)$. Writing out these conditions in terms of the parameters of the model, we get the first set of constraints stated in the theorem.

2. We need to ensure that at least for some δ buyers will use single relationship with responsive allocation, $\pi^{d_i}(\delta \mid t) = \bar{\pi}^{d_i s_1}(t)$ and $\pi^{d_{\bar{i}}}(\delta \mid t) = \bar{\pi}^{d_{\bar{i}} s_2}(t)$. Having supplier-side constraints for maintaining a dual relationship both in direct and mediated sourcing, one can derive that for δ lower than $\delta_s^d = G_s/(\eta_s + G_s)$, no dual relationship strategies can be maintained both in direct and mediated sourcing. Similarly, we can find the lowest δ where the preferred single relationship responsive strategy for each of the buyers can be sustained, $\delta_s^{d_i s_1}$ and $\delta_s^{d_{\bar{i}} s_2}$. The second set of conditions requires that single responsive sourcing with the preferred supplier can be maintained for a wider range of δ than any of the dual relationship strategies, $\delta_s^{d_i s_1}, \delta_s^{d_{\bar{i}} s_2} \leq \delta_s^d$. The last set of constraints ensures that at δ_s^d, buyer-side constraints are satisfied with a slack, establishing existence of $\hat{\delta}$.

3. Last, at $\hat{\delta}$ direct sourcing performs better than mediated, as the best profit-mediated sourcing can achieve: $\bar{\pi}^m(\hat{\delta} \mid t) = \max\{\bar{\pi}^{d_i s_1}(t) + \bar{\pi}^{d_{\bar{i}} s_1}(t), \bar{\pi}^{d_i s_2}(t) + \bar{\pi}^{d_{\bar{i}} s_2}(t)\} < \pi^d(\hat{\delta} \mid t) = \bar{\pi}^{d_i s_1}(t) + \bar{\pi}^{d_{\bar{i}} s_2}(t)$. ☐

References

Aghion, P., R. Holden. 2011. Incomplete contracts and the theory of the firm: What have we learned over the past 25 years? *J. Econom. Perspect.* **25**(2) 181–197.

Allon, G., J. A. Van Mieghem. 2010. Global dual sourcing: Tailored base-surge allocation to near- and offshore production. *Management Sci.* **56**(1) 110–124.

Cachon, G. P., M. A. Lariviere. 2005. Supply chain coordination with revenue-sharing contracts: Strengths and limitations. *Management Sci.* **51**(1) 30–44.

Cheng, W.-G. 2010. Li & Fung signs Walmart deal that may generate $2 billion. *Bloomberg* (January 28), http://www.bloomberg.com/apps/news?pid=newsarchive&sid=aSDzLcEyoNas.

Chod, J., D. Pyke, N. Rudi. 2010. The value of flexibility in make-to-order systems: The effect of demand correlation. *Oper. Res.* **58**(4, Part 1) 834–848.

Debo, L. G., J. Sun. 2004. Repeatedly selling to the newsvendor in fluctuating markets: The impact of the discount factor on supply chain. Working paper, Carnegie Mellon University, Pittsburgh.

Friedman, T. L. 2007. *The World Is Flat: A Brief History of the Twenty-First Century*, 2nd ed. Farrar, Straus, and Giroux, New York.

Fung, V. K., W. K. Fung, Y. Wind. 2007. *Competing in a Flat World: Building Enterprises for a Borderless World*. Pearson Education, Upper Saddle River, NJ.

Goyal, M., S. Netessine. 2011. Volume flexibility, product flexibility, or both: The role of demand correlation and product substitution. *Manufacturing Service Oper. Management* **13**(2) 180–193.

Kouvelis, P., M. J. Rosenblatt, C. L. Munson. 2004. A mathematical programming model for global plant location problems: Analysis and insights. *IIE Trans.* **36**(2) 127–144.

Li, C., L. G. Debo. 2005. Strategic dynamic sourcing from competing suppliers: The value of commitment. Working Paper E2005E20, Tepper School of Business, Carnegie Mellon University, Pittsburgh.

Li, C., L. G. Debo. 2009. Second sourcing vs. sole sourcing with capacity investment and asymmetric information. *Manufacturing Service Oper. Management* **11**(3) 448–470.

Li & Fung. 2010. Annual 10 report. Accessed April 20, 2010, http://www.lifung.com/eng/global/dl_pdf?file=/eng/ir/reports/ar2010/ar2010.pdf.

Loveman, G. W., J. O'Connell. 1995. Li & Fung (Trading) Ltd. HBS Case 396075, Harvard Business School, Boston.

Lu, L. X., J. A. Van Mieghem. 2009. Multimarket facility network design with offshoring applications. *Manufacturing Service Oper. Management* **11**(1) 90–108.

Mailath, G. J., L. Samuelson. 2006. *Repeated Games and Reputations: Long-Run Relationships*. Oxford University Press, New York.

McFarlan, F. W., W. C. Kirby, T. Y. Manty. 2007. Li & Fung 2006. HBS Case 307077, Harvard Business School, Boston.

Plambeck, E. L., T. A. Taylor. 2006. Partnership in a dynamic production system with unobservable actions and noncontractible output. *Management Sci.* **52**(10) 1509–1527.

Ren, Z. J., F. Zhang. 2009. Service outsourcing: Capacity, quality and correlated costs. Working paper, Boston University, Boston. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1362036#.

Ren, Z. J., M. A. Cohen, T. H. Ho, C. Terwiesch. 2010. Information sharing in a long-term supply chain relationship: The role of customer review strategy. *Oper. Res.* **58**(1) 81–93.

Roels, G., U. S. Karmarkar, S. Carr. 2010. Contracting for collaborative services. *Management Sci.* **56**(5) 849–863.

Swinney, R., S. Netessine. 2009. Long-term contracts under the threat of supplier default. *Manufacturing Service Oper. Management* **11**(1) 109–127.

Taylor, T. A., E. L. Plambeck. 2007a. Simple relational contracts to motivate capacity investment: Price only vs. price and quantity. *Manufacturing Service Oper. Management* **9**(1) 94–113.

Taylor, T. A., E. L. Plambeck. 2007b. Supply chain relationships and contracts: The impact of repeated interaction on capacity investment and procurement. *Management Sci.* **53**(10) 1577–1593.

Tomlin, B. 2006. On the value of mitigation and contingency strategies for managing supply chain disruption risks. *Management Sci.* **52**(5) 639–657.

Tunca, T. I., S. A. Zenios. 2006. Supply auctions and relational contracts for procurement. *Manufacturing Service Oper. Management* **8**(1) 43–67.

Walmart. 2010. 10-K Annual report pursuant to section 13 and 15(d). Filed on March 20, 2010. U.S. Securities and Exchange Commission, Washington, DC. http://services.corporate-ir.net/SEC/.

Wigand, R. T., R. I. Benjamin. 1995. Electronic commerce: Effects on electronic markets. *J. Comput.-Mediated Comm.* **1**(3).

Wu, S. D. 2004. Supply chain intermediation: A bargaining theoretic framework. D. Simchi-Levi, S. D. Wu, Z.-J. Shen, eds. *Handbook of Quantitaive Supply Chain Analysis: Modeling in the E-Business Era*. Kluwer, London, 67–115.