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# Supply Chain Structures On The Internet: Marketing-Operations Coordination

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**Abstract**

The widespread adoption of the Internet has resulted in the possibility of disintermediation of information flow and physical goods flow: a company selling a product no longer has to own/deliver it to the customer. As a result, supply chain structures arise in which the retailer is primarily concerned with customer acquisition, and the wholesaler takes care of inventory and fulfillment. This form of doing business on the Internet is identical to the practice of drop-shipping that some catalog companies employ. A recent survey indicates that more than 30% of online-only retailers use drop-shipping as a primary way to fulfill orders. Since marketing and operations functions under such arrangement are performed by separate companies, new inefficiencies arise that result in suboptimal system performance.

In this paper, we analyze the interaction between a wholesaler and a single retailer for drop-shipping supply chains. Three distinct drop-shipping models are considered: with a powerful wholesaler, with a powerful retailer and with a wholesaler and a retailer having an equal power. Further, we conduct a comparative analysis between the drop-shipping supply chains, a vertically integrated supply chain, and the traditional structure in which the retailer both holds inventories and acquires customers. Optimal solutions are obtained for both the traditional and drop-shipping models, and we show that both solutions are system sub-optimal. We demonstrate how decision power in the chain affects decision variables and profits. It is found that both channel members prefer drop-shipping agreements over the traditional agreements for a wide range of problem parameters. One of our main results is that none of the mechanisms described in the literature on channel coordination (except for those that allow side payments) are able to induce a optimal system behavior in the presence of customer acquisition expenses. We therefore propose a new coordination scheme where, in addition to using a returns contract (for the traditional supply chain structure) or a penalty scheme (for the drop-shipping structure), the wholesaler subsidizes a part of the retailer's marketing expenses. Extensive comments are provided on the comparative benefits of traditional and drop-shipping supply chains. A link to an interactive web site for numerical experiments is provided at www.nilsrudi.com.

# 1 Introduction

Spun.com, a small CD/DVD Internet retailer, has about 200,000 CD titles listed on its web site. Surprisingly, the company does not hold/own any inventory of CDs. Instead, the company partnered with the wholesaler Alliance Entertainment Corp. (AEC), which stocks CDs and ships them directly to Spun.com's customers with Spun.com labels on the packages. In this way, the retailer avoided an estimated inventory investment of $8M [3], since it only paid the distributor for sold products. AEC calls this distribution system "Consumer Direct Fulfillment." According to the company's web site, "... using AEC as a fulfillment partner gives you more time and resources to focus on attracting more consumers to your store ..." [1]. The list of retailers practicing such forms of Internet business includes Zappos.com [7], Cyberian Outpost [5] and many others.

Drop-shipping is defined in marketing literature as " ... a marketing function where physical possession of goods sold bypasses a middleman, while title flows through all those concerned. The function of drop-shipping involves both the middleman who initiates the drop ship order and the stocking entity that provides drop-shipping services by filling the order for the middleman" (Scheel [33]). Clearly, the above example of Spun.com fits this description. Drop-shipping is different from many of the supply chain structures previously described in the literature in which the wholesaler is involved in the retailer's inventory management. It differs from the traditional consignment agreements in which the retailer holds (but does not own) inventory and decides what the stocking policy should be – under drop-shipping the stocking policy is entirely controlled by the wholesaler. Drop-shipping is close to but different from Vendor Managed Inventory (VMI), since the retailer does not deal with inventories and hence does not incur any inventory-related costs. At the same time, the wholesaler does not have direct access to the retailer's store where she could "rent" space and organize it in such a way that influences demand according to the wholesaler's preferences (as is often the case under VMI). Drop-shipping also differs from outsourcing of inventory management, since under outsourcing the retailer usually still influences stocking quantities for each product.

Prior to the invention of the Internet, the practice of drop-shipping was mainly restricted to two different settings. For large transactions of industrial goods, the wholesaler might have the manufacturer make the shipment directly to the retailer (and in some cases directly to the end customer). This is typically beneficial for shipments that in themselves achieve sufficient economies of scale, making the wholesaler act primarily as a market-maker. The second use of drop-shipping, which is more relevant to our setting, is when a catalog company has the wholesaler drop-ship the product directly to the end customer. This practice, however, has had very limited success, mainly due to problems in the integration and timeliness of information between the business partners, as well as high transaction costs. As a result, even the catalog companies using drop-shipping only use it for bulky and high cost items (see [2]). Hence the potential for drop-shipping has been deemed limited by many marketing books (see literature review in Scheel [33]). With the Internet, however, real time data-integration is readily available at low cost. The combination of the physical concept of drop-shipping with the information integration made possible by the Internet resolves the problems that previously limited the adoption of drop-shipping. A recent survey of Internet retailers [8] indicates that 30.6% of Internet-only retailers use drop-shipping as a primary way to fulfill orders, while only 5.1% of multi-channel retailers primarily rely on drop-shipping.

One of the major differences between selling goods on the Internet and through the conventional brick-and-mortar retailer is the disintermediation of physical goods flow and information flow. In a physical store, a customer selects a product and pays for it at the same time and place that she physically receives the product. On the Internet this does not need to be the case. A customer on the Internet can not observe from where the product is dispatched. Further, Internet customers (similar to mail-order catalog customers) do not expect an immediate delivery of the product. Together, this allows the retailer and the wholesaler to adopt the drop-shipping agreement efficiently at a low cost. Agreements of this type benefit the retailer by eliminating inventory holding costs and overall up-front capital required to start the company. The wholesaler increases her involvement in the supply chain and hence can potentially demand a higher wholesale price, thus capturing more profits. Further, supply chain benefits occur due to risk pooling if the wholesaler performs drop-shipping for multiple retailers. Finally, each party can concentrate all its resources on one task: the retailer on customer acquisition and the wholesaler on product distribution.

Despite several clearly attractive features, drop-shipping introduces new inefficiencies into the supply chain. Under drop-shipping, the wholesaler keeps the decision rights related to stocking policies, while the retailer's main task in the supply chain is customer acquisition. This separation of marketing and operations functions results in inefficiencies, some of which have been the subject of discussion in the literature on marketing-operations coordination. Many questions arise in such a situation: will the supply chain performance under the drop-shipping structure be better than under a traditional structure in which the retailer holds inventory? Further, is it profitable for both the retailer and the wholesaler to engage into this sort of agreement? Can drop-shipping agreements lead to system-optimal performance, and if not, what form of contract can coordinate the supply chain?

To the best of our knowledge, the concept of drop-shipping has not previously been analyzed or even modeled. In this paper we formally introduce the drop-shipping supply chains. Further, we compare traditional supply chain structures in which the retailer carries inventory and acquires customers with supply chain structures employing drop-shipping agreements. Our focus is on the supply chains in which both the retailer and the wholesaler are present. We concentrate on two cost aspects of the distribution channel: marketing (customer acquisition) and operational (inventory). In the case of Internet retailers, there exists vast evidence that these two cost components constitute a dominant portion of the company's budget. Since e-tailers do not have a physical presence that would attract customers by physical location or strong brand name, customer acquisition becomes a major issue. Online-only retailers spend about twice as much of their budget on customer acquisition compared to multi-channel retailers [6]. The typical marketing budget of an Internet-only retailer is 40.5% of sales, while the marketing budget for a multi-channel retailer is 21.4% [8]. A recent survey of online retailers shows that the catalog-based companies spend on average $11 to acquire a customer, compared to the $32 spent by a physical store and $82 by an e-tailer [4]. On the other hand, to be able to compete with traditional retailers, Internet companies typically offer extensive product variety and a high service level that in turn requires a large inventory investment. In addition, at the present time Internet retailing is in its early stages of development, and the demand for products is highly uncertain; hence, large inventories must be carried to maintain high service levels. As demonstrated by the recent penalties the Federal Trade Commission imposed on seven online retailers for late deliveries [6], the consequences of insufficient inventories can be more severe than dissatisfied customers.

To better understand the wholesaler-retailer interaction in drop-shipping supply chains, we focus on a simple model with a wholesaler and a single retailer. Three main models are analyzed and compared in this paper: a traditional vertically integrated channel (Model I for "Integrated"), a traditional vertically disintegrated channel (Model T for "Traditional") and a drop-shipping channel (Model D for "Drop-shipping"). The solution for the drop-shipping channel further depends on the channel power (where power is modeled as being the first mover in a Stackelberg game). Hence, within the drop-shipping model we further consider three sub-models, in which either the wholesaler or the retailer is a Stackelberg leader or where each party has an equal decision power (i.e. moves simultaneously) and the solution is a Nash equilibrium. First, we demonstrate that a unique competitive equilibrium exists in each model, and we find optimal inventory and customer acquisition spending for each channel in analytical form. We find that, for the drop-shipping channel, marketing-operations misalignment results from the fact that these functions are managed by two different firms. In addition, double marginalization is present in both the traditional and drop-shipping structures. Under identical problem parameters, we analytically compare the models in terms of decision variables and profits and show that the drop-shipping models, as well as the traditional model, always lead to underspending on customer acquisition in addition to understocking. We then show that a price-only contract, a revenue sharing contract, or a returns/purchase commitment contract can not coordinate the supply chain when customer acquisition costs are present. For the traditional supply chain, we propose a contract that combines the returns or revenue-sharing coordination mechanisms with the subsidized advertising, and we show that either of these contracts induces coordination. For the drop-shipping model, the similar in structure contract in which the wholesaler subsidizes customer acquisition in combination with a penalty on the retailer for each unsold unit of product is shown to induce the system optimal behavior. The paper is completed by numerical experiments, followed by a summary of the managerial insights and a discussion of current business practices that are in use by the Internet and catalog companies.

The rest of the paper is organized as follows. In the next section, we provide a survey of the relevant literature. Section 3 outlines the notation and modeling assumptions. In Section 4, all three models are presented. In Section 5, we show that none of the channel coordination mechanisms described in the literature can achieve a first-best solution. Optimal coordinating contracts are proposed in the same section. Section 6 contains numerical experiments, and in Section 7 we wrap-up the paper with a discussion of managerial insights and conclusions.

## 2 Literature survey

The practice of drop-shipping has been described qualitatively in the marketing literature (see Scheel [33] and references therein), but, to the best of our knowledge, it has never been formally modeled and analyzed. In a majority of marketing textbooks, the qualitative analysis of drop-shipping is limited to one paragraph. The literature on drop-shipping does not raise the issue of marketing-operations misalignment and power in the supply chain. With the exception of Scheel [33], all the sources we cite either ignore inventory or assume that inventory is held by the retailer.

Operations management has a wealth of literature that deals with the inventory aspects of the supply chain, but ignores marketing expenses like customer acquisition costs (see, for example, Tayur et.al. [37]). At the same time, the marketing literature deals with customer acquisition costs in the form of advertising and sales support (see, for example, Lilien et.al. [24]), but ignores operational issues.

This work belongs to the recent stream of research dealing with the alignment of marketing and operations incentives (see Shapiro [36] and Montgomery and Hausman [26] for discussions of some of the problems that arise from marketing-operations misalignment). Our model differs from the previous literature in several ways. In our paper, the marketing function is customer acquisition that affects demand for the product, while the sales price is exogenous. Since marketing and operational functions are performed by the separate companies and we do not consider information asymmetry, the problem we consider is different from sales agent compensation. The majority of papers in this area assume that the marketing function is to set the sales price or promotion level and manufacturing schedules production (see, for example, Sagomonian and Tang [32] and references therein). De Groote [17] considers product line choice as a marketing function. Eliashberg and Steinberg [18] give an excellent summary of a number of papers modeling operations/marketing interface, but none of the papers they cite models uncertain demand. Porteus and Wang [31] look at the optimal alignment of marketing and operational aspects in a multi-product environment where marketing can affect the demand and manufacturing allocates the capacity. They use a principal-agent framework and cite a number of relevant papers. None of these papers models customer acquisition spending or advertising as a marketing decision variable. Balcer [10] models coordination of advertising and inventory decisions within one company and focuses on a dynamic nonstationary model in which demand is influenced by the level of goodwill. Balcer [11] further extends this model by assuming that the advertising effect lasts for more than one period. Gerchak and Parlar [19] look at a single-period model in which demand is a specific function of the marketing effort. None of these papers consider supply chain issues like contracting and coordination.

While modeling situations related to ours, some papers do not explicitly emphasize marketing-operations coordination issues. Cachon and Lariviere [15], among others, model a situation where the retailer's effort influences demand. They assume, however, that the effort can not be contracted upon, and hence they do not find a contract that coordinates the supply chain. While this assumption is reasonable in the problem setting they use, on the Internet it is possible to contract upon at least some forms of customer acquisition spending. For example, if the retailer pays for advertising based on the volume of click-through and purchase by the customers, then this type of customer acquisition can easily be independently verified and contracted upon. In the last section, we will comment more on the viability of this type of contract and on practical ways to implement such contracts. Narayanan and Raman [28] look at a problem that in some ways is the opposite of drop-shipping, i.e., where the retailer can not affect demand distribution but the manufacturer can. In their paper, the manufacturer's effort is incorporated analogously to the way we use customer acquisition spending by the retailer. Most of their analysis, however, is done with some quite restrictive assumptions about the functional forms of the problem parameters and decision power in the channel. They demonstrate that vertical disintegration of the channel leads to suboptimal performance but do not derive an optimal coordination contract that would mitigate this problem without side-payments. This, again, is due to the assumption that the effort cannot be contracted upon.

Relevant work on supply chain coordination includes revenue sharing contracts (Cachon and Lariviere [15]), penalty contracts (Lariviere [23]) and returns contracts (Pasternak [29] and Kandel [22]). Jeuland and Shugan [21] model marketing effort for the problem of distribution channel coordination under deterministic demand, but ignore inventory issues. The marketing literature has widely addressed a phenomena of subsidized advertising in the context of franchising agreements (see Michael [25]). The only work that addresses subsidized customer acquisition or advertising between two firms that are not bound by a franchising agreement is Berger [12], Berger [13] and Berger and Magliozzi [14], with inventory issues ignored. Corbett and DeCroix [16] consider a shared savings contract, a problem that is different from ours but is similar in mathematical structure: in our problem, customer acquisition expenses affect the demand; in their problem, use-reduction effort affects the consumption of indirect materials. In their problem, however, there is no inventory involved, and both the upstream supplier and the downstream buyer can exert the effort.

There is a wealth of marketing and economics literature addressing Internet-related issues, though, to the best of our knowledge, the practice of drop-shipping has never been mentioned. The most relevant work is Hoffman and Novak [20], who describe customer acquisition models on the Internet. Finally, the only relevant operations management paper addressing supply chain structures on the Internet of which we are aware of is Van Mieghem and Chopra [38], in which the authors qualitatively address the choice of e-business for a given supply chain.

# 3 Notation and modeling assumptions

We model a supply chain with two echelons: wholesaler and retailer. Only a single product and a single firm in each echelon is considered. Demand for the product is uncertain, and mean demand depends on the amount of customer acquisition spending by the retailer (by customer acquisition we imply the total cost a company spends on advertising and marketing promotions). This is an extension of the standard marketing models that usually assume deterministic demand. Since our focus is the wholesaler-retailer interaction, we assume that the unit price is exogenously given, which is a departure from the traditional literature on marketing-operations interface in which the price is a primary marketing decision variable. Further, all the problem parameters are common knowledge (there is no information asymmetry). We use a single-period (newsvendor) framework. The following notation is used throughout the paper:

$Q$ order quantity,

$r$ unit revenue,

$w$ unit wholesale price,

$c$ unit cost,

$A$ customer acquisition spending (includes all types of related marketing activities),

$D(A)$ demand (random variable), parameterized by the customer acquisition spending,

$f_D(\cdot)$ probability density function of the demand,

$\pi_r, \pi_w, \pi$ profit function of retailer, wholesaler, and total supply chain, correspondingly.

To avoid trivial solutions, we assume that $c < w < r$. Superscripts I, T and D will denote vertically integrated, vertically disintegrated (traditional), and drop-shipping supply chains, correspondingly. Further, we will consider three drop-shipping models. In Model DW the wholesaler has channel power, in Model DR the retailer has channel power, and in Model DN the players have equal power. To simplify the exposition, we assume lost sales and no salvage value. We also assume the following quite general form of the demand distribution:

**Assumption 1.** Demand distribution has the following form: $D(A) = \theta(A) + \varepsilon$, where $\theta(A)$ is a real-valued function and $\varepsilon$ is an arbitrarily distributed random variable.

**Assumption 2.** Expected demand is increasing in customer acquisition spending. The first derivative of the expected demand w.r.t customer acquisition expenditure takes all positive values on the interval $A \in (0, \infty)$ and asymptotically goes to zero:

$$\frac{\partial ED(A)}{\partial A} \geq 0, \ \lim_{A \to 0} \frac{\partial ED(A)}{\partial A} = \infty, \ \lim_{A \to \infty} \frac{\partial ED(A)}{\partial A} = 0.$$

**Assumption 3.** Expected demand is concave in customer acquisition spending:

$$\frac{\partial^2 ED(A)}{\partial A^2} \leq 0.$$

The form of the demand function specified in Assumption 1 is used extensively in the operations and economics literature (see Petruzzi and Dada [30] and references therein). Under this assumption, only the mean demand depends on $A$, and the uncertainty is captured by an error term $\varepsilon$. The first part of Assumption 2 is standard in marketing models (see page 265 in Lilien et.al. [24]). We add the conditions that guarantee the existence of the non-degenerate (interior) solution, which is needed for the comparisons of the models. Assumption 3 is supported by empirical evidence from the marketing literature (see, for example, Simon and Arndt [35] and Aaker and Carman [9]).

# 4 Supply chain models without coordination

In this section we will assume that the retailer and the wholesaler are employing a contractual agreement with a fixed transfer price. This might be a result of outside competition or other arrangements existing in the industry.

## 4.1 Model I - vertically integrated supply chain

The wholesaler and the retailer are vertically integrated. They purchase the product at a fixed cost $c$ and sell it to the customers at a fixed price $r$. The integrated retailer-wholesaler is the sole decision maker who chooses both the stocking quantity and the customer acquisition spending. The integrated firm solves the following problem:

$$\max_{Q,A} \pi^I = \max_{Q,A} E_D \left[ r \min(D(A), Q) - cQ - A \right]. \tag{1}$$

Proposition 1. *The firm's objective function is jointly concave in the decision variables and hence there is a unique solution pair $(Q^I, A^I)$ that is characterized by the following system of equations:*

$$\Pr\left(D\left(A^I\right) < Q^I\right) = \frac{r-c}{r}, \tag{2}$$

$$\left.\frac{\partial ED(A)}{\partial A}\right|_{A^I} = \frac{1}{r-c}. \tag{3}$$

Proof: To prove concavity, it is sufficient to show that the diagonal elements of the Hessian matrix of the objective function are negative and that the determinant of the Hessian is positive. The first derivatives are

$$\frac{\partial \pi^I}{\partial Q} = r \Pr(D(A) > Q) - c, \tag{4}$$

$$\frac{\partial \pi^I}{\partial A} = r \Pr(D(A) < Q) \frac{\partial ED(A)}{\partial A} - 1. \tag{5}$$

The second derivatives are

$$\begin{aligned}
\frac{\partial^2 \pi^I}{\partial Q^2} &= -r f_{D(A)}(Q) < 0, \\
\frac{\partial^2 \pi^I}{\partial A^2} &= -r f_{D(A)}(Q) \left(\frac{\partial ED(A)}{\partial A}\right)^2 + r \Pr(D(A) < Q) \frac{\partial^2 ED(A)}{\partial A^2} < 0, \\
\frac{\partial^2 \pi^I}{\partial Q \partial A} &= r f_{D(A)}(Q) \frac{\partial ED(A)}{\partial A} > 0.
\end{aligned}$$

The diagonal elements are clearly negative by Assumptions 1 and 2. Positivity of the determinant is equivalent to the following condition:

$$\frac{\partial^2 \pi^I}{\partial Q^2} \frac{\partial^2 \pi^I}{\partial A^2} > \frac{\partial^2 \pi^I}{\partial Q \partial A} \frac{\partial^2 \pi^I}{\partial A \partial Q}.$$

This can be expanded as follows:

$$-r f_{D(A)}(Q) \times \left[-r f_{D(A)}(Q) \left(\frac{\partial ED(A)}{\partial A}\right)^2 + r \Pr(D(A) < Q) \frac{\partial^2 ED(A)}{\partial A^2}\right] > \left[r f_{D(A)}(Q) \frac{\partial ED(A)}{\partial A}\right]^2.$$

After collecting similar terms we obtain

$$-r^2 f_{D(A)}(Q) \Pr(D(A) < Q) \frac{\partial^2 ED(A)}{\partial A^2} > 0.$$

This is true by Assumption 3 which completes the proof of concavity. Further, it is convenient to substitute the first optimality condition into the second to obtain the final solution. ■

### 4.2 Model T - traditional supply chain

The wholesaler buys the product at a fixed unit cost $c$ and sells it to the retailer at a fixed wholesale price $w$. The retailer holds inventory and sells it to the customers at a fixed price $r$. The retailer here is the sole decision maker who decides on both the stocking quantity and the customer acquisition spending. The retailer's problem is

$$\max_{Q,A} \pi_r^T = \max_{Q,A} E_D \left[r \min(D(A), Q) - wQ - A\right]. \tag{6}$$

The wholesaler buys from the manufacturer quantity $Q^T$ and sells it to the retailer with profit

$$\pi_w^T = (w - c)Q. \tag{7}$$

PROPOSITION 2. *The retailer's objective function is jointly concave in the decision variables and hence there is a unique solution pair* $(Q^T, A^T)$ *that is characterized by the following system of equations:*

$$\Pr\left(D\left(A^T\right) < Q^T\right) = \frac{r - w}{r}, \tag{8}$$

$$\left.\frac{\partial ED(A)}{\partial A}\right|_{A^T} = \frac{1}{r - w}. \tag{9}$$

PROOF: Similar to Proposition 1. ■

Note that although in this model the retailer is the sole decision maker and therefore seems to possess some power in the chain, she also bears all the inventory-related risk. In addition, customer acquisition spending incurred by the retailer not only benefits her but also benefits the wholesaler. As we will demonstrate later, this leads to the suboptimal performance of the channel.

### 4.3 Model D – drop-shipping

The wholesaler buys the product at unit cost $c$, holds inventory, and ships the product directly to the customer upon the retailer's request. The retailer acquires customers and makes sales. She pays wholesale price $w$ per closed sale to the wholesaler, receives fixed revenue $r$ from the customer, and does not hold inventory. Note at this point that under drop-shipping, contracts between the wholesaler and the retailer are not limited to the transfer pricing agreements. Since the product is never physically transferred to the retailer, it is often natural to consider a contract where the revenue is split between the retailer and the wholesaler in proportions $\lambda$ and $1-\lambda$, and there is no need to establish a wholesale price. For example, Scheel [33] indicates that in the drop-shipping business the dominant practice is for the wholesaler to give the retailer a discount over the suggested retail price. We do not consider such agreements since the analysis is identical to the transfer price contracts with $w = (1-\lambda)r$. Three situations arise: either the wholesaler or the retailer might have negotiation power in the supply chain and act as Stackelberg leaders, or it is possible that the players have equal power and therefore the solution is in the form of a Nash equilibrium. We will consider all three situations.

Denote the best response function of the retailer by $R_r(Q)$ and the best response function of the wholesaler by $R_w(A)$. At this point we have not demonstrated either uniqueness or even existence of the equilibrium. It helps, however, to visualize the problem first. We begin by presenting the game graphically (see Figure 1). The picture illustrates the best response curves (parameters are taken from the example in Section 6 with $r = 10$). The point $(A^{DN}, Q^{DN})$ is a Nash equilibrium that is located on the intersection of the best-response curves. A Stackelberg equilibrium with the wholesaler as a leader $(A^{DW}, Q^{DW})$ is located on the retailer's best-response curve, and a Stackelberg equilibrium with the retailer as a leader $(A^{DR}, Q^{DR})$ is located on the wholesaler's response curve. We begin by characterizing the best response curves analytically. For a given $Q$, the retailer's problem is

$$\max_A \pi_r^D = \max_A E_D \left[(r-w)\min(D(A), Q) - A\right]. \tag{10}$$

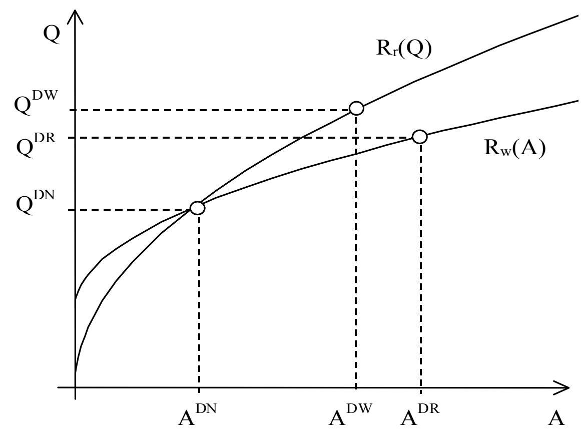


Figure 1: Stackelberg and Nash equilibria.

Note that the objective function is concave, and hence the retailer's first-order conditions characterize the unique best response. The slope of the retailer's best-response function is found by implicit differentiation as follows:

$$\frac{\partial R_r(Q)}{\partial Q} = -\frac{\frac{\partial^2 \pi_r^D}{\partial A \partial Q}}{\frac{\partial^2 \pi_r^D}{\partial Q^2}} = \frac{f_D(Q)\frac{\partial ED(A)}{\partial A}}{f_D(Q)\left(\frac{\partial ED(A)}{\partial A}\right)^2 - \Pr(D(A) < Q)\frac{\partial^2 ED(A)}{\partial A^2}} > 0. \tag{11}$$

Positivity of the slope means that the retailer's customer acquisition spending is increasing in the quantity that the wholesaler stocks. However, due to the complexity of the expression for the slope, we are unable to verify either concavity or convexity of the best response function. Fortunately, this is not essential for any of the later results. Note that Figure 1 shows the retailer's best-response as a convex function, which is the case for the specific problem parameters used. We will now characterize the wholesaler's best response. For a given $A$, the wholesaler's problem is similar to the newsvendor problem:

$$\max_Q \pi_w^D = \max_Q E_D\left[w \min(D(A), Q) - cQ\right]. \tag{12}$$

Again the objective function is concave, and the wholesaler's first-order conditions characterize the unique best response. The slope of the wholesaler's best response function is found by implicit differentiation as follows:

$$\frac{\partial R_w(A)}{\partial A} = -\frac{\frac{\partial^2 \pi_w^D}{\partial Q \partial A}}{\frac{\partial^2 \pi_w^D}{\partial A^2}} = \frac{\partial E(D)}{\partial A} > 0. \tag{13}$$

We see that the stocking quantity of the wholesaler is increasing in the customer acquisition spending by the retailer. This time we can also find the second derivative

$$\frac{\partial^2 R_w(A)}{\partial A^2} = \frac{\partial^2 E(D)}{\partial A^2} < 0,$$

and it follows that the wholesaler's best response function is concave. We are then ready to demonstrate that, when the retailer and the wholesaler have equal power in the channel, there will be a unique Nash equilibrium.

PROPOSITION 3. *There exists a unique, globally stable Nash equilibrium pair* $(Q^{DN}, A^{DN})$ *in the retailer-wholesaler game. It is characterized by the following system of equations:*

$$\begin{aligned} \Pr\left(D\left(A^{DN}\right) < Q^{DN}\right) &= \frac{w-c}{w}, \\ \left.\frac{\partial ED(A)}{\partial A}\right|_{A^{DN}} &= \frac{1}{r-w}\frac{w}{w-c}. \end{aligned}$$

PROOF: Existence of the equilibrium follows from the concavity of the retailer's and the wholesaler's objective functions (see Moulin [27]). To show uniqueness and global stability of the equilibrium, it is sufficient to demonstrate that the multiplication of the slopes of the best response functions is never more than one in absolute value, and hence we have a contraction mapping (Moulin [27]). This is readily verified:

$$\left|\frac{\partial R_r(Q)}{\partial Q} \times \frac{\partial R_w(A)}{\partial A}\right| = \frac{f_D(Q)\left(\frac{\partial ED(A)}{\partial A}\right)^2}{f_D(Q)\left(\frac{\partial ED(A)}{\partial A}\right)^2 - \Pr(D(A) < Q)\frac{\partial^2 ED(A)}{\partial A^2}} < 1. \blacksquare$$

We now consider the problem in which the wholesaler acts as a Stackelberg leader and offers the retailer a "take-it-or-leave-it" contract that specifies a quantity of merchandise the wholesaler is willing to stock. As we saw, the slope of the retailer's best response function has a non-trivial form, and hence it is hard to demonstrate the uniqueness of the equilibrium. However, we will show that there is an interior equilibrium that must satisfy the first-order conditions.

PROPOSITION 4. *Define:*

$$\beta(A^{DW}, Q^{DW}) = \min\left[\frac{w}{w-c}, 1 - \frac{\partial ED(A)}{\partial A} \times \left.\frac{\partial R_r(Q)}{\partial Q}\right|_{A^{DW}, Q^{DW}}\right].$$

*Further, assume that* $f_D(x) = 0$ *on* $(-\infty, 0]$. *Then in a problem with a powerful wholesaler there exists a Stackelberg equilibrium solution pair* $(Q^{DW}, A^{DW})$ *characterized by the following system of equations:*

$$\Pr(D(A^{DW}) < Q^{DW}) = \frac{w-c}{\beta\left(A^{DW}, Q^{DW}\right) w}, \tag{14}$$

$$\left.\frac{\partial ED(A)}{\partial A}\right|_{A^{DW}} = \frac{1}{r-w}\frac{\beta\left(A^{DW}, Q^{DW}\right) w}{w-c}. \tag{15}$$

Proof: The retailer acts second by solving (10). The wholesaler takes into account the retailer's best response function characterized by (11) and solves the following problem:

$$\max_Q \pi_w^D = \max_Q E_D \left[ w \min(D(R_r(Q)), Q) - cQ \right].$$

Since the retailer's best response function is single-valued, the Stackelberg equilibrium exists. Further, we will show that the equilibrium can not be on the boundaries and hence must satisfy the first-order conditions. The first derivative of the wholesaler's objective function is

$$\begin{aligned}
\frac{d\pi_w^D}{dQ} &= \frac{\partial \pi_w^D}{\partial Q} + \frac{\partial \pi_w^D}{\partial A}\frac{\partial R_r(Q)}{\partial Q} \\
&= w \Pr(D(R_r(Q)) > Q) + w \Pr(D(R_r(Q)) < Q) \frac{\partial ED(A)}{\partial A}\frac{\partial R_r(Q)}{\partial Q} - c \\
&= (w - c) - w \Pr(D(R_r(Q)) < Q) \left(1 - \frac{\partial ED(A)}{\partial A}\frac{\partial R_r(Q)}{\partial Q}\right).
\end{aligned}$$

First, suppose that the wholesaler's solution is $Q^{DW} = 0$. $\Pr(D(R_r(0)) < 0) = 0$, and hence

$$\left.\frac{d\pi_w^D}{dQ}\right|_{Q=0} = w - c > 0.$$

This is clearly not an equilibrium. Second, suppose that the wholesaler's solution is $Q^{DW} = \infty$. Note that in the previous proposition we demonstrated that

$$\frac{\partial ED(R_r(Q))}{\partial Q} = \frac{\partial ED(A)}{\partial A}\frac{\partial R_r(Q)}{\partial Q} < 1.$$

Therefore, $\lim_{Q\to\infty} \Pr(D(R_r(Q)) < Q) = 1$ and also $\lim_{Q\to\infty} f_{D(R_w(Q))}(Q) = 0$. Finally,

$$\lim_{Q\to\infty} \frac{\partial ED(A)}{\partial A}\frac{\partial R_r(Q)}{\partial Q} = \lim_{Q\to\infty} \frac{f_{D(R_r(Q))}(Q)\left(\frac{\partial ED(A)}{\partial A}\right)^2}{f_{D(R_w(Q))}(Q)\left(\frac{\partial ED(A)}{\partial A}\right)^2 - \Pr(D(R_w(Q)) < Q)\frac{\partial^2 ED(A)}{\partial A^2}} = 0,$$

and

$$\lim_{Q\to\infty} \frac{d\pi_w^D}{dQ} = -c < 0.$$

Clearly, right boundary is also not an equilibrium. This completes the proof. ■

Note that the first-order condition is necessary but not sufficient for the global optimality of the solution. This, however, is not essential to any of our results since all that matters is that the equilibrium must satisfy the first-order conditions. Suppose now that the retailer acts as a Stackelberg leader and offers the wholesaler a "take-it-or-leave-it" contract that specifies an amount of money the retailer is willing to spend on customer acquisition.

Proposition 5. *In a problem with a powerful retailer, there is a unique Stackelberg equilibrium solution pair* $(Q^{DR}, A^{DR})$ *that is characterized by the following system of equations:*

$$\Pr(D(A^{DR}) < Q^{DR}) = \frac{w-c}{w}, \tag{16}$$

$$\left.\frac{\partial ED(A)}{\partial A}\right|_{A^{DR}} = \frac{1}{r-w}. \tag{17}$$

Proof: The wholesaler acts second by solving (12). The retailer takes into account the wholesaler's best response function characterized by (13) and solves the following problem:

$$\max_A \pi_r^D = \max_A E_D\left[(r-w)\min(D(A), R_w(A)) - A\right].$$

Since the wholesaler's best response function is single-valued, the Stackelberg equilibrium exists. The first derivative is

$$\begin{aligned}\frac{d\pi_r^D}{dA} &= \frac{\partial \pi_r^D}{\partial A} + \frac{\partial \pi_r^D}{\partial Q}\frac{\partial R_r(A)}{\partial A} \\ &= (r-w)\Pr(D<Q)\frac{\partial E(D)}{\partial A} + (r-w)\Pr(D>Q)\frac{\partial R_w(A)}{\partial A} - 1 = (r-w)\frac{\partial E(D)}{\partial A} - 1,\end{aligned}$$

and the second derivative is

$$\frac{\partial^2 \pi_r^D}{\partial A^2} = (r-w)\frac{\partial^2 E(D)}{\partial A^2} < 0.$$

The retailer's objective function is clearly concave, and the uniqueness of the Stackelberg equilibrium follows. Finally, the optimality conditions are found by equating the first derivatives to zero. ■

Note that in Model D, as opposed to Model T, the wholesaler bears all the inventory-related risk. The retailer still incurs all the customer acquisition costs that will benefit not only her, but also the wholesaler. Hence, none of the players has an incentive to behave system-optimally, as we will show later.

### 4.4 Comparative analysis of the models

The interpretation of the first optimality condition (for $Q$) in each model is a standard one for the newsvendor-type models: equating the marginal cost of stocking an extra unit of the product with the marginal benefit. The second optimality condition (for $A$) has a similar interpretation in the marketing literature.

Observation 1. *Denote by* $\eta(A)$ *the elasticity of expected demand w.r.t customer acquisition spending. Formally:*

$$\eta(A) = \frac{\partial ED(A)}{\partial A} \Bigg/ \frac{ED(A)}{A}.$$

*Then retailer's optimality conditions for all Models can be re-written as follows:*

$$
\begin{aligned}
\eta(A^I)\frac{r-c}{r} &= \frac{A^I}{rED(A^I)},\\
\eta(A^T)\frac{r-w}{r} &= \frac{A^I}{rED(A^T)},\\
\eta(A^{DW})\frac{w-c}{\beta w}\frac{r-w}{r} &= \frac{A^{DW}}{rED(A^{DW})},\\
\eta(A^{DR})\frac{r-w}{r} &= \frac{A^{DR}}{rED(A^{DR})},\\
\eta(A^{DN})\frac{w-c}{w}\frac{r-w}{r} &= \frac{A^{DN}}{rED(A^{DN})}.
\end{aligned}
$$

*Each optimality condition is interpreted as follows: the ratio of the total customer acquisition spending to the total expected revenue (right hand side) is equal to the demand elasticity times the retailer's relative marginal profit (left-hand side which is revenue minus marginal cost divided by the revenue).*

The result of Observation 1 parallels a result frequently encountered in the marketing literature (see, for example, page 571 in Lilien et. al. [24]).

Observation 2. *In all models, customer acquisition spending and stocking quantity are strategic complements.*

Proof: A sufficient condition for strategic complementarity is positivity of the cross-partial derivative of the objective function, which can be easily verified. ■

For identical parameters, we can perform analytical comparisons of the models. The following table summarizes the optimality conditions of the five models:

| | | | |
|---|---|---|---|
| Model I | | $\Pr\left(D\left(A^I\right) < Q^I\right) = \frac{r-c}{r}$ | $\frac{\partial ED(A)}{\partial A} = \frac{1}{r-c}$ |
| Model T | | $\Pr\left(D\left(A^T\right) < Q^T\right) = \frac{r-w}{r}$ | $\frac{\partial ED(A)}{\partial A} = \frac{1}{r-w}$ |
| | Powerful wholesaler | $\Pr\left(D\left(A^{DW}\right) < Q^{DW}\right) = \frac{w-c}{\beta w}$ | $\frac{\partial ED(A)}{\partial A} = \frac{1}{r-w}\frac{\beta w}{w-c}$ |
| Model D | Powerful retailer | $\Pr\left(D\left(A^{DR}\right) < Q^{DR}\right) = \frac{w-c}{w}$ | $\frac{\partial ED(A)}{\partial A} = \frac{1}{r-w}$ |
| | Nash equilibrium | $\Pr\left(D\left(A^{DN}\right) < Q^{DN}\right) = \frac{w-c}{w}$ | $\frac{\partial ED(A)}{\partial A} = \frac{1}{r-w}\frac{w}{w-c}$ |

The next Proposition summarizes the comparative behavior of the models under the same wholesale price.

Proposition 6. *Suppose that in all five models the retail price, the wholesale price, the unit product cost, and the demand distribution are identical. Then the following characterizations hold:*

*a*) **Customer acquisition:** $A^I \geq A^T = A^{DR} \geq A^{DW} \geq A^{DN}$, *the customer acquisition spendings are the highest in Model I and the lowest in Model D.*

*b*) **Stocking quantities:** $Q^I \geq Q^T$ *and* $Q^I \geq Q^{DR} \geq Q^{DN}$. *If* $w \leq \sqrt{cr}$ *then* $Q^T \geq Q^{DR} > Q^{DN}$. *If* $w > \sqrt{cr}$ *then* $Q^{DR} > Q^T$ *and* $Q^{DR} > Q^{DN}$. *Further, among the three drop-shipping models, Model DN always has the lowest stocking quantity,* $Q^{DW} \geq Q^{DN}$ *and* $Q^{DR} \geq Q^{DN}$.

*c*) **Retailer's profits:** $\pi_r^{DR} \geq \pi_r^{DN}, \pi_r^{DW} \geq \pi_r^{DN}$, *the retailer makes the lowest profits under the Nash equilibrium.*

*d*) **Wholesaler's profits:** $\pi_w^{DR} \geq \pi_w^{DW} \geq \pi_w^{DN}$.

*e*) **System profits:** *For* $w \leq \sqrt{cr}$, $\pi^I \geq \pi^T \geq \pi^{DR}$. *If* $w > \sqrt{cr}$ *then* $\pi^I \geq \pi^{DR} \geq \pi^T$. *Further, it is always true that* $\pi^{DW} \geq \pi^{DN}$ *and* $\pi^{DR} \geq \pi^{DN}$.

Proof: Results $a$), $b$), and $c$) are obtained by a pair-wise comparison of the first-order conditions and employing the fact that $\partial ED(A)/\partial A$ is decreasing in $A$. Results $\pi_r^{DR} \geq \pi_r^{DN}$ and $\pi_w^{DW} \geq \pi_w^{DN}$, i.e. the Stackelberg leader makes more profits than in a Nash equilibrium, are standard for Stackelberg games (see Simaan and Cruz [34]). The other results in $c$) and $d$) are obtained as follows:

$$\pi_r^{DN} = \pi_r^D(A^{DN}, Q^{DN}) \leq \pi_r^D(A^{DN}, Q^{DW}) \leq \pi_r^D(A^{DW}, Q^{DW}) = \pi_r^{DW},$$

where the first inequality follows from the observation that in Model D the retailer's profit is increasing in $Q$ for a fixed $A$, and the second inequality holds since $A^{DW}$ is an optimal response to $Q^{DW}$. Similarly

$$\pi_w^{DN} = \pi_w^D(A^{DN}, Q^{DN}) \leq \pi_w^D(A^{DW}, Q^{DN}) \leq \pi_w^D(A^{DW}, Q^{DW}) = \pi_w^{DW},$$

and also

$$\pi_w^{DW} = \pi_w^D(A^{DW}, Q^{DW}) \leq \pi_w^D(A^{DR}, Q^{DW}) \leq \pi_w^D(A^{DR}, Q^{DR}) = \pi_w^{DR}.$$

Finally, $e$) follows from the fact that the system profit is jointly concave in $A$ and $Q$, combined with the results in $c$) and $d$). ■

From part $a$) of Proposition 6, we see that vertical disintegration leads to underspending on customer acquisition by the retailer, and in drop-shipping models the retailer underspends more than in the traditional model due to the misalignment of marketing and operations functions. It is interesting to note that the drop-shipping model performs the worst when players have equal power. The customer acquisition spending is closest to the system optimum when the retailer has channel power. The first part of this finding, $A^I \geq A^T$, that vertical disintegration leads to underspending on marketing effort, is similar to the result obtained by Jeuland and Shugan [21]. They, however, ignore inventory issues and consider deterministic price-dependent demand.

The intuition behind part $b$) of the proposition is that not only does vertical disintegration lead to putting too little effort into customer acquisition in Models T and D, but also it leads to understocking. This is an effect caused by the double marginalization that was described in the economics, marketing, and operations literatures. We also see that, for moderate to high wholesale price, the drop-shipping model with a powerful retailer always leads to ordering more than in the traditional model. The model with powerful wholesaler is not that transparent to the analysis, due to the presence of $\beta$ that depends on problem parameters in a non-trivial way. Note, however, that by studying Figure 1 we can see that $Q^{DW}$ can be above or below $Q^{DR}$, depending on the curvature of response functions. The Nash equilibrium again results in the lowest (i.e. the worst) stocking quantity.

Parts $c$) and $d$) state that in a model with Nash equilibrium both players are worse off than in the other two drop-shipping models, and also that the wholesaler prefers the model with a powerful retailer over the other two. This makes Model DR a potential candidate for the best of the three drop-shipping arrangements.

Finally, part $e$) summarizes the most important findings. We see that for a relatively small $w$ there is no hope that either Model DR or DN will outperform the traditional model. However, for moderate to high wholesale prices, Model DR always outperforms the traditional model. Moreover, there is hope that even Model DN outperforms the traditional model for high wholesale prices. Note also that in the condition $w > \sqrt{cr}$, the threshold value $\sqrt{cr}$ is closer to $c$ (the lowest possible wholesale price) than to $r$ (the highest possible wholesale price), and hence this condition accounts for more than 50% of possible values of $w$.

## 5 Supply chain coordination

In the previous section, we demonstrated that the solutions of Models T and D are generally different from the system-optimal solution. In addition to the double marginalization effect, drop-shipping is also plagued by marketing-operations misalignment. Can we come up with a mechanism that will induce coordination? As the next observation shows, a price-only contract is not sufficient.

Observation 3. *In Model T, the sole price-only contract that induces coordination has* $w^T = c$ *in* *which the retailer captures all profits, and in Model D there is no such contract.*

Not only are the price-only contracts inefficient, but also none of the other currently known contracts can coordinate the supply chain when customer acquisition expenses are considered.

OBSERVATION 4. *None of the following contracts – returns, quantity-flexibility, penalty (all as described by Lariviere [23]), revenue sharing (as described by Cachon and Lariviere [15]), or quantity discount (as described by Jeuland and Shugan [21]) – can coordinate the supply chains in Models T or D.*

To our knowledge, the only known contracts that work here are quantity forcing and franchising (Lariviere [23]). These contracts, however, might be difficult to implement in practice, as was noted in the literature. Clearly, in order to coordinate the supply chains considered here, we need a new form of contract. In Model T, we need a mechanism that will allocate a part of inventory risk to the wholesaler and also make the wholesaler bear some part of the marketing expenses. Pasternak [29] and Kandel [22] show that a returns contract in which the wholesaler offers partial credit for returned merchandise achieves supply chain coordination in the absence of marketing aspects. In our case, we extend this contract by adding the notion of subsidized advertising. We will now state and prove our second main result.

PROPOSITION 7. *The following contract achieves supply chain coordination in Model T: the wholesaler sponsors a portion of the retailer's customer acquisition expenses $a = (w - c)/(r - c)$, and at the same time offers the retailer partial credit for all unsold merchandise in the amount $b = ra$ per unit. Under this contract, the retailer and the wholesaler split the total profit in proportions $1 - a$ and $a$, respectively.*

PROOF: The wholesaler's objective function is

$$\pi_w^T = E_D\left[(w-c)Q - b(Q - D(A))^+ - aA\right].$$

By substituting optimal coordination parameters and using the fact that $(Q-D)^+ = Q - \min(Q, D)$, we get

$$\begin{aligned}\pi_w^T &= E_D\left[(w-c)Q - ra(Q - \min(Q,D)) - aA\right] \\ &= aE_D\left[(r-c)Q - rQ + r\min(Q,D) - A\right] \\ &= aE_D\left[r\min(Q,D) - A - cQ\right].\end{aligned}$$

Clearly, the objective function in the brackets is the integrated supply chain's profit. Similarly, the retailer's objective function is

$$\pi_r^T = E_D\left[r\min(D(A),Q) - wQ - (1-a)A + b(Q-D(A))^+\right].$$

Using the same technique we get

$$\begin{aligned}\pi_r^T &= E_D\left[r\min(D,Q) - wQ - (1-a)A + ra(Q - \min(Q,D))\right] \\ &= (1-a)E_D\left[r\min(Q,D) - A - cQ\right].\end{aligned}$$

Hence, the wholesaler and the retailer will choose the system optimal decisions and get a proportion of the profits. This completes the proof. ■

Interestingly, the proportion of profit captured by the wholesaler is equal to the proportion of customer acquisition costs she sponsors. If the wholesaler can influence the wholesale price $w$, she should choose it in combination with $a$, so that $a$ is as high as possible. This finding has an interesting implication for current business practices on the Internet. Currently, many e-tailers are plagued by huge marketing expenditures, while our finding demonstrates that wholesalers might consider subsidizing a significant proportion of these expenditures to their own benefit. Of course, the higher the subsidized advertising, the higher the wholesale price. In practice this would mean that a retailer without sufficient funds for customer acquisition should seek a contract with a wholesaler who would be willing to subsidize a large portion of advertising in exchange for a higher wholesale price.

A different but somewhat similar contract works for Model D. A returns contract will not help here since all the inventory-related risk is with the wholesaler. Hence, we need a contract that would allocate some inventory-related risk to the retailer, while at the same time allocating some marketing expenses to the wholesaler. One such contract would be for the retailer to compensate the wholesaler for each unit of the unsold inventory while the wholesaler subsidizes a portion of customer acquisition expenses. Such contract is similar but different from a contract described by Lariviere [23] in which the wholesaler penalizes the retailer for each lost sale.

PROPOSITION 8. *The following contract achieves supply chain coordination in Model D: the wholesaler sponsors a proportion of the retailer's customer acquisition expenses* $a = (w-c)/(r-c)$, *and at the same time the retailer partially compensates the wholesaler for all unsold merchandise in the amount* $p = c(1-a)$ *per unit. Under this contract, the retailer and the wholesaler split total profit in proportions* $1-a$ *and* $a$, *respectively.*

Proof: Similar to Proposition 7. ■

Insights here are similar: the wholesaler gets a proportion of profits that is equal to the proportion of the customer acquisition expenses she sponsors. It follows that the wholesaler should strive to sponsor a relatively large portion of the retailer's customer acquisition expenses in combination with charging a higher wholesale price. Lariviere [23] notes that penalty contracts are hard to implement in practice, since, in his penalty contract, the wholesaler has to be able to observe lost sales at the retailer, which is impractical. Our penalty scheme is easier (although it might still be hard) to implement since the unsold inventory can easily be accounted for. Note also that both optimal contracts do not depend on the demand distribution, as was noted by Pasternak [29] for pure returns contracts. This leads us to another observation:

Observation 5. *Propositions 7 and 8 hold for any demand distributions, including the ones that do not satisfy Assumptions 1-3.*

The last observation shows that the contracts we propose are robust, as has been repeatedly shown for returns contracts. We can do some comparison of the optimal contracts for Models T and D. First, note that in both cases the wholesaler sponsors the same proportion of the retailer's marketing costs (provided that the wholesale price is the same). This is a convenient property since, in this way, if the wholesaler works with both the traditional and the drop-shipping retailers, she does not need to discriminate among them. Discrimination in terms of subsidized customer acquisition costs might invoke some undesirable consequences due to legal limitations, since such discrimination might be considered as preferential treatment for some retailers. It is, however, possible that the wholesale prices in Models T and D will be different. Since the wholesaler in Model D has more involvement in channel functions and takes inventory risk, she is likely to demand a higher wholesale price. Scheel [33] provides empirical data that indicates 10-20% higher wholesale prices for drop-shipping vs. conventional distribution were established by the wholesalers to cover their extra expenses.

Observation 6. *Suppose $w^T < w^D$. Then in coordinated supply chains, $a^T < a^D$ and $\pi_w^T < \pi_w^D$, the wholesaler sponsors more of the customer acquisition costs and has higher expected profit in the drop-shipping model.*

Drop-shipping requires a certain investment from the wholesaler, since she should be able to handle small shipments directly to the customer. This would lead the wholesaler to demand an increase in the wholesale price, resulting in, as the last observation shows, capturing more profits which are beneficial in the long run.

The penalty contract (as described by Lariviere [23]) and the revenue sharing contract (as described by Cachon and Lariviere [15]) will also, when combined with subsidized advertising, coordinate Model T, but they fail to coordinate Model D. As an example, we consider the revenue sharing contract:

PROPOSITION 9. *The following contract achieves supply chain coordination in Model T: the retailer offers the wholesaler a proportion $\gamma = (w-c)/c$ of the revenues, and at the same time the wholesaler sponsors a portion of the retailer's customer acquisition expenses $\gamma$. Under this contract, the retailer and the wholesaler split the total profit in proportions $1-\gamma$ and $\gamma$.*
PROOF: Similar to Proposition 7. ■

As we can see, not only does the revenue sharing contract work, but it also preserves its powerful property of coordinating the supply chain when demand is a function of price. This is due to the fact that the contract parameters do not depend on the unit revenue $r$. Although powerful, the revenue sharing contract fails to coordinate the drop-shipping supply chain. This result is predictable since, in the drop-shipping model, a portion of the inventory-related risk has to be allocated to the retailer, which can not be achieved with the revenue sharing.

## 6 Numerical experiments

To illustrate all the models and gain additional insights into the differences among the alternative supply chain structures, we will now consider a specific form of the demand distribution and a specific form of its dependence on customer acquisition expenses[1]. Let the random term of the demand follow a uniform distribution, $\varepsilon \sim U[0, \Delta]$. Further, let $\theta(A) = \sqrt{A}$. For numerical experiments, we will assume that $c = 5$ and $\Delta = 1$. The variable of interest is, of course, the wholesale price. This also allows insight into cases where the wholesale price of the drop-shipping supply chains is different from the wholesale price of the traditional supply chain. In what follows, we assume that the price-only contract is used. We analyze three scenarios: $r = 6$, 10, and 40, to illustrate the situations with low, moderate, and high margins. Note that the optimal profits and decision variables can be obtained and compared in closed-form. First, we look at the optimal customer

[1]A link to an interactive web site for numerical experiments is provided at www.nilsrudi.com.

acquisition expense (Figure 2) and stocking quantity (Figure 3).

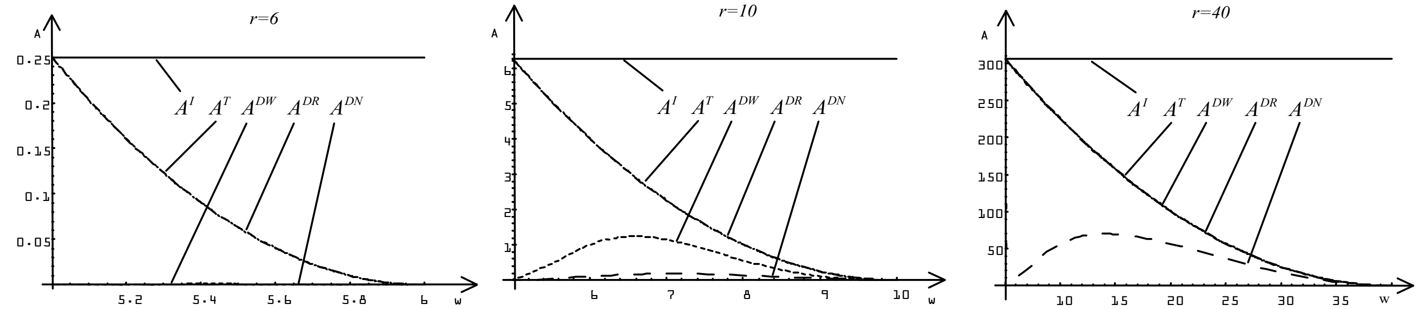


Figure 2: Optimal customer acquisition spending.

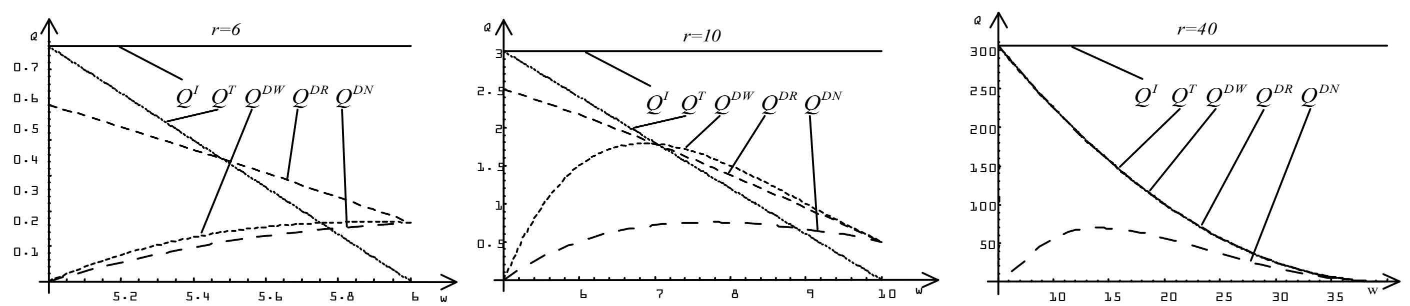


Figure 3: Optimal stocking quantity.

As we can see from both pictures, in Model DN the retailer severely underspends on the customer acquisition and understocks. When margins are high, drop-shipping models with a Stackelberg leader closely resemble the traditional model. We will see this phenomena again later. Finally, Model DW with the powerful wholesaler appears to perform somewhere in between the other two drop-shipping models, approaching Model DN for low margins and Model DR for high margins. We will now consider the retailer's profits (Figure 4).

In terms of the retailer's profit, the drop-shipping models outperform the traditional vertically disintegrated model for a wide range of parameters. The retailer (not surprisingly) is generally better off in Model DR where she has negotiation power. But even when the negotiation power is with the wholesaler (Model DW), the retailer's profit is higher than when the solution is a Nash equilibrium (Model DN) as we demonstrated analytically. Any drop-shipping model dominates the traditional model for moderate to high wholesale prices. We consider the wholesaler's profit next (Figure 5).

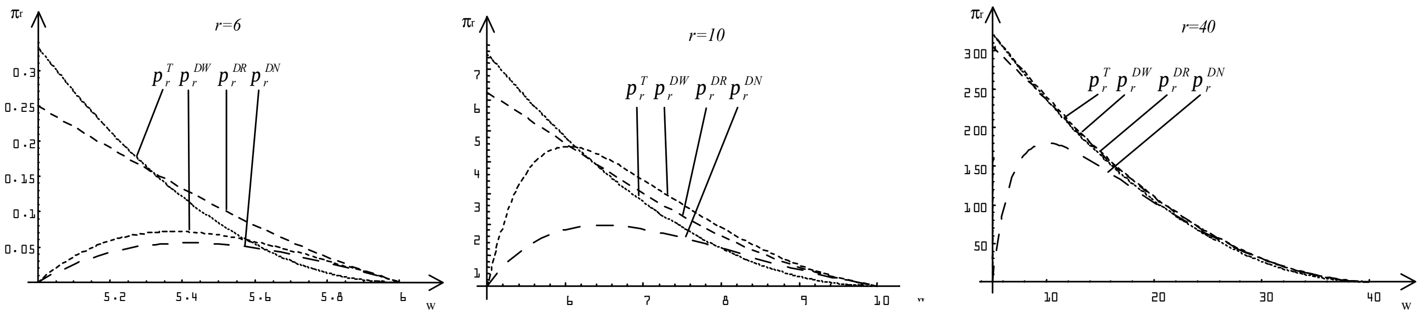


Figure 4: Retailer's profit.

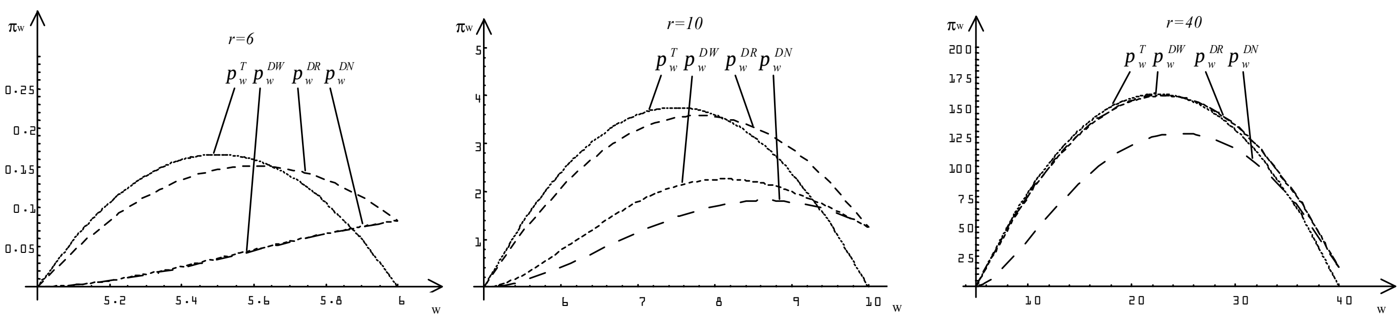


Figure 5: Wholesaler's profit.

Surprisingly, negotiation power does not do the wholesaler much good: she is generally better off when the retailer acts as a leader. The wholesaler's expected profit is virtually the same in the traditional channel structure T as in the drop-shipping structure with powerful retailer DR. When the wholesale price is relatively high, then both players prefer Model DR over Model T – this gives indications for when (i.e. in terms of wholesale price) this model is preferable. The Nash equilibrium is again the least attractive to anyone. Model DW performs somewhere in between Models DR and DN. Finally, we look at the system profits (Figure 6).

The drop-shipping model DR with the powerful retailer proves to be superior under moderate to high wholesale prices, as we demonstrated earlier. Under a very high wholesale price, any drop-shipping model beats the traditional model. Among the three drop-shipping models, Model DN is

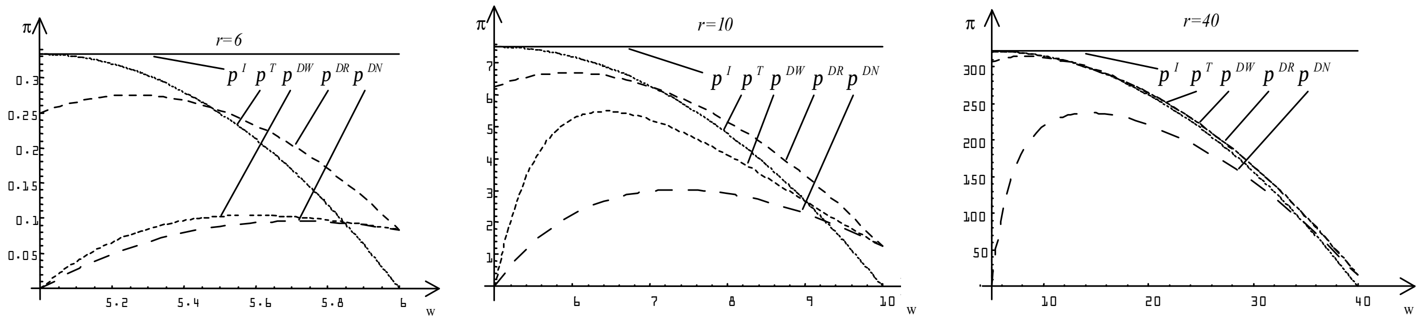


Figure 6: System profit.

consistently the worst, and Model DR is consistently the best.

Several lessons can be learned from the numerical experiments above. First, the drop-shipping agreements are inferior when the parties have equal power. Second, Model DR with a powerful retailer performs very well under moderate to high wholesale prices, and all chain members prefer it over the traditional model. Therefore, the retailer who is able to exert power over the wholesaler (possibly through access to a unique customer base) should opt for drop-shipping while agreeing to a relatively high wholesale price – in this case both channel members benefit. A powerful wholesaler has no good reason to prefer drop-shipping over the traditional agreement. In most situations Model DW (which did not appear very analytically tractable) performs somewhere between the other two drop-shipping models.

Finally, we will illustrate the coordinating contracts. Assume that $c = 5$, $r = 10$, and $\Delta = 1$. We denote profits for the retailer and the wholesaler resulting from the coordinating contract by $\pi_r^C$ and $\pi_w^C$, correspondingly. As we noted before, a returns contract for the traditional supply chain and a penalty contract for the drop-shipping models splits profits in the same proportions. Figure 7 presents retailer's and wholesaler's profits with and without coordination for all models.

Observe that, in our example, under the coordinating contract, the retailer always makes more profit than without the coordinating contract. This is not true in general: under the low unit-revenue and high variability the retailer may be better off without the contract for high wholesale prices. The wholesaler, however, might be better off without coordination for low wholesale prices. Thus, Pareto optimality of the coordinating contract depends on the problem parameters.

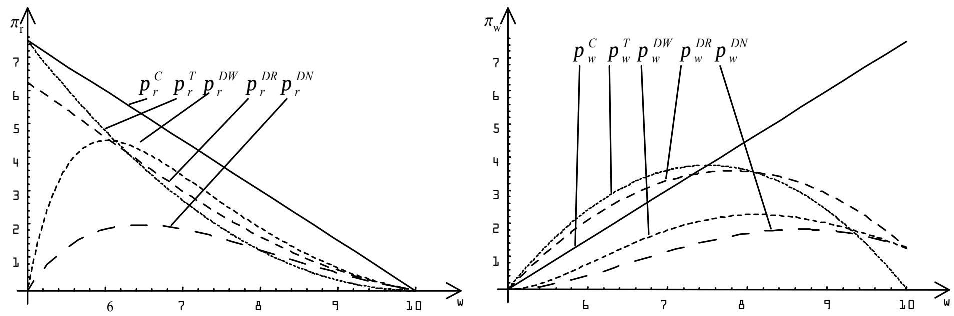


Figure 7: Retailer's and wholesaler's profits with and without coordination.

# 7 Conclusions and discussion

Drop-shipping is a novel way of doing business on the Internet that has been inherited from catalog businesses and has already gained tremendous popularity. It allows retailers to focus on customer acquisition while outsourcing all the distribution tasks to the wholesaler. In this way, e-tailers can reduce the amount of capital required for operations. The wholesaler, on the other hand, can benefit by increasing its involvement into the supply chain operations and hence capture more profit. Currently, large retailers are able to capture a major part of the supply chain profit. Adopting drop-shipping will give wholesalers an opportunity to change this unbalance. Simultaneously, small retailers will benefit since barriers to entry in the form of large up-front inventory investment will diminish.

We find that drop-shipping introduces a conflict between marketing and operations functions that results in inefficiencies in the form of simultaneous understocking and spending too little on customer acquisition. As a result, both the retailer and the wholesaler should choose drop-shipping over the traditional contract only when the wholesale price is moderate to high. For example, if supply chain members decide to move from a traditional way of doing business to drop-shipping, one should consider a simultaneous wholesale price increase. This finding is consistent with the fact that under drop-shipping the wholesaler carries inventory-related risk and therefore should be able to increase the wholesale price and it is also consistent with the existing practice in catalog drop-shipping. Drop-shipping is more attractive when the retailer has the channel's power and can exercise it over the wholesaler. When channel power is equal, the retailer and the wholesaler arrive at a unique competitive equilibrium solution that significantly degrades system performance and usually does not benefit anyone.

We find simple contracts that achieve coordination in both the traditional supply chain and the supply chain with drop-shipping. According to these contracts, the wholesaler subsidizes a portion of customer acquisition expenses while allowing partial returns (imposing a penalty in case of drop-shipping). If the wholesaler can choose the wholesale price, a proportion of the customer acquisition expenses to subsidize, and the returns/penalty value, an arbitrary split of profits can be achieved. In any case, the proportion of profits that the wholesaler captures coincides with the proportion of customer acquisition costs she subsidizes. Therefore, the higher the subsidy, the higher the wholesale price and the higher the wholesaler's profits.

One may wonder if a contract that specifies a proportion of subsidized customer acquisition expenses is enforceable. We have observed that some forms of subsidized marketing expenses are already in use by wholesalers. Alliance Entertainment Corp., a wholesaler that has implemented the drop-shipping agreements, is one example. AEC publishes electronically an "All Media Guide" that is available to retailers working with AEC. According to AEC, the purpose of this database is to "... guide the consumer to make an intelligent purchasing decision and learn more about music and video." To be able to publish this catalog, AEC employs about 600 professional and free-lance writers who create the content. Why would the wholesaler get involved into this completely different form of business? The "All Media Guide" is a form of subsidized customer acquisition expense. Spun.com, a retailer working with AEC according to the drop-shipping agreement, pays a basic weekly price of $1500 for access to the database whereas it would cost Spun.com about $20M to create its own contents [3].

Other methods of sponsoring customer acquisition costs are possible. Many companies now provide tools that register how many visitors saw the advertisement, how many interacted with it, and how many clicked through and made the purchase. Companies providing this kind of service include AdKnowledge, DoubleClick, MatchLogic, and others. By using these tools, both the retailer and the wholesaler can observe the impact of customer acquisition expenditures and contract upon it. As Scheel [33] describes, in the practice of catalog drop-shipping it is conventional for the wholesaler to provide "... free photos, graphics, catalog sheets, color separations or other advertising aids or allowances." This practice seem to indicate that some sort of subsidized customer acquisition exists in drop-shipping.

Our model is an effort to introduce and understand supply chain issues that arise under a drop-shipping supply chain structure. Many extensions to our model are possible. The risk pooling effect when one wholesaler supplies several retailers will make drop-shipping even more appealing than with a single retailer as described in this paper. It is, however, very encouraging to see that even without the risk pooling effect, drop-shipping in many cases outperforms the traditional supply chain structure. With multiple retailers, it is even possible that the system profit under drop-shipping can exceed the profit of a vertically integrated supply chain since the integrated channel does not enjoy the benefits of pooling. Finally, as Scheel [33] suggests, retailers can carry the most popular products in inventory and drop-ship the rest directly from the wholesaler. This dual-sourcing problem rises many further interesting research questions.

## References


[1] Alliance Entertainment Corporation, web site http://www.aent.com/cdf/.

[2] The ABCs of drop-shipping. *Catalog Age*, October 1997, 115.

[3] Cheap tricks. *Forbes*, February 21, 2000, 116.

[4] Customer acquisition costs. *Computer World*, August 21, 2000, 48.

[5] Cyberian Outpost taps Tech Data for online store. *Computer Reseller News*, October 11, 1999, 67.

[6] Online retailers less merry in '00. *Computer World*, August 14, 2000, 1.

[7] Returns happen: reverse logistics online. *Inbound Logistics*, February 2000, 22-29.

[8] The state of eretailing 2000. The supplement to *Eretailing World*, March 2000.

[9] Aaker S. A. and J. M. Carman. 1982. Are you overadvertising? *Journal of Advertising Research*, Vol.22, no.4, 57-70.

[10] Balcer, Y. 1980. Partially controlled demand and inventory control: an additive model. *Naval Research Logistics Quarterly*, Vol.27, 273-288.

[11] Balcer, Y. 1983. Optimal advertising and inventory control of perishable goods. *Naval Research Logistics Quarterly*, Vol.30, 609-625.

[12] Berger, P. D. 1972. Vertical cooperative advertising ventures. *Journal of Marketing Research*, Vol.XI, 309-312.

[13] Berger, P. D. 1973. Statistical analysis of cooperative advertising models. *Operational Research Quarterly*, Vol.24, 207-216.

[14] Berger, P. D. and T. Magliozzi. 1992. Optimal co-operative advertising decisions in direct-mail operations. *Journal of the Operational Research Society*, Vol.43, No.11, 1079-1086.

[15] Cachon, G. P. and M. A. Lariviere. 2000. Supply chain coordination with revenue-sharing contracts: strengths and limitations. University of Pennsylvania working paper.

[16] Corbett, C. and G. A. DeCroix. 2000. Shared savings contracts in supply chains. The Anderson School at UCLA working paper.

[17] De Groote, X. 1989. Flexibility and marketing/manufacturing coordination. *International Journal of Production Economics*, Vol.36, No.2, 153-169.

[18] Eliashberg, J. and R. Steinberg. 1987. Marketing-production decisions in an industrial channel of distribution. *Management Science*, Vol.33, No.8, 981-1000.

[19] Gerchak, Y. and M. Parlar. 1987. A single period inventory problem with partially controllable demand. *Computers and Operations Research*, Vol.14, No.1, 1-9.

[20] Hoffman, D. L. and T. P. Novak. 2000. How to acquire customers on the web. *Harvard Business Review*, Vol.78, No.3, 179-183.

[21] Jeuland, A. P. and S. M. Shugan. Managing channel profits. *Marketing Science*, Vol.2, No.3, 239-272.

[22] Kandel, E. 1996. The right to return. *Journal of Law and Economics*, Vol.XXXIX, 326-356.

[23] Lariviere, M. 1999. Supply chain contracting and coordination with stochastic demand. Chapter 8 in Quantitative Models for Supply Chain Management. S. Tayur, R. Ganeshan and M. Magazine, editors. Kluwer Academic Publishers.

[24] Lilien G. L., P. Kotler and K. S. Moorthy. 1992. Marketing Models. Prentice Hall.

[25] Michael, S. 1999. Do franchised chains advertise enough? *Journal of Retailing*, Vol.75(4), 461-478.

[26] Montgomery, D. and W. Hausman. 1986. Managing the marketing manufacturing interface. *Gestion 2000: Management and Perspective*, Vol.5, 69-85.

[27] Moulin, H. 1986. Game theory for the social sciences. New York University Press.

[28] Narayanan, V. G. and A. Raman. 1998. Assignment of stocking decision rights under incomplete contracting. Harvard University working paper.

[29] Pasternak, B. A. 1985. Optimal pricing and return policies for perishable commodities. *Marketing Science*, Vol.4, No.2, 166-176.

[30] Petruzzi N. C. and M. Dada. 1999. Pricing and the newsvendor problem: a review with extensions. *Operations Research*, Vol.47, No.2, 183-194.

[31] Porteus, E. L. and S. Wang. 1989. On manufacturing/marketing incentives. *Management Science*, Vol.37, No.9, 1166-1181.

[32] Sagomonian A. G., C. S. Tang. 1993. A modeling framework for coordinating promotion and production decision within a firm. *Management Science*, Vol.39, No.2, 191-203.

[33] Scheel, N. T. 1990. Drop Shipping as a Marketing Function. Greenwood Publishing Group.

[34] Simaan, M. and J. B. Cruz, Jr. 1976. On the Stackelberg strategy in nonzero-sum games. In "Multicriteria decision making and differential games", G. Leitmann, editor. Plenum Press, NY.

[35] Simon, J. and J. Arndt. 1980. The shape of advertising function. *Journal of Advertising Research*, Vol.20, 11-28.

[36] Shapiro, B. 1977. Can marketing and manufacturing coexist? *Harvard Business Review*, Vol.55, 104-114.

[37] Tayur, S, R. Ganeshan and M. Magazine. 1998. Quantitative Models for Supply Chain Management. Kluwer Academic Publishers.

[38] Van Mieghem, J. and S. Chopra. 2000. What e-business is right for your supply chain? Forthcoming, *Supply Chain Management Review*.