Group Buying on the Web: A Comparison of Price-Discovery Mechanisms

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Web-based group-buying mechanisms are being widely used for both business-to-business (B2B) and business-to-consumer (B2C) transactions. We survey currently operational online group-buying markets, and then study this phenomenon using analytical models. We build on the literatures in information economics and operations management in our analytical model of a monopolist offering Web-based group-buying under different kinds of demand uncertainty. We derive the monopolist's optimal group-buying schedule under varying conditions of heterogeneity in the demand regimes, and compare its profits with those that obtain under the more conventional posted-price mechanism. We further study the impact of *production postponement* by endogenizing the timing of the pricing and production decisions in a two-stage game between the monopolist and buyers. Our results have implications for firms' choice of price-discovery mechanisms in e-markets, and for the scheduling of production and pricing decisions in the presence (and absence) of scale economies of production.
(*Group Buying; Pricing; Demand Uncertainty; Quantity Discounts; Price Discovery; Demand Heterogeneity*)

1. Introduction

Group-buying schemes have been in vogue for many years, particularly in the context of selling on television via the popular Home Shopping Network. Web-based variants of group buying have recently received a lot of attention as part of the wave of innovative online market-based mechanisms such as auctions, reverse auctions, and Priceline's "name-your-own-price" scheme. While there is a rich history of analytical research in auctions, spanning at least 40 years, we believe that this paper is the first analytical model of group buying.

To illustrate how group buying works, consider the sale of a particular product—say the Compaq iPaq 3650 (a personal digital assistant)—by a Web-based group-buying operator. Suppose the retail price of the iPaq 3650 is \$500. The seller (group-buying operator) might announce a base unit price of \$500. To entice buyers, the seller offers to sell at the discounted unit price of \$480 if at least three units are demanded, which drops to \$450 each if at least five units are demanded, and \$400 per unit if demand is for eight units or more. In effect, quantity discounts are offered—not on an individual customer's order, *but on the total of all customer orders*. The seller publicly announces, and commits to, his pricing scheme and a closing date for the sale. Further, the sale's status—the current number of bidders and the imputed price—is updated dynamically and displayed on the Web. Thus, buyers with different valuations for the product can follow the sales trajectory and jump in with a bid at an opportune moment. Bids are firm commitments (reneging on bids is not allowed), and the product's *current* price acts as a *price ceiling* for the bidder. Eventually, all winning customers get the product at the *same* clearing price, irrespective of what their actual bids were. In contrast to auctions and most other dynamic pricing mechanisms, there is no ex post

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valuation-based price discrimination. Because prices fall with the number of bids, customers who bid early induce other customers to bid, leading to a cascade of more bids and lower prices. In turn, the seller can stimulate demand and increase his revenues by the judicious use of discounts. Thus, in principle, both customers and the seller are better off, leading to Pareto-improving welfare gains.

The remainder of this paper is organized as follows. In the next section, we lay out our research objectives. Section 3 provides a comprehensive review of the current state of praxis by surveying a variety of group-buying practices, worldwide, in the B2B, B2C, and nonprofit sectors. Section 4 reviews the relevant prior research. In particular, two streams of research—the quantity-discounts literature in operations management and the literature on price discovery under demand uncertainty in information economics—serve as the building blocks for our analysis. In §§5 and 6, we develop analytical models of group buying under different kinds of demand uncertainty and compare the performance of group buying versus posted pricing in each case. We derive the conditions under which each dominates. In §7, we discuss the managerial implications of our research and highlight possible extensions.

2. Research Objectives

Group-buy operators seek to aggregate disparate buyers (who can operate remotely and asynchronously) via the Web by providing them price-based incentives for volume purchases. Kauffman and Wang (2001, 2002),[1] the only previous studies by academics to focus on group buying, empirically analyzed patterns in bidder behavior using customer data from MobShop.com. Our section on Praxis (§3) provides a survey (up to October 2002) of worldwide group-buying practices. Further, our analysis focuses on answering two key issues of immediate concern to current practice: (1) Given that a firm uses group buying to sell its products, what is its *optimal* group-buying schedule?[2] (2) How does the performance of this optimal group-buying schedule compare with that of simple (and widely used) posted prices, and what market conditions and product characteristics would vindicate the use of group buying? We believe that this paper is the first to study group buying using rigorous analytical models.

3. Group Buying: The Current State of Praxis

We quote the mission statements of two of the market operators that we surveyed to illustrate that demand aggregation and volume discounting are at the core of group buying.

> Co-buying is co-operative shopping for the 21st century. It's a really simple way of getting better value by bringing people together via the Internet. By bringing together as many members as possible, LetsBuyIt.com can negotiate lower prices with merchant partners (also referred to as suppliers) or manufacturers. The more people, the lower the prices.
>
> LetsBuyIt.com (2003)

> The more we are, the bigger the negotiation power towards trusted suppliers. The immediate result? Prices that fall without having to negotiate on your own. The more we are ("many"), the happier we are ("happy") because everyone pays less and everyone benefits from a better service.
>
> HappyMany (2003)

In our study of *currently operational*,[3] online markets, we found that group buying is a widely deployed price-discovery mechanism in a variety of markets and contexts. We will see that the group-buying mechanism is extensively used in the United States, Europe (including Germany, France, and the United Kingdom), and Asia (including in Egypt, India, Singapore, and Thailand) for many different product categories. This review discusses interesting and representative examples of this deployment.

[1] An extensive list of references from both the trade and academic literatures is available in our online appendix at mansci.pubs.informs.org/ecompanion.html.

[2] Under group buying, the seller offers a *menu of price-quantity tuples*, one of which is eventually realized. For brevity, we refer to the price-quantity schedule offered under group buying as the "group-buying schedule."

[3] As of October 2002.

Given the large number of active group-buying sites (more than 50), an exhaustive review is beyond the scope of this paper. However, a fairly comprehensive list of 26 representative group-buying websites from the B2B, B2C, and nonprofit sectors is provided in the online appendix (at mansci.pubs.informs.org/ecompanion.html).

Group-buying schedules are employed for branded consumer products and intangible services such as bandwidth and network security, in both B2B and B2C markets, and in public and private markets. These markets are characterized by the belief that both suppliers and buyers stand to benefit through group buying. Evidence of this belief is adduced by the websites of both buyer (IRPG, APPA, TBG, GBP)[4] and supplier (LBI, THM) consortia in a variety of markets that prominently tout the benefits of group buying to their members.

The successful U.S.-based group-buying site e.conomy, operated by PricewaterhouseCoopers, allows buyers to purchase indirect goods and services such as office supplies, "temps" (temporary staffing services), furniture, commercial print, computer hardware and software, telecommunications and connectivity, and company travel at substantially reduced prices that result from higher purchase volumes (ECON). Members are assured of an initial maximum price (a "price ceiling"). As they place orders, incrementing the total volume demanded, the resulting price declines are broadcasted until the market clears at a predetermined time. LetsBuyIt.com, quoted in the beginning of this section, is a consumer group-buying market currently functional in the United Kingdom, Germany, and France, that works similarly. A variation on the standard group-buying mechanism that this company permits is that buyers can choose *not* to declare a price ceiling—buyers' greater risk without a price ceiling may be offset by guaranteed availability of the good at the common, lowest price. In the words of LetsBuyIt.com, "Before you join a cobuy, you need to decide whether you would like to buy at the current price—the price reached when the cobuy closes—or at the Best Price only. If you choose to buy at the current price, you will receive the product and you will pay the closing price. If you choose to buy at the Best Price and the Best Price is not reached (i.e., the required number of participant cobuys is not reached), you will not receive the goods. Your order will be cancelled and you will not be charged." Product categories sold in this market include exercise equipment, consumer electronics, sport and leisure, food and wine, and jewelry.

The Group-Buying Partnership in the United Kingdom is a consortium of small- and medium-sized businesses that negotiates volume discounts from suppliers of items such as electricity and gas, computer equipment, office supplies and vehicles, and passes these discounts on to buyers (GBP). They claim on their website that group buying allows "small to medium sized businesses to combine their individual buying power for the overall benefit of each individual member" (GBP). The mechanism works through a process of demand aggregation wherein buyers commit to purchase quantities subject to certain price ceilings—should the consortium succeed in procuring the quantities at or below these price ceilings, buyers are then obliged to follow through on their commitments. This is a direct correlate of our model of *purchasing commitment conditional on demand realization* (§6 of this paper). A different flavor of this practice can be found in the India-based market Chennai Online (COL) whose customers are redistributors. This private electronic group-buying market allows buyers to place orders by specifying price-quantity schedules where purchase is required only if the supplier is able to meet the price specified by the buyers. What is interesting in this context is the order of events that lead to price discovery. In the case of products such as software suites for office use, magazines and periodicals from the popular press and computers (servers and PCs), the supplier announces prices at different levels of demand (price-quantity schedules) and the buyers place bids serially until the market clears at a particular price. In a second category of goods that includes kitchen appliances, computer peripherals, consumer electronics, and electrical appliances, the sequence

[4] Acronyms refer to websites of companies listed in "Group-Buying Markets" at the end of §3. For an extended list of academic and trade references, refer to the online appendix.

of demand solicitation and production (or procurement) of the goods is reversed. In this case, suppliers commit to a group-buying schedule, and demand is realized when a stable price-quantity tuple is reached. Then, suppliers either produce the goods (kitchen appliances and computer peripherals) or buy them from third parties (consumer electronics and electrical appliances) in exact quantities. Thus, while *production and inventory stocking decisions precede pricing* in the first category (modeled in Case 1, §6 of this paper), the second category is an example of *production postponement* (Case 2, §6, model).

Another version of the group-buying mechanism called StockBuzz (based in Thailand) is operated by Asian producers of high-quality yarn who sell their products to manufacturers of high-end apparel (STBZ). The apparel manufacturers forecast demand based on a number of macroeconomic factors—past sales data, seasonality, and most importantly, retailer feedback. Because most of the manufacturers sell to the same retailers and in the same urban markets, their demand estimates tend to be highly correlated, and reflect consumer demand cycles. The yarn producers, in turn, face uncertainty in demand, which tends to fluctuate between a robust (high demand) regime and a weaker demand regime reflective of an adverse consumer demand cycle. Thus, the yarn producers estimate the probabilities of these two market states, based on prior seasonal data and other available information. Using the two estimated demand schedules as guidelines, they commit to a schedule of prices for different quantities with prices declining in quantities. Buyers (apparel manufacturers) are allowed to place conditional orders, which they are then obliged to honor should the price reach the levels specified in the order contract. In this case, yarn suppliers use group buying as a response to uncertainty about which of the two states of demand will be realized (modeled in Cases 1 and 2, §5 of this paper).

Group-buying mechanisms are also observed in specialized markets. In the hotel and restaurant industry, the Independent Restaurant Purchasing Group (IRPG) brings together more than 3,000 restaurants across the United States and negotiates volume-based discounts with suppliers on their behalf. IRPG argues that the benefits of its group-buying scheme, called the IRPG Volume Rebate Program, for its members are twofold. First, buying power is enhanced for large chains and small restaurants: "Our national and regional contracts are based on the total volume of our group versus that of an individual restaurant. No matter how many restaurants you have, the IRPG can add strength and stability to your purchasing power." Second, many manufacturers insist on minimum volumes for doing business with them, out of efficiency considerations arising from their production and transaction scale economies. Smaller restaurants often find it difficult to meet these minimum criteria. As IRPG argues, "Most restaurants, by themselves, would probably not meet the manufacturer's minimum volumes. However, when combined with those of the entire membership, they exceed the minimum, and in many instances, qualify for further "multi-unit-allowances" normally only available to large chain accounts." In the skin care product market, the market operator The Buying Group (TBG) operates a relatively straightforward group-buying scheme where buyers commit to quantities at a maximum price. The market operator then negotiates a price from suppliers for the aggregate quantity, and shares the benefits of the lower prices with the buyers (here again, we see *"procurement postponement,"* studied in §6 of this paper). A noteworthy feature seen in this market is the preorder option, in which buyers *express an interest* in a product that is *not* currently featured in the market, and pay for their desired quantities up front, at prespecified prices. If there is enough interest, the market operator (in this case, The Buying Group) attempts to procure the product at a price that will make trade possible for at least some buyers. If the market operator succeeds, he charges all buyers (who are willing to pay the clearing price or more) the same floor price. If trade is not possible, the market operator refunds the buyers' paid-up amounts. The requirement that buyers commit to a quantity and price by paying the amounts up front ensures that buyers do not make frivolous bids, and also provides an incentive for the market operator to negotiate with suppliers.

Branded consumer goods are also sold via the group-buying mechanism. Two companies, McNopoly (MPLY) and Online Choice (OLC), operate markets that allow consumers to bid for specific branded items from a menu of offered items. If their suppliers offer discounts that support a market-clearing price, those consumers whose bids for the products were higher than the market-clearing price are required to buy the products; the others exit the market.

In the nonprofit sector, the Maryland Public Service Commission (MPSC) supports individual buyers in their efforts to form buying groups to negotiate better rates for higher aggregate levels of power consumption. Similarly, the American Public Power Association (APPA) and the Environmental Action Foundation have launched a number of group-buying initiatives that bring together consumers to negotiate lower rates with power utilities across the United States.

To summarize, we find evidence of widespread deployment of group buying as a price-discovery mechanism in both B2B and B2C sectors. A key feature that sets *all* group-buying schemes apart from other market mechanisms is suppliers' beliefs that getting buyers to precommit to a price-quantity schedule where the prices are monotonically declining in *total* purchase quantities (and not just an individual buyer's purchase quantities) will maximize supplier revenues by inducing greater buyer demand. Thus, group buying is often targeted toward buyers with low bargaining power—individual consumers or small to medium-sized businesses. In fact, many companies across all types of products, services, and countries, explicitly and prominently claim that "enhanced buyer bargaining power" is the single biggest advantage of group buying. The group-buying intermediary Printing Industries of New England (PINE) asserts on its website, "PINE has made arrangements with several companies—companies you use in running your business—to provide discounts on their products and services. PINE combines the overall buying power of its 513-member companies to negotiate these discounts. These are discounts you may not be able to receive if you were to directly negotiate with each company" (PINE). The construction industry's portal site in India, BuildByte (BBYT) puts it even more succinctly, "Bigger the volume—Lesser the price."

We saw that group-buying schemes can differ in the order of events leading to price discovery. In some cases, suppliers first commit to a price-quantity schedule leading to demand realization, and then produce (or procure) the products in volumes exactly calibrated to the realized demand. In other cases, suppliers first produce (or procure) products and then sell via a group-buying market through a volume discounting mechanism. Ceteris paribus, the former approach leads to higher supplier profits but is not always feasible due to long production/procurement lead times. However, the important practical question of *whether* to adopt group buying when production postponement is or is not feasible hinges on the *relative* performance of group buying vis-à-vis posted pricing in these two cases. Because the answer is by no means obvious, our model and analysis in §6 attempts to shed light on this question. More generally, the widespread use of group buying in practice is predicated on a number of unverified, seemingly "commonsensical" assumptions (reflected above in the quotes from various companies). This paper aims to provide a more analytical response to this discourse, and verifies the extent to which these underlying beliefs are true under various market conditions, through mathematical modeling.

Group-Buying Markets

APPA: American Public Power Association. www.md-electric-info.com/index.html.

BBYT: BuildByte Construction Portal (Indian). www. buildbyte.com/.

COL: Chennai Online Bazaar (India). www.chennaionline.com/services.

ECON: Operated by PricewaterhouseCoopers. www.pwcglobal.com.

GBP: The Group Buying Partnership. www.groupbuying.co.uk/products.htm.

IRPG: Independent Restaurant Purchasing Group. www.independentrestaurants.com/.

LBI: LetsBuyIt.com. www.letsbuyit.com/lbisite/index.jsp.

MPLY: McNopoly.com. www.mcnopoly.com/.

MPSC: Maryland Public Service Commission. www.md-electric-info.com / info-center / aggregators.html.

OLC: Online Choice. www.onlinechoice.com/home/default.asp.

PINE: The Printing Industries of New England. www.pine.org/MS/groupbuying.htm.

STBZ: The StockBuzz Market. www.stockbuz.com.

TBG: The Buying Group. www.the-buying-group.com.

THM: HappyMany. www.happymany.com/index_en.html.

4. The Group-Buying Mechanism: Theoretical Underpinnings

It is useful to conceptualize the group-buying mechanism as composed of two interacting components: (1) demand uncertainty faced by the seller, and (2) a quantity discount scheme offered by the seller. The relevant literatures on Quantity Discounts and Information Economics are discussed below.

4.1. Quantity Discounts

There are two popular forms of quantity discounts: (1) *all units* and (2) *incremental* (Nahmias 1997). Under *all units*, the discount is applied to all the units in a given order; under the *incremental* discount scheme, the discount applies only to additional units beyond prespecified breakpoints. *All* the companies operating group-buying schemes offer all-units discounts rather than incremental quantity discounts (see the survey in §3). This avoids penalizing early bidders (presumably, those with higher expected utility from the good) and encourages their early entry into the market, promoting the "bandwagon effect."

Quantity discounts have been studied as an instrument to (1) *facilitate transactions efficiencies* in trade, in situations involving scale economies (cf. Kohli and Heungsoo 1989, Lee and Rosenblatt 1986, Monahan 1984, Weng 1995), or (2) *structure incentives* in a vertical market (cf. Anand et al. 2003, Cachon 2003, Maskin and Riley 1984, Tang et al. 2001, Weng 1995). Dolan (1987) provides an extensive review of the early research on quantity discounts in the economics, operations management, and marketing literatures. (The reader wishing to delve deeper is referred to the online appendix for an extended list of trade and academic references.)

The study of quantity discounts as an enabler of transactions efficiencies in trade is closely related to the concept of Economic Order Quantity (EOQ). Monahan (1984) extends the idea of EOQ by deriving the optimal price-quantity schedule that a supplier should offer, given that the buyer subsequently optimizes her profits by ordering appropriate quantities. While Monahan (1984) assumes that the supplier produces in lot sizes that mimic the buyer's orders, Lee and Rosenblatt (1986) extend the analysis to the case where the supplier can use a different lot size from the buyer. Quantity discounts are also used by sellers to encourage early season purchases, to reduce their risk in environments characterized by demand uncertainty (cf. Cachon 2003, Tang et al. 2001).

Weng (1995) studies the joint problem of garnering transaction efficiencies (i.e., minimizing operating costs as above) and aligning incentives in the channel. He shows that under price-sensitive demand and scale economies, franchise fees are needed in addition to quantity discounts to maximize profits and coordinate the channel. Anand et al. (2003) show that when the classical single-period vertical contract is extended to a dynamic setting, two-part tariffs (a version of quantity discounting) cannot coordinate the channel when the buyer can carry inventories strategically. This failure of coordination holds true even in a deterministic, stationary environment and in the absence of scale economies.

4.2. Information Economics

While transaction efficiencies, and "augmented buyer bargaining power," may be part of the proffered rationale for all Web-based *demand aggregation* models, the major use in practice of group-buying channels has been for *price discrimination* through demand discovery.[5] Cremer and McLean (1985, 1988) analyze the case of selling to buyers with *interdependent demands*, with application to auctions. In their model, when this interdependency is known to the seller, there exists an ex post Nash equilibrium in which the seller is able to extract as much surplus as he would with full information, i.e., the information rent paid by the seller to the buyers is zero.

[5] For a discussion of the use of quantity discounts for second-degree price discrimination, see Tirole (1988).

Anand and Mendelson (1997) analyze the coordination problem faced by buyers with *interdependent costs*, where the interdependency arises due to the manufacturer's scale diseconomies.

While group buying, unlike auctions, does not lead to ex post price discrimination among different buyers (who are all charged the same price), it does aim to set the price dynamically based on market-wide demand. Thus, a paper that is closely related to the domain of our research is Maskin and Riley's (1984) study of a monopolist facing an adverse selection problem. Maskin and Riley demonstrate that when certain conditions (most notably, an increasing hazard rate function for the distribution of buyers' types and linear production costs) are met, the seller's profit-maximizing price-quantity schedule inducing self-selection among different buyer types has the structure of quantity discounts. This paper differs from theirs both semantically and technically, and ultimately in some of the results.

Semantically, group buying is a phenomenon distinct from the more traditional setting of quantity discounts. Group buying is one form of a quantity discount whereby the seller declares demand bands within which price is stable while price declines between bands (higher demand bands are characterized by lower prices). Where our modeling primitives overlap with those of Maskin and Riley (1984), we show that under a variety of settings discussed in our analysis, group buying (which is a special case of quantity discounts) is not optimal, and can perform no better than simple posted prices (trivially, by mimicking the latter, it can do no worse). This demonstrates that the form of discounts matters and that group buying is not the optimal form of volume discount. Where the primitives of our model diverge from Maskin and Riley's (1984)—specifically in a case where the demand curves intersect (see §5.2 for details) or where the marginal costs of production are nonlinear—we show that group buying dominates posted prices depending on the nature and extent of the heterogeneity in the demand regimes that the supplier faces.

5. Models of Demand Uncertainty

In the survey of §3, we found that in diverse industries, the group-buying operator acted as a de facto monopolist. In fact, the mechanism would seem to promote a monopolistic structure among group-buying operators. Given that the group-buying operator aggregates potential buyers to increase their collective bargaining power, and also in some cases, to meet minimum quantity thresholds, the nature of the business favors a single, large buyer group over multiple smaller buyer groups. Thus, we see consolidation in different businesses—for example, StockBuzz aggregating apparel manufacturers on behalf of yarn sellers, IRPG aggregating 3,000 restaurants to negotiate supplier discounts, or PINE wielding the bargaining power of its 513-member companies in the printing sector. In the B2C sector, the lack of competition is exacerbated by the relative novelty of the group-buying scheme to end consumers, and the specialized (niche) product lines. For these reasons, we focus on a monopolistic seller in the analysis of this paper; the extension of our framework to competing group-buying operators is a topic for future research.

In the models that follow, we will analyze the impact of different kinds of demand uncertainty on the monopolist seller's optimal group-buying pricing strategy, and compare its performance with that of simple posted prices.

5.1. Model of Parallel Demand Regimes

We construct a theoretical model of a monopolist seller facing demand uncertainty. The seller has an estimate of the demand for his product (at every possible price) but does not know it exactly. The monopolist operates in one of two demand regimes (which we term high/low), each of which is equally likely. The monopolist cannot observe or infer the demand regime prior to the pricing decision. The market consists of a fixed number of buyers transacting within a single period. Each buyer demands exactly one unit of an indivisible good. The monopolist seeks to sell a quantity Q. The demand for the monopolist's product is determined by a number of factors, including product attributes and consumer preferences, the availability of complementary or substitute products, and a host of macroeconomic factors. He has to choose from one of two pricing mechanisms: group buying or posted prices.

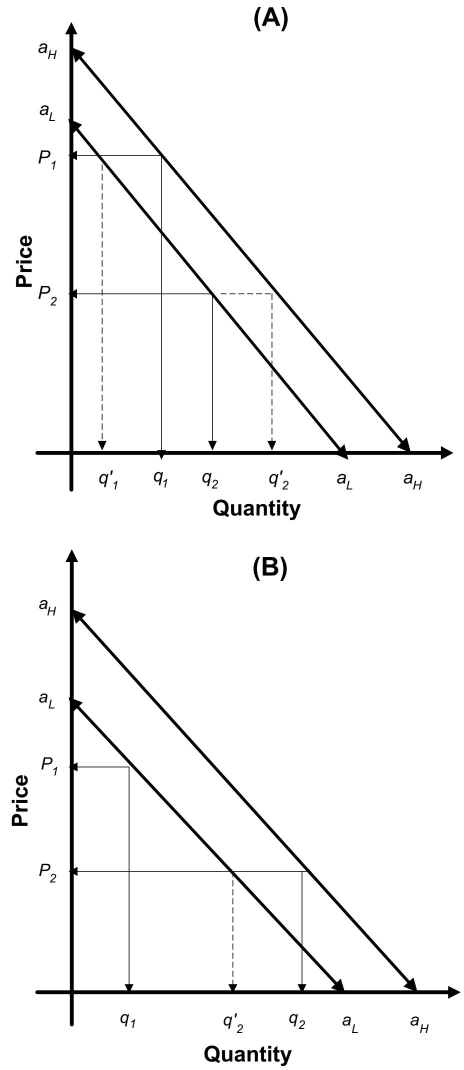
We preserve the general feature of all group-buying schemes—price is decreasing in the *total* quantity demanded. In this model, the price-quantity schedule consists of two or more price points corresponding to different quantities demanded. Further, the *offered price*[6] should be decreasing in the quantity ordered, or equivalently, we need that $\forall(q_i, p_i)$ and (q_j, p_j): $q_j > q_i \Rightarrow p_j \leq p_i$. Note that implicitly, the pricing structure is akin to *all units* rather than *incremental* quantity discounts. With the above formulation, we turn to the monopolist's revenue maximization problem under group buying. We assume that demand[7] for the good is linear, and given by

$$q = a_h - p \quad \text{and} \quad q = a_l - p$$

in the high and low demand regimes, respectively. This formulation results in parallel demand curves for the two equiprobable[8] regimes as discussed above. The parameters of each demand regime are common knowledge to the potential buyers and the seller. However, only the buyers can infer which regime is perfectly operative, based on their individual preferences, i.e., their positions on the demand curves (because the curves do not intersect). We will consider the case when the two regimes have nonparallel (intersecting) demand curves in §5.2. The two demand regimes are shown in Figure 1(a). The *high* demand regime is the outer demand curve.

Thus, the monopolist's problem is to pick a price-quantity schedule that will maximize his expected total revenue[9] without knowing which of the two demand regimes is realized. Because there are only two demand regimes, the monopolist will pick a pair of price-quantity tuples $[(q_1, p_1), (q_2, p_2)]$, with one tuple corresponding to each regime such that the expected revenue is maximized, subject to the

Figure 1 **(a) The Monopolist Attempts to Set the Higher of the Two Price Points from the High Demand Regime. (b) The Higher Price Point is Captured from the Low Demand Regime While the Lower Price Point is Captured from the High Demand Regime.**



[6] We distinguish between offered and realized prices here because a single price may be realized which is one of the many offered prices.

[7] See the online appendix of mathematical proofs and derivations for how the generic demand curves are normalized to arrive at this formulation.

[8] Our results are qualitatively unchanged by generalizing these probabilities to p and $(1-p)$.

[9] Because production precedes pricing in our model, we are justified in treating the marginal cost as sunk and, therefore, maximizing revenues (as opposed to revenues net of production costs). It will be clear from inspection that the solution and the ordering of market mechanisms by revenues will not change if a positive marginal cost were to be factored into the analysis. When pricing precedes production, the marginal cost might matter: in this case (studied later in §6), our analysis assumes a nonzero marginal cost.

condition that $q_2 > q_1$ and $p_2 \leq p_1$. The notation $[(q_1, p_1), (q_2, p_2)]$ means that the seller charges the price p_1 when the total sales quantity is $\leq q_1$, and p_2 when the total sales quantity is $> q_1$ but $\leq q_2$. In this shorthand for the schedule under group buying, the price p_1 is to be interpreted as the *base price*, and the quantity q_1 is to be interpreted as a *quantity ceiling* corresponding to the base price, i.e., the quantity *up to* which the price p_1 will be operative. Thus, if the total sales quantity is any number less than or equal to q_1, the sales price will be p_1. If the total quantity demanded in the market *exceeds* q_1, the lower price p_2 will obtain.[10] In the absence of capacity (or procurement) constraints, the monopolist supplier would simply set $q_2 = +\infty$, or a large number. Further, *incentive compatibility constraints have to be satisfied*, to ensure that under each regime, the price-quantity pair that is operationalized is the one that the monopolist intended for that regime. Thus, under each regime, the equilibrium outcome should be that the customers, while maximizing their own value, *prefer* the price-quantity pair intended for that demand regime, rather than the alternative. The implementation of this idea, in connection with the well-known *revelation principle* of economics,[11] will become clearer in the exposition below.

The seller has two alternatives: (1) set the higher price point from the high demand regime and, therefore, the lower price point from the low demand regime (this would imply that the seller expects to realize a higher quantity of sales from the low demand regime), or (2) set the lower price point (and, therefore, higher sales quantity) from the high demand regime and the higher price point (and, therefore, lower sales quantity) from the low demand regime. Figures 1(a) and (b) illustrate alternatives (1) and (2), respectively, which we analyze below.

[10] We use this notation for simplicity. It is worth noting that the interpretation of a price-quantity tuple such as (q_1, p_1) under group buying is different from the take-it-or-leave-it price-quantity tuples more commonly observed in the literature (in which the buyer(s) only have the option of buying exactly q_1 at the price p_1). In effect, pricing under group buying is a monotonically decreasing step function of total quantities demanded.

[11] For an excellent exposition of the revelation principle, see Mas-Colell et al. (1995) or Myerson (1991).

Case 1. *Higher price point is set from the high demand regime* (*see Figure* 1(a)). In Figure 1(a), $q_1 = a_h - p_1$ and $q_2 = a_l - p_2$. The quantity q_1 acts as a limit for the higher price p_1. The seller will offer the following pricing scheme:[12]

$$\text{Price } P = \begin{cases} p_1 & \text{if quantity } q \leq q_1 = a_h - p_1, \\ p_2 & \text{otherwise,} \end{cases}$$

subject to the constraints[13] $p_1 \geq p_2$ and $q_1 \leq q_2$. Under this scheme, the price (outcome) will always be p_2 irrespective of the demand regime that is realized. Consider the following two scenarios: If the lower demand regime is realized, the price that will prevail is p_2 and the quantity sold will be given by $q_2 = a_l - p_2$. If the higher demand regime is realized, then the seller would want the price to remain at p_1, however, buyers in this demand curve would demand a quantity given by $q_2 = a_h - p_2$, which is greater than $a_h - p_1$. As a result, the seller would have to offer the lower price corresponding to the higher quantity level. This leads us to our first result about the seller's optimal revenue.

Lemma 1. *The seller's total revenue in expectation when he chooses the higher price point from the higher demand regime is given by*

$$\pi^*[(q_1, p_1), (q_2, p_2)] = \frac{(a_h + a_l)^2}{16}, \qquad (5.1)$$

and the optimal price P^* *is given by* $P^* = (a_h + a_l)/4$.

Proof. The proof of Lemma 1 and all propositions in this paper are provided in the online appendix. □

The above scheme is in essence a single-price scheme (fixed price) because only a *single price will prevail* irrespective of which demand regime is realized.

Case 2. *The seller picks the lower price point from the high demand regime and the higher price point from the low demand regime* (*see Figure* 1(b)). In this case, the seller will offer the following pricing scheme:

$$\text{Price } P = \begin{cases} p_1 & \text{if quantity } q \leq q_1 = a_l - p_1, \\ p_2 & \text{otherwise,} \end{cases}$$

[12] It will be clear by inspection that this pricing scheme maximizes the seller's revenues under Case 1.

[13] These constraints result from the definition of group-buying mechanisms: higher quantities lead to lower prices.

subject to the constraints $p_1 \geq p_2$ and $q_1 \leq q_2$.

Now, the separator between the two pricing points is the quantity q_2', which ensures that, in the event the low demand regime is realized, the price does not slide down to p_2. In this case, separation of prices across the two demand regimes seems possible.[14] Of course, if the seller could individually maximize revenues in the two markets, the revenue-maximizing prices in the high and low demand markets would be, respectively, $p_1^* = a_l/2$ and $p_2^* = a_h/2$, with the corresponding sales quantities $q_1^* = a_l/2$ and $q_2^* = a_h/2$. However, this solution is infeasible under the group-buying mechanism, because the constraint that the price should be *decreasing* in quantity demanded is violated (because $p_1^* > p_2^*$ and $q_1^* > q_2^*$). Because separate maximization of revenues across the two demand regimes leads to an infeasible price-quantity schedule, we need to maximize the seller's revenue within the feasible set of prices. Lemma 2 provides the optimal solution.

Lemma 2. *The optimal (revenue-maximizing) prices and seller profits under group buying are given by*

$$\begin{cases} p_1^* = p_2^* = \dfrac{a_l + a_h}{4} \quad \text{and} \quad \pi_G[(p_1, q_1), (p_2, q_2)] \\ \quad = \dfrac{(a_l + a_h)^2}{16} \quad \text{if } a_l \geq a_h(\sqrt{2} - 1), \\ p_1^* = p_2^* = \dfrac{a_h}{2} \quad \text{and} \quad \pi_G[(p_1, q_1), (p_2, q_2)] \\ \quad = \dfrac{a_h^2}{8} \quad \text{otherwise}. \end{cases}$$

In particular, any feasible group-buying schedule that sets the prices such that $p_1^* \neq p_2^*$ yields revenues less than the above solution.

Remarks. Because $p_1^* = p_2^*$ under the optimal group-buying scheme (i.e., the price is independent of the demand regime), the monopolist can clearly do as well using posted prices, by setting his price $p^* = p_1^*$ ($= p_2^*$). The seller's revenues under group buying and posted prices are identical.

To summarize, the price p_1 always slides down to p_2 in Case 1, thereby establishing a *single-price equilibrium* across the two demand regimes. In Case 2, the monopolist is able to implement a separation of prices based on quantity demanded, but the revenues from a single posted price dominate the resulting revenues from group buying. Proposition 1 derives from Lemmas 1 and 2.

[14] Recall that the seller's objective is to implement a different price in each demand regime to optimize his total expected revenue.

Proposition 1. *In the model of demand uncertainty with parallel demand regimes, the seller's revenues from group buying can never exceed his revenues from simple posted prices. In fact, the optimal (revenue-maximizing) group-buying scheme simply mimics the optimal posted price. Any deviation from posted pricing (such as differential pricing to discriminate between realized demand regimes) leads to suboptimal revenues for the seller.*

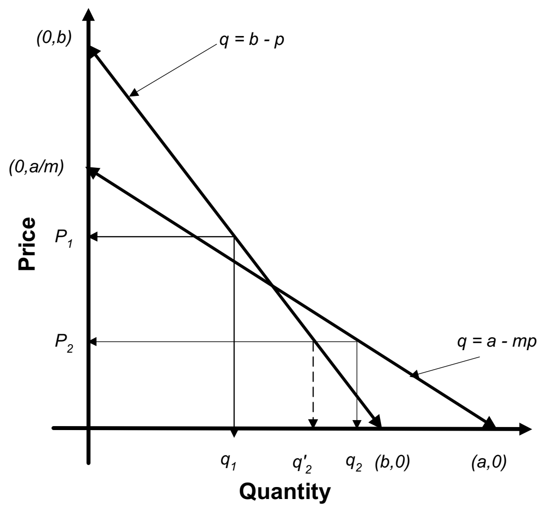
5.2. Model of Intersecting Demand Regimes

In the previous section, we considered the case of demand uncertainty in which the two demand regimes were parallel. This implied that at any price, the quantity demanded under one demand regime dominated that demanded under the other. On the other hand, intersecting demand regimes represent uncertainty about *market size* (density of buyer distribution) and *valuations*. Most models deal with only one of the two kinds of uncertainty. We now consider demand uncertainty where one demand regime does not universally dominate the other. Specifically, we study the case when the two demand regimes cross: one regime may result in a higher quantity demanded for one range of prices, while the other regime may dominate over another range of prices (see Figure 2). We derive the optimal revenues from group buying and posted prices and compare the two.

Figure 2 illustrates the case of intersecting demand curves. The generic linear demand curve is given by $Q = A - mp$. Let the two curves be given by $q = a' - m_1 p$ and $q = b' - m_2 p$, where $a' > b'$ and $m_1 \geq m_2$. Let $m = m_1/m_2$. We normalize m_2 to 1 so that the two demand curves are given by $q = a - mp$ and $q = b - p$, where $a > b$ and $m \geq 1$. Further, as seen in Figure 2, the two curves intersect only when $b > a/m$ (thereby making it a binding constraint for the existence of intersecting demand regimes).

Each demand regime can occur with equal likelihood, and the seller has to set prices before the

Figure 2 Intersecting Demand Curves: Neither Demand Regime Dominates the Other Universally



demand regime is realized.[15] Under group buying, the seller picks a price-quantity schedule as before. He offers prices of p_1 and p_2 for quantities demanded up to the thresholds q_1 and q_2, respectively, where $q_1 \le q_2$ and $p_1 \ge p_2$. We now determine the optimal values of p_1 and p_2, and the corresponding expected revenues, under group buying.

Lemma 3. *For the model of intersecting demand regimes described above, the profit-maximizing, group-buying, price-quantity schedule is given by*

$$\text{Price } P^* = \begin{pmatrix} p_1^* \\ p_2^* \end{pmatrix} = \begin{cases} \dfrac{b}{2} & \text{if quantity demanded } q \le b - \dfrac{a}{2m}, \\ \dfrac{a}{2m} & \text{otherwise.} \end{cases} \tag{5.2}$$

The seller's expected revenue is

$$\pi(p_1^*, p_2^*) = \frac{a^2 + mb^2}{8m}. \tag{5.3}$$

[15] Because the demand curves intersect at just one point, all buyers other than the one atomistic buyer at the point of intersection can perfectly infer which regime is operative from their individual preferences, i.e., their positions on the demand curves.

We now derive the seller's optimal price and revenues under posted pricing, and compare these with the optimal prices and revenues under the group-buying mechanism.

Proposition 2. *In the case of intersecting demand regimes,*

(i) *The profit-maximizing price and revenues under posted pricing are given by*

$$p^* = \frac{a+b}{2(m+1)} \quad \text{and} \quad \pi(p^*) = \frac{(a+b)^2}{8(m+1)}.$$

(ii) *The difference in revenues between the optimal schedules for group buying and posted pricing is given by* $\pi_g - \pi_p = (a - bm)^2/(8m(m+1)) > 0$.

(iii) *Thus, the revenue to the seller from group buying strictly dominates the revenue from posted pricing.*

Thus, unlike the earlier case of parallel demand curves (in which the two demand regimes had identical slopes), group buying outperforms posted prices for intersecting demand curves, in which the two demand regimes have different slopes. Group buying does better under greater demand heterogeneity (reflected in the parameter m), because it enables the seller to set (nonlinear) price-quantity schedules that optimize revenues under each demand regime, thus, maximizing total expected revenues. With greater heterogeneity in demand regimes, it is easier to induce a self-selective second-degree[16] price discrimination among customers, via quantity-discount schemes. However, when the seller relies on posted prices, the single quoted price forces the seller to make a trade-off between revenues in one demand regime and revenues in the other, which leads to lower overall expected revenues. In contrast, demand homogeneity would neutralize the advantage of pricing flexibility (enabling second-degree price discrimination) that group-buying pricing mechanisms offer. Proposition 3 establishes that the above intuition holds, with $m = m_1/m_2$ being a measure of the difference in the slopes of the two demand curves (which induces the heterogeneity).

Proposition 3. *The gains from using the group-buying mechanism increase as the demand heterogeneity* (m) *increases.*

[16] See Tirole (1988).

6. Pricing and Production: Timing and Scale Economies

Our previous models implicitly assumed a certain sequence of events. For example, the assumption of zero marginal costs is reasonable when production costs are sunk, i.e., the commitment to production quantities precedes the pricing decision. When pricing follows production, there are fewer degrees of freedom in the pricing decision, under both group buying and posted prices. Put differently, under a different sequence of events, with greater freedom in the *timing of the pricing decision*, group buying might outperform simple posted pricing even more. A second issue is the absence of scale economies in our previous models. After all, because group buying is an extension of traditional quantity discounting, its greatest benefit might be precisely to maximally exploit scale economies. This section casts the spotlight on these two issues. In the relative performance of group buying versus posted prices, (1) what is the impact of economies of scale, and (2) does the order of production versus pricing matter? We analyze two different scenarios and the effect of scale economies in each: (1) *production precommitment*, and (2) *production postponement*. Under production precommitment, the firm's pricing decisions are made after and, hence, are constrained by commitment to production/procurement quantities. Production precommitment is almost inevitable under long production or supply lead times, when the firm has to commit ex ante to purchase or production quantities. Production postponement is feasible when production or procurement lead times are sufficiently small. Here, the firm determines its production/procurement quantity after observing the demand as a function of its price or price-quantity schedule.[17]

Under both posted prices and group buying, the firm is better off under postponement (when this is feasible), because the additional market information is useful in tailoring production. Our interest, however, is in comparing the *relative performance* of the two market mechanisms with and without postponement, to study the effect of the production-pricing sequence on the choice of market mechanism.

In all the models in this section, we assume that there is a risk-neutral, profit-maximizing monopolist selling to two buyers (customers) with heterogeneous "types" (values). Each customer buys at most, one unit of the good, and seeks to maximize her expected value. Customers' valuations are drawn i.i.d. from the standard uniform distribution (i.e., uniformly and independently from the unit interval $[0, 1]$). While the distribution is common knowledge, only the corresponding customer knows her own exact valuation.

Case 1. *Production precommitment*. In this case, all production is ex ante, i.e., the monopolist supplier commits to the total production quantity before the revelation of demand through the price (or price-quantity schedule). We model the discovery of the optimal group-buying schedule as a game between the monopolist and the buyers. The sequence of events is as follows. The monopolist first determines his production quantity and then picks a price-quantity schedule, and buyers choose to buy or abstain. The monopolist folds the expected resulting demand from the stage game to arrive at the optimal price-quantity schedule. Recall that, under group buying, each customer's bid creates positive externalities for all other customers by lowering the expected price.[18] Hence, each customer needs to factor in the probability of bidding by other customers (which is a function of their values) in determining her own bid. A customer will buy (bid) if her value is greater than the *expected* price. Thus, a customer may bid even when the current price under group buying is greater than her value for the good. This may induce other customers to bid, further lowering prices. A direct approach to comparing the relative performance of the two mechanisms (posted prices and group buying) is to derive the optimal prices and profits under each—to solve the group-buying problem, we may employ the revelation principle (cf. Myerson 1991). However, in this case, we may build on Myerson (1981) to compare the two mechanisms without deriving the optimal group-buying schedule.

[17] For an analytical treatment of postponement under demand uncertainty, and its relationship to information, see Anand and Mendelson (1998).

[18] Kauffman and Wang (2001) find evidence of the positive externality effect on customer bids in their empirical study.

Myerson (1981, p. 60) focuses on the *auction* of a single, indivisible object. His result on the optimal auction (extended for the multiunit case) is stated below without proof:

> Suppose the seller has k indivisible units, and there are n buyers whose valuations are independent uniform draws from the unit interval $[0,1]$. The optimal auction is to set a reservation price equal to $p^* = \max_{p\in[0,1]} p\cdot(1-p) = 1/2$, and allocate the k units to the k highest bidders at a price equal to the larger of the reservation price and the highest losing bid.

The preceding implies that when $k = n$, the realized auction price is exactly the reservation price, and *the optimal auction is equivalent to a posted-price mechanism*. The critical observation is that Myerson's (1981) mathematical specification of the "auction" is quite general in terms of probabilities of different bidders winning the good, and expected money transfers between the seller and buyers. Both group buying and posted prices fit within these specifications. Proposition 4 builds on the preceding observations to compare the two mechanisms under production precommitment.

Proposition 4. *Under production precommitment, the equilibrium solution and the supplier's profits are identical under group buying and posted pricing.*

Proposition 4 applies under production precommitment for both linear production costs and scale economies, because the production costs are "sunk" before pricing and demand realization. Thus, with production precommitment, the best that the supplier can do under group buying is to mimic the optimal posted pricing scheme—offering quantity discounts does not improve the supplier's profits. This result on the inefficacy of quantity discounts (as mediated by the group-buying mechanism) even under scale economies is contrary to previous research that argued that quantity discounts contributed to transaction efficiencies, particularly under production scale economies (cf. Kohli and Heungsoo 1989, Lee and Rosenblatt 1986, Monahan 1984, Weng 1995). The crucial difference is that the greater coordination costs under group buying offset the improved transaction efficiency from quantity discounting.

Case 2. *Production Postponement*. This model differs from that of Case 1 in the sequence of production and pricing. The altered sequence of events is as follows: the supplier first quotes a price-quantity schedule, and buyers then respond with their purchase decisions (demand is realized). Finally, the supplier tailors his production to exactly satisfy his commitments (orders). In this case too, the monopolist determines the optimal price-quantity schedule (one that maximizes revenues) by backward induction. We assume that the cost of producing i units is c_i, for $i = 1, 2$; without loss of generality, we set $c_0 = 0$, i.e., there are no production-independent fixed costs. Our analysis focuses on the effect of economies of scale in production, thus, we assume that marginal costs are weakly decreasing, i.e., $c_2 - c_1 \le c_1$. The limiting case of $c_2 - c_1 = c_1$ corresponds to linear production costs.

In this case, we need to *explicitly derive the optimal group-buying and posted-pricing solutions to compare their performance*; indirect approaches such as invoking the optimal auction solution of Myerson (1981) are not helpful. Under group buying, we denote the price vector by $[p_1, p_2]$, where p_1 is the unit price for one unit of sales, and p_2 the unit price otherwise—the quantity discount per unit is thus $(p_1 - p_2)$. We solve the group-buying problem using the revelation principle (cf. Myerson 1991). Proposition 5 derives the unique, subgame-perfect equilibrium for this game, under both posted prices and group buying.

Proposition 5. *Under production postponement, the unique subgame-perfect equilibrium and supplier profits for posted pricing and group buying are as given below.*

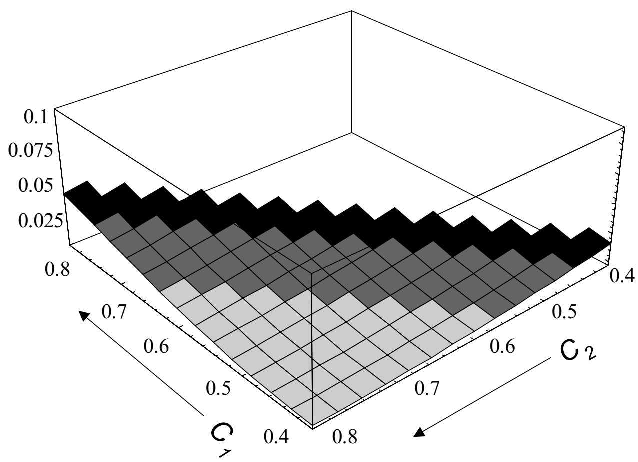
(i) *Posted pricing*:
$$p^* = \frac{1-c_1+c_2}{2-2c_1+c_2} \quad \textit{and} \quad \pi_p^* = \frac{(1-c_1)^2}{2-2c_1+c_2}.$$

(ii) *Group buying*:
$$p_1^* = \frac{1+c_1}{2},$$
$$p_2^* = \frac{1}{6}\left(4+c_2-\frac{6(1-c_1+c_2)}{2-2c_1+c_2} - \sqrt{1+3(2-c_1)c_1+(c_2-4)c_2}\right),$$

and
$$\pi_{GB} = \frac{1}{108}(52-72c_1+36c_1^2-15c_2-18c_1c_2+9c_1^2c_2+12c_2^2 - 2c_2^3+2(1+3(2-c_1)c_1+(c_2-4)c_2)^{3/2}).$$

We find that in this (final) case, the profits for the monopolist from group buying dominate those under posted pricing. As Figure 3 illustrates, group buying

Figure 3 **Profit Comparisons when Pricing Precedes Production Under Scale Economies: Group Buying Does Better than Posted Pricing for the Seller**



does provide an *exploitable informational advantage* over simple posted pricing.

The difference in seller profits under group buying and posted pricing when production costs change is a function of two factors: (1) *absolute profitability*—when costs (c_1 or c_2 or both) increase, profits fall under both group buying and posted pricing. *A drop in absolute profitability tends to drive the profit difference down as well*; (2) *production scale economies*. Observe that under linear production costs,[19] the profit expressions of Proposition 5 reduce to $\pi_p^* = \pi_{GB}^* = (1-c_1)^2/2$. In fact, *the two market mechanisms yield identical profits to the seller in this limiting case alone*. Further, the *degree* of scale economies (measured by the concavity of production costs) is *increasing* in c_1 and *decreasing*[20] in c_2. Thus, ceteris paribus, as c_1 increases or c_2 decreases, the *relative* production cost of the second unit vis-à-vis the first decreases. From the preceding discussion, it becomes clear that when c_2 increases, *both* of the above drivers, absolute profitability and scale economies, work in the same direction and drive down the profit difference as seen in Figure 3. A more interesting case is when c_1 increases: also from the preceding discussion, the absolute profitability driver will cause the profit difference $\pi_g - \pi_p$ to fall, while the scale economies driver will cause the profit difference $\pi_g - \pi_p$ to increase in c_1. Overall, the direction of change of the profit difference when c_1 increases, depends on which of the two drivers dominates. Figure 3 shows that, in fact, the difference in monopoly profits between group buying and posted pricing is an increasing function of c_1 for the entire feasible range of c_1 (and c_2). Thus, surprisingly, *the impact of the scale economies driver dominates that of the absolute profitability driver for the entire feasible range of* c_1, illustrating the significance of production scale economies under production postponement.

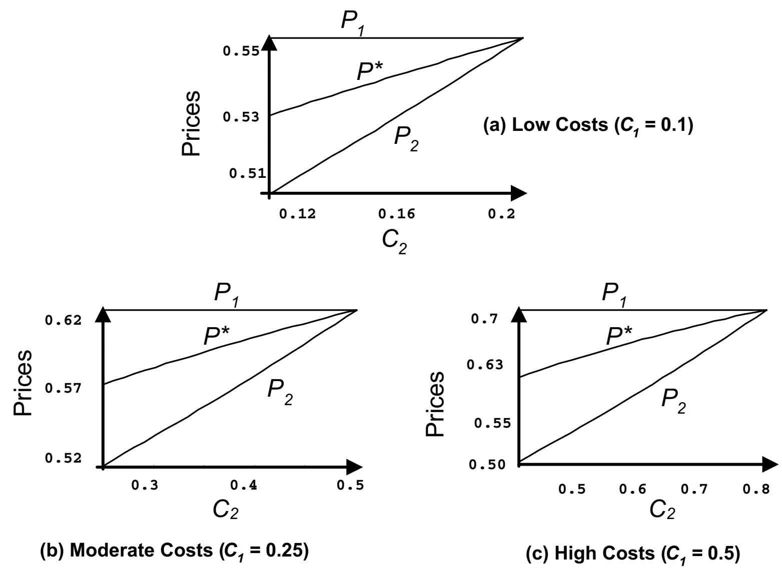
Figures 4 and 5 shed further light on the behavior of prices and profits under scale economies under the two mechanisms. The cost parameter for the first unit, c_1, is set to one of three values: Low ($c_1 = 0.1$), Moderate ($c_1 = 0.25$), and High ($c_1 = 0.5$). For each fixed c_1, the cumulative production cost for two units, c_2, is varied along its entire feasible range. Figure 4 plots the optimal prices under group buying and posted prices. It turns out that $P_1 \geq P^* \geq P_2$ in all cases, with the equality holding exactly when $c_2 = 2 \cdot c_1$. In fact, P_1 is independent of c_2, but an increasing function of c_1. Intuitively, the seller cares about the value of P_1 only when exactly one unit is sold, because this is the only scenario under which P_1 affects revenues. But then, the only cost that matters is c_1. Both P^* and P_2 are increasing in c_2, and eventually converge to P_1^* when $c_2 = 2 \cdot c_1$. Under posted pricing, *the seller has to balance out the benefit of sales at a higher price* (in the event of high customer valuations) *versus the risk of losing sales at the higher price* (if low customer valuations).

This trade-off is reflected in the optimal posted price P^*. Group buying affords the monopolist greater flexibility. Because the probability of one customer having a high valuation and the other having a low valuation is high, the seller sets P_1^* to be high to trap the high value customer's demand when one customer has a high valuation and the other has a low valuation. This risk is offset by the safety net of a lower P_2^*, to make the sales when both customers have moderate valuations. Of course, group buying has its drawbacks—when both customers have high valuations, the price settles down to P_2^*, leaving money on the table; and when both customers have low

[19] Linear production costs imply $(c_2 - c_1) = c_1 - 0$, i.e., $c_2 = 2 \cdot c_1$.

[20] Because marginal production costs are c_1 and $c_2 - c_1$ for the first and second units, respectively.

Figure 4 Price and Profit Comparisons Under Varying Costs



Notes. c_1 varies from 0.1 (low) to 0.5 (high), while c_2 varies between c_1 and $2c_1$. This is the range of values for c_2 that is feasible under production scale economies. P_1 and P_2 are the prices under the optimal group-buying schedule, while P^* is the optimal posted price.

valuations, no sales are made. But these events have a relatively low probability. Furthermore, *the cost savings from production postponement mean that these losses are less than they would have been if production commitments had to be made before orders are revealed*. Figure 5 shows that for any fixed level of c_1, the profit difference is greatest for $c_2 \approx c_1$ (maximum scale economies); it falls as c_2 increases, and eventually becomes 0 when $c_2 = 2 \cdot c_1$.

To summarize, when production can be tailored to meet revealed demand, scale economies allow the exploitation of nonlinear pricing under group buying, which outperforms posted pricing. Clearly, revelation of demand information (through a nonlinear price-quantity schedule) and the optimal exploitation of that information (via sequencing production after pricing) together play a role in driving our results. In other words, neither *postponement* nor scale *economies* alone justifies the use of group buying. However, when *both* coexist, group buying outperforms simple prices for the seller.

7. Conclusion and Extensions

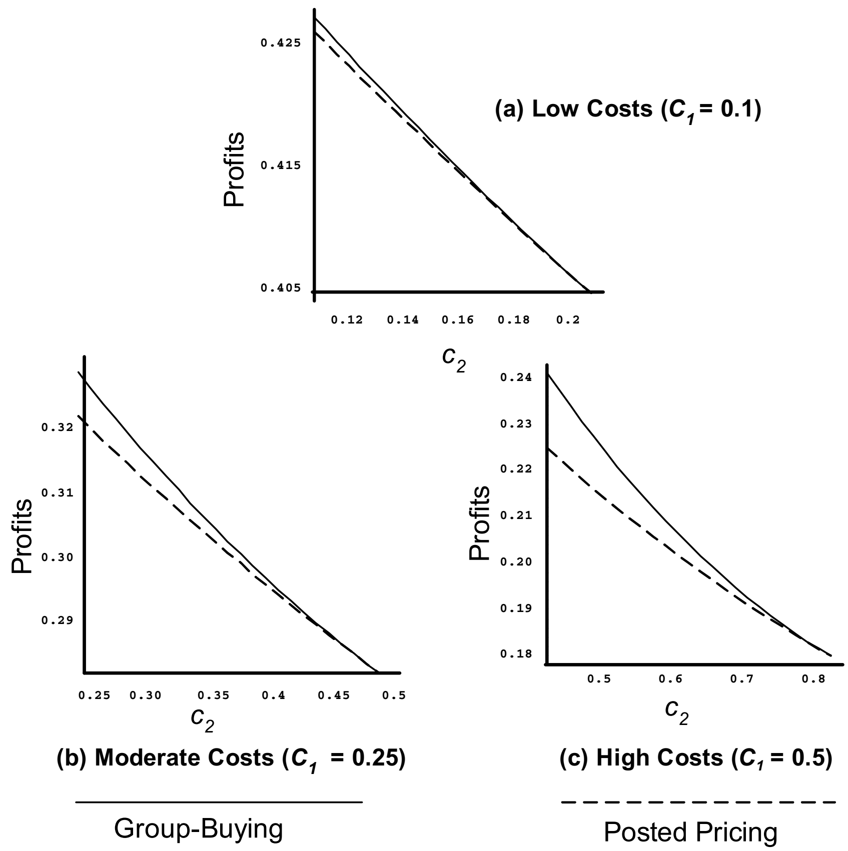
Because group buying does not permit ex post price discrimination among customers with different valuations, it cannot outperform posted prices in the absence of demand uncertainty.[21] Thus, demand uncertainty is a *sine qua non* for the viability of the group-buying mechanism. Our analysis showed that group buying outperformed posted pricing under (1) demand heterogeneity (§5), and (2) production postponement in combination with scale economies (§6). We briefly summarize our findings in each context below.

The analysis in §5 showed that under heterogeneous demand regimes, the seller is able to use group buying to price discriminate and capture some of the revenues lost by setting a single price across both demand regimes. As the demand regimes become more *similar*, the situation begins to resemble the cases analyzed in Proposition 1: the advantage of group buying over posted pricing shrinks and finally vanishes.[22]

[21] Observe that if the final price under group buying can be perfectly predicted, setting a list price equal to this realized price will do equally well for the seller.

[22] For the advantage of group buying to vanish, the demand regimes do not need to be *identical*. It is enough if they are *alike*, as for example, if their slopes are the same, even though they may have different offsets.

Figure 5 Profit Comparisons Under Varying Costs



Notes. c_1 varies from 0.1 (low) to 0.5 (high). Low ($c_1 = 0.1$), moderate ($c_1 = 0.25$), and high ($c_1 = 0.5$), for feasible values of c_2. This is the range of values for c_2 that is feasible under production scale economies.

We also found that the value of group buying depends on the *nature* of the uncertainty about buyer valuations in the market. When the distribution that characterizes buyer valuations is known beforehand, sellers are almost always better off by running a posted-price market, in fact, the only exception was the combination of *production postponement* and *scale economies* (§6). Neither production postponement nor scale economies was *individually* enough for group buying to outperform list prices.

Other disadvantages of the group-buying mechanism vis-à-vis posted pricing were not modeled in this paper. Specifically, group buying involves *delays* and *uncertainty* before the final price is realized, for both buyers and sellers. The delay before consummation of trade leads to utility decay for all parties, and uncertainty coupled with *risk aversion* (on the part of either party to the trade) leads to further devaluation of the eventual trade. Because buyers anticipate the delay, their willingness to pay during the bidding phase is lowered, leading to a downward shift in the demand curve under the group-buy mechanism. This may well result in some adverse selection wherein the buyers who value the product least (and therefore, suffer the least utility decay) may be attracted to the group-buying market. These issues should be addressed in future research.

Another important area for future research, not studied in the models of this paper, is the impact of competition. Under competition (or under oligopoly), group-buying markets may be run for three reasons: (1) the market can be segmented between price-sensitive buyers and buyers whose demand for the product is relatively inelastic,[23] which allows price-sensitive buyers to choose the group-buying option, (2) a consortium of buyers may emerge to negotiate discounts on behalf of buyers for products that are characterized by production or logistical scale economies (such as office supplies, pulp and paper, and utilities), and (3) a consortium of suppliers may aggregate small to marginal retailers for whom the costs of running individual discount programs may be substantial.

Bounded rationality may limit the effectiveness of these markets. Group buying is a relatively complex mechanism demanding sophisticated calculations by both sellers and buyers. Individual consumers, in particular, may be unable (due to bounded rationality) to make complex calculations, or at least experience a disutility from this process.

Another possible extension of this research is to group-buying mechanisms under uncertainty about product quality. When buyers can get signals about product quality from the bids of other buyers (similar to common values auctions), group-buying mechanisms can be a powerful way for the seller to induce buyers to signal product quality information to each other. Future research could extend our model to study the impact of these different factors—delays, uncertainty, risk aversion, bounded rationality, and adverse selection. The impact of competition and multiple markets concurrently functioning could be modeled through a dynamic simulation.

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An electronic companion to this paper is available at mansci.pubs.informs.org/ ecompanion.html.

[23] This holds especially when there is a strong *inverse* correlation between delay sensitivity and price sensitivity and, hence, a *direct* correlation between delay sensitivity and willingness to pay. In fact, some group-buying sites offer products (e.g., electronic items) that are less than state of the art at steep discounts, while the latest product is sold via Web-based posted prices or traditional brick-and-mortar channels. This quality-based, second-degree price discrimination reduces the cannibalization of the sales of high-margin, high-quality items by low-margin items.

References
Anand, K. S., H. Mendelson. 1997. Information and organization for horizontal multimarket coordination. *Management Sci.* **43**(12) 1609–1627.

——, ——. 1998. Postponement and information in a supply chain. Working paper, The Kellogg School, Northwestern University, Evanston, IL.

——, R. Anupindi, Y. Bassok. 2003. Strategic inventories in vertical contracts. Working paper 02-05-06, The Wharton School, University of Pennsylvania, Philadelphia, PA.

Cachon, G. P. 2003. The allocation of inventory risk and advanced purchase discounts in a supply chain. Working paper, The Wharton School, University of Pennsylvania, Philadelphia, PA.

Cremer, J., R. P. McLean. 1985. Optimal selling strategies under uncertainty for a discriminating monopolist when demands are interdependent. *Econometrica* **53**(2) 345–362.

——, ——. 1988. Full extraction of the surplus in Bayesian and dominant strategy auctions. *Econometrica* **56**(6) 1247–1257.

Dolan, R. J. 1987. Quantity discounts: Managerial issues and research opportunities. *Marketing Sci.* **6**(1) 1–22.

Kauffman, R. J., B. Wang. 2001. New buyers' arrival under dynamic pricing market microstructure: The case of group buying discounts on the Internet. *J. Management Inform. Systems* **18**(2) 157–188.

——, ——. 2002. Bid together, buy together: On the efficacy of group buying business models in Internet-based selling. P. B. Lowry, J. O. Cherrington, R. R. Watson, eds. *The E-Business Handbook*. CRC Press, Boca Raton, FL, 99–137.

Kohli, R., P. Heungsoo. 1989. A cooperative game theory model of quantity discounts. *Management Sci.* **35**(6) 693–707.

Lee, H. L., M. Rosenblatt. 1986. A generalized quantity discount pricing model to increase supplier's profits. *Management Sci.* **32**(9) 1177–1185.

Maskin, E., J. Riley. 1984. Monopoly with incomplete information. *RAND J. Econom.* **15**(2) 171–196.

Mas-Colell, A., M. D. Whinston, J. R. Green. 1995. *Microeconomic Theory*. Oxford University Press.

Monahan, J. P. 1984. A quantity discount pricing model to increase vendor profits. *Management Sci.* **30**(6) 720–726.

Myerson, R. B. 1981. Optimal auction design. *Math. Oper. Res.* **6**(1) 58–73.

——. 1991. *Game Theory: Analysis of Conflict*. Harvard University Press, Cambridge, MA.

Nahmias, S. 1997. *Production and Operations Analysis*, 3rd ed. McGraw-Hill, Irwin.

Tang, C. S., K. Rajaram, A. Alptekinoglu, J. Ou. 2001. The benefits of advance booking discount programs: Model and analysis. *Management Sci.* Forthcoming.

Tirole, J. 1988. *The Theory of Industrial Organization*. MIT Press, Cambridge, MA.

Weng, Z. K. 1995. Channel coordination and quantity discounts. *Management Sci.* **41**(9) 1509–1522.

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