Aggregation and Disaggregation of Information Goods: Implications for Bundling, Site Licensing, and Micropayment Systems

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ABSTRACT

We analyze pricing strategies for digital information goods that are based on aggregation or disaggregation. Bundling, site licensing, and subscription pricing can be analyzed as strategies that aggregate consumer utility across different goods, different consumers, or different time periods, respectively. Using micropayments for rental of software "applets," or other discrete units of information, can be thought of as disaggregation. We show that reductions in marginal costs made possible by low-cost digital processing and storage of information will favor aggregation of information goods, while reductions in transaction and distribution costs made possible by ubiquitous networking tend to make disaggregation more profitable.

Furthermore, offering the goods simultaneously in the aggregated package and as separate components may dominate strategies of both pure aggregation and pure disaggregation. Our model demonstrates how the increasing availability of information goods over the Internet will lead to increased use of both disaggregation-based pricing strategies, taking advantage of micropayment technologies, and aggregation strategies, whereby information goods will be offered in bundles, site licenses, and subscriptions.

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1. Introduction

The emergence of the Internet as a way to distribute digital information, such as software, news stories, stock quotes, music, photographs, video clips, and research reports, has created new opportunities for the pricing of information goods. Providers of digital information goods are not sure how to price them and are struggling with a variety of revenue models. Because perfect copies of these goods can be created and distributed almost costlessly, some of the old rules, such as “price should equal marginal cost,” are not applicable (Varian, 1995).

As noted by Varian (1995), Bakos and Brynjolfsson (1996, 1999a), Odlyzko (1996), Chuang and Sirbu (1997), and others, the Internet has also created new opportunities for repackaging content through bundling, site licensing, subscriptions, rentals, differential pricing, per-use fees, and various other mechanisms; others may yet be invented. All these schemes can be thought of as either aggregating or disaggregating information goods along some dimension. For instance, aggregation can be done across products, as in the case of bundling digital goods for sale in an applications software “suite” or providing access to an online service for a fixed fee. Aggregation can also be done across consumers, as with the provision of a site license to multiple users for a fixed fee, or over time, as with subscriptions (Odlyzko, 1996; Varian, 1995, 1996). Fishburn, Odlyzko, and Siders (1997) argue that the choice between aggregation and disaggregation cannot be made based on utility maximization, and ultimately rely on noneconomic arguments to predict that aggregation will dominate when marginal production and distribution costs become negligible.

In this chapter, we generalize the model of bundling introduced in Bakos and Brynjolfsson (1996, 1999a) by including a parameter that indexes the cost of distributing goods over a network. This, in addition to the parameter for the marginal cost of production introduced in our earlier work, allows us to compare pricing strategies based on aggregation and disaggregation. We find that lower transaction and distribution costs tend to make unbundling (disaggregation) more attractive for sellers, while lower marginal costs of production tend to make bundling (aggregation) more attractive. We then demonstrate how some of our earlier results on bundling can be generalized to other types of aggregation, such as site licensing and subscriptions. We find that, as with bundling, aggregating information goods across consumers or across time is often an effective strategy that maximizes societal welfare and the sellers’ profits; however, aggregation is less attractive when marginal costs are high or when consumers are very heterogeneous.

In section 2, we present the basic argument for the impact of aggregation on profits and efficiency. In section 3, we present a simple mathematical model demonstrating how changes in production and transaction costs affect the profitability of bundling and unbundling goods. In section 4, we show how the formal results can be applied to questions of site licensing, subscriptions, and micropayments. Section 5 discusses some implications for practice and suggests questions for further research.

2. Aggregation Changes Demand

Most goods can be thought of as aggregations, or bundles of smaller goods (Lancaster, 1966). For instance, a spreadsheet program is a bundle of components—the ability to calculate sums, to produce charts, to print in various fonts, and so on (Brynjolfsson and Kemerer, 1996). Similarly, the purchase of a durable good is equivalent to a series of rental contracts (Christensen and Jorgenson, 1966), and sharing of books or videocassettes can be seen as multiple separate transactions (Varian and Roehl, 1996).

Why Aggregate?

There are two main reasons that sellers may wish to use aggregation when selling information goods. First, aggregation can directly increase the value available from a set of goods, because of technological complementarities in production, distribution, or consumption. For instance, it is more cost-effective to deliver a few hundred pages of news articles in the form of a Sunday newspaper than to separately deliver each of the individual components only to the people who read it, even if most of the Sunday bundle ends up in the recycle bin without ever being read. Likewise, having a consumer purchase a movie on videocassette may be cheaper than repeatedly renting it, or for the seller to attempt charging members of the household separately for viewing it. These cost savings increase the surplus available to be divided between the buyer and the seller, although they may also affect the way the surplus is divided.

Second, aggregation can make it easier for the seller to extract value from a given set of goods by enabling a form of price discrimination. This effect of aggregation is subtler and, in the case of bundling, has been studied in a number of articles in the economics literature (Adams and Yellen, 1976; McAfee, McMillan, and Whinston, 1989; Schmalensee, 1984). While the benefits of aggregation due to cost savings are relatively easy to see, the price discrimination effect does not seem to be as widely recognized, although it can dramatically affect both efficiency and profits (Bakos and Brynjolfsson, 1996, 1999a).

The Effects of the Internet and Digitization

Ubiquitous low-cost networking, low-cost digital processing, and low-cost storage of information will profoundly affect the incentives for sellers to aggregate goods that can be delivered in digital form, whether to take advantage of cost savings or to price-discriminate. For example, the Internet is making it feasible to disaggregate news stories that were formerly aggregated in a newspaper simply to economize on transaction and distribution costs. The Internet has also made detailed monitoring and micropayment systems feasible, making it more attractive to sell small units of information, perhaps for use within a limited period of time, by a limited number of people or in a limited set of situations. As a result, many observers have predicted that software and other types of content will increasingly be disaggregated and metered, for instance as on-demand software "applets" or as individual news stories and stock quotes. For instance, Bob Metcalfe writes, "When the Internet finally gets micromoney systems, we'll rent tiny bits of software for seconds at a time. Imagine renting a French spelling checker for one document once" (Metcalfe 1997).

On the other hand, the near-zero marginal costs of reproduction for digital goods make many types of aggregation more attractive. While it is uneconomical to provide goods to users who value them at less than the marginal cost of production, when the marginal cost is zero and users can freely dispose of goods they do not like, then *no* users will value the goods at less than their marginal cost. As a result, economic efficiency and, often, profitability are maximized by providing the maximum number of such goods to the maximum number of people for the maximum amount of time. In this paper, we show that selling goods in large aggregates will often achieve this goal.

Thus, goods that were previously aggregated to save on transaction or distribution costs may be disaggregated, but new aggregations of goods will emerge to exploit the potential for price discrimination, creating new efficiencies and profit opportunities. We show that strategies involving bundling, site licensing, and subscriptions can each be understood as a response to the radical declines in production, distribution, and transaction costs for digital information goods, while micropayments can be seen as both a consequence and a cause of radically lower transaction and distribution costs.

Graphical Intuition: The Case of Bundling

The possibility of extracting more value from consumers by aggregating information goods can be illustrated by graphically analyzing the effect of bundling on the demand for information goods. Consider a simple linear demand curve for all goods, and assume that the initial fixed costs of producing a good are significant, but that after the first unit, marginal production costs, denoted by c, are close to zero. At price p, the number of units purchased will be q, resulting in profits of pq. However, as long as $p > c$, some consumers who value the good at more than its production costs will not be willing to pay as much as p. As a result, these consumers do not get access to the good, creating a deadweight loss, denoted by the shaded region in Figure 1. In addition, there are consumers who would have been willing to pay more than p for access to the good, but who have to pay only p to receive it. These consumers enjoy a consumers' surplus, as indicated in Figure 1.

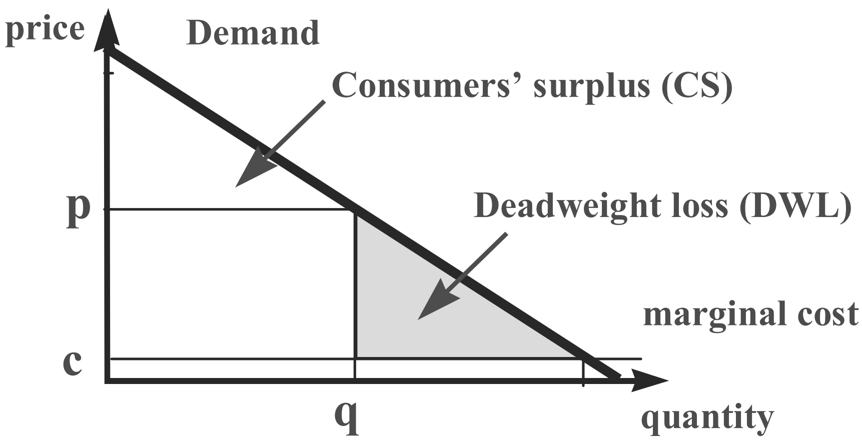

Figure 1: Deadweight loss from sales of a zero-marginal-cost information good

If the seller is able to price-discriminate, charging a different price to every consumer based on his or her willingness to pay, it will be able to increase its profits. Perfect price discrimination will maximize the seller's profits and will eliminate both the consumers' surplus and the deadweight loss (Varian 1995). If the seller cannot price-discriminate, however, the only single price that would eliminate the inefficiency from the deadweight loss would be a price equal to the marginal cost, which is close to zero. Such a low price would not generate sufficient revenues to cover the fixed cost of production and is unlikely to be the profit-maximizing price. Yet any significant positive price will inefficiently exclude some consumers.

Aggregation can sometimes overcome this dilemma. Consider two information goods, say a journal article and a music video, and suppose that each is valued between zero and one dollar by some consumers, generating linear demand curves such as the one in Figure 1. Suppose further that a consumer's valuation of one good is not correlated with his or her valuation of the other, and that access to one good does not make the other more or less attractive.

What happens if the seller aggregates the two goods and sells them as a bundle? Some consumers—those who valued both goods at one dollar— will be willing to pay two dollars for the bundle, while others—those who valued both goods at almost zero—will not be willing to pay even a penny. The total area under the demand curve for the bundle, and hence the total potential surplus, is exactly equal to the sum of the areas under the separate demand curves. However, most interestingly, bundling changes the shape of the demand curve, making it flatter (more elastic) in the neighborhood of one dollar and steeper (less elastic) near either extreme, as shown in Figure 2.[1]

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1. See Salinger (1995) for a detailed graphical analysis of the two-goods scenario.

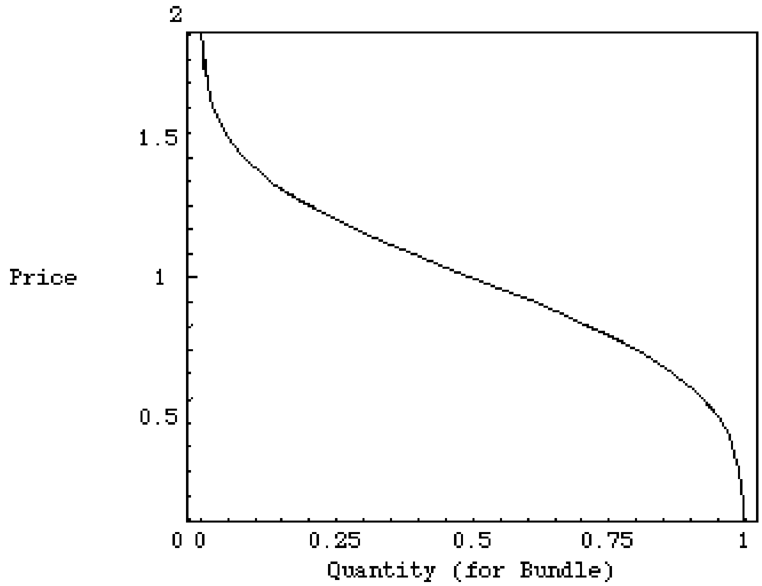

Figure 2: Demand curve for a bundle of two information goods with independently distributed uniform valuations

As more goods are added, this effect becomes more pronounced. For instance, the demand for a bundle of 20 goods, each of which has an independent, linear demand ranging from zero to one dollar, is shown in Figure 3.

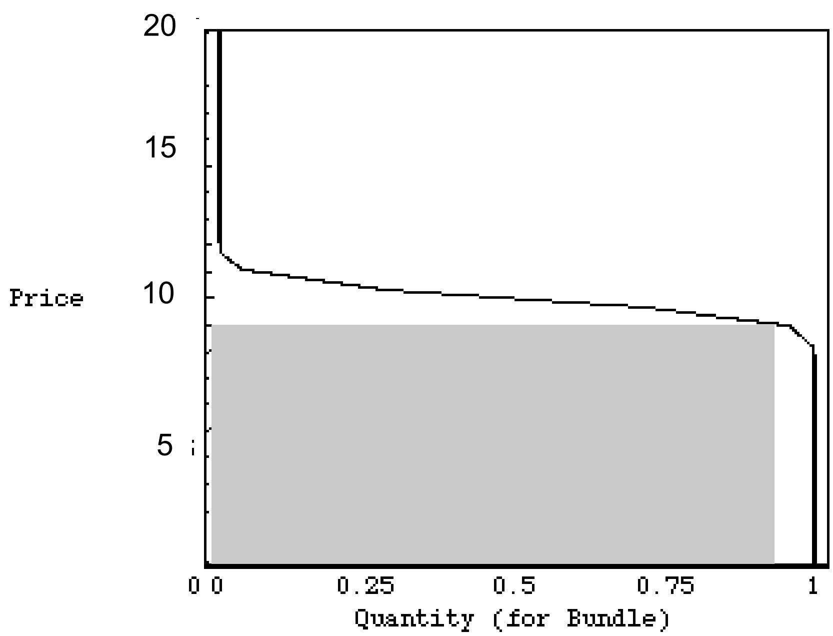

Figure 3: Demand curve for a bundle of 20 information goods with independently distributed uniform valuations

A profit-maximizing firm selling a bundle of 20 goods will set the price slightly below the $10 mean value of the bundle, and almost all consumers will find it worthwhile to purchase the bundle. In contrast, only half the consumers would have purchased the goods if they had been individually sold at the profit-maximizing price of 50 cents, so selling the goods as a bundle leads to a smaller deadweight loss and greater economic efficiency. Furthermore, the seller will earn higher profits by selling a single bundle of 20 goods than by selling each of the 20 goods separately. Thus, the shape of the bundle's demand curve is far more favorable both for the seller and for overall economic efficiency.

Why Does the Shape of the Demand Curve Change as Goods Are Added to a Bundle?

The law of large numbers implies that the average valuation for a bundle of goods with valuations drawn from the same distribution will be increasingly concentrated near the mean valuation as more goods are added to the bundle. For example, Figure 4 shows the uniformly distributed probability of a consumer's valuation for a good with the linear demand shown in Figure 1.

Figure 4: Uniform probability density function for a good's valuation

If a second good is bundled with the first, the probability density function for the consumer's valuation for the bundle of two goods is the convolution of the two uniform distributions, which will be shaped like an inverted *V* (Figure 5).

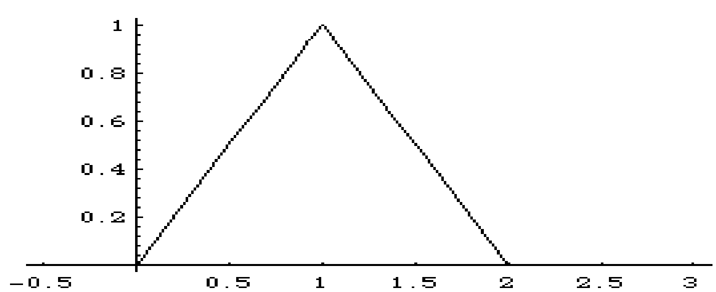

Figure 5: Convolution of two uniform probability density functions

As more and more goods are added to the bundle, the sum of valuations becomes more concentrated around the mean, reflecting the law of large numbers (Figure 6). That is, the high and low values for individual goods tend to "average out" so that consumers' valuations for the bundle include proportionately more moderate valuations. For example, some people subscribe to America Online for the news, some for stock quotes, and some for horoscopes. It is unlikely that a single person has a very high value for every single good offered; instead, most consumers will have high values for some goods and low values for others, leading to moderate values overall.

Sellers can take advantage of the fact that demand for the bundle (adjusted for the number of goods) will be more concentrated around the mean valuation than in the case of individual goods. The distribution of valuations for the bundle of 20 goods shown in Figure 6 corresponds to the demand curve shown in Figure 3.

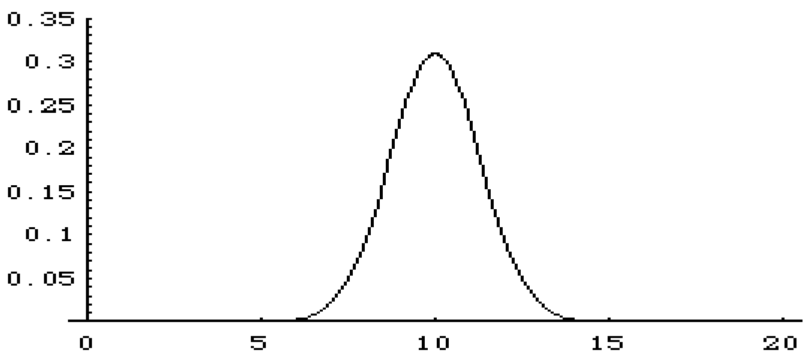

Figure 6: Convolution of 20 uniform probability density functions

Thus, bundling can be thought of as a type of price discrimination, except that instead of increasing the menu of prices to better match the heterogeneous distribution of consumers, bundling reduces the effective heterogeneity of the consumers so that a single price can effectively and efficiently allocate goods to them. Like the Procrustean bed, bundling changes consumers' demands so that a single price fits them all.

If consumers' demands remain heterogeneous even after bundling, then a mixed bundling strategy, which offers a menu of different bundles at different prices, will dominate pure bundling (which is simply a special case of mixed bundling). However, when consumers' valuations for the goods in the bundle are not correlated, the profit advantage of mixed bundling over pure bundling diminishes as the number of goods in the bundle increases.

Similar effects result in other types of aggregation, such as aggregation across consumers, as in the case of selling a single site license for use by multiple consumers. This analogy is explored more fully in section 4. The law of large numbers, which underlies these aggregation effects, is remarkably general. For instance, it holds for almost any initial distribution, not just the linear one shown graphically above.[2] Furthermore, the law does not require that the valuations be independent of each other or even that the valuations be drawn from the same distribution.

The desirability of bundling as a device for price discrimination can break down when consumers' valuations are correlated with one or more common variables. Similarly, applying the same type of analysis to study the impact of marginal costs, we find that when marginal costs are high, unbundling may be more profitable than bundling.

3. A Model for Aggregation and Disaggregation

The above insights can be modeled more formally. In particular, the aggregation of information goods into bundles entails several types of costs:

- *Production cost:* the cost of producing additional units for inclusion in the bundle. For instance, storage, processing, or communications costs incurred in the process.
- *Distribution cost:* the cost of distributing a bundle of information goods.
- *Transaction cost:* the cost of administering transactions, such as arranging for payment.
- *Binding cost:* the cost of binding the component goods together for distribution as a bundle. For example, formatting changes necessary to include a good in the bundle.
- *Menu cost:* the cost of administering multiple prices for a bundle. If a mixed bundling strategy for n goods is pursued, as many as 2^n prices (one for each separate sub-bundle of one or more goods) may be required.

We now focus on the impact of production costs and distribution/transaction costs, which seem to be most important for determining the desirability of aggregation; similar reasoning can be applied to the binding and price administration costs.

Consider a setting with a single seller providing n information goods.[3] Let p_n^*, q_n^*, and π_n^* denote the profit-maximizing price per good for a bundle of n goods, the corresponding sales as a fraction of the population, and the seller's resulting profits per good. Assume that

A1: The marginal cost of producing copies of all information goods and the marginal distribution and transaction cost for all information goods are zero.

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2. There are several versions of the law of large numbers, but in general the random variables being combined must have only finite variance.

3 This setting, the assumptions, and the main result for bundling information goods are derived from Bakos and Brynjolfsson (1996).

A2: Each buyer can consume either 0 or 1 unit of each information good and resale is not permitted.

A3: For all n, buyer valuations are independent, identically distributed (i.i.d.) with continuous density functions, nonnegative support, finite mean μ, and finite variance σ^2.

By applying the law of large numbers to the above setting, we derived the following proposition and the corresponding corollary in Bakos and Brynjolfsson (1996, 1999a):

Proposition 1 (minimum profits from bundling zero-marginal-cost i.i.d. goods):

Given assumptions A1, A2, and A3, bundling n goods allows the seller to capture as profits at least a fraction $\left[1-2\left(\frac{(\sigma/\mu)^2}{n}\right)^{\frac{1}{3}}+\left(\frac{(\sigma/\mu)^2}{n}\right)^{\frac{2}{3}}\right]$ of the area under the demand curve.

Corollary 1 (bundling with symmetric distribution of valuations):

Given assumptions A1, A2, and A3, if the distribution of valuations is symmetric around the mean, a fraction of the area under the demand curve of at least $\left[1-\frac{3}{2}\left(\frac{(\sigma/\mu)^2}{n}\right)^{\frac{1}{3}}+\frac{1}{2}\left(\frac{(\sigma/\mu)^2}{n}\right)^{\frac{2}{3}}\right]$ can be captured by bundling n goods.[4]

We now extend the original model by substituting Assumption A4 for Assumption A1:

A4: The marginal cost for producing each information good is c, and the sum of distribution and transaction costs for any individual good or bundle is d.

Assumption A4 implies that the total incremental cost of supplying a bundle of n information goods is $nc + d$.

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[4] For example, if consumer valuations are i.i.d. with a distribution symmetric around the mean and a coefficient of variation $\mu/\sigma = 1/\sqrt{3}$ (e.g., uniformly distributed in $[0,2\mu]$), the seller can realize profits of at least 80% of the total area under the demand curve with a bundle of 100 goods. For most common distributions of independent valuations, this corollary provides a conservative lower bound; for instance, with valuations uniformly distributed in $[0,2\mu]$, this level of profits can actually be achieved by bundling eight goods.

Corollary 2 (bundling with production, distribution, and transaction costs):

Given assumptions A2, A3, and A4, bundling n goods results in profits of π_B^* for the seller, where $\pi_B^* \geq \left(\mu - c - \frac{d}{n}\right)\left[1 - 2\left(\frac{(\sigma/\mu)^2}{n}\right)^{\frac{1}{3}} + \left(\frac{(\sigma/\mu)^2}{n}\right)^{\frac{2}{3}}\right]$.

Selling the goods individually, the seller faces a downward-sloping demand curve $q_i(p_i) = \int_p^\infty f(x)dx$ for each individual good, and will select the optimal price p_i^* and corresponding quantity q_i^* that will maximize profits , resulting in profits of π_i^*.

When the number of goods is large, bundling will be superior to unbundled sales in the limit as long as $\pi_B^* \approx \mu - c > \pi_i^*$. Furthermore, if there is no consumer with a valuation greater than $v_{\max}$, unbundled sales will be profitable only as long as $c + d \leq v_{\max}$.

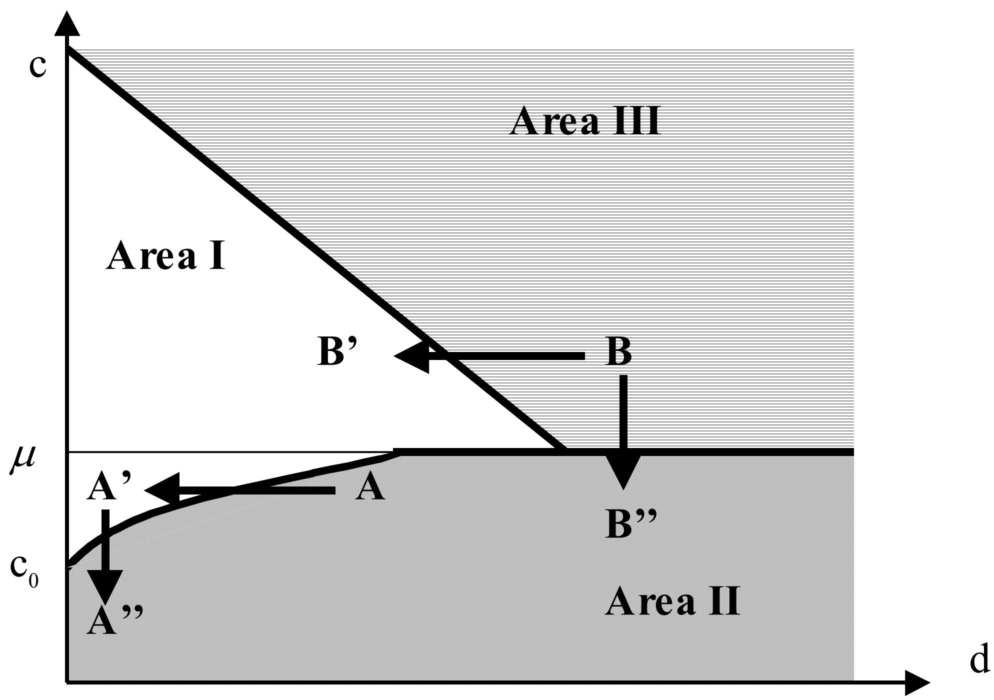

Figure 7: Phase diagram for bundling and unbundling strategies as a function of marginal cost and transaction/distribution cost

Figure 7 depicts the impact of c and d on the desirability of bundling large numbers of goods. In Area I, unbundled sales dominate bundling. In Area II, bundling is more profitable than unbundled sales. Finally, in Area III, the marginal production, distribution, and transaction costs are high enough to make both bundled and unbundled sales unprofitable.[5]

A reduction in distribution or transaction costs can make unbundling more attractive than bundling (a move from A to A'). For example, it is often argued that as micropayment technologies and electronic distribution reduce *d*, there will be a move toward "atomic" pricing, that is, price per use (Metcalfe 1996, 1997). However, as soon as the marginal cost falls below a certain threshold c_0, bundling becomes more profitable than unbundling, even if distribution and transaction costs are zero, as demonstrated by the move from A' to A". While bundling is optimal in the neighborhood of A mainly as a way to economize on distribution and transaction costs, the benefits of bundling in the neighborhood of A" derive from its ability to enable the seller to extract more profits from consumers. Therefore, the types of bundles observed in a world of high production, distribution, and transaction costs (near A) may differ substantially from the types of bundles observed in a world with very low production, distribution, and transaction costs.

A reduction in *c*, *d*, or both can move a good from Area III (no trade) to either Area I (unbundled sales, if the primary reduction is in the distribution and transaction costs) or Area II (bundled sales, if the primary reduction is in the marginal cost of production).

The threshold level c_0 below which bundling becomes unambiguously more profitable than unbundling depends on the distribution of the underlying valuations. For example, consider consumer valuations that are uniformly distributed in $[0, v_{\max}]$, which corresponds to a linear demand function. Selling the goods individually, the seller faces a downward-sloping demand curve $q_i = \frac{v_{\max} - p_i}{v_{\max}}$ for each individual good, resulting in a monopolistic equilibrium price of $p_i^* = \frac{v_{\max} + c + d}{2}$ for each good, and corresponding profit of $\pi_i^* = \frac{(v_{\max} - c - d)^2}{4v_{\max}}$ as long as $c + d \leq v_{\max}$. Selling the information goods in bundles of *n* goods results in profits $\pi_B^*(n)$, where

$$\pi_B^*(n) \geq \left(\frac{v_{\max}}{2} - c - \frac{d}{n}\right)\left[1 - 2\left(\frac{1}{3n}\right)^{\frac{1}{3}} + \left(\frac{1}{3n}\right)^{\frac{2}{3}}\right].$$

5. A similar diagram can be drawn to show when bundling or unbundling is economically efficient from a social-welfare standpoint. Unfortunately, the regions in which bundling and unbundling are socially efficient are not identical to the regions in which each is profitable. In particular, bundling is socially inefficient in a substantial portion of Area II near the frontier with Area I.

When the number of goods is large, bundling will be superior to unbundled sales in the limit as long as $\frac{v_{\max}}{2} - c > \frac{(v_{\max} - c - d)^2}{4v_{\max}}$ $c \le \frac{v_{\max}}{2}$ and $c + d \le v_{\max}$. If $c + d > v_{\max}$, unbundled sales will be unprofitable, while bundled sales will be unprofitable if $c > \frac{v_{\max}}{2}$. In this case, c_0 is approximately 0.41 $v_{\max}$. Figure 8 shows a "phase diagram" of the corresponding profitability areas.

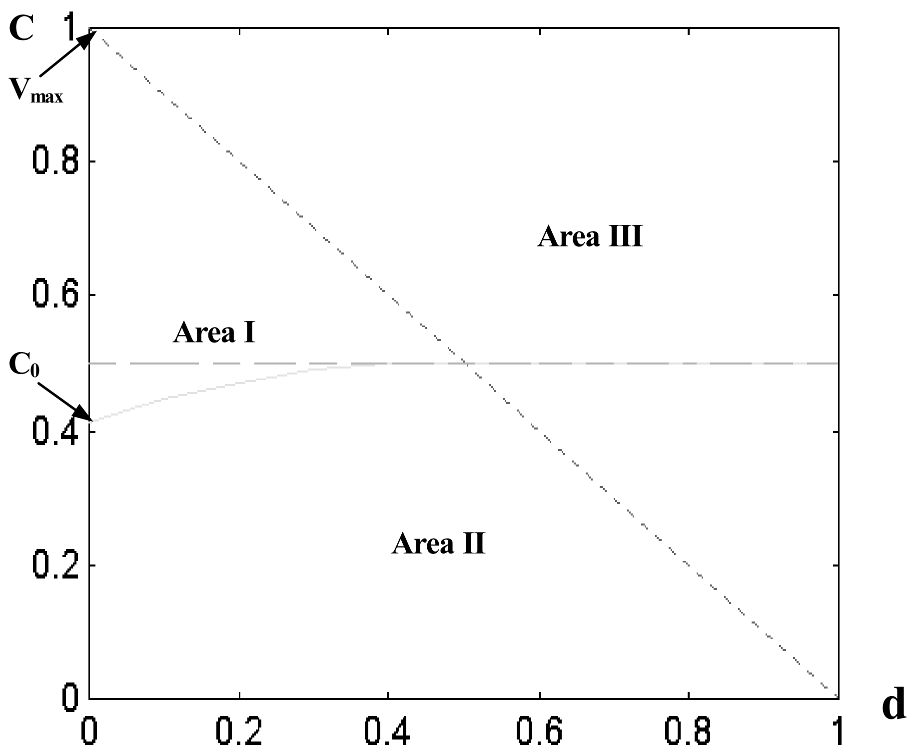

Figure 8: Phase diagram for bundling and unbundling strategies as a function of marginal production cost and distribution/transaction cost when valuations are uniformly distributed

It can be argued that linear demand functions and the corresponding uniform distribution of valuations are not appropriate for information goods. For example, most consumers may have exactly zero valuation for 90% of the news stories provided by a news service, and a linear demand for the remaining 10%. The resulting piecewise linear demand curve would be similar to the one used by Chuang and Sirbu (1997) and to several numerical examples presented in Odlyzko (1996).

When many consumers have zero valuations for any given good, the effects of any marginal costs will be amplified and the region in which bundling is profitable will be reduced. This is because any bundle will likely include numerous goods with no value to any given consumer; if these goods are costly to provide, they will tend to reduce the value created by providing the bundle to that consumer. For instance, when consumers have nonzero valuations for only 10% of the goods, the threshold value, c_0, at which bundling becomes unprofitable relative to bundled sales declines by a factor of 10 to 0.041 $v_{\max}$.

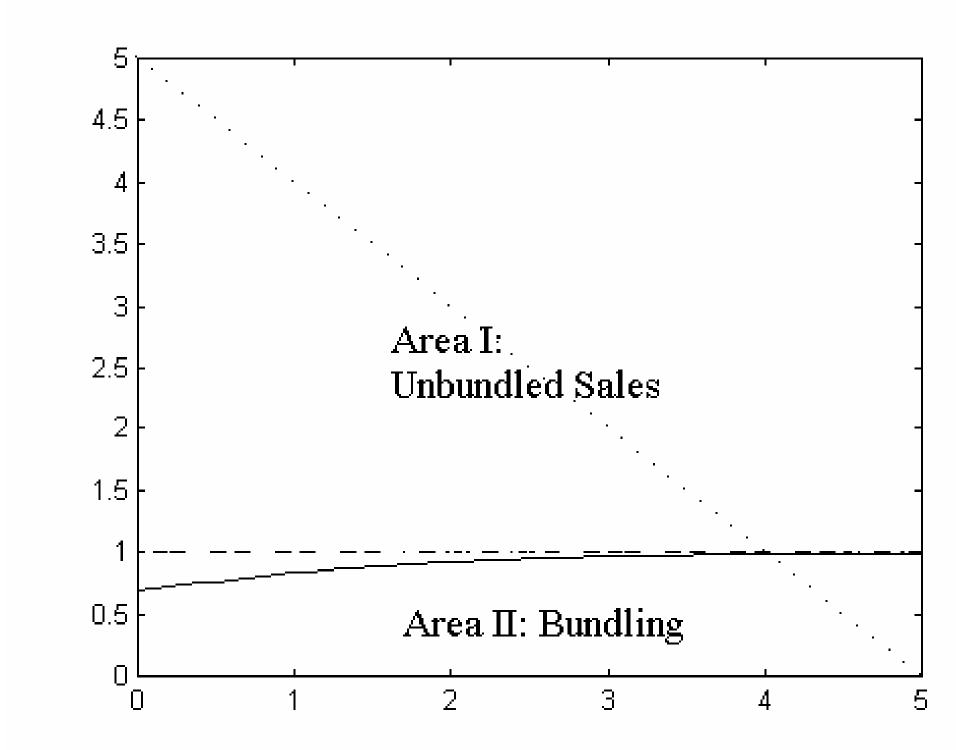

Figure 9: Phase diagram for bundling and unbundling strategies as a function of marginal production cost and distribution/transaction cost when valuations are exponentially distributed

As another example, when valuations are distributed exponentially—so that only a small number of people have high valuations and a long tail of people have low valuations but no one quite has a zero valuation—and marginal costs are near zero, bundling can allow sellers to profitably provide the goods to the long tail of people who have relatively low valuations for the good. Because the number of such people may be very large, the efficiency and profit effects can be substantial: One could grow quite rich by selling a joke per day to 10 million people, even if most of them valued the joke at only a penny or less. However, as soon as marginal costs begin to approach the average consumer's valuation, bundling becomes unprofitable. In contrast, because the exponential distribution assumes there is always a positive probability that someone will have a valuation equal to or greater than any finite number, unbundled sales are never completely unprofitable; they simply require a price greater than the sum of production, distribution, and transaction costs. Figure 9 shows the "phase diagram" with the corresponding two areas of profitability.

4. Site Licensing and Subscriptions

The preceding section focused on the benefits of aggregation in the context of bundling. As has been noted in two examples by Odlyzko (1996) and several analytical models by Bakos and Brynjolfsson (1999c) and Bakos, Brynjolfsson, and Lichtman (1999), parallel arguments can be made for aggregation in other dimensions, such as site licensing (aggregation across users) and subscriptions (aggregation over time).

Site Licensing

As with bundling, there are many reasons that a firm may choose to sell its products through a site license instead of selling them to individual users. For instance, site licensing can reduce administrative costs and transaction costs; reduce or eliminate the need to check for piracy at a given customer's site; facilitate interoperability and foster positive network externalities; and reduce maintenance costs through standardization of software configurations. Many of these costs can be modeled as creating a fixed transaction cost, t, per sale, analogous to the distribution/transaction cost parameter, d, in section 3. When this cost is sufficiently high, aggregation (site licensing) will be more profitable than disaggregation (individual sales).[6]

As shown by Bakos and Brynjolfsson (1999c), an analysis similar to that for bundling shows that site licensing can also be seen as a mechanism for aggregation that increases seller profits and reduces the inefficiency of withholding a good from consumers who value it at more than its marginal cost. Where bundling aggregates a single consumer's valuations for many products, site licensing aggregates many consumers' valuations for a single product. As with bundling, the law of large numbers will lead to a distribution of valuations for the site license that, after adjusting for the number of users, is less dispersed and more predictable than the distribution of individuals' valuations for the same good.

For instance, some researchers at a university may have high valuations for Mathematica and be willing to pay $500 for access to it; other users might value it only at $50; and still others might be willing to pay $5 or $10 to have easy access to the program in case it is needed in the future. Wolfram Research, the manufacturer of Mathematica, could set a high price and exclude potential users with low valuations, or set a low price that fails to extract most of the surplus from the high-valuation users.[7] Alternatively, Wolfram could offer a site license to the university that gives all potential users access to Mathematica. The value of such a site license

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6. Varian (1997) develops a model for sharing information goods that can be applied to site licensing; however, his analysis is driven by transaction cost considerations rather than the aggregation effects.

7. If Wolfram Research can identify the users who have high and low values, it can also price-discriminate by charging different prices to different users. However, because users can often disguise their true valuations, price discrimination typically leaves some rents in the hands of high-value users and excludes some low-value users from access to the good.

to the university is equal to the sum of all potential users' individual valuations. This amount is larger than the profits that can be obtained through individual sales. Thus, both profits and efficiency may be increased if the seller pursues a site license.

If the seller does not offer the goods for sale to individual users, then in principle it could offer the site license for a price just slightly less than the expected sum of individual valuations (i.e., at a price $p \approx m^*\mu$, where m is the number of individuals at the site and μ is the average valuation for the good in this population). Almost all sites would find this price acceptable, and thus almost all users would get access to the good.[8] As with bundling, in the limit, aggregation virtually eliminates inefficiency and maximizes profits, at the expense of consumers' surplus.

One important difference between site licensing and bundling is that the site-licensing strategy requires an agent who has authority to purchase information goods on behalf of their ultimate consumers. An agent may not have perfect information about the preferences of end users, and his or her incentives may not be perfectly aligned with those of the end users; this may reduce the benefits of a site-licensing strategy.

Subscriptions

Our model of aggregation can also be applied to dimensions such as time and space. For example, when the good can be costlessly provided over time, it may be more profitable to sell it as a long-term subscription than to sell individual uses in short periods of time. Since a given user may sometimes have high valuations for the good and sometimes low valuations, per-use (or short-term) pricing might inefficiently exclude use during low-valuation periods, even when the cost of provision is zero. Greater efficiency and profits can result from charging a single subscription fee and giving the user long-term access to the good, by an argument corresponding to those for bundling and site licensing.[9]

Similarly, allowing the user to access the good from multiple locations may also provide some of the benefits of aggregation; a requirement that the good be used only on a specific machine or in a specific location would undermine these benefits. Without aggregation, some users might forgo access to the good in places where their valuations were low; when the costs of providing additional access are even lower (or zero), this would create an inefficiency.

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8 When individual copies are also available at a price that would leave some surplus in the hands of some consumers, the seller cannot extract the full value of the product through a site-licensing strategy. If the seller attempted to do so, the buyers would be collectively better off by individually buying or not buying the product.

9 A subscription may provide the user with different goods over time; in such cases, the logic of bundling applies directly. However, even when a subscription provides the *same* good in different time periods, the aggregation effects may still be important, since consumer valuations for the good may vary with time. If these valuations are serially correlated, however, the benefits of aggregation will tend to be lower (Bakos and Brynjolfsson, 1996).

There are many other ways to "disaggregate" goods. Technologies such as micropayment systems, cryptolopes, autonomous agents, and object technology are enabling sellers to charge different prices when information goods are disaggregated in various ways. For instance, a seller of software, in principle, could charge users a price for each time a function of its product is invoked on a particular machine. Although such "atomic" pricing may become feasible, it would reduce or eliminate the benefits of aggregation and thus it might reduce efficiency and profits.

When to Use Micropayments: "Mixed Aggregation" Can Dominate Pure Aggregation

Our model indicates that complete disaggregation or "mixed aggregation" (which involves simultaneously selling both an aggregate and disaggregated components) can be more profitable than aggregation strategies in three specific circumstances.

First, if marginal costs are nontrivial, disaggregation can economize on these costs by allowing users to "opt out" of components with a marginal cost greater than their marginal benefit. For example, if the marginal cost of providing an additional component or servicing an additional user is c, a seller that charges a fixed price p plus an additional price of c per component or user will avoid the inefficiency of including too many components in the sale or servicing too many users. If c is very low, micropayment technology may be required to enable the seller to profitably pursue such a strategy.

Second, if some consumers are willing to pay more for all goods, mixed aggregation may be beneficial if it can help sort consumers. For instance, if consumers with high valuations tend to prefer to use more goods or use the goods more often, a mixed-aggregation strategy can induce them to self-select and pay higher prices for larger aggregations.

Third, even when marginal costs are negligible and consumers are homogeneous, large aggregations of goods (or users) may be required to fully extract profits and to maximize efficiency. Therefore, if the seller can aggregate over only a small number of goods, consumers, or time periods, it may be optimal to also offer some goods outside the bundle, site license, or subscription.

Aggregation and Disaggregation on Multiple Dimensions

Aggregation can also be practiced on multiple dimensions simultaneously. For instance, bundles of goods can be offered on a site-license basis to multiple users for an extended period of time. This strategy may enable the seller to get closer to full efficiency and earn higher profits, since aggregation along one dimension will not generally exhaust the benefits of aggregation in other dimensions. Indeed, when the valuations of the goods are independently distributed and these goods have zero marginal cost, the optimal strategy will be to offer the largest possible bundle of goods through the largest possible site license for the broadest possible set of conditions, and to charge a price low enough to get almost all users to participate. This strategy captures as profits nearly the entire possible surplus from the goods.

In practice, it might make sense to aggregate in some dimensions while disaggregating in other dimensions. For instance, if marginal costs are not negligible, it may be appropriate to offer only subsets of the goods in each of several bundles so that users can choose the sets of goods they find most valuable and avoid the production cost for the ones they do not. Similarly, the seller could choose to disaggregate (or avoid aggregating) in those dimensions that are most effective in getting users to reveal their valuations while aggregating in other dimensions.

5. Conclusion

The Internet is precipitating a dramatic reduction in the marginal costs of production and distribution for digital information goods, while micropayment technologies are reducing the transaction costs for their commercial exchange. These developments are creating the potential to use pricing strategies for information goods based on aggregation and disaggregation. Because of the ability to cost-effectively aggregate very large numbers of information goods, or, at the other end of the spectrum, offer small components for individual sale, these strategies have implications for information goods that are not common in the world of physical goods.

In particular, aggregation can be a powerful strategy for providers of information goods. It can result in higher profits for sellers as well as a socially desirable wider distribution of the goods, but it is less effective when the marginal production costs are high or when consumers are heterogeneous. Aggregation strategies can take a variety of forms, including bundling (aggregation across different goods), site licensing (aggregation across different users), and subscriptions (aggregation over time). These strategies can reduce buyer heterogeneity by aggregating a large number of goods, users, or time periods, and can also reduce distribution and transaction costs. Therefore, a decision to aggregate information goods should be based on the trade-off between the benefits of aggregation and the marginal costs of production and distribution. Low distribution costs make aggregation less attractive, while low marginal production costs make aggregation more attractive.

On the other hand, the low distribution and transaction costs offered by ubiquitous networking and micropayment technologies enable the use of disaggregation strategies such as per-use fees, rentals, and sale of small components. Disaggregation strategies enable sellers to maximize their profits by price discriminating when consumers are heterogeneous. For example, the number of goods desired by individual consumers may be correlated with their valuations for these goods, as when a professional stock trader demands more financial news stories and has higher valuation for these stories than an individual investor. The seller can take advantage of this correlation by incorporating the signal that reveals the consumer’s valuation, that is, the number of news stories purchased, in the pricing of the goods, resulting in some type of pay-per-use pricing. In general, the pricing scheme used should incorporate all signals that may reveal a consumer's willingness to pay, and micropayment technologies can enable the implementation of such schemes.

The optimal pricing strategy will often involve mixed aggregation, that is, the simultaneous availability of information goods in aggregates of different sizes and compositions as well as individually. Mixed aggregation will be more desirable in three cases: first, when consumers are very heterogeneous, as it provides a device for price discrimination; second, when the marginal production costs are significant, as this increases the cost of offering goods to consumers who do not value them; and finally, when the number of goods for sale is relatively small, as the aggregation benefits of the law of large numbers will not be as powerful and the menu costs of administering the prices for all bundles offered will not be as high.

Our analysis of aggregation provides a framework in which to understand the pricing strategies of online content providers such as America Online and the Microsoft Network, the widespread use of site licensing of software and data access by companies such as Wolfram Research and Reuters, and subscription pricing in the sale of information goods by companies such as Netscape and *The Wall Street Journal.* It can also explain how the dramatic reduction in marginal production, distribution, and transaction costs precipitated by the Internet is leading to pricing strategies based on both aggregation and disaggregation. Because the reasons for aggregating information goods when production and distribution costs are very low differ substantially from the reasons for aggregating goods when these costs are high, the content and nature of the aggregations (e.g., bundles) may differ substantially in these two situations.

In the models presented in this paper, we have focused on the demand-reshaping effects of aggregation and disaggregation, and have ignored their strategic aspects. In a related paper (Bakos and Brynjolfsson 1999b), we find that the profit-enhancing potential of bundling will often be increased when competitors are forced to respond.[10] The analysis in this chapter suggests that there may be similar competitive benefits in site licensing and subscription strategies.

Finally, aggregation also has significant effects on social welfare. Specifically, aggregation strategies can substantially reduce the deadweight loss from monopoly, but they can also lower the surplus left to consumers.

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10 Specifically, in the presence of fixed production costs (and low or zero marginal costs), aggregation can drive competitors out of the market, even when their products are qualitatively superior. Such a response will often increase the profitability of aggregation.

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