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

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ABSTRACT

We analyze pricing strategies that are based on aggregation or disaggregation of digital information goods. For instance, 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. On the other hand, unbundling magazine articles for individual sale, or using micropayments for renting software "applets" correspond to a strategy of disaggregation. We show that reductions in marginal costs made possible by low-cost digital processing and storage of information will favor aggregation, while reductions in transaction and distribution costs made possible by ubiquitous networking tend to make disaggregation of information goods more profitable. Our analysis 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 where 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 unsure 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 sensible (Varian, 1995).

It has been argued that because electronic markets lower search and transaction costs, the Internet will promote the creation of new markets, leading to an increased number of markets in individual goods and services (Bakos, 1997; Malone, Yates and Benjamin, 1986). The result has even been likened to "friction-free capitalism" (Gates, 1995). These predictions, however, focus on physical goods and services. In this paper, we find that for information goods, the decline in the marginal cost of reproduction associated with digitization often provides a countervailing force to the reduction in transaction costs associated with ubiquitous networking. Consequently, some of the disaggregating effects of the Internet are mitigated or even reversed.

As noted by Varian (1995), Bakos and Brynjolfsson (1996), 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 of these schemes can be thought of as either aggregating or disaggregating information goods along some dimension. For instance, aggregation can take place across products, as when software programs are bundled for sale in a software "suite" or when access to the various content of an on-line service is provided for a fixed fee. Aggregation can also take place 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) analyze some related aspects of bundling in a duopoly setting and argue that a bundling strategy will typically prevail when marginal production and distribution costs become negligible.

In this paper, we extend the analysis of bundling introduced in (Bakos & Brynjolfsson, 1996) by modeling the distribution and transaction costs associated with providing information goods. Considering the distribution and transaction costs in addition to the marginal cost of production, we 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 also demonstrate that 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 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 and provide a graphical intuition. 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 aggregation in other dimensions, such as site licensing and subscriptions. Section 5 discusses extensions of the model to "mixed" aggregation—the simultaneous sale of both aggregates and their sub-components—and addresses issues related to micropayments. Section 6 discusses some implications for practice and suggests questions for further research.

2. Aggregation Changes Demand

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

Why Aggregate?

There are two main reasons that sellers may wish to aggregate 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 them, even if most of the Sunday bundle ends up in the recycle bin without ever being read. Likewise, purchasing a movie on videocassette may be cheaper than repeatedly renting it or attempting to separately charge members of the household for viewing it. These cost savings increase the surplus available to be divided between the buyer and seller, although they may also affect how the surplus is divided. Similarly, including certain types of functionality together in a software application can create value greater than the sum of its parts.

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 (e.g., Adams and Yellen, 1976; McAfee, McMillan and Whinston, 1989; Schmalensee, 1984). While the benefits of aggregation due to technological complementarities are relatively easy to see, the price discrimination effect does not seem to be as widely recognized outside the economics literature, although it can dramatically affect both efficiency and profits (Bakos and Brynjolfsson, 1996).

The Effects of the Internet and Digitization

Ubiquitous low-cost networking and low-cost digital processing and storage of information will profoundly affect the incentives of sellers to aggregate goods that can be delivered in digital form, enabling them to take advantage of cost savings and to price discriminate. For example, the Internet is making it feasible to disaggregate news stories that formerly were 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 in 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, 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 for reproducing digital goods make many types of aggregation more attractive. While it is uneconomical to provide goods to consumers 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* consumers will value the goods at less than their marginal costs. Consequently, economic efficiency and often profitability are maximized by providing the maximum number of such goods to the maximum number of consumers for the maximum amount of time. In this paper, we show that selling goods in large aggregates will often achieve this goal.

In the new information economy goods that had previously been 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 responses 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 impact of aggregation on the profitability of selling 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 that 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 only have to pay *p* to receive it. These consumers enjoy a consumers' surplus as indicated in Figure 1.

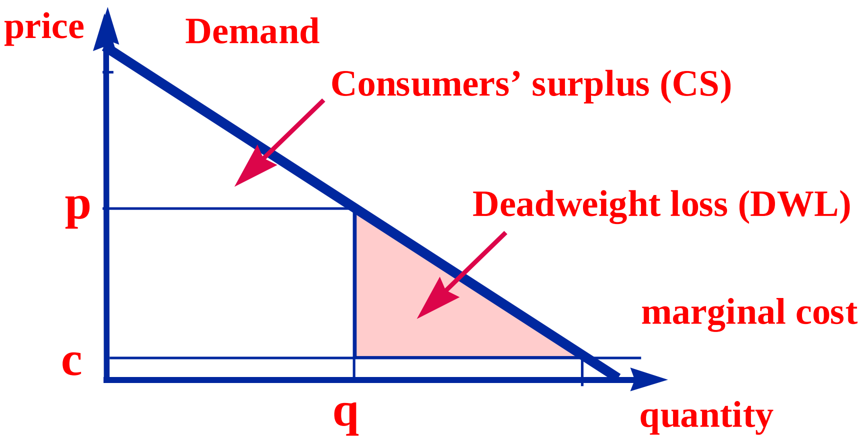

Figure 1: Deadweight loss from sales of a zero-marginal-cost information good

If the seller is able to price discriminate, charging different prices to every consumer based on their willingness to pay, it will be able to increase its profits. Perfect price discrimination will maximize the sellers' 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 by consumers between zero and one dollar, generating linear demand curves like the one in Figure 1. Suppose further that a consumer's valuation of one good is not correlated with his or her valuation for 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— would 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 2A. [1] As more goods are added, this effect becomes more pronounced. For example, Figure 2B shows the demand for a bundle of 20 goods, each of which has an independent, linear demand ranging from zero to one dollar.

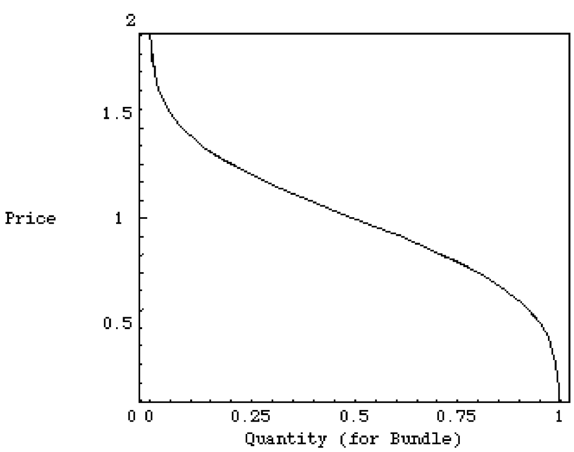

Figure 2A: Demand curve for a bundle of two information goods with independently distributed uniform valuations

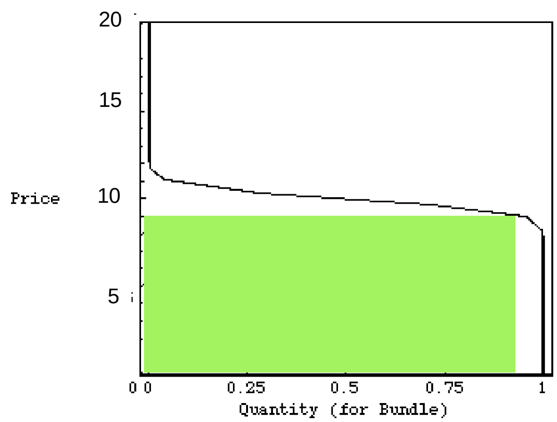

Figure 2B: Demand curve for a bundle of 20 information goods with independently distributed uniform valuations

A profit-maximizing firm selling a bundle of 20 goods will set the price slightly below the mean value of the bundle of $10, 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

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

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 3 shows the uniformly distributed probability of a consumer's valuation for a good with the linear demand shown in Figure 1.

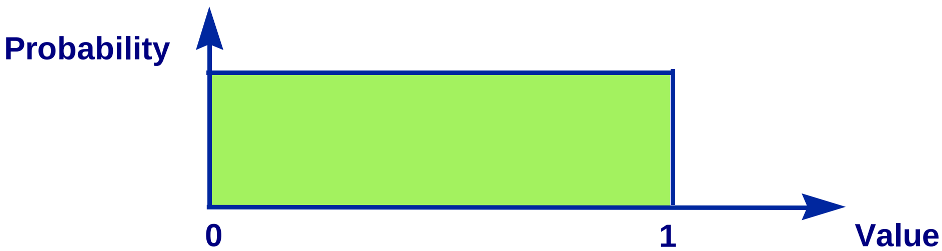

Figure 3: Uniform probability density function for a good's valuation

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 4). 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. 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 other goods, leading to moderate values overall.

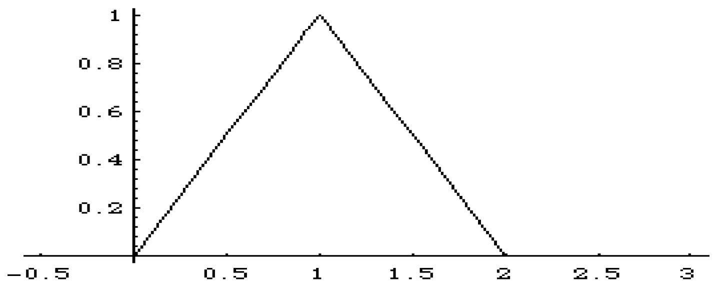

Figure 4: Convolution of two uniform probability density functions

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. 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' willingness to pay, so that a single price can effectively and efficiently allocate goods to them. Like the Procrustean bed, bundling changes consumer's demand 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.

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

Bundling may not offer a desirable device for price discrimination when consumers' valuations are correlated with one or more common variables, although price discriminating for different bundles may alleviate this problem (Bakos and Brynjolfsson, 1996). Similarly, as shown in the next section, 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:

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

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

A2: Each buyer can consume either 0 or 1 units 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, non-negative 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 corresponding Corollary in (Bakos and Brynjolfsson 1996):

<u>Proposition 1 (Minimum profits from bundling zero marginal cost i.i.d goods):</u>

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 maximum possible consumers' surplus (i.e., the area under the demand curve).

<u>Corollary 1 (Bundling with symmetric distribution of valuations):</u>

Given assumptions A1, A2, and A3, if the distribution of valuations is symmetric around the mean, then 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:

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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 $[0,2\mu]$), then 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, 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.

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*.

<u>Corollary 2 (Bundling with production, distribution and transaction costs):</u>

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 $\pi_i(p_i) = (p_i - c - d) \cdot q_i(p_i)$, 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 $v_{\max}$, then unbundled sales will be profitable only as long as $c + d \leq v_{\max}$.

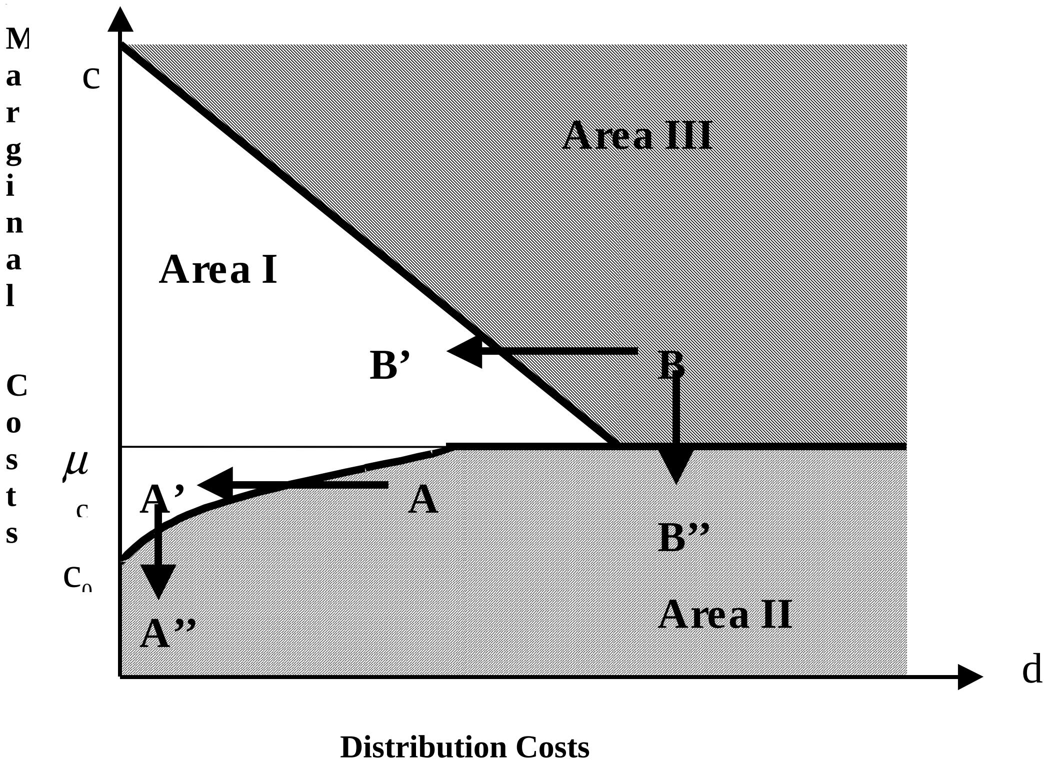

Figure 5: Phase diagram for bundling and unbundling strategies as a function of marginal cost and transaction/distribution cost.

Figure 5 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 “fine-grained” pricing, e.g., 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

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.

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 of 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 $c + d \le v_{\max}$. Selling the information goods in bundles of *n* goods results in profits $\pi_B^*(n)$, where $\pi_B^*(n) \ge \left(\frac{v_{\max}}{2} - c - \frac{d}{n}\right)\left[1 - 2\left(\frac{1}{3n}\right)^{\frac{1}{3}} + \left(\frac{1}{3n}\right)^{\frac{2}{3}}\right]$.

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 $c + d > v_{\max}$, then 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 6 shows a "phase diagram" of the corresponding profitability areas.

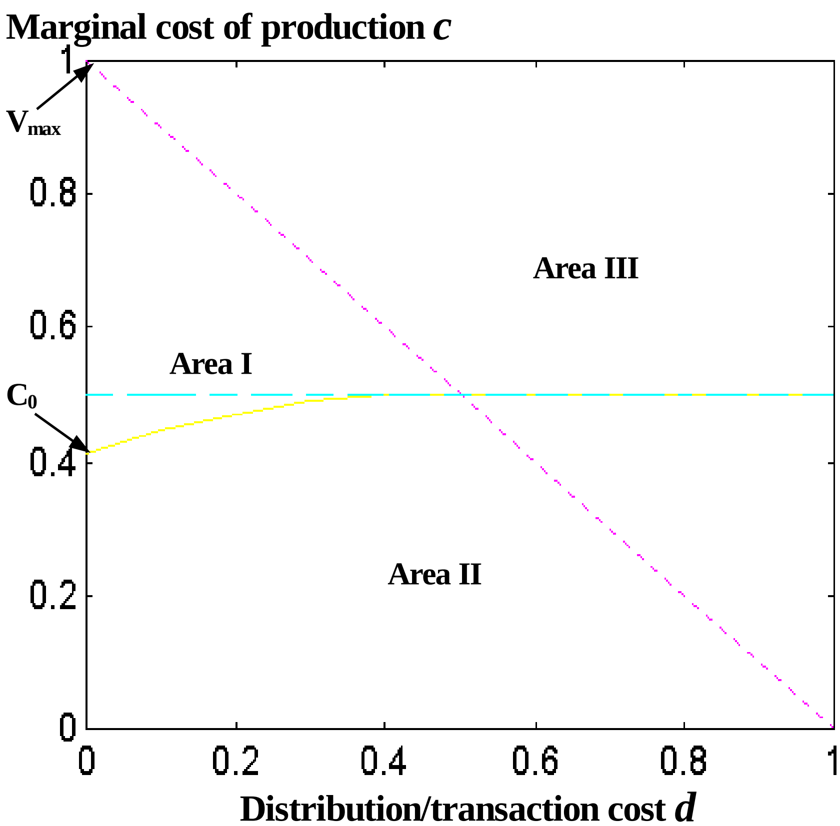

Figure 6: Phase diagram for bundling and unbundling strategies as a function of marginal production cost and distribution or transaction cost when valuations are uniformly distributed

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 non-zero 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 $v_{\max}$.

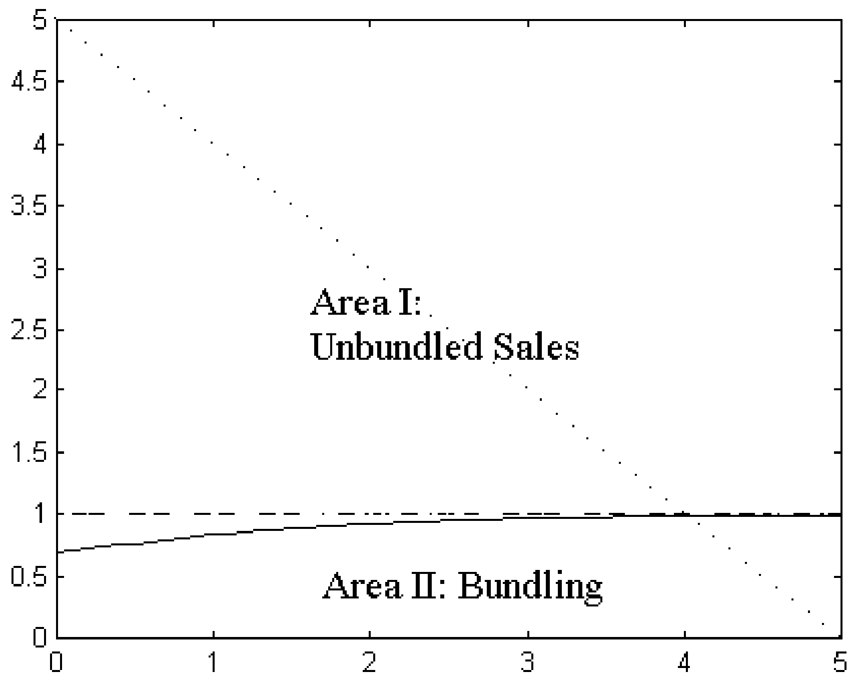

Figure 7: Phase diagram for bundling and unbundling strategies as a function of marginal production cost and distribution or transaction cost when valuations are exponentially distributed.

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 a relatively low value for the good. Because the number of such people may be very large, the efficiency and profit effects can be substantial. For example, one could generate significant revenues by selling a joke a day to millions of people, even if most people only valued the joke at a penny or less. In fact, business models based on this and similar ideas were proposed in the earlier days of the web. However, as soon as marginal costs begin to approach the average consumers' 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 7 shows the "phase diagram" with the corresponding two areas of profitability.

4. Aggregation by Other Means: Site licensing and Subscriptions

The preceding section focused on the benefits of aggregation in the context of bundling. Parallel arguments can be made for aggregation in other dimensions, such as site licensing (aggregation across users) and subscriptions (aggregation over time). For instance, Odlyzko (1996) provides an example in which site licensing works analogously to bundling and enables a seller to extract more surplus form sales of a software package. Of course, site licensing can be beneficial even in the absence of aggregation effects. For instance, Varian (1997) develops a model for sharing information goods that highlights the tradeoffs between production costs and sharing costs; this model can also be applied to site licensing. In contrast to our assumption that the valuation of an agent representing a group of *n* consumers is the sum of the *n* individual valuations, he assumes that the agent's valuation is *n* times the *minimum* valuation in the group (so that all final consumers are implicitly charged the same price). Consequently he obtains no aggregation effects, but still finds that site licensing can be profitable when sharing costs are relatively low.

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 transactions 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 per sale, analogous to the distribution and transaction cost parameter, *d*, in section 3. When this cost is sufficiently high, aggregation (site licensing) will be more profitable than disaggregation (individual sales).

Our analysis 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 that 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 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 value users.[6] 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 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. 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 $p = \Sigma v_i, - \varepsilon = m\mu - \varepsilon$ where v_e are the valuations of individuals at the site, m is the number of individuals, μ is the average valuation in the population, and ε is a small number). Almost all sites would find this price acceptable, and thus almost all users would get access to the good. Under similar assumptions to those applied in the analysis of bundling, aggregation can significantly reduce inefficiency and increase 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

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6 If Wolfram Research can identify which users have high and low values, it could also price discriminate by charging different prices to different users. However, because valuations are not generally perfectly correlated with observable characteristics and 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 See Varian (1996) for a detailed discussion of these issues.

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. Furthermore, the implicit assumption that the organizations are price takers may be less appropriate for large sites. In reality, the representative of a site may be in a position to bargain for a share of the total surplus. (See Bakos and Brynjolfsson (1997a) for a further discussion of these issues with respect to site licensing.)

Subscriptions across time and space

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 multiple time periods, 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-value periods, even when the cost of provision is zero. By charging a single subscription fee and giving the user long-term access to the good, greater efficiency and profits can result by an argument corresponding to those for bundling and site licensing.

Of course, a subscription may provide the user with *different* (but perhaps related) goods over time, as with magazine or journal subscriptions. In such cases, the logic of bundling applies directly. As pointed out in (Bakos and Brynjolfsson, 1996), if consumer valuations are correlated to an underlying variable, such as their interests, seller profits may be maximized by offering information bundles that induce consumers to self-select according to their underlying type. For example, a higher price may be extracted from readers of a specialty magazine because all articles are related to a topic of interest to them, while the aggregation benefits can still be obtained as different readers will place higher value on different articles.

The aggregation effects may still be important even when a subscription provides the *same* good in different time periods. For instance, a 1-year subscription that provides unlimited access to the online version of Encyclopedia Britannica aggregates valuations more than hourly charges do. As valuations for the same good by the same user are likely to be serially correlated over time, the benefits of aggregation over time may be lower than they are for uncorrelated goods or users (Bakos and Brynjolfsson, 1996).

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.

5. "Mixed Aggregation": Simultaneously aggregating and disaggregating goods

Aggregation or disaggregation can 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. Even when the seller does not have good knowledge of how particular goods are valued by particular users at particular times, this strategy may enable the seller to get close to full efficiency and earn higher profits, since aggregation along one dimension will generally not exhaust the benefits of aggregation in other dimensions. Indeed, under conditions analogous to A1-A3 discussed above, 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. Under these conditions, this strategy captures as profits nearly the entire possible surplus from the goods.

In practice, complete aggregation of this form is not likely to be optimal. Typically, some form of "mixed aggregation," which involves simultaneously offering the complete aggregation along with subsets of the aggregate for sale simultaneously, will be more profitable. This approach often makes it possible to induce consumers with higher valuations to pay more for larger aggregates without pricing lower-value consumers out of the market. In addition, it may make sense to aggregate in some dimensions while disaggregating in other dimensions. The seller could choose to disaggregate (or avoid aggregating) on those dimensions that are most effective in getting users to reveal their valuations while aggregating on other dimensions. For instance, if the seller knows that using a product during certain "prime hours" is highly correlated with high user valuations, it might make sense to disaggregate along that dimension to charge a premium for those time periods. Similarly, if user valuations for certain goods are correlated (e.g., magazine articles on a special-interest subject), it may be beneficial for the seller to disaggregate article collections on different subjects, practicing second-degree price discrimination.

Sellers can also offer a flexible "menu of bundles" from which buyers design the actual bundle they purchase. For instance, the seller of a collection of N goods could allow buyers to pay a price p_n and select any n goods ($n \le N$). This strategy may result in higher profits because, among other things, the number of goods selected may be a good proxy for the buyers' willingness to pay, thus allowing the sellers to price discriminate.

Disaggregation may also be appropriate if marginal costs are not negligible. In this case it may make sense to offer only subsets of the goods to subsets of users for subsets of time periods so that users could choose the subsets they find most valuable, and avoid the production cost for the ones they do not. This logic also applies if consumers incur a non-negligible marginal cost for goods in the bundle they purchase, such as a cognitive, storage or search cost.

Aggregation and disaggregation on multiple dimensions

There are many other ways to aggregate or disaggregate goods. Technologies like 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, the seller of a software applet could, in principle, charge users a price each time a particular function of the product is invoked on a particular machine while certain other programs are also running and certain other people are logged into the network, etc. In principle, a good could have a price for every potential state of the world that is observable and verifiable.

Such fine-grained “micro-pricing” is increasingly feasible and it clearly opens the door to sophisticated differential pricing schemes that may allow a seller to extract greater profits from a given good. However, our analysis indicates that micropricing will also reduce or eliminate the benefits of aggregation. Therefore, it might reduce efficiency and profits, especially when the buyers' valuations for use in particular circumstances are more heterogeneous than their total valuations.

When to use micropayments

Our analysis indicates that in three circumstances complete disaggregation or "mixed aggregation" can be more profitable than a strategy of aggregation.

First, if marginal costs are non-trivial, then 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*, then a seller who 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, than micropayment technology may be required to enable the seller to pursue such a strategy profitably. An implication of this analysis is that it may make sense to unbundle costly or contestable services such as bandwidth usage, data storage or computationally intensive functions from a package of digital information goods and services. The benefits of aggregation may be outweighed by the costs of providing these services freely, as indicated in area I of figure 5.

Second, if some consumers are willing to pay more for all goods, then 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. Furthermore, if consumers are heterogeneous in their overall valuations and the seller has a good idea of how these valuations are correlated with use of the good in different circumstances, then disaggregation will often be more attractive. For instance, it might make sense to charge extra for real-time stock quotes or access to data during business hours, even if these services are not more costly to provide, because consumers of such goods are likely to have systematically higher valuations than other consumers. In contrast, if consumers have relatively homogeneous total valuations (but are not necessarily homogeneous in their valuations for using the good in particular circumstances) then aggregation is more likely to be effective.

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 only aggregate over a small number of goods, consumers, or time periods, then it may be optimal to also offer some goods outside the bundle, site license, or subscription.

6. 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 the 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. Dissagregation 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 valuation for these goods, as when a professional stock trader demands more financial news stories and has higher value 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, i.e., 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, i.e., the simultaneous availability of information goods in aggregates of different sizes and composition, 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 that do not value them. 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 to understand the pricing strategies of on-line content providers such as America Online and the Microsoft Network, the widespread use of site licensing of software and data access by companies like Wolfram Research and Reuters, and subscription pricing in the sale of information goods by companies like 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 particular, the Internet is likely to lead to the disaggregation of digital goods that were formerly aggregated for purely technological reasons, but then to aggregations of these goods based on consumer demand. In some cases, the composition of the final aggregates will be determined by the consumers of these digital goods rather than their producers.

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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