Journal of Information Science
http://jis.sagepub.com/

Collaborative pricing model for bundling information goods

Wei-Lun Chang and Soe-Tsyr Yuan

Journal of Information Science 2008 34: 635 originally published online 3 April 2008
DOI: 10.1177/0165551507084632

JIS

Collaborative pricing model for bundling information goods

Wei-Lun Chang

Department of BA, Tamkang University, No. 151, Ying-chuan Rd, Tamsui, Taipei County, Taiwan

Soe-Tsyr Yuan

Department of MIS, National ChengChi University, No. 64, Sec.2, Zhi-Nan Rd, Taipei City, Taiwan

Abstract.

The information economy engenders consideration of certain issues such as information goods cost/pricing, technology infrastructure, and information policy in the era of knowledge economy. Due to the unique cost structure and product characteristics of information goods, conventional pricing strategies are unfeasible, and a differential pricing strategy is crucial. Nevertheless, few models exist for pricing information goods in the e-service industry. This study proposes a novel collaborative pricing model in which customers are active participants in determining product prices and adopt prices and services that meet their changing needs. This study also shows that the collaborative pricing model generates an optimal bundle price at equilibrium with optimal profit and utility. Theoretical proofs and practical implications justify this pricing model, which is essential for future information goods pricing in the information economy.

Keywords: collaborative pricing; information goods; bundling

1. Introduction

The information economy, defined as the exchange of information goods and services, as opposed to physical goods and services, has been the subject of numerous investigations [1,2]. This concept is utilized to characterize an economy with an increased role played by informational activities and information industry. The information economy engenders consideration of issues such as cost/pricing of information goods, technology infrastructure, and information policy.

Shapiro and Varian [3] broadly defined 'information goods' as anything that can be digitized, encoded as a stream of bits, and transmitted over an information network. Information goods include books, movies, software programs, web pages, songs and music, television programs, and newspaper columns. Furthermore, information goods are characterized by high fixed production costs and extremely low reproduction costs [4].

Correspondence to: Wei-Lun Chang, No. 151, Ying-chuan Rd, Tamsui, Taipei County, Taiwan. Email: wlchang@ms10.hinet.net.

Information also has properties referred by economists as 'public good externalities', which means the benefits derivable from a particular quantum of information can be widely enjoyed, and additional consumers satisfied, at zero cost [5]. Moreover, price fluctuation is the major difference between most commodities and information goods. The price of most commodities tends to fall within a predictable range; however, this rule cannot strictly be applied to information goods.

Due to the unique cost structure and product characteristics of information goods, conventional pricing strategies are unfeasible, and a differential pricing strategy is crucial. Varian identified two key pricing issues: price discrimination, and bundling [6]. Price discrimination, in general, attempts to optimize prices using different perspectives, rather than merely lowering prices. For example, from a producer's perspective (i.e. desire to maximize profits), a producer charges different users different prices for information goods based on their willingness-to-pay (WTP).

Bundling is an approach used to reduce the heterogeneity of consumer WTP, and a producer can increase profit by increasing the average WTP attained, through use of bundling [7,8]. Consequently, the number of bundles, bundle strategies, and factors associated with bundling are the principal issues when using bundling. Numerous studies have developed methods for pricing information goods. Nevertheless, these models have significant shortcomings to overcome: they lack consumer involvement in the pricing process, only the producer's perspective (either cost-based or profit-based) is considered, and price is determined without maximizing consumer satisfaction. Dynamic pricing has recently emerged as a method for overcoming these shortcomings.

Dynamic pricing adjusts prices for consumers based on the value customers ascribe to a product or service. Various mathematical models have been applied to dynamic pricing [9,10]. Narahari et al. [11] categorized pricing models into the following five types: inventory-based models; data-driven models; game theory models; machine learning models; and simulation models (any combination of other model types). In a typical digital goods market, the environment continually changes, with uncertain consumer demands and fluctuating prices. Models based on machine learning are thus desirable, as they can accommodate new data, and alter the pricing strategy to best suit the present pricing environment [12]. This study extends current pricing methods by considering the perspectives of both consumers and producers.

This study presents a novel collaborative pricing model for pricing of information goods. Collaborative pricing is an emergent issue in this era of collaborative design. Instead of thinking about finding customers for their products, companies need to think about finding products for their customers [13]. Collaborative design allows firms to become more deeply embedded in their customers' design and development process by furnishing prototypes. This flexible pricing approach allows customers to align the timing and amount of their payments with their forecast growth [14].

This article also provides a collaborative process that produces several prototypes via a trial-and-error pricing process, discusses consumer and producer beliefs in maximizing utility and profit, and provides a feasible model for service bundling by interacting with consumers and discovering their actual needs. The remainder of this paper is organized as follows. Section 2 presents a brief discussion of the literature regarding versioning and bundling information goods. Section 3 outlines the proposed collaborative pricing model, which optimizes consumer and producer surplus, social welfare (SW) and payoff enhancement. Finally, Section 4 presents conclusions and a discussion.

2. Background

Versioning comprises pricing methods grounded in producer perspectives, and optimizes prices in terms of vertically differentiating the goods markets. By examining total surplus from an economic perspective, Varian [6] indicated that the optimal versioning solution is the best pricing regime for information goods. When vertically differentiating a market, with ambiguous market segmentation, three versions are generally appropriate [15].

Shapiro and Varian [3] identified the appropriate number of versions in terms of factors such as delay, convenience, comprehensivity, manipulation, community, annoyance, speed, data processing, user interface, image resolution, and support. For instance, for a product that is not judged on its level of convenience, is delivered slowly, and requires complex manipulation, the number of versions should be small and they should be well differentiated. Bhargava and Choudhary [16] identified several features that impact versioning approaches – network effects, advertising revenue, nonlinear utility function, and the threat of competitors entering the market. For example, only an advertising agency benefits from high advertising revenue demanded for unacceptable versions; high threat of a competitor entering the market requires various versions to segment the market and differentiate products.

In addition to versioning, bundling optimizes prices in terms of packaging goods in various configurations, thereby reducing heterogeneity in consumer valuations [17,18]. Generally, two orientations exist for bundling methods – qualitative factors and quantitative modeling. Using qualitative modeling, Varian [6] determined that product bundling has the profitable result of reducing heterogeneity of consumer WTP. A producer can sell at an average WTP by creating product bundles; that is, consumer heterogeneity is a typical qualitative factor when determining the scale of profits.

For instance, when consumers are very heterogeneous, differentiating WTP is difficult, as is determining which products to bundle. Bakos and Brynjolfsson [18] investigated competition in the context of bundling. Their results indicated that large bundles generate significant advantages in competitive markets. Furthermore, bundling also reduces competitor incentive to innovate.

For quantitative modeling, some studies developed mathematical models for exploring ways to create appropriate bundles, bundle prices, and the appropriate number of information products in bundles. For example, Altinkemer and Jaisingh [19] demonstrated that profits increase when the number of information goods in bundles increases. In their model, consumer surplus was achieved by considering bundle prices and demand. The quality level (e.g. a bundle with many information goods has a high quality) and consumer types (e.g. different customers value a bundle of a given quality differently, and some customers are willing to pay more than others) were also considered.

The outcomes demonstrated that maximum profits could be generated by overcoming constraints (e.g. non-negative surplus) and satisfying assumptions. The results also suggested that profits increased linearly as the number of information goods in bundles increased, and that consumer perceptions of various bundles affected consumer WTP. Additionally, bundles with both information products and physical goods may increase total profits due to a lower marginal cost than when selling products in a bundle separately (when the marginal cost of physical goods exceeds a threshold).

Chang et al. [20] developed an algorithm designed to search for appropriate goods bundles dynamically and efficiently. This algorithm uses two-phase path pruning to search for the top K bundles, each of which consists of M components with pair-wise inter-component relations. The speed of the search for the top K bundles was fast, and the costs associated with production and transactions were reduced simultaneously (e.g. bundling decreases manufacturing, packaging, and shipping costs, thus enabling more efficient transactions).

Additionally, the online bundle-purchasing problem (OBPP) is a new computational challenge generated by e-commerce technology [21]. The OBPP considers the time frame when maximizing overall consumer satisfaction. Buyer satisfaction was formalized with a multi-attribute utility approach that considers buyer attitudes toward quality, reputation, and risk. At specific times, a buyer must decide whether to purchase a bundle or take the risk of letting the opportunity pass. That is, the work attempted to maximize consumer satisfaction when purchasing a bundle during a given period. The result revealed a decision procedure that exploits time frames and yields a higher expected utility than a naïve decision procedure that simply pursues the optimal bundle.

An integrated recommender system was developed by Somefun and Poutré [22] to identify a collection of (sub)bundles and their dynamic prices using customer preferences. In their study, consumer preferences were formulated as maximum consumer utility, determined by perceived value, purchasing cost, and transaction searching cost. Thus, the number of products in a bundle with maximum utility were identified using the customer's perspective. Optimal bundle price could then be calculated by summing the prices of the products in the bundle and subtracting a discount based on the number of information products in the bundle (i.e. the discount is positively correlated with the number of products in a bundle).

Furthermore, many practical applications exist for bundling in a range of industries. Kivisaari and Luukkainen [23] investigated content-service bundling in the telecommunications industry.

Table 1
Critical assessment for related research

Focus	Research	Goal	Research result
Versioning	Shapiro and Varian (1997)	Investigate the best versioning policy for producers.	Identify the appropriate number of versions as being 3, and find several factors for preparing a version (delay, convenience, comprehensivity, manipulation, community, annoyance, speed, data processing, user interface, image resolution, and support).
	Bhargava and Choudhary (2001)	Examine factors that influence the versioning method.	Certain factors for information goods pricing are found for generating a version (i.e. network effects, advertising revenues, nonlinear utility function, threat of entry).
Bundling	Varian (1995)	Discuss pricing policies for information goods.	Product bundling increases profits, by reducing the heterogeneity of the consumers' WTP.
	Bakos and Brynjolfsson (2000)	Investigate the effect of bundling on competition.	Large bundles may provide significant advantages in competition.
	Altinkemer and Jaisingh (2002)	Devise a mathematical model for exploring ways to determine appropriate prices and bundles.	Profits increase when the numbers of information goods are increased in bundles.
	Chang et al. (2003)	Propose an algorithm to search for appropriate bundles of goods dynamically and efficiently.	The speed of determining the top *K* bundles is fast. The costs associated with production and transactions are reduced simultaneously.
	Buffett and Spencer (2004)	Aim to maximize satisfaction with a purchased bundle, given certain time frames for the online bundle-purchasing problem.	A decision procedure that exploits the time frame factor and pursues the best bundle is proven to yield a higher expected utility than a naïve decision procedure.
	Somefun and Poutre (2003)	Present a framework for an integrated recommender system to identify a collection of (sub)bundles and dynamic prices.	Customer references are formulated as a maximum utility; the optimal bundle price is equal to the sum of the prices for the goods in a bundle minus an adjustable amount.

A new content-based pricing model for the Internet was developed, for controlling content consumption, and assisting producers in creating bundles and bundle prices. Altinkermer [19] investigated bundling of e-banking services, where it can be useful to offer flexible and adjustable bundles to consumers. Usage patterns could be shared among consumers who were then empowered to make good choices of bundles to purchase.

3. Model formulation

3.1. Collaborative pricing model

Collaborative pricing is an emerging issue in this era of collaborative design. Collaborative design allows firms to become deeply embedded in their customers' design and development processes by developing prototypes [24–27]. Similar in concept to collaborative design, collaborative pricing allows customers to actively participate in pricing products (based on their WTP) and tailors' prices and services to consumers' changing needs (Figure 1). An interactive pricing process can be considered as a combination of collaborative prototyping, needs prediction, price estimation, and profits maintenance. These four sub-processes are as follows:

1. Select one of the available versions
The consumer chooses one of the versions generated and packaged by the various service providers. Clearly, the consumer would seek a version containing bundled services that could satisfy their current

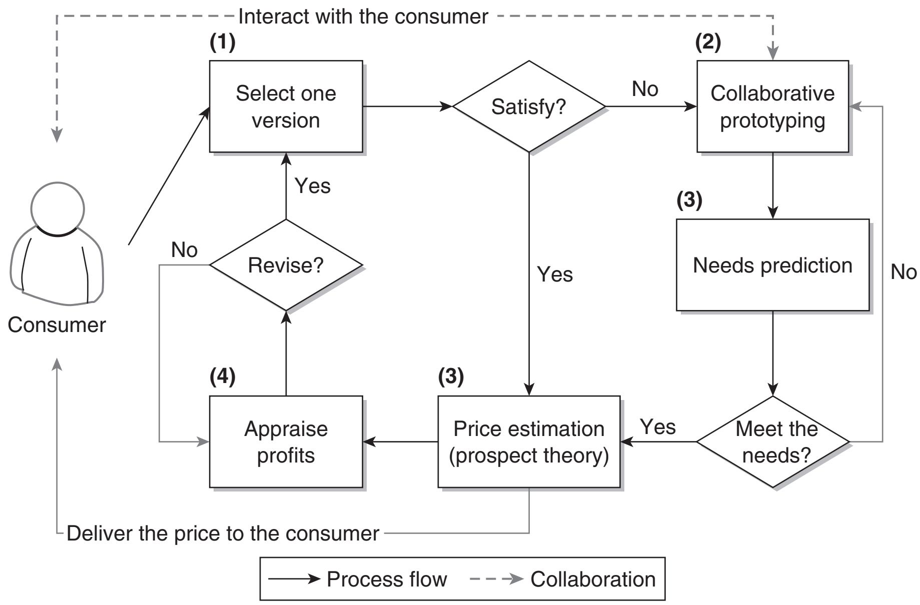

Fig. 1. Collaborative pricing process.

needs. If the version satisfies these needs without further modification, the price will then be estimated immediately; otherwise, the process will proceed to the collaborative prototyping process.

2. Collaborative prototyping
The initial version is now modified (based on the customer's profile, pricing history, and service information) into a new bundle. If some needs remain unmet, the collaborative prototyping loop will be repeated.

3. Needs prediction and price estimation
This study adopts the prospect theory as the theoretical foundation for predicting and furnishing bundles. When the prototyping is complete, our method will choose the prototype displaying optimal utility, as perceived by the consumer. A price will be determined which simultaneously takes into account the prototype testing efforts, design fee for customization, and the costs of the services.

4. Appraise profits and revise versions
The system appraises the profits for each version periodically. The version with the lowest profit is then replaced or revised automatically, based on a knowledge base. This process will proceed iteratively and proactively.

We define a collaborative pricing model as a model that has the objectives of maximizing WTP and profits, allows consumers and producers to actively collaborate when pricing products or bundles, and generates an optimal bundle price at equilibrium.

$$CP_{\text{Model}} = \text{Optimal}(P_{\text{Profit}}, C_{\text{Utility}}) \tag{1}$$

The problems in existing pricing strategies for versioning are that (1) prices are not optimal and are merely based on mass customization and (2) customer participation is extremely limited when determining prices. Therefore, this study attempts to prove that an optimal price exists, based on the aims of collaborative pricing and in terms of supply and demand.

We assume that bundling is a well-known and efficient approach for determining prices for information goods [28–30]. This study presents a collaborative pricing model that has an optimal bundle price P_B at equilibrium, with optimal profit and utility. Thus, profit increases from a version price P_V to a bundle price P_B. Likewise, consumer surplus increases as P_V moves toward P_B.

3.1.1 Collaborative pricing and payoff

We will now explore the heterogeneity of internet consumers, and assume that two economic agents exist in the model. Profit is optimized via collaborative pricing in terms of delivering prototypes interactively. Theoretically, equilibrium is efficient and optimal based on the law of supply and demand. Bundle prices are always higher than version prices, as a result of the difference between personalization (bundle) and mass customization (version). Hence, we assume that the bundle price is higher than version price when collaboration generates high WTP.

The conditions relating the variables in what follows are $P_R > P_B > P_V > C > 0$; $1 \geq q > 1/2$; n, m are integers, and $n > m > 0$, where P_R is reservation price, P_B is bundle price, P_V is version price, C is cost for each service, q is probability of choosing a collaborative pricing process (the probability is assumed to be higher than $1/2$ if collaborative pricing is more profitable than non-collaborative), n is the number of services in a bundle, and m is the number of services in a version.

Theorem 1. When consumers are heterogeneous, a service provider maximizes profits by offering collaborative pricing, provided that the buyer's reservation price exceeds the service provider's customized price (for either a version or a bundle).

In an efficient market, the equilibrium point is offered at a specified quantity and price. The bundle price is always greater than the version price when the bundle price is generated via a collaborative process. Consumer surplus of the bundle price compared to the version price is enhanced when a collaborative bundle price exists. Theorem 1 is split into two lemmas: profits (lemma 1) and consumer surplus (lemma 2).

Lemma 1 compares the profits obtained via collaborative and non-collaborative pricing, based on the law of supply and demand. Profits increase when a service provider prices a bundle via a collaborative process. Lemma 2 confirms that consumer surplus (utility) is greater than the reservation price. Thus, proof of theorem 1 shows that the bundle (collaborative) price is optimal compared to the version and reservation prices.

Lemma 1. Compared with a non-collaborative price P_V, offering collaborative price P_B improves profits by $q(P_B + P_V - C(n + m) - (P_V - mC))$.

Proof. The collaborative and non-collaborative profits are
$\Pi_{CP} = q(P_B - nC)$ and $\Pi_{NP} = (1 - q)(P_V - mC)$, where

$$P_B - nC \geq 0 \text{ and } P_V - mC \geq 0 \tag{2}$$

We assume that non-prototyping is more profitable, so $\Pi_{CP} < \Pi_{NP}$.
Replace Π_{CP} and Π_{NP} with equation (2) such that

$$q(P_B - nC) - (1 - q)(P_V - mC) < 0 \tag{3}$$

Reduce the left-hand side to q, giving

$$q(P_B - nC + P_V - mC) < (P_V - mC) \tag{4}$$

where $P_B > P_V$ and $n \geq m$ according to the assumptions. Consequently,

$$2q(P_V - mC) < (P_V - mC)$$

Which would require $q < 1/2$, contradicting the original assumption $1 \geq q > 1/2$, meaning that the assumption in equation (2) must be false. That is, $\Pi_{CP} > \Pi_{NP}$ is true. Hence, the difference between two strategies is

$$\mathbf{\Pi}_{CP} - \mathbf{\Pi}_{NP} = q(P_B + P_V - C(n + m) - (P_V - mC)),$$
$$\text{If } q > \frac{(P_V - mC)}{(P_B + P_V - (n + m)C)}, \mathbf{\Pi}_{CP} > \mathbf{\Pi}_{NP}$$

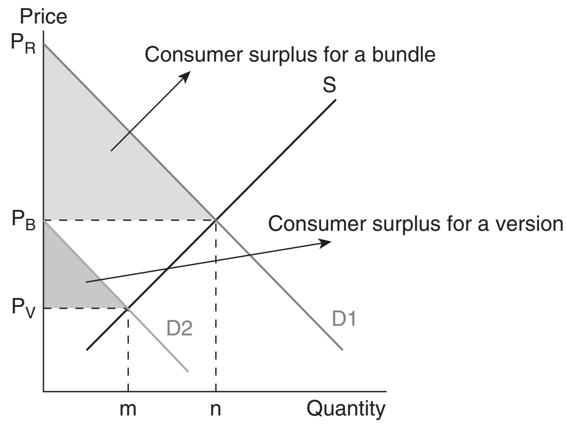

Fig. 2. Consumer surplus for bundle and version prices.

3.1.2. Collaborative pricing and utility

Utility (consumer surplus) is the gap between reservation price (P_R) and version price (P_V), as shown in Figure 2. Equilibrium is efficient and optimal, according to the law of supply and demand. The bundle price used is generated through a collaborative process that can satisfy maximum perceived utility. Thus, we assume that optimal price (i.e. bundle price P_B) is the equilibrium price on the supply/demand curve. Thus, when offering collaborative pricing with price P_B, utility is elevated compared with the non-prototyped price. We assume that the supply and demand curve is a straight line, and that the area is the aggregate of consumer surplus. Moreover, we assume the optimal price is between one-quarter and three-quarters of the sum of the reservation and version prices.

Lemma 2. Compared with reservation price P_R, offering collaborative price P_B improves consumer surplus by

$$\frac{nP_R - mP_V - P_B(n+m)}{2}$$

Proof. The aggregate consumer surplus for a bundle of services is CS_{CP}, and the aggregate consumer surplus for a version of services is CS_{NP}; consumer surpluses for collaborative prototyping and non-prototyping are

$$CS_{CP} = \frac{n(P_R - P_B)}{2} \quad \text{and } CS_{NP} = \frac{m(P_B - P_V)}{2} \tag{5}$$

Using the assumptions $P_R > P_B > P_V > C > 0$ and $\frac{3(P_R + P_V)}{4} \geq \mathrm{P_B} \geq \frac{P_R + P_V}{4}$, we can obtain the following equations.

$$(P_R - P_B) < (P_B - P_V), \text{ if } \frac{3(P_R + P_V)}{4} \geq P_B \geq \frac{P_R + P_V}{2} \tag{6}$$

and

$$(P_R - P_B) > (P_B - P_V), \text{ if } \frac{3(P_R + P_V)}{4} < P_B < \frac{P_R + P_V}{2} \tag{7}$$

To prove that consumer surplus will be enhanced, we assume $CS_{CP} < CS_{NP}$, which would indicate that consumer surplus for collaborative prototyping is lower than without prototyping; hence,

$$\frac{n(P_R - P_B)}{2} < \frac{m(P_B - P_V)}{2} \tag{8}$$

Multiplying both sides by 2 gives $n(P_R - P_B) < m(P_B - P_V)$.

This equation is now considered separately for the conditions where bundle price is greater or lower than half of the sum of the reservation and version prices. In the first condition, where the bundle price is greater:

$$(1) \quad \text{if} \quad \frac{3(P_R + P_V)}{4} \geq P_B \geq \frac{(P_R + P_V)}{2}, \text{ then } P_R - P_B < P_B - P_V$$

The original assumption in equation (8) is equivalent to

$$nP_R + mP_V < (n+m)P_B < \frac{3}{4}(n+m)(P_R + P_V), \text{ as } \frac{3(P_R + P_V)}{4} \geq P_B \tag{9}$$

We now separate the two cases where m is greater or less than half of n.

Taking equation (9), we seperate P_R and P_V to different sides, giving $P_R(3m - n) > P_V(m\text{-}3n)$. This can be reduced to

$$\frac{3m - n}{m - 3n} < \frac{\frac{3n}{2} - n}{\frac{n}{2} - 3n} = -\frac{1}{5}$$

(for the case where $n > m$, which contradicts the assertion that P_R and P_V are both greater than zero. Thus, the original assumption is false;

$n(P_R - P_B) > m(P_B - P_V)$ is true if $P_B \geq P_R + P_V/2$ and $m \geq n/2$.

Conversely, when m is less than half of n, we can derive $m < \frac{n}{2} < n < nm$.

Equation (9) then gives

$$\frac{P_V}{P_R} < \frac{3m - m}{m - 3mn} = \frac{2m}{m(1 - 3n)} = \frac{2}{(1 - 3n)} < 0$$

The inequality again contradicts the assertion that P_R and P_V are both greater than zero. Thus, the original assumption is false; $n(P_R - P_B) > m(P_B - P_V)$ is true *if*

$$P_B \geq \frac{P_R + P_V}{2} \qquad \text{and} \quad m < \frac{n}{2}$$

In the second condition, the bundle price is lower than half the sum of P_R and P_V:

$$(2) \ \frac{P_R + P_V}{4} < P_B < \frac{P_R + P_V}{2} \text{ . then } P_R - P_B > P_B - P_V \text{ and } n > m$$

The original assumption in equation (8) can be reduced to $n(P_R - P_B) < m(P_B - P_V)$, which is false since it contradicts $(P_R - P_B) > (P_B - P_V)$ in equation (7) and $n > m > 0$. Thus, $n(P_R - P_B) > m(P_B - P_V)$ is true if $P_B < P_R + P_V/2$.

Hence, the assumption in equation (8) is false; that is, $CS_{CP} > CS_{NP}$ is true. Consumer surplus is greatest when applying collaborative prototyping, and the difference is

$$CS_{CP} - CS_{NP} = \frac{nP_R - mP_V - P_B(n+m)}{2}$$

Table 2 presents a comparison of the collaborative and non-collaborative pricing methods. If the producers consider collaborative pricing method as the benchmark, other methods may cause loss of either profit or consumer surplus, as shown by the proofs above.

3.2. Social welfare optimization

Generally, obtaining the equilibrium value for a bundle price is difficult, which may result in market inefficiency. Inefficiency (i.e. deadweight loss) is a loss of economic efficiency that occurs when

Table 2
Prices, profits, and consumer surplus

	Collaborative Pricing	Non-collaborative Pricing
Price	P_B	P_V
Profit	$\Pi_{CP} = q(P_B - nC)$	$\Pi_{NP} = (1-q)(P_V - mC)$
Consumer Surplus	$CS_{CP} = \frac{n(P_R - P_B)}{2}$	$CS_{NP} = \frac{m(P_B - P_V)}{2}$
Lost profit compared to collaborative pricing	0	$q(P_B + P_V - C(n+m) - (P_V - mC))$
Lost consumer surplus compared to collaborative pricing	0	$\frac{nP_R - mP_V - P_B(n+m)}{2}$

a product or service is not at equilibrium. An equilibrium price is optimal, without any deadweight loss, and equilibrates the supply and demand curve.

A difference between conventional products and information goods is found in the processes for generating an equilibrium price. For information goods, we assume that a bundle price P_B exists at equilibrium within a linear combination of utility, testing efforts and costs. This price can be generated through a collaborative process that allows a customer and a provider to participate and interact when determining a price, with the underlying objectives of maximum WTP and optimal profit.

P_R is the consumer reservation price, P_O the over-estimated price, P_U the under-estimated price, P_B the optimal (equilibrium) price, P_A the producer's acceptable price, P_F the price floor the producer is willing to accept when the price is over-estimated, P_C the price ceiling the consumer is willing to pay when the price is under-estimated, n is the number of services in a bundle at optimal price, and m is the number of services in a bundle at an over-estimated/under-estimated price.

Social welfare is the sum of consumer surplus (CS) and producer surplus (PS); SW values for P_O and P_U are $\mathrm{SW}_{\mathrm{Po}}$ and $\mathrm{SW}_{\mathrm{Pu}}$:

$$\mathrm{SW}_{\mathrm{PO}} = \mathrm{CS}_{\mathrm{PO}} + \mathrm{PS}_{\mathrm{PO}} = \frac{m}{2}(P_R + P_O - P_A - P_F) \tag{10}$$

$$\mathrm{SW}_{\mathrm{Pu}} = \mathrm{CS}_{\mathrm{Pu}} + \mathrm{PS}_{\mathrm{Pu}} = \frac{m}{2}(P_R - P_U - P_A + P_C) \tag{11}$$

$$\mathrm{SW}_{\mathrm{PB}} = \mathrm{CS}_{\mathrm{PB}} + \mathrm{PS}_{\mathrm{PB}} = \frac{(P_R - P_B)n}{2} + \frac{(P_B - P_A)n}{2} = \frac{n}{2}(P_R - P_A) \tag{12}$$

Theorem 2. Social welfare is optimized at the equilibrium price; otherwise, SW has a deadweight loss (for either an over-estimated or an under-estimated price).

Our proof of theorem 1 shows that the bundle (collaborative) price is optimal for both the consumer and the service provider. Proof of Theorem 2 provides evidence that SW is optimal when the bundle price is at equilibrium. Lemma 3 and lemma 4 demonstrate that deadweight loss exists when the price is over-estimated and under-estimated, respectively.

Lemma 3. Compared with an over-estimated price P_O, offering an optimal price P_B enhances SW by removing a deadweight loss $1/2\ [(n-m)(P_R - P_A) - m(P_O - P_F)]$.

Proof. First, we assume the following conditions: $P_R > P_O > P_B > P_U > P_A$ and $n > m > 0$. To simplify, we also assume that the supply and demand curves are straight lines. Thus, deadweight loss is the difference between SW at the bundle price and at the over-estimated price:

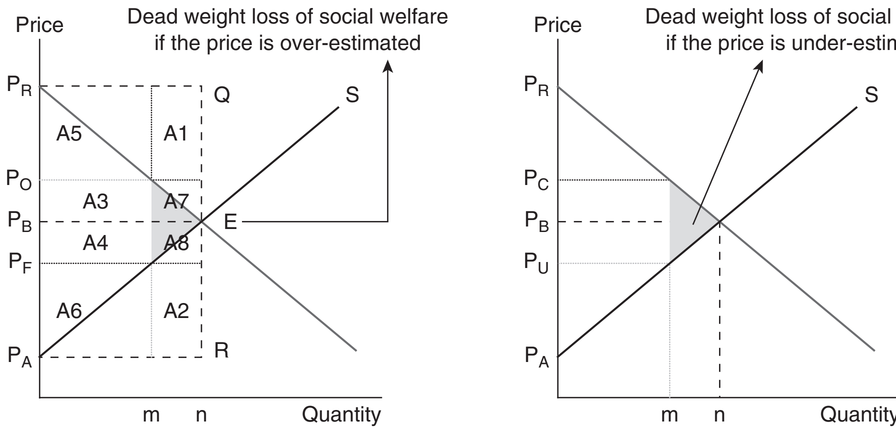

Fig. 3. Deadweight loss for over-estimated and under-estimated prices.

$$SW_{PB} - SW_{PO} = \frac{1}{2}[(n-m)(P_R - P_A) - m(P_O - P_F)] \tag{13}$$

We assume $1/2\ [(n-m)(P_R - P_A) - m(P_O - P_F)]. < 0$, meaning that the deadweight loss is positive (i.e. $SW_{PB} < SW_{PO}$). Notably, $P_F > P_A$ holds, according to $P_R > P_O > P_B > P_F > P_A$, when price is over-estimated; thus, $P_R - P_A > P_R - P_F$ is true. That is,

$$P_R - P_A > P_O - P_F \text{ holds, since } P_R > P_O \text{ and } P_R - P_A > P_R - P_F \tag{14}$$

The remainder of the proof is separated into the following two conditions: $m \geq n/2$ and $m < n/2$.

If $m \geq n/2$, the original assumption can be reduced to $(n - m)(P_R - P_A) < m(P_O - P_F)$.

In Figure 3, the area of rectangle $P_R P_B EQ$ is equal to rectangle $P_B P_A RE$, given that P_B is at the equilibrium point; also, the triangles inside areas A5, A6, A7, and A8 are in symmetric pairs. Hence, area A1 is equal to area A3; similarly, area A4 is equal to area A2. Thus:

$$A3 + A4 = A1 + A2 \tag{15}$$

Additionally, the sum of area A3 plus area A4 is equal to $m(P_O - P_F)$, and the sum of areas A1, A2, A7, and A8 is equal to $(n-m)(P_R - P_A)$. Equation (15) thus becomes

$$A3 + A4 = m(P_O - P_F) = A1 + A2 < A1 + A2 + A7 + A8 \tag{16}$$

But as $A1 + A2 + A7 + A8 = (n - m)(P_R - P_A)$, this contradicts $(n - m)(P_R - P_A) < m(P_O - P_F)$. Hence, the original assumption is false and $((n - m)(P_R - P_A) - m(P_O - P_F)) > 0$ is true.

If $m < n/2$, then $m < n - m$. The original assumption can then be reduced to

$$(n - m)(P_R - P_A) < m(P_O - P_F) \tag{17}$$

The condition $m < n/2$ can be substituted in, giving

$$(n - m)(P_R - P_A) < m(P_O - P_F) < (n - m)(P_O - P_F) \tag{18}$$

Equation (18) indicates that $(P_R - P_A) < (P_O - P_F)$, which contradicts equation (14). Thus, the initial assumption is false, and $((n - m)(P_R - P_A) - m(P_O - P_F)) > 0$ is true for all in. In summary, $SW_{PB} > SW_{PO}$ is true, and deadweight loss is $1/2\ [(n-m)(P_R - P_A) - m(P_O - P_F)]$.

Table 3.
Prices, social welfare, and deadweight loss

	Over-estimated price	Under-estimated price	Optimal price
Price	P_O	P_U	P_B
Social welfare	$SW_{PO}=\frac{m}{2}(P_R+P_O-P_A-P_F)$	$SW_{PU}=\frac{m}{2}(P_R-P_U-P_A+P_C)$	$SW_{PB}=\frac{n}{2}(P_R-P_A)$
Deadweight loss compared to optimal price	$1/2[(n-m)(P_R-P_A)-m(P_O-P_F)]$	$1/2\ [(n-m)(P_R-P_A)-m(P_U-P_O)]$	*0*

Lemma 4. Compared with an under-estimated price P_U, offering an optimal price P_B improves SW by removing a deadweight loss $\frac{1}{2}\ [(n-m)(P_R-P_A)+m(P_U-P_C)]$.

Proof. We assume the deadweight loss is the difference between SW at the bundle price and at the under-estimated price;

$$\mathrm{SW_{PB}}-\mathrm{SW_{Pu}}=\frac{1}{2}[(n-m)(P_R-P_A)+m(P_U-P_C)] \tag{19}$$

We assume $\frac{1}{2}\ [(n-m)(P_R-P_A)+m(P_U-P_C)]<0$, meaning that deadweight loss is positive (i.e. $\mathrm{SW_{PB}}<\mathrm{SW_{Pu}}$). $P_C > P_A$ holds when the price is under-estimated.

As $P_R - P_A > P_R - P_C$, $P_R - P_A > P_U - P_C$ (since $P_R > P_U$ must be true). $[(n - m)(P_R - P_A) + m(P_U - P_C)] < 0$ contradicts the constraints $n - m>0$, $P_R - P_A > 0$, $P_U - P_C > 0$.

Thus, the assumption is false, and $[(n - m)(P_R - P_A) + m(P_U - P_C)] > 0$ is true. That is, $\mathrm{SW_{PB}} > \mathrm{SW_{Pu}}$ is true and the deadweight loss is $\frac{1}{2}\ [(n-m)(P_R-P_A)+m(P_U-P_C)]$.

3.3. *Payoff enhancement*

Typically, producers determine prices via a versioning paradigm. The goal of versioning is to get customers to sort themselves into groups via different product values; both product design and price are adjusted to effect this sorting [30]. A version can include bundled information goods. For example, Microsoft provides enterprise and home editions of Microsoft Office; each version includes certain applications.

Producers maintain versions based on profits. An un-profitable version can be improved, or replaced with a new version. However, profit is enhanced if and only if the price of the new version is higher than either the original price of the specific version replaced, or the average price of all versions.

In what follows, P_B is the optimal (equilibrium) price, P_A is the producer acceptable price, P_{V*} is the average price of all versions, $P_{V'}$ is the price for a newly revised version, P_V is the price of the previously revised version, n is the number of services in a bundle at the optimal price, r is the average number of services in the initial versions, m is the number of services in the new version, and k is the number of services in the lowest priced of the initial versions.

Theorem 3. The profit for a newly revised version is always enhanced. The enhancement is either wide (when price $P_{V'}$ is $> P_{V*}$) or narrow (when price $P_{V'} > P_V$). $P_{V'}$ is the price for the newly revised version based on coefficients from the mean error rate equation $\lambda = \beta_0 + \beta_1{*}S + \beta_2{*}C + \beta_3{*}\mathrm{OF} + \beta_4{*}V + \beta_5{*}S\mathrm{a} + \beta_6{*}P + \varepsilon$. Lemma 5 confirms the profit when the new price is greater than the average price of all previous versions (see left side of Figure 4). Lemma 6 proves that a new, higher, price must produces a greater profit than the old version did (see right side of Figure 4). The outcomes demonstrate that a service provider should set a new price that is greater than either the average price or the previous version price.

Lemma 5. Compared with an average version price P_{V*}, offering a higher price $P_{V'}$ improves producer surplus by $\frac{1}{2}(P_A(r-m)+mP'_V-rP_{V^*})$.

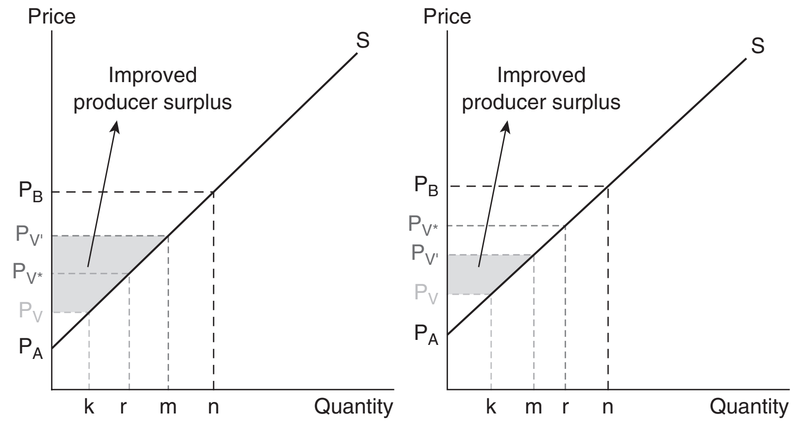

Fig. 4. The improved producer surplus at the new price.

Proof. First, we assume $n > m$, $r > k$, $P_B > P_{V'}$ and $P_{V^*} > P_V > P_A$. Bundle price should be optimal and greater than the price of a newly revised version; the price of both old and new versions is always lower, as the bundle price is assumed optimal.

If the new price is higher than the average price, then $P_{V'} > P_{V^*}$, as a result of which, $P_{V'} - P_A > P_{V^*} - P_A$ and $m > r$ must be true. Producer surpluses for the new and average prices are

$$\mathrm{PS}_{V'} = \frac{(P_{V'} - P_A)m}{2} \quad \text{and} \quad \mathrm{PS}_{V^*} = \frac{(P_{V^*} - P_A)r}{2}$$

As this study wants to prove $\mathrm{PS}_{V'} > \mathrm{PS}_{V^*}$, we assume that

$$\mathrm{PS}_{V'} < \mathrm{PS}_{V^*} \tag{20}$$

Equation (20) can be reduced to $(P_{V'} - P_A)m < (P_{V^*} - P_A)r$; however, this cannot be true, as $P_{V'} - P_A > P_{V^*} - P_A$ and $m > r$. Hence, the original assumption is false; $\mathrm{PS}_{V'} > \mathrm{PS}_{V^*}$, and the producer surplus is improved by $\frac{1}{2}\,(P_A(r-m) + mP_{V'} - rP_{V^*})$.

Lemma 6. Compared with the previous price P_V, offering a higher price $P_{V'}$ improves producer surplus by $\frac{1}{2}\,(P_A(k-m) + mP_{V'} - kP_V)$.

Proof. If the new price is higher than the previous price, then $P_{V'} > P_V$. Thus, $P_{V'} - P_A > P_V - P_A$ and $m > k$ hold. Producer surplus for the new price and previous price are

$$\mathrm{PS}_{V'} = \frac{(P_{V'} - P_A)m}{2} \quad \text{and} \quad \mathrm{PS}_{V} = \frac{(P_V - P_A)k}{2}$$

This study wants to prove that $\mathrm{PS}_{V'} > \mathrm{PS}_V$, thus, we assume

$$\mathrm{PS}_{V'} < \mathrm{PS}_V \tag{21}$$

Equation (21) can be reduced to $(P_{V'} - P_A)m < (P_V - P_A)k$, which contradicts $P_{V'} - P_A > P_V - P_A$ and $m > k$. Hence, the original assumption is false; $\mathrm{PS}_{V'} > \mathrm{PS}_{V'}$ and the producer surplus is improved by $\frac{1}{2}\,(P_A(k-m) + mP_{V'} - kP_V)$.

Lemma 7. The improved producer surplus mentioned in lemma 6 (i.e. narrow enhancement) is smaller than that mentioned in lemma 5 (i.e. wide enhancement).

Table 4
Price and producer surplus

	Enhanced price for a revised version	Average price among initial versions	Previous price for the revised version
Price	$P_{V'}$	P_{V^*}	P_V
Producer surplus	$\frac{(P_{V'}-P_A)m}{2}$	$\frac{(P_{V^*}-P_A)r}{2}$	$\frac{(P_V-P_A)k}{2}$
Lost profit compared to enhanced price	0	$\frac{1}{2}\ (P_A(r-m)+mP_{V'}-rP_{V^*})$	$\frac{1}{2}(P_A(k-m)+mP_{V'}-kP_V)$

Proof. This study wants to prove $\frac{1}{2}\ (P_A(k-m)+mP_{V'}-kP_V)<\frac{1}{2}\ (P_A(r-m)+mP_{V'}-rP_{V^*});$ thus, we assume that $\frac{1}{2}\ (P_A(k-m)+mP_{V'}-kP_V)>\frac{1}{2}\ (P_A(r-m)+mP_{V'}-rP_{V^*}).$ The original equation can then be reduced to $k(P_A-P_V)>r(P_A-P_{V^*})$.

Conversely, $(P_A-P_V)>(P_A-P_{V^*})$, since $P_B>P_{V'}$ $P_{V^*}>P_V>P_A$. However, (P_A-P_V) and $(P_A-P_{V^*})$ are both negative; thus we multiply both by minus one, giving $(P_V-P_A)<P_{V^*}-P_A)$.

As $r>k$, $k(P_A-P_V)<r(P_A-P_{V^*})$ is always true, and contradicts the original assumption $k(P_A-P_V)<r(P_A-P_{V^*})$. Hence, the original assumption is false, and is true. The improved $\frac{1}{2}\ (P_A(k-m)+mP_{V'}-kP_V)<\frac{1}{2}\ (P_A(r-m)+mP_{V'}-rP_{V^*});$ producer surplus mentioned in lemma 6 (narrow enhancement) is smaller than that in lemma 5 (wide enhancement).

4. Managerial implications

An e-service is an information product that facilitates services via the internet, including e-commerce and non-e-commerce services. An e-service is an interactive content-centered and internet-based customer service, driven by the customer and integrated with related organizational customer support processes and technologies. The goal of e-service provision is to strengthen the relationship between customers and providers [31].

E-services have different properties to most physical goods, such as that they are experience goods (you must experience an information good to determine what it is), return to scale (information typically has a high fixed production cost and a low marginal reproduction cost), and public goods (information goods are typically non-rival and sometimes non-excludable).

The e-service business is an emerging industry that has evolved from the existing service industry. Nevertheless, pricing models are entirely different from conventional models because of the diverse structure of information goods. That is, a customized pricing model is needed for the e-service industry. A collaborative pricing model provides opportunities for overcoming the difference between the goals of sellers and buyers, which is significant for newcomers to the e-service industry.

This study presents a theoretical proof of the collaborative pricing model using economic theory (the law of supply and demand) and confirms the feasibility of collaborative pricing. Certain implications are outlined for managers as guidelines.

1. Collaborative pricing is essential to e-service providers
Although the e-service industry is still developing, collaborative pricing is essential to its success. The collaborative pricing model verifies that bundle pricing via a collaborative process is optimal from the perspectives of both consumers and service providers. Additionally, the model indicates that revising prices periodically always enhances service provider profit. We would suggest to managers that collaborative pricing is essential in the Internet environment.

The e-service industry differs from the conventional service industry, which generally requires face-to-face interactions. The internet facilitates effortless collaboration for co-produced value when bundling e-services. Hence, collaborative pricing will prove to be the optimal solution for pricing e-services.

2. The feasibility is proved from economic perspective
This study utilizes the law of supply and demand to prove the theoretical feasibility from an economic perspective. Theorems 1–3 and lemmas 1–6 verify that profits, consumer surplus, and SW are optimal using economic theory. Analytical results indicate that the collaborative pricing scheme is feasible. That is, managers do not need to be concerned with the feasibility of the collaborative pricing model.

Rather, service providers must furnish an environment – the infrastructure for the collaborative pricing model – that enables interaction over the internet. The theoretical feasibility of our collaborative pricing model suggests that the collaborative pricing model is practicable for the immature e-service industry.

3. Furnishing a roadmap for e-service pricing
The pricing model indicates the feasibility of the e-service industry and is a roadmap for information goods pricing. Product and service pricing have significant implications for all industries, but conventional pricing methods do not suit this new, internet-based, industry.

E-service providers must identify effective pricing models to increase profits and consumer satisfaction. The collaborative pricing model allows companies to implement a win–win strategy. That is, problems associated with both low profits and poor customer satisfaction are solved when e-service providers adopt the collaborative pricing model.

5. Discussion

This study provides theoretical proofs that support the feasibility of collaborative pricing. However, there are still limitations and possible directions for future research. The proposed collaborative pricing model is useful in pricing information goods and services within the internet-based environment, but the model may not be practical for other environments. Furthermore, there are other synthesized methods that may be incorporated into the pricing process. For instance, a synthesized method might include real-time needs prediction during the collaborative process (e.g. using the Markov chain approach) or accurate measurement of utility (e.g. using expected utility theory) based on different notions from various fields (e.g. economic, psychology). In addition, empirical research using an autonomous pricing system should be conducted, to re-confirm the feasibility of applying the collaborative pricing model. Finally, a real-life implementation of the collaborative pricing process is still required, in order to prove its applicability and appropriateness in the field.

6. Conclusion

Collaborative pricing has emerged recently as a means of overcoming the dilemma that sellers want to maximize profits and consumers want to maximize cost savings. Collaborative pricing is a method that extends current pricing methods and considers consumers and producers simultaneously.

Three features for future consideration are identified – collaboration, consumer involvement, and price discrimination. Once a consumer experiences a product, he/she will pay a premium for that product. Unlike conventional differential pricing methods, collaborative pricing optimizes prices for both consumers and producers.

Proof of theorem 1 confirms that collaborative pricing enhances both profits and consumer surplus. We believe this novel collaborative pricing model should guide future pricing research for information goods.

This study investigated two pricing strategies for information goods; versioning and bundling (theorems 2 and 3). This study confirms that SW is optimally based on an equilibrium bundle price (lemmas 3–7). Theoretically, bundle price is optimal and achieves maximum efficiency (i.e. without any deadweight loss). The results also verify the feasibility and practicability of bundling and versioning information goods.

Finally, this study has two principal findings: (1) the collaborative pricing model is essential for information goods pricing and (2) the collaborative pricing model is feasible. In addition, this study provides a roadmap for future e-service pricing, in that the collaborative pricing model is theoretically sound and can be used as a roadmap for e-service practitioners.

7. References

[1] G.J. Stigler, The economics of information, *Journal of Political Economy* 69(3) (1961) 213–225.

[2] B. Stiller, P. Reichl and S. Leinen, pricing and cost recovery for internet services: practical review, classification, and application of relevant models, *Economic Research and Electronic Networking* 2(1) (2001), 149–171.

[3] C. Shapiro and H.R. Varian, *Information Rules; A Strategic Guide to the Network Economy* (Harvard Business School Press, Boston, MA, 1998).

[4] R. Aron, A. Sundararajan, and S.S. Viswanathan, Intelligent agents in electronic markets for information goods, *Decision Support Systems* 4(4) (2006) 764–786.

[5] B. Cronin, Towards information-based economies, *Journal of Information Science* 12(1) (1985) 129–137.

[6] H. Varian, Pricing information goods, *Proceedings of the Symposium on Scholarship in the New Information Environment* (Harvard Law School, Harvard, MA, 1995).

[7] I. Simonson and A. Drolet, Anchoring effects on consumers' willingness-to-pay and willingness-to-accept, *Journal of Consumer Research* 31 (2004) 681–690.

[8] M. Agarwal and S. Chatterjee, Complexity, uniqueness, and similarity in between-bundle choice, *The Journal of Product and Brand Management* 12(6) (2003) 358–376.

[9] G.D. Eppen, W.A. Hanson and R.K. Martin, Bundling-new products, new markets, low risk, *Sloan Management Review* 32(4) (1991) 7–14.

[10] P.K. Kannan and P.K. Kopalle, Dynamic pricing on the internet: importance and implications for consumer behavior, *International Journal of Electronic Commerce* 5(3) (2001) 63–83.

[11] Y. Narahari, C.V.L. Raju and S. Shah, *Dynamic pricing models for electronic business* (Technical report, Electronic Enterprises Laboratory, Department of Computer Science and Automation, Indian Institute of Science, 2003).

[12] A. Sundararajan, Nonlinear pricing of information goods, *Proceedings of the 2nd International Industrial Organization Conference* (2004).

[13] S.M. Sawhney, Beyond Relationship Marketing: The Rise of Collaborative Marketing, *Articles of CRM Today*. Available at: http://www.crm2day.com/library/EpVppyEAAuvYLagcNF.php (accessed 28 August 2007).

[14] S. Buckley, *Overcoming Roadblocks to Collaborative Pricing* (Whitepaper of the Technology Executives Club). Available at: http://www.technologyexecutivesclub.com/Articles/marketing/collaborativepricing.php (accessed 28th August 2007).

[15] K.L. Wang, Pricing Strategies for Information Products: A Review, *IEEE International Conference on e-Commerce Technology for Dynamic E-Business (CEC04EAST)* (Beijing, China, September 13–15 2004).

[16] H.K. Bhargava and V. Choudhary, Information goods and vertical differentiation, *Journal of Management Information Systems* 18 (2001) 89–106.

[17] R.P. McAfee, J. McMillan and M.D. Whinsto, Multi-product monopoly, commodity bundling, and correlation of values, *Quarterly Journal of Economics* 114 (1989) 371–384.

[18] Y. Bakos and E. Brynjolfsson, Bundling and competition on the internet, *Marketing Science* 19(1) (2000) 63–82.

[19] K. Altinkemer, Bundling e-banking services, *Communications of the ACM* 44(6) (2001) 45–47.

[20] Y.C. Chang, C.S. Li and J.R. Smith, Searching dynamically bundled goods with pairwise relations, *Proceedings of the ACM conference on Electronic Commerce (EC'03)* (San Diego, CA, June 9–12 2003).

[21] S. Buffett and B. Spencer, A decision procedure for bundle purchasing with incomplete information on future prices, *International Journal of Electronic Commerce* 8(4) (2004) 131–144.

[22] D.J.A. Somefun and J.A. La Poutré, *Bundling and Pricing for Information Brokerage: Customer Satisfaction as a Means to Profit Optimization* (Report, December 19, 2003).
[23] E. Kivisaari and S. Luukkainen, Content-based pricing of services in the mobile internet, *Proceedings of the seventh IASTED International Conference on Internet and Multimedia Systems and Applications* (Honolulu, HI, 2003).
[24] W. Abernathy and R. Rosenbloom, Parallel and sequential R&D strategies: application of a simple model, *IEEE Transactions on Engineering Management* 15(1) (1968) 2–10.
[25] R.R. Nelson, Uncertainty, learning, and economics of parallel search and development efforts, *The Review of Economics and Statistics* 43 (1961) 351–364.
[26] V. Srinivasan, W.S. Lovejoy and D. Beach, Integrated product design for marketability and manufacturing, *Joural of Marketing Research* 34 (1997) 154–163.
[27] S.H. Thomke, Managing experimentation in the design of new products, *Management Science* 44(6) (1998) 734–762.
[28] B. Klaus, D. Dimitrov and C.J. Haake, Bundling in exchange markets with indivisible goods, *Economics Letters* 93 (2006) 106–110.
[29] S. Martin, Strategic and welfare implications of bundling, *Economics Letters* 62 (1999) 371–376.
[30] H. Varian, Versioning information goods, The Economics of Digital Information (Working paper, MIT Press, Cambridge, MA, 1997).
[31] de Ruyter, K.M. Wetzels and M. Kleijnen, Customer adoption of e-service: an experimental study, *International Journal of Service Industry Management* 12 (2) (2001) 184–207.