Bundling Can Signal High Quality*

Very Preliminary and Full of Mistakes

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Abstract

Bundling experience goods can signal high quality, even in simple static models. When consumers have heterogeneous preferences, bundling two goods can restrict sales to consumers who have high valuations for both goods. Because sales are reduced, bundling is less costly for a firm that produces two high-quality products (and has higher production costs) than for a firm that produces two low-quality products (and has lower production costs). Similarly, when some consumers are informed about product quality, bundling can signal high quality because it restricts sales for any low-quality firm that imitates a high-quality firm. In a simple model in which the high-quality firm’s price is constrained by the ability of low-quality firm to imitate it, bundling increases the price and profit of firms with high-quality products (and makes pooling equilibrium relative less attractive).

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1 Introduction

While tying and bundling have been viewed with suspicion by US courts, firms give product quality as an explicit efficiency defense in antitrust cases. This paper shows that product bundling can signal to consumers that a firm’s experience goods are high quality. In the basic model, consumers do not observe quality at the time of purchase, but infer quality from the firms bundling decision and prices. Because consumers are heterogeneous, bundling limits sales to consumers who value both products. Because bundling reduces sales, bundling is less costly for high quality firms who also have higher costs then it is for low quality firms who have lower costs. This implies that bundling can be used to signal high product quality.

Perhaps more importantly, when some consumers are informed about product quality, bundling raises the cost of imitating a high quality firm because low quality firms lose sales of both products when consumers observe that just one is low quality. In both cases consumers are heterogeneous and bundling makes it more costly for low quality firms to imitate high quality firms.

The paper is organized as follows. Section 2 discusses some of the related literature. Section 3 describes the basic model and shows that bundling can signal high quality in a simple model in which consumers are all uniformed. Section 4 considers a more general model with some informed consumers and shows that bundling can reduce the size of the price distortions that arise when only prices are used to signal quality. Finally, section 5 provides some concluding remarks.

2 Literature

Much research has focused on the reasons for product bundling, but few papers have considered bundling’s impact on product quality. Adams and Yellen (1976) and McAfee, McMillan and Whinston (1989) show bundling can help firms to extract greater surplus from consumers. See also Fang and Norman (2006). Elhauge and Nalebuff (2014) show that bundling or tying allows firms to use consumption of a tied nondurable goods as a proxy for consumers’ valuation of a durable good. Whinston (1990), Nalebuff (2004), and others show that bundling can be used to foreclose competition(see the survey by Nalebuff, 2008). Salinger (1995) argues that bundling may also reduce the costs of production and distribution of products. Dana and Fong (2011) and Baranes, et al. (2011) argue that bundling facilitates tacit collusion.

A few papers suggest that bundling can solve an attribution externality and increase quality. In the law end economics literature, Bork (1978) and Posner
and Easterbrook (1981) suggest that when consumers use low-quality products, then low overall performance may be erroneously attributed to the producer of related high-quality products, and so by tying or bundling the products together, the seller can eliminate this externality. But as they point out, consumers don’t necessarily need to have their choices constrained to solve this problem – they typically have private incentives to sole source when purchasing. Iacobucci (2003) more formally highlights the importance attribution problem (see also Bar-Gill, 2006).

Dana and Spier (2017) show that product bundling can lead to higher quality by improving monitoring even in the absence of the attribution problem. Bundling can improve both the quality of monitoring and the effectiveness of consumer punishment strategies. The show that these are even more effective in the presence of attribution problems. Dana and Spier (2015) make the related point that minimum purchase requirements can improve monitoring in a simple homogeneous-goods model.

At least two other papers consider models in which product bundling signals high quality, but unlike the two static models in this paper, both of these papers exploit dynamic aspects of the consumers’ purchase decisions. First, Schwartz and Werden (1996) consider a closely related signaling model in which a privately-informed firm uses tying to signal the quality of its durable good. By tying the sale of the durable good to a nondurable one, the firm can shift the rents from the durable to the nondurable and help overcome the hidden-information problem. In contrast, this paper uses the fact that consumers are heterogeneous and bundling restricts sales to show that bundling can signal high quality.

Similarly, Choi (2003) shows that an firm will an established branded product can bundle it with a new product to signal quality. By irreversibly committing to bundle its products, the firm is using its future rents on the established product as a bond to signal quality of the new product – bundling constrains consumers to stop buying both products when they discover the new product is low quality.

In contrast, this paper emphasizes that bundling can signal high quality by restricting total sales (similar to the way a high price signals high quality in Bagwell and Riordan, 1991), and by making it more costly for low-quality firms to imitate high quality firms when consumers have heterogeneous information about quality.

3 The Model

A single firm sells two products. With probability $\theta$ the firm produces a high-quality product and with probability $1 - \theta$ it produces a low-quality product.
High-quality products cost $c_h$ and low-quality products cost $c_l$ where $c_h > c_l$. The two products may have perfectly correlated quality, or independently distributed quality.

Conditional on wanting the good, all consumers will pay $v_l > c_l$ for low-quality products and $v_h > c_h$ for high-quality products. Consumers choose whether or not to purchase the goods given their beliefs about the firm’s product quality.

The firm can choose whether to bundle its products or not, and it simultaneously sets a price for each product or a price for the bundle.

The paper considers two variations on the model. In the first model, consumers vary in whether or not they want each good - only some want both goods. In the second model, they vary in whether or not they observe the quality of each good. Both of these assumptions imply that bundling impacts the demand for the firms’ products.

Throughout the paper the focus is on perfect Bayesian equilibria that satisfy the intuitive criterion.

### 3.1 Heterogeneous Preferences

Consumers have heterogeneous preferences. They vary in whether or not they want each good. A fraction $s$ want both goods. A fraction $(1 - s)$ want just one of the two goods – they are equally likely to want either good 1 or good 2.

For simplicity, suppose that quality is perfectly correlated, so with probability $1 - \theta$ both products are low-quality products.

#### Without Bundling

When bundling is not feasible, no separating equilibrium can exist. Neither firm will charge less than $v_l$ (profits increase in price below $v_l$ regardless of consumers’ beliefs), and if the high-quality firm sets an equilibrium price above $v_l$ then the low-quality firm would strictly prefer to charge that price as well – the low-quality firm’s revenue increases and its sales and production costs are unchanged.

Let $\bar{v} = \theta v_h + (1 - \theta) v_l$. Clearly no pooling equilibrium exists at a higher price since demand would be zero, and the low quality firm would prefer to charge $v_l$ regardless of consumers’ beliefs.

This implies the following result:

**Proposition 1.** If bundling is not feasible, all perfect Bayesian equilibrium are pooling equilibrium in which both types charge $p \in [v_l, \bar{v}]$. The strategies are supported by a variety of beliefs including the beliefs that the firm is a low-quality firm if it charges an off-the-equilibrium path price.
Proof. Clearly such pooling equilibria are perfect Bayesian equilibria. The strategies can be supported with the beliefs that the firm is low-quality at any other price. And we have shown above that no separating equilibria exist.

It is also easy to see that no other pooling equilibria exist. At any lower price, both types would be better off charging \( v_l \) even if consumers believed such a firm had low quality. And at any higher price, sales would be zero, so the low-quality firm would be strictly better off charging \( v_l \) even if consumers knew it was low quality.

Note that these pooling equilibria also satisfy the intuitive criterion. In general, let \( b(p) \) denote consumer beliefs about the probability a firm is high-quality if it charges price \( p \). And let \( \pi_h(p, b) \) and \( \pi_l(p, b) \) denote each type’s profits if they charged price \( p \) and consumers believe \( b \) when the equilibrium prices are \( p_l \) and \( p_h \) and the equilibrium beliefs are \( b(p) \). Then the intuitive criterion holds if there is no \( p \) for which \( \pi_h(p, 1) > \pi_h(p_h, \theta) \) and \( \pi_l(p, 1) < \pi_l(p_l, \theta) \). That is, there is no price \( p \) such that high-quality firm would earn higher profits at \( p \) if consumers thought that the deviating firm was a high-quality firm, but the low-quality firm would not, even if consumers thought that the deviating firm was a high-quality firm.

These pooling equilibria satisfy the intuitive criterion because in this simple model the firm’s demand is only affected by consumers’ beliefs about quality, not by price directly. So \( \pi_h(p, 1) > \pi_h(p_h, \theta) \) implies \( \pi_l(p, 1) > \pi_l(p_l, \theta) \) because \( p_l = p_h \) so the two types face the same demand increase (the deviation demand is weakly higher because all consumers purchase when \( b(p) = 1 \) and \( p < v_h \)) and the same price increase. And the high type has higher costs, so if the high type’s profits rise, the low type’s profits rise.

**Bundling**

Now suppose that bundling is feasible. In this case, a separating equilibrium can exist in which the high-quality firm bundles and charges \( 2v_h \) and the low quality firm does not bundle and charges \( v_l \) for both goods. For a separating equilibrium to exist, three conditions must hold. First, the high-quality firm must prefer to bundle and set the high price (\( 2v_h \) for the bundle) as opposed to imitating the low-quality firm, which is true if and only if \( \pi_h^b(2v_h, 1) > \pi_h(v_l, 0) \), or

\[
s(2v_h - 2c_h) \geq s(2v_l - 2c_h) + (1 - s)(v_l - c_h)
\]

or

\[
\frac{2s}{1 - s} \geq \frac{v_l - c_h}{v_h - v_l}.
\]  

(1)
Second, the low-quality firm must prefer to not bundle and set the low price \((v_l)\) and not imitate the high-quality firm by bundling and setting a high price \((2v_h)\), which is true if and only if \(\pi_l(v_l, 0) > \pi^b_l(2v_h, 1)\), or
\[
s(2v_l - 2c_l) + (1 - s)(v_l - c_l) \geq s(2v_h - 2c_l).
\]
or
\[
\frac{2s}{1 - s} \leq \frac{v_l - c_l}{v_h - v_l}.
\] (2)

And finally, neither the high-quality or low-quality firm wants to deviate to any other price, or to any price/bundling decision combination. So (1) and (2) are necessary conditions for a separating equilibrium to exist.

Other separating equilibrium can also exist, but when the above separating equilibrium exists then it is the only one which satisfies the intuitive criterion. This is because the firm's profits are higher at \(2v_h\) and the low quality firm would not charge \(2v_h\) even if consumers thought it were high quality, so the belief that the firm is not high-quality fails the intuitive criterion.

A pooling equilibrium can also exist in which neither firm bundles. But again no pooling equilibrium exists with \(p > \bar{v}\) since sales are zero and the low-quality firm would prefer \(p = v_l\) regardless of consumers’ beliefs.

So a pooling equilibrium consists of a price \(\hat{p}\) where \(\hat{p} \in [v_l, \bar{v}]\) and beliefs \(b(p)\) such that

1. \(\pi_l(\hat{p}, \theta) \geq \pi_l(p, b(p))\);
2. \(\pi_l(\hat{p}, \theta) \geq \pi^b_l(p, b(p))\);
3. \(\pi_h(\hat{p}, \theta) \geq \pi_h(p, b(p))\); and
4. \(\pi_h(\hat{p}, \theta) \geq \pi^b_h(p, b(p))\)

for all \(p\), where \(\pi^b_i\) denotes the firm’s profit when the firm bundles. Of course the low-quality firm won’t bundle unless the high-quality firm also wants to bundle, so the second condition can be ignored. And we have already seen that the first and third are easily satisfied when \(b(p) = 0\) for off-the-equilibrium path prices. For simplicity, suppose \(b(p) = 0\) for off-the-equilibrium path prices in every pooling equilibrium we discuss.

Note that a pooling equilibrium that exists when bundling is not feasible is still a perfect Bayesian equilibrium when bundling is feasible, but it may not satisfy the intuitive criterion with respect to the decision to bundle. (Deviations in price alone never fail the intuitive criterion). But when bundling is feasible, the high-quality firm can deviate by bundling, and bundling is less costly for the high-quality firm than the low-quality firm.
It follows that a pooling equilibrium will satisfy the intuitive criterion if 1) $\pi_h(\hat{p}, \theta) \geq \pi_h^b(p, 1)$ for all $p$, so the high type would not deviate even if consumers believed the deviating firm was the high type, or if 2) $\pi_l(\hat{p}, \theta) < \pi_l^b(p, 1)$ for all $p$ such that $\pi_h(\hat{p}, \theta) < \pi_h^b(2p, 1)$, so the high type cannot convince consumers that the it is the high type when it deviates.

We can rewrite the first condition as

$$\pi_h(\hat{p}, \theta) > \pi_h^b(2v_h, 1)$$

(3)

because this implies no deviation is profitable even when consumers expect high quality, that is, this implies $\pi_h(\hat{p}, \theta) \geq \pi_h^b(p, 1)$ for all $p$. And equation (3) cannot hold in any pooling equilibrium where $\hat{p} < \bar{v}$ unless it also holds in a pooling equilibrium for $\hat{p} = \bar{v}$, since this is the pooling equilibrium that gives the high-quality firm the highest equilibrium profits and the deviation profits do not depend on the pooling price, so this is the candidate pooling equilibrium in which a deviation is least likely to be profitable – in a pooling equilibrium the beliefs, $b(\hat{p})$, are independent of $\hat{p}$ so the left hand side of (3) is increasing in $\hat{p}$.

So, writing out the profit functions, a sufficient condition for a pooling equilibrium to exist is

$$s(2\bar{v} - 2c_h) + (1 - s)(\bar{v} - c_h) \geq s(2v_h - 2c_h)$$

or equivalently,

$$\frac{2s}{1 - s} \leq \frac{\bar{v} - c_h}{v_h - \bar{v}}.$$  

(4)

We can get a second sufficient condition from condition 2. The second condition requires that

$$\pi_l(\hat{p}, \theta) \leq \pi_l^b(2p, 1)$$

(5)

for any price $p$ at which

$$\pi_h(\hat{p}, \theta) \leq \pi_h^b(2p, 1)$$

(6)

that is, the high cost firm cannot change consumers’ beliefs.

So a pooling equilibrium exists at $\hat{p} = v_l$ if

$$\pi_l(v_l, \theta) \leq \pi_l^b(2v_h, 1).$$

(7)

So even if the high type gains from deviating to $2v_h$, so does the low-quality firm, so the beliefs that quality is low at off-of-the-equilibrium path prices satisfy the intuitive criterion.

Using the profit functions, a pooling equilibrium exists if

$$s(2v_l - 2c_l) + (1 - s)(v_l - c_l) \geq s(2v_h - 2c_l)$$

7
or
\[
\frac{2s}{1 - s} \geq \frac{v_l - c_l}{v_h - v_l}. \tag{8}
\]
This implies that believing that the deviating firm is low-quality won’t satisfy the intuitive criterion when the high-quality firm wants to deviate.

This implies the following results:

**Proposition 2.** When bundling is feasible, if
\[
\frac{v_l - c_h}{v_h - v_l} \leq \frac{2s}{1 - s} \leq \frac{v_l - c_l}{v_h - v_l}, \tag{9}
\]
then a pure-strategy separating perfect Bayesian equilibrium satisfying the intuitive criterion exists in which the low-quality firm charges \(p_l = v_l\) and the high-quality firm bundles and sets \(p_h = v_h\) (charges \(2v_h\) for the bundle).

For all values of \(s\) that don’t satisfy (9), a pure-strategy pooling perfect Bayesian equilibrium satisfying the intuitive criterion exists in which both high and low quality firms charge the same price \(p\).

**Proof.** The discussion above makes it clear that (9) is a necessary condition for a separating equilibrium to exist at the described prices. And it is clear that no other pure-strategy separating equilibrium exists. Low types must be charging \(v_l\) since that is the most profitable price if consumers think they are low types. And by the intuitive criterion high types must be charging \(2v_h\). If they were charging less they could deviate to \(2v_h\) and increase their profits and such a deviation is never profitable for low types.

It only remains to show that there exist beliefs such that no other deviation is profitable for either type.

... Note that we have also shown that when \(s\) is outside the range defined by (9) then a pooling equilibria exists. Equation (4) and
\[
\frac{v_l - c_h}{v_h - v_l} \leq \frac{\bar{v} - c_h}{v_h - \bar{v}}
\]
imply that pooling equilibria exists when \(s\) is below the lower cutoff and (8) implies that pooling equilibria exist when \(s\) is above the upper cutoff.

Note that pooling equilibria and separating equilibria may coexist. This is obviously true for \(s\) satisfying
\[
\frac{v_l - c_h}{v_h - v_l} \leq \frac{2s}{1 - s} \leq \frac{\bar{v} - c_h}{v_h - \bar{v}}
\]
but is probably true for $s$ satisfying
\[
\frac{\bar{v} - c_h}{v_h - \bar{v}} \leq \frac{2s}{1 - s} \leq \frac{v_l - c_l}{v_h - v_l}
\]
as well, and is also true outside the interval defined by (9) since separating equilibria with lower prices can exist.

Notice also that separating equilibria fail to exist for two reasons. If $s$ is too large, then low quality firms want to imitate high quality firms and charge a high price, so a separating equilibrium does not exist, while if $s$ is too small then high quality firms prefer to pool with low quality firms and sell at a higher volume but lower margin.

Also, note that if $c_h = c_l$ then no separating equilibrium exists. If both high and low types have the same costs, they either both prefer the higher price or neither prefer the higher price. So bundling is only useful as a signal here when the high quality firms find it less costly to restrict output then low quality firms, which requires the assumption that $c_h > c_l$.

And most importantly, note that mixed strategy separating equilibrium also exist. In particular, high quality can be sustained without bundling when the high quality firm charges $v_h$ and consumers mix between purchasing and not purchasing. But when a separating equilibrium exists in mixed strategies, without bundling there may also exist pooling equilibria. But with bundling, these pooling equilibria vanish.

### 3.2 Heterogeneous Information

Now suppose that consumers want to purchase both goods, but consumers have an imperfect signal of quality. A fraction $x$ observe the product quality of each good directly. Moreover, this probability is independently distributed, so $x^2$ consumers observe the quality of both goods, $2x(1-x)$ observe the quality of just one good, and $(1-x)^2$ observe the product quality of neither good.

Also, suppose now that quality is independently distributed, so the quality of one good is not informative about the quality of the other good.

In this case, if bundling is not feasible, a separating equilibrium always exists – the firm sets a high price for its high quality product or product and $v_l$ for its low-quality product or products. This is clearly the case when $x = 1$ and consumers are fully informed. Then the high-quality firms prefers to charges $v_h$ and low-quality firm charges $v_l$. Even though the low-quality firm can imitate the high-quality firm, it isn’t ever profitable.

To understand why a separating equilibrium always exists, suppose the high quality firm sets a price very close to, but above $v_l$, the low-quality firm sets $v_l$,
and consumers believe quality is low if they see any other price. This is because the low-quality firm looses a fraction of $x$ of its demand, so a small price increase is not worthwhile.

In fact, the prices in a separating equilibria satisfying the intuitive criterion are unique. The high quality firm charges the highest price in can that isn’t sufficiently attractive for the low-quality firm to imitate. When $x$ is sufficiently large, that price will be $v_h$.

**Proposition 3.** For any $x$, a separating equilibrium satisfying the intuitive exists and the equilibrium prices are uniquely defined – the low quality firm’s price is $v_l$ and the high quality firm’s price is $p_h(x) : [0, 1] \rightarrow (v_l, v_h)$ where $p_h(x)$ is strictly increasing in $x$.

A pooling equilibria satisfying the intuitive criterion also exist when $x$ is sufficiently small.

**Proof.** In any separating equilibrium, the low-quality firm must set a price equal to $v_l$, the price that maximizes its profits given that consumers know its type. Deviating to $v_l$ would always increase profits, regardless of consumer beliefs.

And a separating equilibrium clearly exists, as argued above.

And, if two separating equilibria exist, each with a different price for the high-quality firm, then it follows (from the definition of an equilibrium) that the low-quality firm prefers to set a price of $v_l$ rather than set either of the prices chosen by the high-quality firm, even though consumers would believe that it was the high-quality firm. But this implies that consumers’ off-the-equilibrium-path beliefs in the lower priced separating equilibrium do not satisfy the intuitive criterion – the high-quality firm can deviate to the higher price and consumers should believe it is the high-quality firm. So the separating equilibrium satisfying the intuitive criterion is unique.

If a pooling equilibrium satisfying the intuitive criterion exists, it follows that the price must be strictly greater than $v_l$ since otherwise the high-quality firm could deviate to a price just above $v_l$ and make higher profit, and that the price must be weakly lower than $v$ since otherwise uninformed consumers would not purchase and the low-quality firm would be better off charging $v_l$. But if $x$ is too large, then a deviation to a price above $v$ will still be profitable and so no pooling equilibria exists.

Note that the proposition ignores partial-pooling equilibria for now.

Now suppose that bundling is feasible. Notice that bundling is costless if the firm is a high-quality, but bundling is costly for the low-quality firm because consumers who observe even one low quality product won’t purchase the bundle.
So if the low-quality firm imitates, it will sell only $2(1 - x)^2$ units – only the consumers who are completely uninformed will buy.

Bundling restricts sales for the low-quality firm, so it makes imitation less profitable, which implies that a separating equilibrium exists for a wider range of values of $x$.

**Proposition 4.** Suppose that $x$ is sufficiently large that when bundling is not feasible, a pooling equilibrium does not exist. Then when bundling is feasible, a separating equilibrium satisfying the intuitive criterion exists and the equilibrium prices are uniquely defined – the firm with a low-quality product does not bundle and its price is $v_l$ for its low quality product and $p_h(x)$ for its high quality product, and the firm with two high quality products bundles and sets a price $2p_b^h(x)$ where $p_b^h(x) > p_h(x)$ so the firm earns strictly higher profits when bundling is feasible.

Note that a firm with two high quality products benefits from bundling because it makes it easier to separate itself from the firms with only one high quality product. But these firms cannot charge more than $p_h(x) + v_l$ for their bundle because a firm with two low quality products would imitate that price.

4 Discussion of a More General Model

In this section we discuss a more general model that closely follows Bagwell and Riordan (1991). Note that in this model, I believe the firm prefers to use high prices as a signal of quality rather than bundling, at least when the price needs to be distorted a lot. It is also much harder than I anticipated. So I may drop this section (and just give intuition).

A unit mass of infinitely-lived, risk-neutral consumers demand a single unit of two experience goods, product 1 and product 2. Consumers have a homogeneous reservation value $p_L$ for good $i$ if good $i$ is low quality, and heterogeneous reservation values $v_i \sim U[p_L, p_L + 1]$ if good $i$ is high quality. I assume that consumers’ reservation values for the two goods are independently distributed when both goods are high quality.

Some consumers observe both products’ quality and hence know both of their reservations values. Other consumers know only their reservation value contingent on quality, but don’t observe quality. These consumers believe the firm produces a high quality product with probability $r$. I assume that the quality of the two goods is independently distributed, so the probability that both products are high quality is $r^2$.

The firm’s cost is $c_h$ for each unit of output if quality is high and is $c_l$ if quality is low.
The timing is as follows. The firm observes its quality for each product and then chooses whether or not to bundle its products and simultaneously sets its price: two prices, $p_1$ and $p_2$, if it decides not bundle, and one price, $p_b$, if it decides to bundle.

Consumers then decide whether or not to purchase. Informed consumers purchase good 1 if $v_1 > p_1$ and good 2 if $v_2 > p_2$, and they purchase the bundle if $v_1 + v_2 \geq p_b$. Uninformed consumers have beliefs about quality given the observed price and they purchase good 1 if $E[v_1|p_1] > p_1$ and good 2 if $E[v_2|p_2] > p_2$, and they purchase the bundle if $E[v_1 + v_2|p_b] \geq p_b$.

5 Conclusion


References


