Consumers' Trust in Multi-attribute Experience-goods Sellers*

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Abstract

A monopolist sells experience goods with observable and experience attributes. The attributes are termed complements(substitutes) if increasing one attribute raises(lowers) the marginal value of the other. The equilibrium observable attribute increases (decreases) in the seller's discount factor when the two attributes are complements(substitutes). For products with both experience attributes, turning one of them observable can lower the remaining experience attribute and the profit. Committing to myopically sub-optimal levels on the observable attribute can promote consumers' trust and raise the profit. Our theory also suggests that an exogenously imposed minimum quality standard can undermine trust building when attributes are substitutes.

*The first author would like to acknowledge the RGC Grant (Project Number 16400614) for its financial support. We also thank the audiences for useful comments at the Econometric Society Australasian Meeting, the International Industrial Organization Conference, the Asian Econometric Society Meeting, the HKUST Workshop on Industrial Organization, the Singapore Economic Review Conference, the European Winter Meetings of the Econometric Society, the University of Hong Kong, and Lingnan University of Hong Kong.

1 Introduction

The concept of experience goods, first introduced by Nelson (1970), refers to products of which valuation is assessed only through consumption. Examples of experience goods abound; some commonly cited examples include restaurant dining, durable goods, health care products, professional services, and platform services. Due to their practical relevance, experience goods have received considerable attention in the literature. Since the seminal work by B. Klein and Leffler (1981), many theoretical studies are devoted to exploring how firms' concern for future businesses serves as a driving force for them to exert costly efforts to ensure high quality of their products despite its unobservability at the time of trade. Some notable results are presented in Shapiro (1983) and Hörner (2002).

One common feature of those dynamic models is that the experience goods are generally depicted as single-attribute products. [1] However, in real life, a substantial subset of experience products carries multiple attributes. Moreover, some of these attributes are observable or even contractible prior to purchase, while other attributes remain unobservable until the product has been consumed. To elaborate on this point, consider a smart phone as an example. Hardware specifications, such as processor speed, screen resolution, and camera megapixel counts are observable attributes in the sense that they are included in the product description which consumers have easy access to and some are even court-verifiable information. Meanwhile, the ultimate user experience of a phone also depends on other harder-to-assess-in-advance factors, such as the friendliness of the user interface and other software implementations. The assessment of these attributes requires consumers to spend sufficient time with the product.

Another observation about real-life experience goods is that the observable and experience attributes are often interdependent in the way they contribute to the overall valuation. Milgrom and Roberts (1992) and Roberts (2004) emphasize the relevance of studying how interactions among changes in different variables would affect organizational performances. Following their tradition, we define the interdependent relation across two sets of attributes as follows: When an increase in one attribute raises the marginal valuation on another attribute, we say the two attributes are *complements*, and when an increase in one attribute lowers the marginal value of another attribute, we say the two attributes are *substitutes*. [2]

To illustrate the potential complementarity between observable and experience attributes, let us revisit the smart-phone example. While a large and high-resolution display is typically appreciated by consumers, if poor software implementations cause the touch panel to be sluggish and the device to frequently crash, the added value of a high-quality display is quite limited. Another example of

[1] Strausz (2009) and Qian, Gong and Chen (2015) are two exceptions and will be discussed in Section 2.

[2] The relationship between the observable and experience attributes can be complements for some levels of attributes and substitutes for some other levels. We do not study this case because it is difficult to obtain useful insights when the relationship across attributes is not coherent and systematic.

complementary attributes is restaurant decor and its food quality. The number of functions and durability of electrical appliances are also complements, in that consumers derive more benefits from a well-designed appliance over its lifetime when the product is expected to have a longer service lifespan. Common in these examples, the first product attribute is more readily observable prior to purchase than the second.

Substitutable product attributes with different observability are also common. For example, when consumers decide whether to subscribe membership of online streaming services [3], two factors are taken into consideration: whether it offers an extensive selection of licensed videos and whether it exclusively produces high-quality "original" contents. When the platform successfully builds the reputation on high quality of featured programs, most subscribers can spend their streaming time on newly distributed shows and movies. The size of the media archive in this case will not be their major concern. However, if the platform fails to constantly supply compelling exclusive contents, the consumer's evaluation criterion will be primarily on how many titles she has access to as a premium member. Apparently, purchases of distribution rights on licensed titles are much more credible business strategies than the promise of big investment in producing high-quality original contents.

One can see that in the same vein, the qualities of many professional services are determined by both observable attributes such as the "availability" of toolboxes and data sets as well as unobservable ones such as professional knowledge, skills and talents. Data brokers collect and purchase (both personal and commercial) datasets, then conduct analysis, write advisory reports and sell the reorganized information to customers. The company's purchased licenses of datasets are more observable than the quality of its analytic services. When the data broker's information is raw and limited, a professional team with excellent data-processing talents is essential to help the customer make better decisions. On the other hand, if the broker possesses a wide range of datasets of satisfactory qualities, then the licensed access to these data per se is valuable to subscribers. Similar story extends to many digital services such as cloud storage and platform recommendation, where the observable attributes are the variety or comprehensiveness of the service and the unobservable attributes are the quality of the core operations.

Arguably, the classical single-dimension setting is a reasonable simplification of an *independent* multi-attribute environment, as one can consider the observable attribute as contributing to the minimum quality of the experience good and the experience attribute as adding to it to make a higher-quality experience good. However, an *interdependent* value model of attributes with different observability allows us to explore more insights that are relevant to many important markets listed above.

[3]The market size of online streaming services is expanding rapidly in recent years. The global market volume amounted to almost 400 billion USD in 2021. Netflix alone, generated almost 30 billion USD revenue in 2021. See https://www.precedenceresearch.com/video-streaming-market and Netflix annual report 2021, available at https://ir.netflix.net/financials/annual-reports-and-proxies/.

Overview of Results

To understand how the interdependence between observable and experience attributes affects the seller's incentive to gain trust from consumers, we first present a model of the multi-attribute experience product in Section 3. In particular, we consider a product with one observable and one experience attribute, and that the seller is attempting to build trust on high quality of experience attribute. We define two attributes as *complements(substitutes)* if they are *supermodular(submodular)* in consumer's value function. We also map the standard models of single-attribute products or multi-attribute products with independent valuations into our framework.

In Section 4, we study the seller's behavior both on- and off-equilibrium paths. Our first result is that the observability of one attribute makes the seller always set the quality level on that attribute at the *static optimal level* given consumers' belief about the unobservable attribute; On the equilibrium path where consumers trust that the experience attribute is high, the seller sets the observable attribute at the conditional optimal level, which maximizes the profit and most effectively sustains the trust system. Once the seller has deviated in the experience attribute and lost consumers' trust, on the punishment path, he will re-optimize the choice of observable attribute based on consumers' worst belief about the experience attribute. By contrast, if two attributes are independent in the consumer's utility, then the seller's choice of the observable attribute should remain the same, regardless of consumers' belief about the experience attribute. The flexibility of adjustment on the observable attribute therefore creating a tension between facilitating trust-building *on the equilibrium path* and undermining trust-building through recovering business *off the equilibrium path*.

Another observation is that, in the period in which the seller deviates in the experience attribute, he refrains from deviating in the observable attribute, as a simultaneous deviation in the observable attribute would cause suspicion and trigger immediate loss of consumers' trust. To avoid such immediate punishment, the seller needs to maintain the on-path level of observable attribute on the deviation period, followed by re-adjustment in the remaining punishment phase. As a result, deviation in quality in the multi-attribute environment takes two steps to complete, and as will become clear in our analysis, deviation is characterized by a V-shaped quality trend in the case of substitute attributes. This stands in sharp contrast to deviation behavior in single-attribute or multi-attribute experience goods with only experience attributes, wherein the seller optimally deviates in all attributes privately within one step and stays at that level afterward.

In Proposition 1, we characterize the optimal equilibrium and predict that the level of the observable attribute increases in the seller's patience (discount factor) when two attributes are complements but decreases in the seller's patience when two attributes are substitutes. The opposite directions come from the opposite marginal incentives. As the seller becomes more patient, he can support a higher degree of trust on the equilibrium path, therefore the marginal benefit of investment on the observable attribute increases(decreases) due to complementarity(substitutability),

resulting in a higher(lower) level of observable quality.

Again, in the case where two attributes are independent, such marginal incentive disappears and the seller can treat the supply on the observable quality as an independent decision to make without any intertemporal incentive involved. Therefore, the level of observable attribute should not vary in the seller's patience.

We then explore the effect of attribute transparency in Section 5. Technological changes can turn an experience attribute into an observable attribute. For example, consumers' easy access to the Internet could lead to reclassification of experience goods into search goods (L. R. Klein, 1998). In Proposition 2, we first characterize the equilibrium when *both* attributes are experiential. Then we compare the equilibrium outcomes across two scenarios and predict the effects of making one of the experience attributes observable in Proposition 3. Recall that in the single-attribute experience goods setting, transparency completely solves moral hazard problem and leads to unambiguously (weakly) higher quality and profit. In contrast, when two substitute attributes are originally both experience attributes, making *only* one of them observable can have a countervailing effect on trust-building, overall product quality and the seller's profitability. Intuitively, if both product attributes are experiential, *both attributes* will stay at the minimal level once the punishment phase is triggered. Therefore, the seller relies solely on consumers' trust. When one of them is made observable, the seller can credibly adjust it to the optimal level and raise the profit as Lemma 2 predicts. But it also makes the deviation more appealing, because upon the loss of consumers' trust, the observable attribute can be reoptimized accordingly to partially restore the profit. Therefore, the overall effect of partial transparency is complex and depends on the interdependent nature of two attributes and the original level of trust system.

We further study the value of commitment in Section 6. It is well-known that in dynamic strategic scenarios, commitment can help players achieve better outcomes. [4] The similar argument should also apply in our framework. Indeed, in Proposition 4 we show that the seller can enhance the trust-building and achieve a higher profit through committing to a fixed level of the observable attribute over time. What's more interesting is the pattern of such commitment. In particular, we find that the seller will sometimes distort the observable quality, away from the static optimal level predicted by Lemma 2, to further penalize shirking behavior in order to facilitate trust-building. Intuitively, such distortion destroys social surplus, both on and off equilibrium path. It is nevertheless valuable because it reinforces the seller's incentive to keep their promises and supports the equilibrium experience attributes at some level that cannot be sustained without commitment power.

We also discuss the policy implications regarding the commitment issue. In the case of complementary attributes, a commitment to a minimum quality standard on the observable attribute can effectively raise the equilibrium experience quality as well as the profit. However, in the case of sub-

[4] For example, Section 3.2.3 in Fudenberg and Tirole (1991).

stitute attributes, improvement cannot be achieved through a minimum quality standard. In fact, we show that an externally imposed minimum quality standard on the observable attribute (say, enacted by a consumer-protection agency or the government) may lead to a lower overall quality of the product and lower profit. Instead, the effective policy in this case should involve imposing a *quality ceiling* on the observable attribute.

Finally, we discuss various other implications and applications, some of which go beyond the scope of our paper, in Section 7.

2 Related literature

The literature on experience goods has taken two broad directions. The first approach analyzes in *static* models how firms utilize various communication devices to convince consumers of their high qualities. Based on the fundamental insight of Nelson (1970, 1974), Schmalensee (1978) and Kihlstrom and Riordan (1984) build various versions of signaling models to capture how advertisements are adopted as a signaling device for experience goods sellers. Notably, Wolinsky (1983), Cooper and Ross (1984) and Milgrom and Roberts (1986) propose that, alongside advertising, price can also convey information about product quality.

The second approach studies how repeated interactions mitigate issues arising from information asymmetry in experience goods markets. [5] Following Cabral (2005)'s terminology, we further categorize dynamic models of experience goods into those about trust building and those about reputation building.

This paper studies the trust mechanism, where firms' concerns for future profits in a repeated relationship motivate them to exert costly efforts. Shapiro (1983) and Allen (1984) show that, even in a competitive market, a premium above the marginal cost is necessary for sellers to compensate their investment in reputation and forestall temptation from myopic shirking. There is no consensus on the effects of competition on qualities of experience goods. According to Hörner (2002), competition endogenously allows consumers to be unforgiving of firms' cheating behavior, and therefore induces more efforts in quality improvement. In contrast, Kranton (2003) argues that competition may erode the price premium, and hence threaten product quality. Bar-Isaac (2005) and Dana and Fong (2011) point out two contrasting non-monotonic relationships between market structures and qualities.

Reputation models, on the other hand, concern how Bayesian buyers' beliefs about the seller's "characteristics" [6] type evolve over time according to the outcomes in previous period(s), which are oftentimes noisy signals of the seller's type. Bar-Isaac (2003) represents reputation formation

[5] See Bar-Isaac and Tadelis (2008) and Cabral (2005) for comprehensive surveys on dynamic trading between informed sellers and uninformed buyers.

[6] We borrow the term from Pei (2020), which unifies the commitment type approach and dynamic signaling approach in a reputation game.

purely as a learning process of buyers and shows that the posterior belief would eventually converge to the truth as more and more new information arrives. Mailath and Samuelson (2001) and several studies that follow consider dynamic models with both adverse selection and moral hazard in which the competent sellers exert high efforts to differentiate with the inept firms.

A small number of studies push beyond the single-dimensional environment, either implicitly or explicitly. The first set of papers mainly deals with the issue of planned obsolescence, in which durability specifically serves as the observable attribute. Choi (2001) shows that the observable durability of a product can be used as a signal for the unobservable quality. Strausz (2009), which is most closely related to our paper, analyzes how reducing durability can increase the frequency of purchase and enhance firms' incentive to produce the experience attribute at a high level. Our model, on the other hand, applies to more general scenarios than the special case in which the observable attribute is durability, and we investigate how the interdependence between the observable and experience attributes affects the experience goods seller's building of consumers' trust, which, to the best of our knowledge, no existing work has yet studied. [7].

Another set of papers, while extending information asymmetry to multiple dimensions, also does not consider interdependence among attributes in the consumer's value. Bar-Isaac, Caruana and Cuñat (2012) characterize a model in which a monopolist produces multi-attribute goods with two independent stochastic characteristics and consumers decide whether to gather information about quality at a cost and, if so, which dimension to acquire. Surprisingly, they find that cheap information can cause a negative result in customers' surplus, profit, and welfare. To analyze how branded firms of high experience qualities react to entry of counterfeit products, Qian, Gong and Chen (2015) also use a model of products with both observable and experience attributes. Apart from the difference in the research questions that we pose, the environments and information structures also differ. Specifically, our model of repeated game, moral hazard, and interdependent attributes stands in sharp contrast with their model of static game, adverse selection, and independent attributes, respectively. Z. Chen, Stanton and Thomas (2024) study a duopoly market of experience goods where valuations *across* firms are correlated and explores how the information spillover shapes the competition dynamics and welfare implications.

Bundling is a common practice and has been extensively studied in industrial organization and marketing. When sellers bundle products or services which are interdependent in consumers' preferences, the bundled product can be viewed as a multi-attribute good with complementary or substitute attributes. Some examples are city passes for multiple museums or for substitute tourist attractions such as zoos and aquariums and cable TV subscription plans bundling various TV chan-

[7]To help the reader understand the intuition of their findings, Dana and Fong (2011) conceptualize an experience good as a combination of a primary product with observable quality and a secondary upgrade with unobservable quality. However, their discussion only considers the case in which these attributes are additively separable in consumers' valuation. In other words, they do not consider interdependence between the two attributes, which is central in our analysis.

nels. [8] For that reason, our paper is closely related to those studying bundling of complement and substitute products, such as Adams and Yellen (1976), Armstrong (2013), Bakos and Brynjolfsson (1999), Y. Chen and Riordan (2013), McAfee, McMillan and Whinston (1989), Mulhern and Leone (1991) and O'Brien and Shaffer (2005). Our study differs from them in an important way; we focus on bundling of search and experience products in a dynamic setting which these papers do not study.

The remainder of the paper is organized as follows. In Section 3, we describe the formal model. Then we proceed to characterize the optimal equilibrium and derive some properties of the optimal equilibrium in Section 4. In Section 5, we discuss how changing one attribute from experience to observable impacts the seller's choice of both attributes. In Section 6, we analyze the strategy of using commitment on the observable attribute to promote consumers' trust in the experience attribute. Section 7 discusses additional applications and concludes.

3 Model

Environment and Technology An infinitely-lived monopolist sells to a unit mass of homogeneous consumers who have unit demand in each period. Time is discrete and indexed by $t = 1, 2, \ldots$. The product has two attributes: *search attribute* and *experience attribute*. The search attribute is observable [9] to consumers whether they purchase the product or not and the experience attribute is observed only after the consumer purchases and consumes the product. Denote the levels of the two attributes as $s \geq \underline{s}$ and $e \geq \underline{e}$, respectively. The lower bounds on the observable and experience attributes can be interpreted as minimum qualities regulated by law or guaranteed by verifiable warranty. We measure the levels of these attributes by the money that the seller spends on these attributes per unit of production. In other words, the seller's unit cost is [10]

$$c = s + e.$$

Preferences and Payoffs The value of the product to each consumer is denoted by an increasing, strictly concave [11] , twice continuously differentiable function:

$$v = v(s, e)$$

[8] The city pass example is borrowed from Armstrong (2013).

[9] The search and information acquisition process is not the focus of our model, therefore we assume consumer can acquire perfect information about search attribute and search cost is normalized to zero. We maintain the terminology to keep in line with the literature.

[10] Given how the attributes are measured, it is natural to also impose the restrictions $\underline{s} \geq 0$ and $\underline{e} \geq 0$.

[11] More precisely, we assume the Hessian matrix of v is negative definite, which is stronger than strict concavity. See Theorem 1.E.12 and Theorem 1.E.13 in Takayama (1985).

We will use v to measure the overall quality of the product. Throughout the paper, we impose the variant "Inada" conditions [12] on social surplus function $v - c$ to guarantee the existence and uniqueness of the optimal solution.

The key ingredient of our model is the interdependency between two attributes. In particular, we define two product attributes as *complements* if v is supermodular, i.e.,

$$\frac{\partial^2 v}{\partial e \partial s} > 0,$$

and *substitutes* if v is submodular, i.e. [13],

$$\frac{\partial^2 v}{\partial e \partial s} < 0$$

An alternative way to consider the complementarity and substitutability is through cost function. In fact, there are some subtle while interesting discrepancies between two modeling choices. We provide a discussion on this topic in Section 6.

We restrict our attention to cases of complementary and substitute attributes for ease of exposition. These cases are mutually exclusive but not exhaustive of all possible cases. All players share a common discount factor $\delta \in (0, 1)$.

Each player's period payoff is normalized to zero when there is no trade. If consumers purchase from the seller, the seller's period payoff/profit is:[14]

$$\pi = p - s - e$$

and the buyers' period payoff is

$$v(s, e) - p$$

Timeline and Solution Concept At the beginning of each period, the firm simultaneously chooses s and e, and sets a price p for the product. After observing p and s, consumers form a belief about the experience attribute e and decide whether to purchase from the seller. If consumers buy the product, they become perfectly informed of e and all players collect their stage payoffs. At the end of each period, all actions in that period become common knowledge. In other words, this is a repeated game of perfect monitoring.

The appropriate equilibrium concept for our setting would be weak Perfect Bayesian equilibrium

[12] In particular, we assume $v_s > 0, v_e > 0, v_s(\underline{s}, \cdot) > 1, v_e(\cdot, \underline{e}) > 1, v_s(+\infty, \cdot) < 1$ and $v_e(\cdot, +\infty) < 1$.

[13] For an example of complementary attributes, consider $v = s^\alpha e^\beta$, with $\alpha, \beta \in (0, 1)$. For an example of substitute attributes, consider $v = \left(\mu_1 s^\alpha + \mu_2 e^\beta\right)^\gamma$, with $\alpha, \beta, \gamma \in (0, 1)$ and $\mu_1, \mu_2 > 0$. Note that the interdependency defined here is a cardinal property, namely, it preserves under affine transformation of utility representation. See Abbas (2018) for a comprehensive treatment on foundations and properties of multiattribute utilities.

[14] We drop the time subscript as the problem is stationary.

(PBE).

Benchmark Cases for Comparison

To help us better understand how incorporating the multi-attribute feature with differential observability into the standard experience goods model would affect consumers' trust and the equilibrium outcome, consider the following the benchmark alternatives for later comparison.

Single Attribute This is the standard setting of experience goods with a single quality dimension. The value of the seller's product can be expressed as $u_2(e)$. The analysis of the single-attribute model is presented in Section 2.6.2 in Tirole (1988).

Independent Attributes We define two product attributes as *independent* attributes if

$$\frac{\partial^2 v}{\partial e \partial s} = 0.$$

When the two attributes are independent of each other, it is equivalent to say that the total value of the goods is additively separable in two attributes, i.e.

$$v(s, e) = u_1(s) + u_2(e).$$

Then we can treat the independent model as a combination of two separate "products" markets. The "product" s with perfect information can be isolated from the other "product" e, of which the analysis is equivalent to that of the **single-attribute** experience product.

Two Experience Attributes In this case, there are two attributes, both unobservable to the consumers until the product is consumed. Following the same notation $v = v(s, e)$ and the same assumptions, we characterize the equilibrium for this market and compare it with the benchmark hybrid model in *Section* 5.

4 Analysis

4.1 Preliminary

We focus on the optimal equilibrium, i.e., the PBE that yields the highest profit for the seller. Just like in single-attribute experience goods models with unit demands, for any given consumers' belief about the seller's attributes, consumers' trust in high experience quality provision is most effectively sustained by pricing the product at their reservation value, as it leads to the highest

profit on the equilibrium path, while keeping the gain from shirking on production cost unchanged. [15] Hence, on the equilibrium path, the seller charges $p = v(s, e)$.

We first define the (static) optimal observable attribute conditional on a given level of experience attribute e as

$$s^*(e) \equiv \arg\max_{s \geq \underline{s}} v(s, e) - s - e \tag{1}$$

The first order condition is

$$v_s(s^*(e), e) = 1$$

The first best experience attribute is

$$e^{FB} = \arg\max_{e \geq \underline{e}} v(s^*(e), e) - s^*(e) - e.$$

It follows that the first best observable attribute is $s^{FB} = s^*\left(e^{FB}\right)$.

The strict concavity of $v(s, e)$ ensures that $s^*(e)$ is a well-defined function and (s^{FB}, e^{FB}) is unique.

4.2 Static Nash Equilibrium: Punishment Path

In the static game, since the experience attribute is costly to produce and unobservable to the buyer, the seller's optimal choice of experience attribute is $\underline{e}$ regardless of the consumers' belief. Therefore, consumers should be pessimistic about the quality and always believe that the firm chooses $\underline{e}$. It implies that the seller sets the observable attribute at the level of $s^*(\underline{e})$. The overall quality and profit are at the levels of $v(s^*(\underline{e}), \underline{e})$ and $\pi^{SN} = v(s^*(\underline{e}), \underline{e}) - s^*(\underline{e}) - \underline{e}$, respectively.

It is clear that adopting the same strategy in every period also constitutes an equilibrium in an infinitely repeated game, where consumers always hold the most skeptical belief and the seller always supplies the product with $e = \underline{e}$ and $s = s^*(\underline{e})$. Moreover, this is the least profitable equilibrium for the seller as the seller can always set $s = s^*(\underline{e})$, and extract all the surplus generated by the most adversarial belief $e = \underline{e}$.

Nevertheless, a higher level of experience attribute e may be sustainable when the seller can build trust mechanism with consumers in repeated trading.

4.3 Characterization of the Optimal Equilibrium

To construct the most profitable equilibrium, consider the following strategies: In each period, the seller proposes a triple (s, e, p) with $e > \underline{e}$, and long-lived consumers believe that the seller will keep the promise and provide experience quality e in that period, so long as they observe the on-path

[15] Since the major friction in our model is hidden effort, the seller's highest attainable profit also captures the upper-bound of the social surplus generated by the market.

observable attribute and price, s and p, in that period. For the remaining periods, if the seller has always fulfilled (s, e, p) in the past and continues to choose s and p in the current period, then the buyers believe that the firm is still going to choose the same e. If the seller has ever deviated in the past or deviates in s or p in the current period, then the players revert perpetually to the static Nash equilibrium where consumers believe that $e = \underline{e}$. This grim trigger strategy profile is standard in repeated games with perfect monitoring, and for the purpose of characterizing the optimal equilibrium and the equilibrium payoff set, it is without loss of generality. [16]

Given the off-path strategies, for any particular period, some level of the experience attribute $e > \underline{e}$ can be sustained in equilibrium if and only if the following incentive compatibility (IC) constraint is satisfied [17]

$$\frac{v(s,e) - s - e}{1-\delta} \geq v(s,e) - s - \underline{e} + \delta \frac{\pi^{SN}}{1-\delta} \tag{2}$$

Alternatively, we shall rewrite (2) as

$$\underbrace{\frac{\delta}{1-\delta}\left[v(s,e) - s - e - \pi^{SN}\right]}_{\text{discounted payoff flow from trust-building}} \geq \underbrace{e - \underline{e}}_{\text{cost-saving from shirking}} \tag{3}$$

This expression explains the intuition that the seller is trading off between the myopic cost-saving from shirking (shown on RHS) and the future loss of profit flow due to the loss of consumers' trust (shown on LHS).

The optimal equilibrium is therefore the solution to the following problem:

$$\max_{s \geq \underline{s}, e \geq \underline{e}} v(s,e) - s - e \tag{4}$$
$$\text{s.t. } (3)$$

First, we point out the existence and uniqueness of the optimal equilibrium (s, e) are guaranteed due to strict concavity of the objective function and the convexity and compactness of the constraint set.

Lemma 1 (Uniqueness)**.** The optimal equilibrium $(s(\delta), e(\delta))$ is unique.

The following observation simplifies the characterization of the optimal equilibrium.

[16] In our setting, any equilibrium profit of the seller falling between the optimal equilibrium level and the static Nash level can be achieved by public randomization between the optimal equilibrium and the static Nash equilibrium.

[17] Clearly, if the seller is determined to deviate, a simultaneous deviation on the observable attribute is dominated by sticking to the original equilibrium observable attribute as it will trigger the worst possible belief immediately so long as the equilibrium profit is higher than π^{SN}.

Lemma 2 (Conditional Optimality of Observable Attribute)**.** For any level of consumer's belief on the experience attribute e, the seller sets the observable attribute at $s = s^*(e)$. Moreover,

$$\frac{ds^*(e)}{de} \begin{cases} > 0 & \text{if } e \text{ and } s \text{ are complements,} \\ < 0 & \text{if } e \text{ and } s \text{ are substitutes.} \end{cases}$$

According to Lemma 2, given some level of consumer's belief on the experience attribute, there is no further distortion on the level of the observable attribute. This comes from the fact that there is no informational friction on the observable attribute, therefore the seller has the incentive to maximize the total profit, conditional on consumer's belief on the experience attribute. It will be clear, however, that there are distortions in both attributes in equilibrium if the first best level of quality is not sustainable. Lemma 2 clarifies that any distortion in the observable attribute is indirectly induced through the distortion in the experience attribute. Notice that conditional optimality also holds when the firm deviates. The next result characterizes the seller's behavior when he decides to shirk on the experiential quality.

Corollary 1 (**Two-Step Deviation**)**.** If the seller deviates in quality in some period t_0, he deviates to $(s^*(e), \underline{e})$. From period $t_0 + 1$ on, he further adjusts to choose $(s^*(\underline{e}), \underline{e})$ afterwards. Moreover,

(a) If the two attributes are complements, $s^*(e) > s^*(\underline{e})$ and $v(s^*(\underline{e}), \underline{e}) < v(s^*(e), \underline{e}) < v(s^*(e), e)$.

(b) If the two attributes are substitutes, $s^*(e) < s^*(\underline{e})$ and the overall quality exhibits a V-shape transition around the deviation phase, namely, $v(s^*(e), \underline{e}) < \min\{v(s^*(\underline{e}), \underline{e}), v(s^*(e), e)\}$. Furthermore, $v(s^*(\underline{e}), \underline{e}) < v(s^*(e), e)$ if $|v_{se}| < |v_{ss}|$.

Corollary 1 follows immediately from the grim trigger strategies. While this is a simple result, it marks an interesting difference between the multi-attribute problem and its single-attribute counterpart. In the standard moral hazard model, when the seller shirks on quality, he deviates to the lowest possible quality $u_2(\underline{e})$ and stays at that quality level perpetually. Even when there are two (or more) attributes, but if both are experiential, it is easy to see that the seller would deviate to the quality $v(\underline{s}, \underline{e})$ and remain at that level perpetually as well.

By contrast, when one attribute is observable and the other attribute is experiential, deviation in quality takes two periods to complete. The seller first deviates in the experience attribute to produce $(s^*(e), \underline{e})$. While he would like to also shirk on the observable attribute, doing so would trigger consumers' suspicions of his deviation because of the signaling role of the observable attribute. One period after, consumers detect the deviation, lose trust in the seller and always believe no quality investment will be made on the experience attribute. Then, the seller will further adjust the observable attribute to $s^*(\underline{e})$, leading to the perpetual quality of $v(s^*(\underline{e}), \underline{e})$.

When attributes are complements, after being caught shirking, the seller will adjust the observable attribute down from $s^*(e)$ to $s^*(\underline{e})$, in order to maximize his profit on the punishment path, which results in a further decrease in the overall quality. When attributes are substitutes, total quality will bounce back after the period of deviation, leading to a V-shaped quality time trend. Given our rather general specification of $v(\cdot,\cdot)$, without imposing further restrictions, we cannot sign the difference between the overall qualities on- and off-the-equilibrium path when two attributes are substitutes. This is because the decrease in the experience attribute on the punishment path will lead to an increase in the observable attribute, rendering the total change in quality ambiguous. A sufficient condition to ensure that the overall quality on the equilibrium path is higher than that on the punishment path is $|v_{se}| < |v_{ss}|$. This condition states that an increase in the observable attribute lowers the marginal utility of itself (a perfect substitute) more than it lowers the marginal utility of the experience attribute (an imperfect substitute). It seems to be an intuitive condition which is satisfied for many products. Figure 1 depicts two plausible time trends of the overall quality if the seller deviates in the experience attribute (in period t_0) for the respective cases of complementary and substitute attributes, with $|v_{se}| < |v_{ss}|$ being satisfied for the case of substitute attributes.

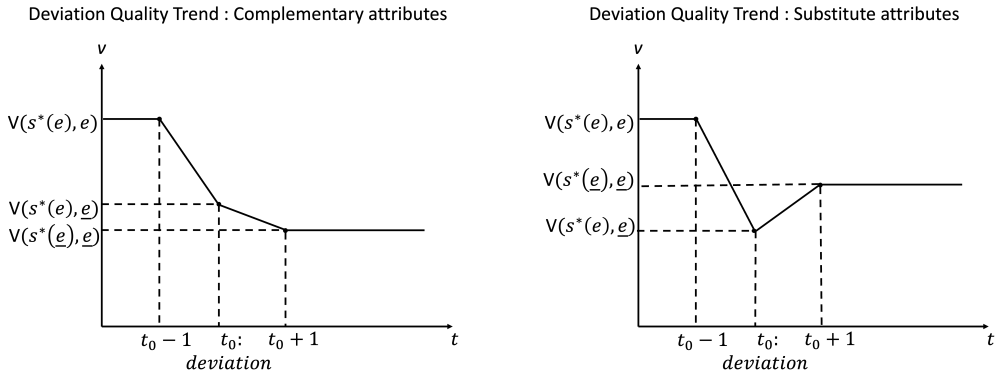


Figure 1: Quality trend following deviation

Formally speaking, the deviation is an off-the-equilibrium-path behavior in our setting of perfect monitoring. However, if we generalize the model to make the monitoring environment imperfect so that even if the firm chooses a high input level, the realized experience attribute will still be low with some positive probability, then the two-step adjustment in overall quality will be expected in equilibrium.

The V-shaped quality pattern associated with a deviation in quality implies that when we observe a partial recovery in an experience good seller's sales after the firm loses business due to some major lapse in product quality, it does not necessarily mean that the firm has regained consumers' trust. It may simply be an outcome of the firm's adjustment strategy. Following the loss of consumers' trust on unobservable quality, what the firm can do is naturally to strengthen the

observable attribute of its product and partially recover the business by shifting the selling point.

Based on Lemma 2, the optimal equilibrium is the solution to the following single-variable program:

$$\max_{e \geq \underline{e}} v\left(s^*\left(e\right), e\right) - s^*\left(e\right) - e \tag{5}$$

$$\text{s.t. } (3)$$

The following proposition characterizes the optimal equilibrium.

Proposition 1. Let $\left(s^{FB}, e^{FB}\right)$ be the unconstrained solution to (5). There exist two cutoffs $\underline{\delta}, \overline{\delta}$ with $0 \leq \underline{\delta} < \overline{\delta} < 1$, such that for any discount factor δ, the optimal equilibrium is characterized as follows:

(i) The firm offers the first-best quality $v\left(s^{FB}, e^{FB}\right)$ if and only if $\delta \geq \overline{\delta}$.

(ii) For $\delta \in (\underline{\delta}, \overline{\delta})$, the optimal product attributes $\left(s\left(\delta\right), e\left(\delta\right)\right)$ are unique and satisfy the following properties:

(a) $e\left(\delta\right) \in (\underline{e}, e^{FB})$ is the inverse function of:

$$\delta\left(e\right) = \frac{e - \underline{e}}{v\left(s^*\left(e\right), e\right) - s^*\left(e\right) - \underline{e} - \pi^{SN}} \tag{6}$$

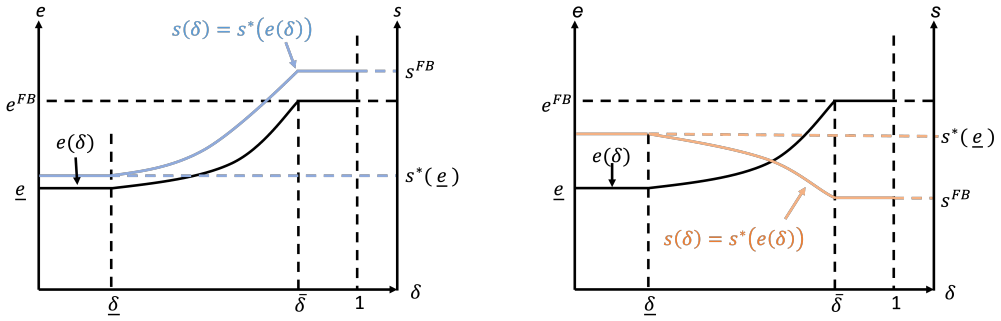
and $e\left(\delta\right)$ is increasing in δ;

(b) $s\left(\delta\right) = s^*\left(e\left(\delta\right)\right)$, and $s\left(\delta\right)$ is increasing(decreasing) if s and e are complements(substitutes).

(iii) For $\delta \leq \underline{\delta}$, or on the punishment path, $\left(s\left(\delta\right), e\left(\delta\right)\right) = \left(s^*\left(\underline{e}\right), \underline{e}\right)$.

According to Proposition 1, for the seller to provide some above-the-minimum experience attribute, the discount factor must be above some cutoff value $\underline{\delta} > 0$. As δ increases, the future business becomes more valuable to the seller so he can support a higher level of the product's experience quality $e\left(\delta\right)$. Once the discount factor reaches the cutoff value $\overline{\delta} \in (\underline{\delta}, 1)$, the first-best quality becomes sustainable (i.e., $e\left(\delta\right) = e^{FB}$). This property of $e\left(\delta\right)$ holds whether the two attributes are complements or substitutes, as depicted by black curves in both panels of the following Figure 2:

Recall that when the two attributes are independent, the overall quality of the good is $v(s, e) = u_1(e) + u_2(s)$. In this case, the seller will set the observable attribute at the first best level $s^* = \arg\max_{s \geq \underline{s}} u_2\left(s\right) - s$, independent of the discount factor. This is because adjusting the observable attributes does not affect the seller's incentives to invest in the experience attribute, and the first best observable attribute maximizes consumer's willingness to pay for any level of experience attribute. The seller's choice of the experience attribute is qualitatively the same as in the case of single-attribute experience good. In this case, the multi-attribute good is isomorphic to the standard



(a) Complementary Attributes (b) Substitute Attributes

Figure 2: Attribute levels and discount factor

single-attribute experience good because we can regard the observable attribute s^* as the minimum quality guaranteed by the seller.

When attributes are interdependent, the seller will choose the observable attribute based on the chosen experience attribute, which in turn depends on the seller's discount factor. The interdependency between the observable and the experience attributes generates the following new insights. First, the seller chooses different observable attributes on and off the equilibrium path. Second, the chosen quality of observable attribute changes in different directions as the long-run profit becomes more valuable to the seller. In particular, it is increasing in the discount factor if two attributes are complements and decreasing in the discount factor if two attributes are substitutes. Intuitively, when the seller gets more patient, the equilibrium level of experience attribute increases. A higher experience attribute raises(lowers) the marginal return from investment on the observable quality due to complementarity (substitutability), resulting in a higher(lower) equilibrium observable attribute.

Third, compared to the first-best level, when the solution is interior, the seller underinvests in the observable attribute if the attributes are complements and overinvests in the observable attributes if the attributes are substitutes. The contrasting relationships between the observable attribute and the discount factor are depicted by the colored curve on the left and right panels of Figure 2.

The equilibrium behavior of our model is consistent with the observations that many restaurants with reputations for great food invest more in beautiful decorations [18], and ever since the rise of streaming platforms, the big winners of Emmy Awards and Oscars (HBO Max, Netflix, Apple TV) do not have a comparable size of media library as Amazon Prime Video. [19] In fact, Netflix has been trimming down the proportion of licensed titles and building up the reputation of "Netflix

[18]For some examples illustrating the ways that high-end restaurants invest in their interior designs, see Architecturaldigest.com (2017), "Gorgeous Interiors from the World's 50 Best Restaurants" available at https://www.architecturaldigest.com/gallery/gorgeous-interiors-worlds-50-best-restaurants/all#main-content.

[19]Source: https://www.businessofapps.com/data/netflix-statistics/.

Originals" over the years. [20]

5 Effect of Making an Experience Attribute Observable

As discussed in Section 1, advancements in technologies or government policies intended to protect consumers can make an experience attribute observable prior to purchase (Jin & Leslie, 2003; L. R. Klein, 1998). [21] In a single-attribute setting, such change in observability unambiguously (weakly) improves product quality and seller's profit as it eliminates all the information friction in experience goods market. To study the impact of such informational change in a multi-attribute setting, in this section, we first analyze the benchmark case in which the seller supplies a multi-attribute product with *both* attributes being experiential. By comparing the equilibrium outcome with Proposition 1, we can identify the impact of making one of the experience attributes observable. For tractability, when we make this comparison, we restrict attention to the case in which the consumers' valuation of the product is symmetric, i.e., $v(s,e) = v(e,s)$.

Proposition 2 (Multi-attribute Pure Experience Good Benchmark)**.** Suppose both s and e are experience attributes, and $v(s,e)$ is symmetric with $\underline{s} = \underline{e}$. Then, the optimal equilibrium attributes, denoted by $\tilde{s}(\delta)$ and $\tilde{e}(\delta)$, are equal, i.e., $\tilde{s}(\delta) = \tilde{e}(\delta)$.

Define $\tilde{e}^{FB} := \arg\max_{e \geq \underline{e}} v(e,e) - 2e$. There exist two cutoffs $\underline{\delta}_1, \overline{\delta}_1$ with $0 \leq \underline{\delta}_1 < \overline{\delta}_1 < 1$, such that for any discount factor δ, the optimal equilibrium is characterized as follows:

(i) The seller offers the first-best quality $v\left(\tilde{e}^{FB}, \tilde{e}^{FB}\right)$ if and only if $\delta \geq \overline{\delta}_1$.

(ii) For $\delta \in (\underline{\delta}_1, \overline{\delta}_1)$, the product attribute $\tilde{e}(\delta)$ is unique and determined by the inverse function of

$$\delta(\tilde{e}) = \frac{2(\tilde{e} - \underline{e})}{v(\tilde{e}, \tilde{e}) - v(\underline{e}, \underline{e})} \tag{7}$$

(iii) For $\delta \leq \underline{\delta}_1$, or on the punishment path, $\tilde{e}(\delta) = \underline{e}$ and seller's profit remains at $\pi_1^{SN} := v(\underline{e}, \underline{e}) - 2\underline{e}$.

(iv) *Both* attributes are increasing in δ.

Before we analyze the effects of making an experience attribute observable, let us first comment on the finding in Proposition 1 that when the two attributes are substitutes, the observable one decreases in the discount factor. This phenomenon is likely to be unique to our model of hybrid substitute attributes. It is obvious that when there is no informational friction at all, the quality

[20] "https://www.whats-on-netflix.com/news/50-of-netflixs-library-is-now-made-of-netflix-originals/"

[21] Jin and Leslie (2003) cited the following examples of mandatory disclosure policies in the United States: "food labeling, energy efficiency of new home appliances, gas mileage of new cars, and accounting disclosures for publicly traded firms."

level of a product's attribute should be independent of discount factor. From Proposition 2, we further know that in models of multi-attribute pure experience goods, a substitute relationship between attributes no longer implies a negative relationship between the discount factor and one of the attributes. In fact, when a consumer's utility function is symmetric , both attributes increase in the discount factor.

We now turn to the main objective of this section, i.e., analyzing the effect of making *one* of the experience attributes observable. Denote the equilibrium profit in the benchmark hybrid model and pure experiential model by $\Pi(\delta)$ and $\tilde{\Pi}(\delta)$, respectively. The following proposition summarizes the comparison results between Proposition 1 and Proposition 2:

Proposition 3. Suppose that $v(s,e)$ is symmetric. The following statements are true:

(i) $\underline{\delta}_1 > \underline{\delta}, \bar{\delta}_1 > \bar{\delta}$ if the two attributes are complements and $\underline{\delta}_1 < \underline{\delta}, \bar{\delta}_1 < \bar{\delta}$ if they are substitutes.

(ii) For $\delta \in (\underline{\delta}_1, \bar{\delta})$, $\tilde{s}(\delta) = \tilde{e}(\delta) \leq e(\delta) < s(\delta) \leq s^{FB} = e^{FB}$ for complementary attributes and $e(\delta) \leq \tilde{s}(\delta) = \tilde{e}(\delta) \leq s^{FB} = e^{FB} \leq s(\delta)$ for substitute attributes.

(iii) If the attributes are complements, $\Pi(\delta) \geq \tilde{\Pi}(\delta)$, and the inequality is strict when $\delta \in (0, \bar{\delta}_1)$.

(iv) If two attributes are substitutes, there exists some $\underline{d} > \underline{\delta}_1$ and $\bar{d} < \bar{\delta}_1$, such that:

$$\Pi(\delta) > \tilde{\Pi}(\delta) \text{ if } \delta \in (0, \underline{d}); \quad \Pi(\delta) < \tilde{\Pi}(\delta) \text{ if } \delta \in (\bar{d}, \bar{\delta}).$$

Proposition 3 describes the effect of bringing *partial* transparency to a multi-attribute experience product. The first observation is that the first attribute increases ($s(\delta) > \tilde{s}(\delta)$) when it becomes observable. This is intuitive because now the seller's quality investment on this attribute is no longer subject to any information friction, which was restricted at some suboptimally lower level before the change. Moreover, when it becomes observable, if the seller deviates in some period, he can only shirk on the second attribute instead of both, which refrains his gain from deviation. While it lowers the cost-saving level from shirking, the credibility of the choice on the observable attribute also allows the seller to readjust *on the punishment path*. As a consequence, the punishment of shirking is not as harsh as the pure-experience goods case, that is, $\pi^{SN} > \pi_1^{SN}$. The overall effect on the equilibrium quality and profit depends on the nature of interdependency between two attributes and the discount factor.

In complementary case, higher first attribute means higher marginal surplus from improvement on the second attribute, hence strengthening the seller's incentive to make the quality investment on the experience attribute. Although the seller can also observably adjust the first attribute on the punishment path as well, $s^*(\underline{e})$ and $\underline{e}$ are only moderately different as s^* and e move in the same direction. Therefore, this countervailing force is dominated by the positive effect and the seller

can effectively build trust on higher experience quality and unambiguously earn higher equilibrium profit.

When the attributes are substitutes, however, the implications are no longer clear. In fact, contrasting to the complementary case, the sustainable level of the second attribute is lowered ($e(\delta) \leq \tilde{e}(\delta)$). The intuition is the following: with a higher first attribute, the marginal benefit of supplying high quality on the second attribute decreases due to substitutability. Meanwhile, after triggering the punishment phase, the seller's loss of profit is no longer significant because he can largely recover his business by supplying the conditionally optimal level of observable attribute $s^*(\underline{e})$, which is a substantial improvement upon $\underline{e}$ [22] as s^* and e move in opposite directions. Overall, the firm's fallback position following the reputation breakdown becomes too attractive compared to the pure experiential case, where all the stakes hinge on the long-term trusting relationship. Therefore, for the same level of experience attribute, it becomes harder for the seller to keep his promise. [23]

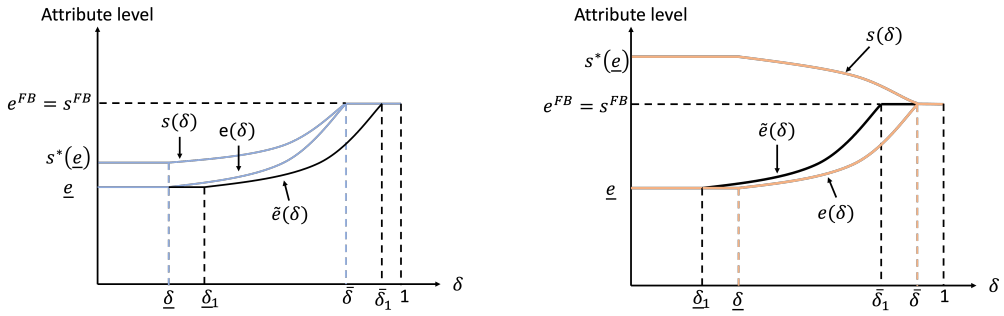
The implications on the equilibrium profit are two-fold. When the discount factor is relatively low, the seller cannot build much trust anyway and both attributes are already of low qualities. Making one attribute observable incentivizes him to make the quality investment on at least one attribute, therefore creates more surplus. On the other hand, when the seller is patient enough, he can originally maintain high qualities on both attributes solely by the trust system. Partial transparency in this case only makes him more tempted to shirk on another attribute, hurting the original trust mechanism and rendering the relationship less profitable. [24]

The following Figure 3 illustrates how the first and the second attributes of a multi-attribute pure experience good will change after the first attribute is made observable. In both panels, $\tilde{e}(\delta)$ is the equilibrium attribute of a multi-attribute pure experience good, as characterized in Proposition 2. Once the first experience attribute is made observable, the equilibrium levels of first (observable) and the second (experience) attributes are $s(\delta)$ and $e(\delta)$, respectively, as characterized in Proposition 1. The left panel depicts the comparison in case of complementary attributes and the right panel depicts the comparison in the case of substitute attributes:

[22] In this case, $s^*(\underline{e}) > s^{FB} > \underline{e}$.

[23] The channel presented here is reminiscent of the substitutability across two types of incentive contracts in Baker, Gibbons and Murphy (1994). In their Principal-Agent model, when the imperfect objective measure becomes sufficiently informative, the contractual parties cannot sustain a relational contract that relies on the perfect yet subjective performance measure, because once the firm reneges on the relational contract, it can always resort to formal contract, which remains reasonably effective in terms of incentive provision. We thank Jin Li for bringing the similarity to our attention.

[24] Wolitzky (2023) also shows that making the quality more observable can decrease the equilibrium quality level and price in a *one-shot, imperfect monitoring* environment. Nonetheless, it's a positive result as the quality is over-supplied in a nosier environment. In his model, the observable signal only provides information about the hidden quality. Therefore, the underlying rationale is quite different from our marginal incentive argument.



(a) Complementary Attributes (b) Substitute Attributes

Figure 3: Impacts of turning an experience attribute into observable attribute

6 Value of Commitment on Observable Attribute

An important insight from the analysis in Section 5 is that the seller's flexibility to choose the observable attribute differently on and off the equilibrium path constitutes a double-edged sword. On the one hand, the seller can optimally choose a level of observable attribute to raise the equilibrium profit given consumers' belief about the product's experience attribute and doing so provides him stronger incentive to maintain the high experience attribute. On the other hand, upon losing consumers' trust, the seller can re-optimize his observable attribute from $s^*(e)$ to $s^*(\underline{e})$ to raise its punishment-path profit. Such ability to partially reduce the punishment can weaken the incentive to supply the high experience attribute.

This observation implies that the best-case scenario for the experience goods seller is to have the freedom to endogenously choose the observable attribute, but then commit not to revise it afterwards. In this section, we explore the extent to which the commitment power on the observable attribute can enhance trust-building in the product's experience attribute, and study how the equilibrium outcome would be affected when commitment is possible. In the existing literature, commitment to a specific quality level has mostly been considered synonymously as commitment to a minimum quality standard. In this section, we will also assess the policy effectiveness of setting a minimum quality standard in our multi-attribute experience good setting.

One way to implement the commitment to a level of observable quality is to assume the observable attribute is also verifiable. When it is not verifiable, the seller can still commit to a level of observable attribute by taking other actions, such as signing long-term contracts with suppliers of known qualities [25], purchasing machines that produce parts of known qualities or publicly releasing a plan on their future production schedule. In our analysis, we only consider once-and-for-all commitments. In other words, the seller cannot make a commitment that is contingent on the history

[25] For example, Uniqlo signs 10-year contracts with its supplier Toray for high-tech fabrics. So, even when consumers' belief about other aspects of their clothing changes, they still know that Uniqlo will use fabrics of the same technologies from Toray.

of the game, or more specifically, he cannot commit to different levels of the observable attributes on and off the equilibrium paths.

Suppose the seller can commit to a fixed observable attribute, [26] meaning that the seller perpetually fixes the observable attribute at the same level, both on the equilibrium path and on the punishment path. Then, the IC constraint becomes:

$$\frac{v(s,e)-s-e}{1-\delta} \geq v(s,e)-s-\underline{e}+\delta\frac{v(s,\underline{e})-s-\underline{e}}{1-\delta} \tag{8}$$

The optimal equilibrium is the solution to:

$$\max_{s\geq\underline{s},e\geq\underline{e}} v(s,e)-s-e \tag{9}$$
$$\text{subject to (8).}$$

Since $v(s,\underline{e})-s \leq v(s^*(\underline{e}),\underline{e})-s^*(\underline{e})$ for any $s \geq \underline{s}$, (8) is a more relaxed constraint than (2), it follows immediately that the seller can achieve a (weakly) higher profit through commitment to a fixed level of the observable attribute. The next result characterizes the optimal equilibrium under partial commitment in detail:

Proposition 4. Suppose the seller can commit to the same fixed observable-attribute level both on and off the equilibrium path. Denote the observable and experience attributes in the optimal equilibrium by $(s_c(\delta), e_c(\delta))$. There exist two cutoffs $\underline{\delta}_c, \overline{\delta}_c$ with $0 < \underline{\delta}_c < \overline{\delta}_c < 1$ such that for any discount factor, the optimal equilibrium is characterized as follows:

(i) The firm offers the first-best quality $v\left(s^{FB}, e^{FB}\right)$ if and only if $\delta \geq \overline{\delta}_c$, where $\overline{\delta}_c < \overline{\delta}$.

(ii) The firm can only offer the minimum quality $e_c(\delta) = \underline{e}$ if $\delta < \underline{\delta}_c$, with $\underline{\delta}_c < \underline{\delta}$.

(iii) For $\delta \in (\underline{\delta}_c, \overline{\delta}_c)$,

- $e_c(\delta)$ is strictly increasing and $e_c(\delta) > e(\delta)$;
- $s_c(\delta) > s^*(e_c(\delta)) > s(\delta)$ if s and e are complements;
- $s_c(\delta) < s^*(e_c(\delta)) < s(\delta)$ if s and e are substitutes.

Proposition 4 describes how commitment power on the observable attribute affects the seller's ability to establish consumers' trust in his experience attribute and what level of commitment he should make.

[26] In principle, we can allow the seller to commit to a sequence of observable levels over time. However, due to the stationarity of our problem, the intertemporal coordination of different committed observable levels would not achieve any extra benefit than solving the static problem. Therefore, it would still be optimal for him to commit to a constant level over all periods.

First, seller's commitment power on the observable attribute uniformly reinforces his incentive to build trust. The thresholds for sustaining qualities above the minimum level and the first-best level become lower. A higher level of experience quality, overall quality and surplus can be guaranteed given the same discount factor, as shown in the diagram below.

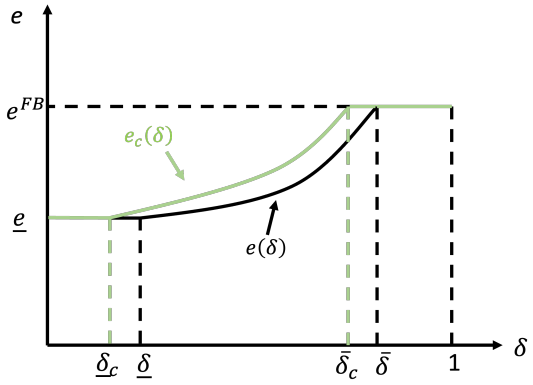
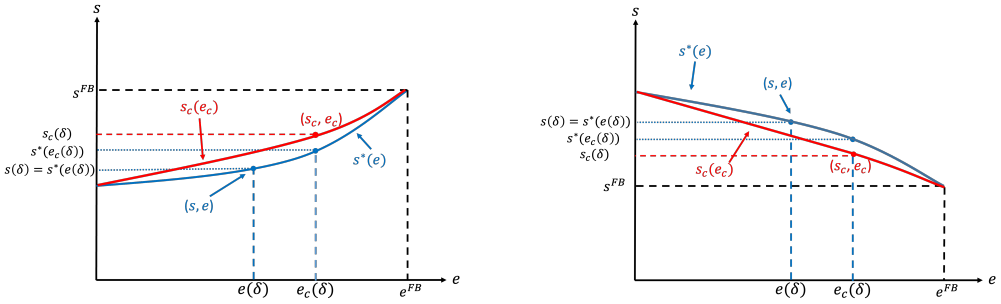


Figure 4: Improving experience attribute via commitment on observable attribute

Second and perhaps more interestingly, the seller will no longer choose the myopically optimal observable attribute conditional on the equilibrium experience attribute. Namely, $s_c(\delta) \neq s^*(e_c(\delta))$ when solutions are interior. When s and e are complements, the seller will commit to a higher level of the observable attribute than the conditional optimal level given the equilibrium experience attribute e_c, which in turn, is higher than the level under no commitment; and when s and e are substitutes, the seller will commit to a quality level much lower than the counterpart under no commitment. Hence, in both cases, if the seller can commit, it will move the observable attribute further away from the static Nash equilibrium level as illustrated by the figures below.



(a) Complementary Attributes (b) Substitute Attributes

Figure 5: Equilibrium observation attributes with and without commitment

The intuition that accounts for the distortion on the observable attribute is as follows. It is true that any deviation on $s^*(e)$ is surplus-destructive on the equilibrium path and myopically sub-

optimal. Nonetheless, it also serves a disciplining tool to forestall the temptation to shirk as it further lowers the off-path profit. [27] Such positive incentive effect on trust-building therefore drives the seller to forfeit the conditional optimality in order to gain consumer's trust. Consequently, the self-handicapping commitment can help sustain a higher level of experience attribute and equilibrium profit when the seller is not patient enough to sustain the first-best qualities. [28]

On a high level, the distortionary level of commitment plays exactly the opposite role of partial transparency in Section 5. It demonstrates how much the seller is willing to restrict his choice on the observable attribute in order to build trust with consumers on the experience attribute. Notice that this distortion only emerges when attributes are interdependent, as the unequal levels of "money-burning" by distortion on and off equilibrium paths come from the unequal marginal returns of quality investments on s.

Cost Interdependency and Strategic Commitment

In the benchmark model, we maintain the assumption that the consumers' valuation is interdependent in two attributes while the production cost is *independent*. In this section, we consider a generalized cost function $c(s,e)$ to allow potential *interdependency* between s and e in production cost.

In the path-breaking work, Milgrom and Roberts (1990) introduces *supermodularity* and monotone comparative statics methods into a comprehensive yet *frictionless* environment to study firms' multidimensional strategies in response to different parameters in complex manufacturing activities. In spirit of their setup, we also focus on the cases where both valuation v and cost c share the same *systematic* effect on the firm's profitability, namely, v_{se} has the same sign as $-c_{se}$. [29] From now on, we call two attributes complements if they are supermodular in both v and $-c$, and substitutes if they are submodular in both v and $-c$. By modifying the assumption on cost function and Inada condition, we can rewrite a generalized version of (4):

$$\begin{aligned} &\max_{s\geq\underline{s},e\geq\underline{e}} v(s,e)-c(s,e) \\ \text{s.t. } &\frac{v(s,e)-c(s,e)}{1-\delta}\geq v(s,e)-c(s,\underline{e})+\delta\pi^{SN} \end{aligned} \tag{10}$$

Slightly abusing the notation, we also redefine the (static) conditional observable attribute

[27] The fact that s_c is further away from $s^*(\underline{e})$ means that the marginal return from such investment on the observable attribute is even lower on the punishment path than on the equilibrium path.

[28] Wolitzky (2023) also shows that quality overprovision can serve as commitment force for the seller to price properly and increase the offer acceptance rate.

[29] When v_{se} has the opposite sign to c_{se}, the interdependency between two attributes plays contrasting roles in generating social surplus. The trade-off between complementary in valuation and cost composition becomes ambiguous unless the functional forms are further specified.

accordingly:

$$s^*(e) \equiv \arg\max_{s \geq \underline{s}} v(s,e) - c(s,e)$$

Intuitively, complementarity and substitutability in cost efficiency should play a symmetric role as in valuation in terms of surplus production. Nonetheless, the following result tells another "strategic commitment" story, which is not observed when cost is independent.

Proposition 5. Denote the solution to (10) by $(\hat{s}(\delta), \hat{e}(\delta))$. Then for any $\hat{e}(\delta) \in (\underline{e}, e^{FB})$, $\hat{s}(\delta) < s^*(\hat{e}(\delta))$ if two attributes are substitutes and $\hat{s}(\delta) > s^*(\hat{e}(\delta))$ if two attributes are complements.

Now we observe another scenario where the observable attribute is designed at some conditional suboptimal level. The subtlety lies in the IC condition once we have cost interdependency. In principle, the seller would explore the cost interdependency and intentionally distort the observable attribute against the myopically optimal level, in order to cut down the potential marginal cost-saving from shirking on the experience attribute. Hence, the seller has strict incentives to strategically leverage such self-discipline effect facilitates trust-building.

When is Minimum Quality Standard effective?

It is common for consumer-protection agencies or the government to impose minimum quality standards on products for the purpose of consumer welfare enhancement. For practical reasons, these minimum quality standards are often imposed on certain attributes of the products and not on the overall qualities, and they tend to be imposed on attributes which are more readily observable or verifiable. For example, fuel efficiency, energy efficiency standards, and staff-to-child ratio are only one attribute of cars, electrical appliances, and child-care providers, respectively, and they are also more readily observable or verifiable. If the observable attribute and the experience attribute are independent, imposing the minimum quality standard on the observable attribute unambiguously increases the product's overall quality. However, when the two attributes are interdependent, whether the minimum quality standard improves the overall quality hinges on the nature of the interdependence between attributes.

When the attributes are complements, in the absence of commitment, the observable attribute is lower on the punishment path than on the equilibrium path. A minimum quality standard that limits the seller's freedom to lower the observable attribute on the punishment path will reduce the seller's deviation payoff, hence make it easier to sustain a high equilibrium experience attribute and a high overall quality. Nevertheless, when attributes are substitutes, the minimum quality standard imposed on the observable attribute may ironically lead to a lower overall quality. To see this, note that the observable attribute is lower on the equilibrium path than on the punishment path in the absence of a minimum quality standard. So, any minimum quality standard is more likely to be binding on the equilibrium path than on the punishment path. When this occurs,

the minimum quality standard lowers the on-the-equilibrium-path profit but does not affect the punishment-path profit. This will make it more difficult for the seller to gain consumers' trust, and in turn leads to a lower experience attribute on the equilibrium path. It is also not difficult to see that the minimum quality standard leads to efficiency loss in this case. Recall that, according to Lemma 2, the observable attribute is chosen at the conditionally optimal level. So, social efficiency is increasing in the experience attribute (up until the first best is achieved). The equilibrium under minimum quality standard is less socially efficient because (i) the experience attribute is lower and (ii) the observable attribute is no longer conditionally optimal.

7 Discussions and Conclusion

In this paper, we show that modeling experience goods as multi-attribute products allows us to answer questions and generate insights that cannot be adequately done using a single-attribute experience-good model. By explicitly studying the interdependence between the observable and experience attributes of experience goods, this paper has shown that the endogenous differential selections of observable attributes with and without consumer's trust lead to countervailing effects on the seller's ability to gain consumers' trust for his product's equilibrium experience attribute. Analysis of our framework generates some nonstandard implications, especially when the two attributes are substitutes. We find that in a multi-attribute experience goods setting, a deviation in quality takes two periods to complete, and a product's observable attribute may increase or decrease in the seller's discount factor. For experience goods with purely experience attributes, when one of the experience attributes becomes observable, other experience attribute(s) may suffer and overall quality and total surplus may decrease. When the seller can commit to the observable attribute, he will sometimes distort the observable quality from the conditional optimal level to better facilitate trust-building on the unobservable attributes. Finally, a minimum quality standard imposed on the observable attribute may lead to a lower overall quality of the product.

A natural extension is to generalize the analysis to an oligopoly or competitive setting. We believe that the importance and effects of interdependence between the two attributes would remain with such extension just as many insights derived in a single-attribute experience goods model are relevant both when firms are monopolists and when they compete.

We believe there are other potential applications of our framework which are yet to be explored. For example, even if firms only produce single-attribute products, there can still be interdependence between products sold by different firms in consumers' utility functions. Studying such interdependence in a dynamic setting would be interesting. First, as we pointed out in the Section 2, when these products are bundled in sales, the bundled products can be considered as multi-attribute products. Even if these products are sold separately, our analysis is still relevant. Suppose consumers are likely to purchase both products from the firm. When a consumer buys product 1 of observable

quality s_1 and product 2 of experience quality e_2 from the firm, she will derive the utility $v(s_1, e_2)$. It would be interesting to know how the interdependence between the two products in consumers' utility functions affect the firms' respective equilibrium qualities in a dynamic setting.

Going one step further, we can ask how the interdependence across different single-attribute products affects firms' umbrella branding decisions. The typical repeated-game setting of umbrella branding implicitly or explicitly assumes that experience goods are either purchased by different consumers or, if they are purchased by the same consumers, they enter the consumers' utility functions additively separately (e.g., , Andersson, 2002; Cabral, 2009; Cai and Obara, 2009; Rasmusen, 2016). However, many real-life products are interdependent in consumers' utility functions. As an example, Procter and Gamble owns multiple brands of laundry detergents. For consumers who may simultaneously use multiple brands of laundry detergents or actively choose among them, improvement in the quality of *Tide* liquid detergent can lower the marginal utility of the quality improvement of *Dreft* powder detergent, measured in terms of willingness-to-pay. On the other hand, the improvement of the quality of their *Gain* fabric softener may raise the marginal utilities of the quality of their detergents, measured in terms of willingness to pay. We conjecture that introducing interdependence between products into analyses of umbrella branding is likely to generate interesting new insights.

Proofs of Formal Findings

Proof of Lemma 1 (p. 12)

Following the strict concavity assumption on $v(s, e)$, the objective function $f(s, e) = v(s, e) - s - e$ is strictly concave.

Next, we show that the feasible set is convex. Observe that the IC constraint (3) can be rewritten as

$$e - \delta\left(v\left(s^*(e), e\right) - s^*(e)\right) \leq \underline{e} - \delta\left[v\left(s^*\left(\underline{e}\right), \underline{e}\right) - s^*\left(\underline{e}\right)\right] \equiv B(\delta). \tag{11}$$

Assume (s_1, e_1) and (s_2, e_2) both satisfy the IC constraints, which means that

$$e_1 - \delta\left(v(s_1, e_1) - s_1\right) \leq B(\delta),$$
$$e_2 - \delta\left(v(s_2, e_2) - s_2\right) \leq B(\delta).$$

Then for any $\alpha \in (0, 1)$,

$$\alpha e_1 + (1-\alpha)e_2 + \delta(\alpha s_1 + (1-\alpha)s_2) - \delta[\alpha v(s_1, e_1) + (1-\alpha)v(s_2, e_2)] \leq B(\delta).$$

For $v(s,e)$ is a strictly concave function,

$$\alpha v\left(s_1,e_1\right)+(1-\alpha)v\left(s_2,e_2\right)<v(\alpha s_1+(1-\alpha)s_2,\alpha e_1+(1-\alpha)e_2).$$

Therefore, we obtain that

$$(\alpha e_1+(1-\alpha)e_2)-\delta(v(\alpha s_1+(1-\alpha)s_2,\alpha e_1+(1-\alpha)e_2)-(\alpha s_1+(1-\alpha)s_2))<B\left(\delta\right).$$

So $(\alpha s_1+(1-\alpha)s_2,\alpha e_1+(1-\alpha)e_2)$ also satisfies the IC constraint, confirming the convexity of the constraint set.

The uniqueness of $\left(s\left(\delta\right),e\left(\delta\right)\right)$ follows from the strict concavity of the objective function and the convexity of the constraint set. □

Proof of Lemma 2 (p. 12)

For any (s,e) where $s\neq s^*\left(e\right)$ and (s,e) satisfies (11), consider the following pair $\left(s^*\left(e\right),e\right)$. Since $v\left(s^*\left(e\right),e\right)-s^*\left(e\right)>v\left(s,e\right)-s$, the pair $\left(s^*\left(e\right),e\right)$ also satisfies (11). However,

$$v\left(s^*\left(e\right),e\right)-s^*\left(e\right)-e>v\left(s,e\right)-s-e,$$

which contradicts the optimality of (s,e).

Recall that $v_s(s^*(e),e)=1$. By the Implicit Function Theorem, we have

$$v_{ss}(s^*(e),e)\frac{ds^*(e)}{de}+v_{se}(s^*(e),e)=0,$$

and

$$\frac{ds^*\left(e\right)}{de}=-\frac{v_{se}(s^*(e),e)}{v_{ss}(s^*(e),e)}. \tag{12}$$

Since $v_{ss}(s^*(e),e)<0$, $\frac{ds^*(e)}{de}>0$ if $v_{se}(s^*(e),e)>0$, i.e., s and e are complements, and $\frac{ds^*(e)}{de}<0$ if $v_{se}(s^*(e),e)<0$, i.e., s and e are substitutes. □

Proof of Corollary 1 (p. 13)

The first part is simply characterization of Nash reversion strategies following the deviation.

For the second half, first consider the case of complementary attributes. $s^*\left(e\right)>s^*\left(\underline{e}\right)$ follows immediately from Lemma 2, and $v\left(s^*\left(e\right),e\right)>v\left(s^*\left(e\right),\underline{e}\right)>v\left(s^*\left(\underline{e}\right),\underline{e}\right)$ simply because v increases in both e and s.

Now consider the case of substitute attributes. $s^*\left(e\right)<s^*\left(\underline{e}\right)$ also follows immediately from Lemma 2 and

$$\begin{aligned}\frac{dv}{de} &= v_s \frac{ds^*(e)}{de} + v_e \\ &= \frac{ds^*(e)}{de} + v_e \\ &= -\frac{v_{se}(s^*(e), e)}{v_{ss}(s^*(e), e)} + v_e.\end{aligned}$$

The second equality is due to the first-order condition $v_s(s^*(e)) = 1$. $|v_{se}| < |v_{ss}|$ implies that $-\frac{v_{se}(s^*(e),e)}{v_{ss}(s^*(e),e)} > -1$. Since $v_e > 1$, and it follows that $\frac{dv}{de} > 0$ and $v(s^*(\underline{e}), \underline{e}) < v(s^*(e), e)$. □

Proof of Proposition 1 (p. 15)

(s^{FB}, e^{FB}) is defined as the first-best attributes with $s^{FB} = s^*(e^{FB})$. For the first-best attributes to be sustainable, it is necessary that (s^{FB}, e^{FB}) satisfies the IC constraint to produce the first best quality:

$$e^{FB} - \delta\left(v\left(s^{FB}, e^{FB}\right) - s^{FB}\right) \leq \underline{e} - \delta\left[v(s^*(\underline{e}), \underline{e}) - s^*(\underline{e})\right].$$

Then we have

$$\delta \geq \overline{\delta} \equiv \frac{e^{FB} - \underline{e}}{\left[v(s^{FB}, e^{FB}) - s^{FB}\right] - \left[v(s^*(\underline{e}), \underline{e}) - s^*(\underline{e})\right]}. \tag{13}$$

If the discount factor is greater than $\overline{\delta}$, the firm has no incentive to shirk. Therefore $\left(s^{FB}, e^{FB}\right)$ are sustainable under the condition $\delta \geq \overline{\delta}$.

Now, we focus on the case of $\delta < \overline{\delta}$. Set the Lagrangian of the constrained problem (5):

$$\mathcal{L}(e, \lambda_1, \lambda_2) = v(s^*(e), e) - s^*(e) - e - \lambda_1\left[e - \delta\left(v(s^*(e), e) - s^*(e)\right) - B(\delta)\right] - \lambda_2(\underline{e} - e).$$

The Kuhn-Tucker conditions reduce to

$$\begin{aligned}&\mathcal{L}_e = v_e(s^*(e), e) - 1 - \lambda_1\left(1 - \delta v_e(s^*(e), e)\right) + \lambda_2 = 0, \\ &\lambda_1 \geq 0, \text{ with } \lambda_1 = 0 \quad \text{if} \quad e - \delta\left(v(s^*(e), e) - s^*(e)\right) < B(\delta), \\ &\lambda_2 \geq 0, \text{ with } \lambda_2 = 0 \quad \text{if} \quad e > \underline{e}.\end{aligned}$$

If the IC constraint is not binding, $\lambda_1 = \lambda_2 = 0$. Then $v_e(s^*(e), e) = \frac{1+\lambda_1-\lambda_2}{1+\lambda_1\delta} = 1$, and the first-best attribute is achieved, which contradicts the condition (13). Henceforth, a trust-building equilibrium with $e > \underline{e}$ is sustainable only if it survives the IC constraint and e is determined by:

$$v_e(s^*(e), e) = \frac{1 + \lambda_1}{1 + \lambda_1\delta} \geq 1.$$

Since the IC constraint binds,

$$\delta = \frac{e - \underline{e}}{\left[v\left(s^*\left(e\right), e\right) - s^*\left(e\right)\right] - \left[v\left(s^*\left(\underline{e}\right), \underline{e}\right) - s^*\left(\underline{e}\right)\right]}. \tag{14}$$

Inverse Differentiation Theorem yields:

$$\frac{de}{d\delta} = \frac{\left\{\left[v\left(s^*\left(e\right), e\right) - s^*\left(e\right)\right] - \left[v\left(s^*\left(\underline{e}\right), \underline{e}\right) - s^*\left(\underline{e}\right)\right]\right\}^2}{\left[v\left(s^*\left(e\right), e\right) - s^*\left(e\right)\right] - \left[v\left(s^*\left(\underline{e}\right), \underline{e}\right) - s^*\left(\underline{e}\right)\right] - \left(e - \underline{e}\right) v_e\left(s^*\left(e\right), e\right)}.$$

The numerator is always positive. Let the denominator be denoted by D. It is clear that $\lim_{e \to \underline{e}} D = 0$. Furthermore,

$$\begin{aligned}
\frac{dD}{de} &= -\left(e - \underline{e}\right)\left[v_{ee}\left(s^*\left(e\right), e\right) + v_{es}\left(s^*\left(e\right), e\right)\frac{ds^*\left(e\right)}{de}\right] \\
&= -\left(e - \underline{e}\right)\left[v_{ee}\left(s^*\left(e\right), e\right) - v_{es}\left(s^*\left(e\right), e\right)\frac{v_{se}\left(s^*\left(e\right), e\right)}{v_{ss}\left(s^*\left(e\right), e\right)}\right] \\
&= -\frac{\left(e - \underline{e}\right)}{v_{ss}\left(s^*\left(e\right), e\right)}\left[v_{ss}\left(s^*\left(e\right), e\right) v_{ee}\left(s^*\left(e\right), e\right) - v_{es}\left(s^*\left(e\right), e\right) v_{se}\left(s^*\left(e\right), e\right)\right] \\
&> 0.
\end{aligned}$$

Therefore $D > 0$ must hold, which implies $\frac{de}{d\delta} > 0$ for any $e > \underline{e}$.

We conclude that $de/d\delta > 0$ for any solution $e > \underline{e}$. Since

$$\frac{ds^*(e)}{d\delta} = \frac{ds^*(e)}{de}\frac{de}{d\delta},$$

the sign of $\frac{ds^*(e)}{d\delta}$ must follow the sign of $\frac{de}{d\delta}$, which, according to Corollary 1, is determined by the interdependent nature of two attributes.

Now we solve for $\underline{\delta}$ using (14). By the L'Hôspital rule,

$$\underline{\delta} = \lim_{e \to \underline{e}} \delta\left(e\right) = \lim_{e \to \underline{e}} \frac{1}{v_e\left(s^*\left(e\right), e\right)} < 1.$$

Finally, it is clear that for $\delta < \underline{\delta}$, the pair $\left(s^*\left(\underline{e}\right), \underline{e}\right)$ is the only possible equilibrium strategy. □

Proof of Proposition 2 (p. 17)

When both attributes are experiential, the optimal one-shot deviation is to provide $\underline{s}$ and $\underline{e}$, claim s and e and earn the difference. After shirking, consumers will forever believe that $s = \underline{s}$ and $e = \underline{e}$ and the seller will earn $v\left(\underline{s}, \underline{e}\right) - \underline{s} - \underline{e}$ instead of $v\left(s, e\right) - s - e$ thereafter. This implies that IC

constraint for a multi-attribute pure experience goods seller is

$$\frac{v(s,e)-s-e}{1-\delta} \geq v(s,e)-\underline{s}-\underline{e}+\delta\frac{v(\underline{s},\underline{e})-\underline{s}-\underline{e}}{1-\delta},$$

which can be simplified as:

$$\delta\frac{v(s,e)-s-e-[v(\underline{s},\underline{e})-\underline{s}-\underline{e}]}{1-\delta} \geq s+e-\underline{s}-\underline{e} \tag{15}$$

Therefore, the optimal strategy $(\tilde{s},\tilde{e})$ in equilibrium is the solution of the following program:

$$\begin{gathered}\max_{s\geq\underline{e},e\geq\underline{e}} v(s,e)-s-e \\ \text{subject to (15)}.\end{gathered} \tag{16}$$

We first prove that under the assumption of symmetric v, the solution to (16) must have $\tilde{s}=\tilde{e}$.

Proof. Suppose $(\tilde{s},\tilde{e}) \geq (\underline{e},\underline{e})$ with $\tilde{s}\neq\tilde{e}$ solves (16). We can construct another pair $\left(\frac{\tilde{s}+\tilde{e}}{2},\frac{\tilde{e}+\tilde{s}}{2}\right)$. By concavity and symmetry of $v(s,e)$,

$$v\left(\frac{\tilde{s}+\tilde{e}}{2},\frac{\tilde{s}+\tilde{e}}{2}\right) > \frac{v(\tilde{s},\tilde{e})+v(\tilde{e},\tilde{s})}{2} = v(\tilde{s},\tilde{e}).$$

It further implies that the newly constructed pair is incentive compatible:

$$\delta\frac{v\left(\frac{\tilde{s}+\tilde{e}}{2},\frac{\tilde{s}+\tilde{e}}{2}\right)-\frac{\tilde{s}+\tilde{e}}{2}-\frac{\tilde{s}+\tilde{e}}{2}-[v(\underline{s},\underline{e})-\underline{s}-\underline{e}]}{1-\delta} > \frac{\tilde{s}+\tilde{e}}{2}+\frac{\tilde{s}+\tilde{e}}{2}-\underline{s}-\underline{e}=\tilde{s}+\tilde{e}-\underline{s}-\underline{e}.$$

This contradicts the optimality of the solution $(\tilde{s},\tilde{e})$. Therefore, it must be the case that $\tilde{s}(\delta)=\tilde{e}(\delta)$. □

Equipped with the claimed property, the constrained optimization problem (16) can be rewritten as a single-variable program:

$$\begin{gathered}\max_{e\geq\underline{e}} v(e,e)-2e \\ \text{subject to } \delta[v(e,e)-v(\underline{e},\underline{e})] \geq 2(e-\underline{e}).\end{gathered}$$

For the first-best attribute $(\tilde{e}^{FB},\tilde{e}^{FB})$ to be sustainable, the necessary condition is that IC holds:

$$\delta \geq \bar{\delta}_1 = \frac{2(\tilde{e}^{FB} - \underline{e})}{v(\tilde{e}^{FB}, \tilde{e}^{FB}) - v(\underline{e}, \underline{e})}.$$

We then consider the case when $\delta < \bar{\delta}_1$ and the first-best attribute is not achieved. Define

$$\mathcal{L}(e, \lambda_1, \lambda_2) = v(e, e) - 2e + \lambda_1 \{\delta[v(e, e) - v(\underline{e}, \underline{e})] - 2(e - \underline{e})\} + \lambda_2 (e - \underline{e}).$$

The Kuhn-Tucker conditions reduce to

$$\begin{aligned} &\mathcal{L}_e = \frac{dv(\tilde{e}, \tilde{e})}{de} - 2 + \lambda_1(\delta \frac{dv(\tilde{e}, \tilde{e})}{de} - 2) + \lambda_2 = 0, \\ &\lambda_1 \geq 0, \text{ with } \lambda_1 = 0 \quad \text{if} \quad \delta[v(\tilde{e}, \tilde{e}) - v(\underline{e}, \underline{e})] > 2(\tilde{e} - \underline{e}), \\ &\lambda_2 \geq 0, \text{ with } \lambda_2 = 0 \quad \text{if} \quad \tilde{e} > \underline{e}. \end{aligned} \tag{17}$$

For any solution $\tilde{e} > \underline{e}$, $\lambda_2 = 0$. Moreover, IC constraint must bind, i.e.$\lambda_1 > 0$. To see this, suppose $\lambda_1 = 0$, then by (17), $\frac{dv(\tilde{e}, \tilde{e})}{de} = 2$, contradicting the fact that $e < \tilde{e}^{FB}$. The solution $\tilde{e}$ should therefore satisfy:

$$\begin{aligned} \frac{dv(\tilde{e}, \tilde{e})}{de} &= \frac{2(1 + \lambda_1)}{1 + \lambda_1 \delta} \geq 2, \\ \delta &= \frac{2(\tilde{e} - \underline{e})}{v(\tilde{e}, \tilde{e}) - v(\underline{e}, \underline{e})}. \end{aligned}$$

It follows that

$$\frac{d\tilde{e}}{d\delta} = \frac{[v(\tilde{e}, \tilde{e}) - v(\underline{e}, \underline{e})]^2}{2[(v(\tilde{e}, \tilde{e}) - v(\underline{e}, \underline{e})) - (\frac{dv(\tilde{e}, \tilde{e})}{de})(e - \underline{e})]}.$$

By concavity of $v(e, e)$, $\frac{d\tilde{e}}{d\delta} > 0$ for any $\tilde{e} > \underline{e}$.

Finally, by letting $\tilde{e}$ approach to $\underline{e}$, we have

$$\underline{\delta}_1 = \lim_{\tilde{e} \to \underline{e}} \frac{2(\tilde{e} - \underline{e})}{v(\tilde{e}, \tilde{e}) - v(\underline{e}, \underline{e})} = \frac{2}{v_s(\underline{e}, \underline{e}) + v_e(\underline{e}, \underline{e})} = \frac{1}{v_e(\underline{e}, \underline{e})}.$$

where the last equality comes from the symmetry of v.

When $\delta < \underline{\delta}_1$, there does not exist $\tilde{e} > \underline{e}$ that can sustain consumer's trust in equilibrium, and the equilibrium experience attribute would remain at the static Nash equilibrium level $\tilde{e} = \underline{e}$.

Proof of Proposition 3 (p. 18)

The proof is divided into two steps. Step 1 compares the cutoff discount factors $(\underline{\delta}, \bar{\delta})$ with $(\underline{\delta}_1, \bar{\delta}_1)$. Step 2 then compares the equilibrium attributes $(s(\delta), e(\delta))$ and $(\tilde{s}(\delta), \tilde{e}(\delta))$, together with equilibrium profit $\Pi(\delta)$ and $\widetilde{\Pi}(\delta)$.

Step 1 First, recall that

$$\underline{\delta}_1 = \frac{1}{v_e\left(\underline{e}, \underline{e}\right)},$$
$$\underline{\delta} = \frac{1}{v_e\left(s^*\left(\underline{e}\right), \underline{e}\right)}.$$

Since $v_s\left(s^*\left(\underline{e}\right), \underline{e}\right) = 1$ and $v_s\left(\underline{e}, \underline{e}\right) > 1$, $s^*\left(\underline{e}\right) > \underline{e}$. Therefore, $\underline{\delta}_1 > \underline{\delta}$ if $v_{se} > 0$ and $\underline{\delta}_1 < \underline{\delta}$ if $v_{se} < 0$.

Next, we compare $\bar{\delta}_1$ and $\bar{\delta}$. To begin, for any $e \in (\underline{e}, e^{FB})$, the corresponding cutoff values of discount factor in the hybrid setting and pure experiential setting are determined by:

$$\delta(e) = \frac{e - \underline{e}}{v\left(s^*\left(e\right), e\right) - s^*\left(e\right) - \left[v\left(s^*\left(\underline{e}\right), \underline{e}\right) - s^*\left(\underline{e}\right)\right]},$$
$$\delta_1(e) = \frac{2(e - \underline{e})}{v(e, e) - v(\underline{e}, \underline{e})}.$$

Define

$$A\left(e\right) \coloneqq \frac{1}{\delta\left(e\right)} - \frac{1}{\delta_1\left(e\right)} = \frac{2\left[v\left(s^*(e), e\right) - s^*\left(e\right)\right] - 2\left[v(s^*\left(\underline{e}\right), \underline{e}) - s^*\left(\underline{e}\right)\right] - \left[v(e, e) - v(\underline{e}, \underline{e})\right]}{2\left(e - \underline{e}\right)}.$$

Since $e > \underline{e}$, $A\left(e\right) > 0$ if and only if the numerator is positive, namely,

$$N\left(e\right) \equiv 2\left[v\left(s^*(e), e\right) - s^*\left(e\right)\right] - 2\left[v(s^*\left(\underline{e}\right), \underline{e}) - s^*\left(\underline{e}\right)\right] - \left[v(e, e) - v(\underline{e}, \underline{e})\right] > 0.$$

Observe that $N\left(\underline{e}\right) = 0$ and $N'\left(e\right) = 2[v_e\left(s^*\left(e\right), e\right) - v_e\left(e, e\right)]$. Again, by Lemma 2 and Proposition 1, we know that $s^*\left(e\right) > e$. It follows that if $v_{se} \lesseqgtr 0$, $A\left(e\right) \lesseqgtr 0$, which further implies $\delta_1\left(e\right) \lesseqgtr \delta\left(e\right)$. Because $\delta_1(e)$ and $\delta(e)$ are both increasing functions, we have $e\left(\delta\right) > \tilde{e}\left(\delta\right)$ for complements and $e\left(\delta\right) > \tilde{e}\left(\delta\right)$ for substitutes.

Finally, we look at the first-best case. We first claim that $e^{FB} = s^{FB}$. Suppose not, then

$$\begin{aligned}
&v(\frac{s^{FB} + e^{FB}}{2}, \frac{s^{FB} + e^{FB}}{2}) - \frac{s^{FB} + e^{FB}}{2} - \frac{s^{FB} + e^{FB}}{2} \\
=&v(\frac{s^{FB} + e^{FB}}{2}, \frac{s^{FB} + e^{FB}}{2}) - s^{FB} + e^{FB} \\
>&\frac{1}{2}(v(s^{FB}, e^{FB}) - s^{FB} - e^{FB}) + \frac{1}{2}(v(e^{FB}, s^{FB}) - e^{FB} - s^{FB}) \\
=&v(s^{FB}, e^{FB}) - s^{FB} - e^{FB},
\end{aligned}$$

which contradicts the first-best property of (s^{FB}, e^{FB}). Therefore, $s^{FB} = e^{FB}$ when we have a symmetric utility function $v(s, e)$.

Consequently, the cutoff discount factor for the first-best quality is

$$\bar{\delta}_1 = \frac{2(\tilde{e}^{FB} - \underline{e})}{v\left(\tilde{e}^{FB}, \tilde{e}^{FB}\right) - v\left(\underline{e}, \underline{e}\right)} = \frac{2(e^{FB} - \underline{e})}{v\left(e^{FB}, e^{FB}\right) - v\left(\underline{e}, \underline{e}\right)},$$
$$\overline{\delta} = \frac{e^{FB} - \underline{e}}{\left[v\left(e^{FB}, e^{FB}\right) - e^{FB}\right] - \left[v\left(s^*\left(\underline{e}\right), \underline{e}\right) - s^*\left(\underline{e}\right)\right]};$$

which is just the first-best case of the analysis above, namely,

$$\frac{1}{\overline{\delta}} - \frac{1}{\bar{\delta}_1} = A\left(e^{FB}\right)$$

By continuity, we conclude that $A(e^{FB}) > 0$ and $\overline{\delta} < \bar{\delta}_1$ for complement while $A(e^{FB}) < 0$ and $\overline{\delta} > \bar{\delta}_1$ for substitutes.

Step 2 For any given $e \in (\underline{e}, \tilde{e}^{FB})$, recall that $v_s\left(s^*\left(e\right), e\right) = 1$ and $v_s\left(e, e\right) > 1$, by concavity we have $s\left(\delta\right) = s^*\left(e\left(\delta\right)\right) > e\left(\delta\right)$. For the case of *complementary* attributes, for all δ such that $e\left(\delta\right) < e^{FB}$, $s\left(\delta\right) = s^*\left(e\left(\delta\right)\right) < s^*(e^{FB}) = s^{FB} = e^{FB}$ must hold because $ds^*\left(e\right)/de > 0$. Similarly, for the case of substitute attributes, for all δ such that $e\left(\delta\right) < e^{FB}$, $s\left(\delta\right) > s^{FB} = e^{FB}$ must hold.

Now we check the impact on the profit of making one experience attribute observable. If two attributes are complements, we have shown that for any $\delta < \bar{\delta}$, $s(\delta) > e(\delta) > \tilde{e}(\delta) = \tilde{s}(\delta)$. Then, it must be true that

$$\begin{aligned}\Pi(\delta) &= v(s^*(e(\delta)), e(\delta)) - s^*(e(\delta)) - e(\delta) \\ &> v(s^*(\tilde{e}(\delta)), \tilde{e}(\delta)) - s^*(\tilde{e}(\delta)) - \tilde{e}(\delta) \\ &> v(\tilde{s}(\delta), \tilde{e}(\delta)) - \tilde{s}(\delta) - \tilde{e}(\delta) = \widetilde{\Pi}(\delta),\end{aligned}$$

where the first inequality follows the monotonicity of Π on e before reaching the first-best level, and the second inequality follows the conditional optimality of $s^*(e)$.

Moreover, for $\delta \geq \bar{\delta}$, $s(\delta) = e(\delta) = e^{FB}$ and $\Pi(\delta) = \widetilde{\Pi}(\delta)$.

If two attributes are substitutes, when $\delta \leq \underline{\delta}_1$, $\Pi(\delta) - \widetilde{\Pi}(\delta) = [v(s^*(\underline{e}), \underline{e}) - s^*(\underline{e}) - \underline{e}] - [v(\underline{e}, \underline{e}) - 2\underline{e}] > 0$ by conditional optimality of s^*. When $\delta \geq \bar{\delta}_1$, $\Pi(\delta) - \widetilde{\Pi}(\delta) = [v(s(\delta), e(\delta)) - s(\delta) - e(\delta)] - [v(e^{FB}, e^{FB}) - 2e^{FB}] < 0$. Let $\Delta\pi(\bar{\delta_1}) = D_2 < 0$. By continuity of $\Delta\pi(\delta)$, there must exist $\epsilon_1 > 0$ such that for $\underline{\delta}_1 < \delta < \underline{\delta}_1 + \epsilon_1$, $\Delta\pi(\delta) - \Delta\pi(\underline{\delta}_1) > -D_1$. Let $\underline{d} = \underline{\delta}_1 + \varepsilon_1$, then it must be true that $\Delta\pi(\delta) > 0$ for $\delta < \underline{d}$. Then similarly there exists $\varepsilon_2 > 0$ such that for $\bar{d} = \bar{\delta_1} - \varepsilon_2 < \delta < \bar{\delta_1}$, $\Delta\pi(\delta) < -D_2 + \Delta\pi(\bar{\delta_1}) = 0$.

Proof of Proposition 4 (p. 21)

First, notice that (8) can be simplified as $e - \delta [v(s,e) - v(s,\underline{e})] \leq \underline{e}$. The optimal equilibrium is therefore the solution to

$$\max_{s \geq \underline{s}, e \geq \underline{e}} v(s,e) - s - e \tag{18}$$
$$\text{subject to } e - \delta [v(s,e) - v(s,\underline{e})] \leq \underline{e}.$$

For the first-best attribute (s^{FB}, e^{FB}) to be sustainable, the following IC constraints should be satisfied:

$$\delta \geq \overline{\delta}_c \equiv \frac{e^{FB} - \underline{e}}{v(s^{FB}, e^{FB}) - v(s^{FB}, \underline{e})}.$$

Then we compare the value of $\overline{\delta}$ and $\overline{\delta}_c$. Rewrite the denominator of $\overline{\delta}_c$ as

$$\begin{aligned} v\left(s^{FB}, e^{FB}\right) - v\left(s^{FB}, \underline{e}\right) &= \left[v\left(s^{FB}, e^{FB}\right) - s^{FB}\right] - \left[v\left(s^{FB}, \underline{e}\right) - s^{FB}\right] \\ &> \left[v\left(s^{FB}, e^{FB}\right) - s^{FB}\right] - \left[v\left(s^*(\underline{e}), \underline{e}\right) - s^*(\underline{e})\right]. \end{aligned}$$

due to the fact that $s^*(\underline{e}) = \arg\max_{s \geq \underline{s}} v(s, \underline{e}) - s - \underline{e} = \arg\max_{s \geq \underline{s}} v(s, \underline{e}) - s$. Thus,

$$\frac{e^{FB} - \underline{e}}{v(s^{FB}, e^{FB}) - v(s^{FB}, \underline{e})} < \frac{e^{FB} - \underline{e}}{[v(s^{FB}, e^{FB}) - s^{FB}] - [v(s^*(\underline{e}), \underline{e}) - s^*(\underline{e})]}$$

or equivalently, $\overline{\delta}_c < \overline{\delta}$.

Now, we consider the case of $\delta < \overline{\delta}_c$. The Lagrangian of the maximization problem (18) is

$$\mathcal{L}(s, e, \lambda_1, \lambda_2, \lambda_3) = v(s,e) - s - e - \lambda_1 [e - \delta v(s,e) + \delta v(s, \underline{e}) - \underline{e}] - \lambda_2(\underline{s} - s) - \lambda_3(\underline{e} - e).$$

Write down the Kuhn-Tucker conditions:

$$\begin{aligned} &\mathcal{L}_s = v_s(s,e)(1 + \lambda_1 \delta) - \lambda_1 \delta v_s(s, \underline{e}) - 1 + \lambda_2 = 0, \\ &\mathcal{L}_s = v_e(s,e)(1 + \lambda_1 \delta) - (1 + \lambda_1) + \lambda_3 = 0, \\ &\lambda_1 \geq 0, \text{ with } \lambda_1 = 0 \quad \text{if} \quad e - \delta [v(s,e) - v(s,\underline{e})] < \underline{e}, \\ &\lambda_2 \geq 0, \text{ with } \lambda_2 = 0 \quad \text{if} \quad s > \underline{s}, \\ &\lambda_3 \geq 0, \text{ with } \lambda_3 = 0 \quad \text{if} \quad e > \underline{e}. \end{aligned}$$

Applying the same argument in the proof for Equation (16), the IC constraint (8) must bind

for any solution $e_c \in (\underline{e}, e^{FB})$. Namely, the optimal level (s_c, e_c) should satisfy

$$e_c - \delta \left[v\left(s_c, e_c\right) - v\left(s_c, \underline{e}\right) \right] = \underline{e}, \tag{19}$$

First, observe that e_c is increasing in δ. Rewrite (19) as

$$\delta = \frac{e_c - \underline{e}}{v\left(s_c, e_c\right) - v\left(s_c, \underline{e}\right)} \tag{20}$$

By taking partial derivative of δ on e_c, :

$$\begin{aligned} \frac{\partial \delta}{\partial e_c} &= \frac{v\left(s_c, e_c\right) - v\left(s_c, \underline{e}\right) - (e_c - \underline{e}) v_{e_c}\left(s_c, e_c\right)}{\left[v\left(s_c, e_c\right) - v\left(s_c, \underline{e}\right)\right]^2} \\ &= \frac{\left(e_c - \underline{e}\right)\left[v_e\left(s, \hat{e}\right) - v_e\left(s, e_c\right)\right]}{\left[v\left(s_c, e_c\right) - v\left(s_c, \underline{e}\right)\right]^2} > 0, \end{aligned}$$

where $\hat{e} \in (\underline{e}, e_c)$ by Mean Value Theorem and the last inequality comes from concavity of v. It follows that $e_c(\delta)$, the inverse of $\delta(e_c)$, should also be increasing.

Second, given any δ, we compare the equilibrium attribute levels with and without commitment. Denote $(s(\delta)), e(\delta)) = \left(s^*\left(e(\delta)\right), e\left(\delta\right)\right)$ is the solution of optimization problem (5) and $\left(s_c(\delta), e_c\left(\delta\right)\right)$ is the solution of optimization problem (9).

For any $e(\delta) > \underline{e}$, recall that the optimality conditions of constrained problem (5) are (14), which can be rewritten as

$$e\left(\delta\right) - \delta\left(v\left(s\left(\delta\right), e\left(\delta\right)\right) - s\left(\delta\right)\right) = \underline{e} - \delta(v\left(s^*\left(\underline{e}\right), \underline{e}\right) - s^*(\underline{e})). \tag{21}$$

By optimality of $s^*(\cdot)$, we must have

$$v(s^*\left(e(\delta)\right), \underline{e}) - s^*\left(e(\delta)\right) < v\left(s^*\left(\underline{e}\right), \underline{e}\right) - s^*\left(\underline{e}\right),$$

which is equivalent to

$$\underline{e} - \delta(v\left(s^*\left(\underline{e}\right), \underline{e}\right) - s^*\left(\underline{e}\right)) < \underline{e} - \delta[v(s^*\left(e(\delta)\right), \underline{e}) - s^*\left(e(\delta)\right)]. \tag{22}$$

Combining (21) and (22), we obtain

$$e\left(\delta\right) - \delta\left[v(s\left(\delta\right), e\left(\delta\right)) - v(s\left(\delta\right), \underline{e})\right] < \underline{e}$$

which implies that $\left(s\left(\delta\right), e\left(\delta\right)\right)$ does not violate IC constraints in the optimization problem with commitment. Moreover, $\left(s\left(\delta\right), e\left(\delta\right)\right)$ is *not* a solution for the optimization problem (9), in which IC constraints must bind for optimal solutions. Therefore, the solution to (9) must achieve higher

profit than that to (5), i.e.

$$v(s(\delta), e(\delta)) - s(\delta) - e(\delta) < v(s_c(\delta), e_c(\delta)) - s_c(\delta) - e_c(\delta) \tag{23}$$

Recall that $\pi(s,e) = v(s,e) - s - e$ is a strictly concave function in $\Gamma = \{(s,e)|e \geq \underline{e}, s \geq \underline{s}\}$.

Applying the concavity condition on the inequality (23),

$$\begin{aligned}
&\pi(s_c(\delta), e_c(\delta)) - \pi(s(\delta), e(\delta)) \\
<&\underbrace{(v_s(s(\delta), e(\delta)) - 1)}_{=0 \text{ as } s(\delta)=s^*(e(\delta))}(s_c(\delta) - s(\delta)) + (v_e(s(\delta), e(\delta)) - 1)(e_c(\delta) - e(\delta)) \\
=&(v_e(s(\delta), e(\delta)) - 1)(e_c(\delta) - e(\delta)).
\end{aligned}$$

We already show that $\pi(s_c(\delta), e_c(\delta)) - \pi(s(\delta), e(\delta)) > 0$. It follows that

$$(v_e(s(\delta), e(\delta)) - 1)(e_c(\delta) - e(\delta)) > 0.$$

Given that $v_e(s(\delta), e(\delta) > 1$ for $e(\delta) < e^{FB}$, it must be the case that $e_c(\delta) > e(\delta)$.

Next, we show that $s_c(\delta) > s(\delta)$ when s and e are complements and $s_c(\delta) < s(\delta)$ when s and e are substitutes.

s and e are complements In this case, $v_s(s,e) > v_s(s,e')$ for any $e > e'$. Recall the first line of the Kuhn-Tucker condition,

$$v_s(s_c(\delta), e_c(\delta)) - 1 = -\lambda_1 \delta [v_s(s_c(\delta), e_c(\delta)) - v_s(s_c(\delta), \underline{e})] < 0.$$

Note that by the definition of $s^*(e)$, we have

$$v_s(s^*(e_c(\delta)), e_c(\delta)) - 1 = 0.$$

It must be the case that

$$v_s(s_c(\delta), e_c(\delta)) < v_s(s^*(e_c(\delta)), e_c(\delta)).$$

Combined with $v_{ss} < 0$, it implies that $s_c(\delta) > s^*(e_c(\delta))$. Moreover, $e_c(\delta) > e(\delta)$ and complementarity between s and e imply $s^*(e_c(\delta)) > s^*(e(\delta))$. Therefore, the optimal observable attribute is distorted upwards away from the conditional optimal level:

$$s_c(\delta) > s^*(e_c(\delta)) > s^*(e(\delta)) = s(\delta).$$

s and e are substitutes In this case, $v_s(s,e) < v_s(s,e')$ for any $e > e'$. Contrary to the complementary case,

$$v_s\left(s_c\left(\delta\right), e_c\left(\delta\right)\right) - 1 = -\lambda_1 \delta \left[v_s\left(s_c\left(\delta\right), e_c\left(\delta\right)\right) - v_s\left(s_c\left(\delta\right), \underline{e}\right)\right] > 0.$$

Hence, $v_s\left(s_c\left(\delta\right), e_c\left(\delta\right)\right) > v_s\left(s^*(e_c(\delta)), e_c(\delta)\right)$ in this scenario. For $v_{ss} < 0$, we conclude that $s_c\left(\delta\right) < s^*(e_c\left(\delta\right))$. Similarly, $e_c\left(\delta\right) > e\left(\delta\right)$ and substitution between s and e imply that $s^*(e_c\left(\delta\right)) < s^*(e\left(\delta\right))$. Therefore, we have the opposite conclusion that

$$s_c\left(\delta\right) < s^*(e_c\left(\delta\right)) < s^*(e\left(\delta\right)) = s\left(\delta\right).$$

Finally, we derive the lowest δ below which no $e > \underline{e}$ is sustainable under the environment with commitment. Denote this cutoff value as $\underline{\delta_c}$. We are about to show that $\underline{\delta_c} < \underline{\delta}$.

Consider a commitment to $s_1 > s^*\left(\underline{e}\right)$. The IC constraint for e given fixed $s = s_1$ is

$$f\left(s_1, e\right) = e - \delta v\left(s_1, e\right) - \left[\underline{e} - \delta v\left(s_1, \underline{e}\right)\right] \leq 0.$$

For $\delta > \frac{1}{v_e(s_1, \underline{e})}$,

$$\frac{\partial f\left(s_1, \underline{e}\right)}{\partial e} = 1 - \delta v_e\left(s_1, \underline{e}\right) < 0.$$

Therefore, there exists $\varepsilon\left(s_1\right) > 0$ such that for all $e \in [\underline{e}, \underline{e} + \varepsilon\left(s_1\right)]$, IC constraint $f\left(s_1, e\right) \leq 0$ is satisfied.

Since $\pi_e\left(s, \underline{e}\right) > 0$ by assumption, it is optimal to set $e > \underline{e}$. The positive relationship between s and e is preserved as $s_1 \to s^*\left(\underline{e}\right)$ for $\delta \geq \underline{\delta}$ because $\underline{\delta} = \frac{1}{v_e(s^*(\underline{e}), \underline{e})} > \frac{1}{v_e(s_1, \underline{e})}$ for all $s_1 > s^*\left(\underline{e}\right)$ by complementarity of s and e. Therefore, $\frac{de}{ds}|_{s=s^*(\underline{e}), e=\underline{e}} > 0$ for $\delta \geq \underline{\delta}$.

Now we show that at $\delta = \underline{\delta} = \frac{1}{v_e(s^*(\underline{e}), \underline{e})}$, the seller can commit to some $s > s^*\left(\underline{e}\right)$ to both maintain a reputation of $e > \underline{e}$ and earn a higher profit.

This follows directly from

$$\begin{aligned}
\frac{d\pi\left(s^*\left(\underline{e}\right), \underline{e}\right)}{ds} &= \pi_s\left(s^*\left(\underline{e}\right), \underline{e}\right) + \pi_e\left(s^*\left(\underline{e}\right), \underline{e}\right) \frac{de}{ds}|_{\underline{e}} \\
&= \pi_e\left(s^*\left(\underline{e}\right), \underline{e}\right) \frac{de}{ds}|_{\underline{e}} > 0.
\end{aligned}$$

This implies that under commitment, the firm with the discount factor $\underline{\delta}$ can earn higher profit than $\pi\left(s^*\left(\underline{e}\right), \underline{e}\right)$ by committing to a higher observable attribute than $s^*\left(\underline{e}\right)$. By doing so, it also gets rid of the static Nash level $\underline{e}$ and permits a higher level of experience goods e. Finally, by continuity, $\underline{\delta_c} < \underline{\delta}$.

The argument for the substitution case is analogous. □

Proof of Proposition 5 (p. 24)

First, notice that the constraint in Program (10) can be rewritten as:

$$\delta[v(s,e) - c(s,e)] \geq (1-\delta)[c(s,e) - c(s,\underline{e})] + \delta\pi^{SN}. \tag{24}$$

Similar to previous proofs, we can write down the Lagrangian for (10) as follows:

$$\begin{aligned}\mathcal{L}(s,e,\lambda_1,\lambda_2,\lambda_3) =& v(s,e) - s - e + \lambda_2(s-\underline{s}) + \lambda_3(e-\underline{e}) \\ &+ \lambda_1\{\delta[v(s,e) - c(s,e)] - (1-\delta)[c(s,e) - c(s,\underline{e})] - \delta\pi^{SN}\}.\end{aligned}$$

Clearly, we have two cutoffs of discount factor such that the optimal solution $\hat{e} \in (\underline{e}, e^{FB})$. Since the main focus of the exercise is to study how observable attribute is designed to better facilitate trust-building, we will restrict attention on the interior part of the optimal solution. Recall that Kuhn-Tucker condition requires:

$$\mathcal{L}_s = (1+\lambda_1\delta)[v_s(\hat{s},\hat{e}) - c_s(\hat{s},\hat{e})] - \lambda_1(1-\delta)[c_s(\hat{s},\hat{e}) - c_s(\hat{s},\underline{e})] + \lambda_2 = 0.$$

Observe that $\hat{e} > \underline{e}$ implies $\lambda_2 = 0$ and $\hat{e} < e^{FB}$ implies $\lambda_1 > 0$. Hence, rearranging terms in the equation above yields:

$$(1+\lambda_1\delta)[v_s(\hat{s},\hat{e}) - c_s(\hat{s},\hat{e})] = \lambda_1(1-\delta)[c_s(\hat{s},\hat{e}) - c_s(\hat{s},\underline{e})] \tag{25}$$

When attributes are complements, $c_s(\hat{s},\hat{e}) > c_s(\hat{s},\underline{e})$ and RHS of Equation (25) is positive, meaning that $v_s(\hat{s},\hat{e}) > c_s(\hat{s},\hat{e})$. We must have $\hat{s} < s^*(\hat{e})$. By symmetric arguments, when attributes are substitutes, $\hat{s} > s^*(\hat{e})$.

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