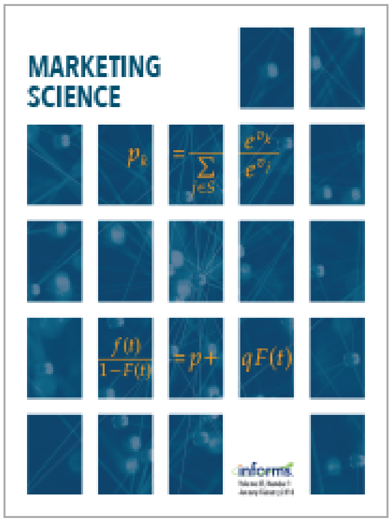

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Customer Bill of Rights Under No-Fault Service Failure: Confinement and Compensation

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Service providers and their customers are sometimes victims of failures caused by exogenous factors such as unexpected bad weather, power outages, or labor strikes. When such no-fault failures occur in confined zones, service providers may confine customers against their will if making arrangements for them to leave is very costly. Such confinements, however, can result in severe pain and suffering, and customer complaints put regulators under pressure to pass a customer bill of rights that allows captive customers to abort failed services. This paper shows that service providers are better off preempting such laws by voluntarily allowing customers to escape the service under failure. Moreover, service providers can profit by targeting compensation to customers based on whether they use or leave the service under failure.

Key words: service failure; customer bill of rights; advanced selling; targeted compensation
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You can check out any time you like, but you can never leave!

—The Eagles, "Hotel California"

1. Introduction

Service delivery is unavoidably subject to failures. Although failures sometimes can be blamed on poor planning or execution by service providers, or on customers' own careless behavior (for example, when they fail to take prescribed medications correctly; see Stewart and Chase 1999, Meuter et al. 2000, Tax et al. 2006), oftentimes they are caused by exogenous factors that cannot be blamed on either party. Examples of such "no-fault" failures include airline delays caused by airport operators or security issues, vacations at a resort island affected by bad weather or local strikes, and performance-art shows that cannot take place on time because of power failures.

When the service is purchased in advance, customers are caught between a rock and a hard place under a no-fault failure. Consuming the failed service involves inconveniences and sometimes pain and suffering, whereas aborting the service could be costly or even impossible (e.g., during a flight) in addition to forfeiting the advanced payment. Service providers, however, typically do not hold themselves responsible for failures caused by uncontrollable factors, and include no-fault clauses in their service contracts. Eurostar, the high-speed passenger train operating between the United Kingdom and Europe, states that its "compensation policy does not apply to delays due to bad weather, events of force majeure (actions and events beyond Eurostar's control), or strikes independent of Eurostar" (SNCB Europe 2011). With no legislation on customer rights, airlines can hold passengers indefinitely on planes during tarmac delays, and "they don't have to provide you with food, water, hygienic toilets, or any medical needs," according to Kate Hanni, the founder of FlyersRights.org (*CBS News* 2009).

Although it is often well understood that such failures are not the service provider's fault, customers can be traumatized when they are unable to abort failed services as they wish—in particular, when the failure is severe. Hanni recalled her 13-hour ordeal of being trapped onboard a plane at the Austin airport, where women made baby diapers out of T-shirts and diabetics were going into shock (*CBS News* 2009).

On February 14, 2007, JetBlue Airways held passengers up for almost 10 hours on a tarmac during a storm, turning Valentine's Day into a hostage crisis (*MSNBC.com* 2007). The ensuing bad publicity pushed the airline to announce a "customer bill of rights" (CBR) that guarantees monetary compensation corresponding to delays (Hewitt 2007). More recently, 51 passengers were stuck overnight on a delayed Continental Express flight at the Rochester, MN airport on August 7, 2009; during the six-hour stranding, "People had children crying. The whole atmosphere of the plane was just one of sort of deteriorating emotional stability" (*CBS News* 2009). Thus, service failures taking place in confined zones can lead to "pain and suffering" that includes physical discomfort such as not being able to move around and psychological stress such as anxiety, frustration, or even panic.

The physical and psychological suffering under lengthy confinements, although intangible, often sparks public outrage and draws media attention that calls for government intervention. Service providers, however, are mostly opposed to such intervention. For example, the airline industry has fought vehemently against legislation for putting a government CBR into place after a January 1999 blizzard that trapped Northwest Airlines passengers for seven hours on a tarmac (Lowy 2009). Since then, new regulations have been proposed, but most of them failed, whereas high-profile confinement incidents continued to occur.[1] In Europe, a CBR requiring airlines to offer compensation for delays, cancellations, or overbooking regardless of the cause was implemented, and the airlines have threatened to challenge it in court (Thomson 2007).

Confining people for a long time, nevertheless, cannot be sustained because it could violate customers' basic rights and eventually trigger laws that impose costly restrictions on providers. A case in point is the airline CBR enacted in the United States on December 21, 2009. Under this CBR, airlines must let passengers off the plane after waiting three hours on a tarmac or face a fine of up to $27,500 per passenger. The bill also requires that food, water, and adequate restrooms be provided during delays. The airline industry said it will comply with the regulations, but it predicted more canceled flights and inconveniences for passengers.

This paper is motivated by the debate regarding recovery policies for severe service failures that potentially violate customers' basic rights, e.g., traumatic tarmac delays. Our research focuses on two important issues of CBR: *confinement* and *compensation*. Specifically, when should a provider allow confined customers to leave under a no-fault failure? Should the provider compensate customers for hardship and damages even when the failure is caused by uncontrollable, exogenous factors?

To address the first question, a model is set up to investigate conditions under which a service provider finds it profitable to hold customers captive under failure, and customers enroll in the service knowing that such confinements may occur. This outcome, defined as *confinement equilibrium*, is hardly sustainable because it invites government intervention. We show that service providers should preempt such intervention by voluntarily letting customers escape under severe failures, even if this policy is costly to implement.

To address the second question, we show that compensating customers who leave differently from those who stay can improve profits. This policy reflects the heterogeneity in customers' pain and suffering under failure. For example, during long takeoff delays, passengers with health problems may endure greater hardship than healthy consumers. Offering a higher compensation for leaving motivates those who suffer the most to escape, which helps reduce damage from confinement and raise consumer surplus. As a result, the provider can profit from charging a higher price for the service. Customers who escape, however, may also differ in their losses from giving up the service. Clearly, missing a flight is more costly for a business traveler compared with a vacationer. When escaping failure is very costly to some customers, offering higher compensation to those who stay under failure can be more profitable.

Although conventional wisdom may suggest offering the same compensation to every customer under failure, our results suggest targeting compensation to customers based on their decisions to consume or to leave the service under failure. Given the compensation schedule, each customer self-selects to leave or stay, partially revealing his or her tolerance to inconveniences. In fact, the compensation is designed to induce customer behavior that improves the provider's profit, rather than provide comfort to customers. As a result, the optimal level of compensation does not depend on the level of pain and suffering from confinement. The exact compensation level depends on the trade-off between having fewer customers realize the discomfort from staying and having fewer of them incur the cost of leaving under failure. While the confinement policy is more relevant to services that are vulnerable to no-fault failures with captive customers including airlines, cruises, trains, vacation resorts, etc., the targeted compensation scheme is also applicable for services that are

[1] Between 2007 and 2009, more than 200,000 domestic passengers were stuck on more than 3,000 planes on a tarmac for three hours or more (Stoller 2009).

easier to escape, such as buses, theaters, sport events, and performing arts.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. In §3, we introduce the base model and characterize the confinement equilibrium. After discussing the implications of a government-enforced CBR, we propose a self-imposed CBR that allows customers to escape and offers targeted compensation. Section 4 presents the discussion and conclusion.

2. Literature Review

Service failure is a leading cause of customer switching (Keaveney 1995), and a well-executed service recovery policy is critical for enhancing satisfaction, building relationships, and preventing customer defections (Chu et al. 1998, Fruchter and Gerstner 1999). Service recovery has received considerable attention in the academic literature (e.g., Davidow 2003, McCollough et al. 2000, Tax et al. 1998) and in the popular press (e.g., Brady 2000, Quick 2000). The extant literature can be classified broadly into "process recovery" such as offering an apology (Bitner et al. 1990, Hoffman et al. 1995, Kelley et al. 1993, Smith et al. 1999) and "outcome recovery" such as offering monetary compensation (e.g., a full or partial refund). Most of the academic studies are empirical or experimental in nature, focusing on customer evaluation of service failures and recovery experiences (e.g., Smith et al. 1999, Hess et al. 2003, Weun et al. 2004, Holloway and Beatty 2003, Maxham and Netemeyer 2002). More recently, Zhu et al. (2004) and Parasuraman (2006) pointed out that analytical modeling can help resolve a host of "trade-off" issues in designing effective service recovery systems. Whereas previous studies examined ways to reduce, prevent, or recover failures that can be blamed directly on the service provider (e.g., poor planning and execution) or on the customers themselves (e.g., not following instructions correctly), we contribute to the literature by using an analytical model to explore pricing and compensation policies for service failures caused by exogenous factors.

Our research is also related to the literature on service cancellations. Xie and Gerstner (2007) propose that service providers can profit by offering compensation to *individual* consumers who must cancel prepurchased services. The motivation for offering compensation is the opportunity for resale, which can materialize only if the cancellation occurs well in advance of service delivery. Guo (2009) examines the profitability of such a cancellation policy in a competitive environment. Biyalogorsky et al. (1999) and Biyalogorsky and Gerstner (2004) show that service cancellations initiated by service providers can be profitable because of arbitrage opportunities under which low price sales are cancelled while high willingness-to-pay consumers arrive, resulting in high price sales. These cancellations, however, are not caused by service failures. Moreover, we examine "on-spot cancellations" triggered by exogenous factors that are unknown until the service delivery, which prevents the possibility of reselling.

Another related research stream addresses profit opportunities from advance selling when consumers are uncertain about their valuations at the time of their purchase (Shugan and Xie 2000, 2004; Xie and Shugan 2001). In these models, customers with schedule conflicts or outside opportunities arising after purchase may decide not to use the service and forgo the advance payments. Our work complements this research by focusing on CBR policies under advance selling.

Many services are delivered to a number of customers simultaneously within a confined zone (e.g., restaurants, ski resorts, trains). When a service facility gets crowded under unexpected high demand, service quality deteriorates, although leaving the facility might be costly for customers. Chen et al. (2009) explore the optimal pricing and compensation strategies for service failures caused by overcrowding. This paper differs from Chen et al. (2009) in several aspects: First, this study considers services purchased in advance of delivery, which raises the monetary risk to consumers who may decide to walk away in case of a service failure. Second, we consider general service failures caused by exogenous factors, not just from crowding because of unexpected demand. Third, Chen et al. (2009) assume homogeneous customers, whereas this paper highlights the importance of recognizing consumer heterogeneity in damage and escape costs when designing targeted compensation policies.

This study is also related to the literature on product failures. Compensation for product failures, misfit, or dissatisfaction typically takes the form of warranties or money-back guarantees (Courville and Hausman 1979, Kendall and Russ 1975, Lutz 1989, Menezes and Currim 1992, Welling 1989, Heiman et al. 2002, Padmanabhan and Rao 1993, Davis et al. 1995). The inconvenience of replacing a product is similar to the discomfort of consuming a service under failure, whereas the hassle of returning a product is similar to the escape cost. However, there are two major differences. First, customers can always discard the product or purchase a replacement from a competitor if consuming the failed product leads to a negative surplus. In the service setting, the production and consumption occur simultaneously, so customers are still in the hands of the service provider when service fails, where the recovery process interacts with the consumption process. Therefore, confinement is unlikely for a product purchase as long as there is no service contract that comes along with it. Second, returned products can be repaired or resold, but salvaging a service under spot cancellation is much harder, if not impossible. This may explain why money-back guarantees for services are not as common as they are for products.

Finally, the industrial engineering and management literature offers research on service recovery related to system failures (e.g., failures of information systems and software), with a focus on root cause analysis and solutions to improve system reliability (Dai and Levitin 2006, Levitin and Dai 2007, Lavoie et al. 2009, Lee et al. 2009). In contrast, this paper focuses on service failures involving confinement and compensation issues. The models employed to analyze the problem are described next.

3. The Model

We first set up a model to characterize a "confinement equilibrium," under which customers are held against their will under failure. This equilibrium is not "legally sustainable" because lengthy confinements could potentially violate customer rights and trigger a government-enforced CBR.[2] We then examine a self-imposed CBR, which can preempt government intervention and improve profits by offering targeted compensations to customers who leave or stay under failure.

For simplicity, we consider two possible states: service delivery with failure and without failure, with probability q and $1-q$, respectively.[3] Under no failure, each consumer receives a valuation V from the service (relative to the outside alternative that is normalized to zero). Let D denote the damage a customer incurs from consuming the failed service, which varies across customers as people differ in their ability of coping with physical and emotional stress. For model tractability, we assume that D is uniformly distributed on $[0, d]$ across consumers. (A numerical analysis suggests that the insights hold under other distributions.) For ease of exposition, we assume zero marginal cost of serving an individual customer. The analysis and results with positive marginal cost do not differ qualitatively.[4] To provide an easy reference, all the notation is summarized in Table A.1 in the appendix.

[2] We focus on severe confinement incidents. Thus, minor confinement incidents, such as a tarmac delay for one or two hours, are viewed as part of "acceptable normal" service delivery and are not considered here.

[3] We assume at-fault failures can be properly addressed by the service provider, so the failures here refer to no-fault failures only.

[4] It can be shown that profit is lower with a positive marginal cost. Sometimes, the provider raises price with the marginal cost, which reduces the enrollment. Under failure, the marginal cost also gives a stronger incentive to offer a higher compensation for customers who leave.

Consumers: Consumers make decisions in two stages. First, anticipating his own damage under failure, each consumer decides to enroll (i.e., prepay for the service) if his expected surplus is nonnegative. The maximum enrollment (i.e., total market size) is normalized to one. Second, upon the service delivery, customers observe whether a failure occurs. When there is a failure, each customer decides whether to consume the service or leave without being served. Note that in the case of on-spot payment, consumers can simply walk away upon failure (e.g., a power outage at a restaurant). Thus, we focus on the setting where consumers fully prepay for the service, which is common for airlines, theaters, and vacation packages (Xie and Shugan 2001).

The Escape Cost: Each consumer who aborts the service incurs an escape cost consisting of two components: the effort exerted to escape the service and the loss from giving up the service. The magnitude of each component varies across industries. For example, escaping an airplane while waiting for takeoff is almost impossible, but leaving a theater under power failure does not take much effort. Whereas the first component is relatively homogeneous among customers, the second component can vary significantly across individuals. For example, when a flight is delayed, a business traveler's loss from giving up the service is likely to exceed that of a leisure traveler.

In some cases, customers are confined temporarily before being able to escape the failed service. For example, for delayed takeoff flights it takes time to make arrangements and bring an aircraft back to the gate so that passengers can leave the plane. Thus, customers who leave under failure might also incur some damage cost from confinement. This cost, borne by all customers, translates into a pure reduction in consumer expected surplus, which lowers price and expected profit accordingly. In this paper, the common damage is normalized to zero, a simplification that does not affect results qualitatively.

To simplify the analysis, we first assume that consumers face the same escape cost E, a reasonable assumption when all customers are unable to escape because of confinement. After deriving conditions under which a confinement equilibrium exists, we compare the expected profit under a government CBR with the expected profit under a self-imposed CBR that allows customers to escape with targeted compensation. Finally, it is shown that similar insights hold under heterogeneous escape costs, although the compensation schedule may be different.

3.1. The Confinement Equilibrium

In this section, we consider the base model where no compensation is offered. In Stage 1, a customer prepurchases the service if the expected surplus is nonnegative. Upon arrival or right after the service starts, the consumer observes whether service failure occurs (Stage 2). Under no failure, all customers consume the service. Under failure each customer self-selects whether to stay or escape, depending on his damage cost D from consuming the failed service and the escape cost E. The two-stage game is solved using backward induction.

Stage 2: Customers' decisions under service failure. In this stage, customers have already paid for the service. Under failure, the surplus from consuming the service is $V-D$, and the surplus from aborting the service is $0-E$. A customer escapes under failure if

$$V-D\leq -E. \tag{1}$$

When no failure occurs, each customer receives a surplus V from consuming the service. Note that the second-stage decision is independent of the price prepaid because the payment is sunk.

Stage 1: Consumers' decision to prepay. A consumer prepays for the service if his expected surplus from participation is nonnegative. This surplus, however, depends on the consumer's decision of whether to leave or stay upon failure. Let $D_0 = V+E$ denote the damage of the marginal consumer who is indifferent between staying and leaving under failure. Any customer with damage cost below D_0 expects to consume the service under failure, obtaining an expected surplus of

$$CS_{\text{stay}} = q(V-D)+(1-q)V-P, \quad D\leq D_0. \tag{2}$$

A customer with damage cost above D_0 expects to leave, so the customer's expected surplus at the time of purchase is

$$CS_{\text{leave}} = q(-E)+(1-q)V-P, \quad D> D_0. \tag{3}$$

Note that (3) is independent of D. Therefore, if $CS_{\text{leave}} \geq 0$, any consumer with $D > D_0$ purchases the service. In this case, the expected surplus of the marginal consumer is $q(V-D_0)+(1-q)V-P$, which equals CS_{leave}. Any consumer with $D\leq D_0$ (who expects to stay under failure) has a nonnegative expected surplus because $CS_{\text{stay}} \geq q(V-D_0)+(1-q)\cdot V-P$ and will participate.

On the other hand, if $CS_{\text{leave}} < 0$, all consumers with $D>D_0$ do not participate because they have identical negative expected surplus. It follows from (2) that consumers with $D\leq (V-P)/q$ obtain a nonnegative expected surplus, CS_{stay}, and therefore prepay for the service.

In sum, the service provider faces two alternative pricing policies.

Case 1. Price is sufficiently low so that everyone participates, and high-damage-cost customers leave the service under failure. In this case, Equation (3) is nonnegative; i.e.,

$$P\leq (1-q)V-qE. \tag{4}$$

Because the market size is normalized to 1, and each customer who participates contributes a profit margin equal to price, P, the service provider's profit is $\pi = P$.

Case 2. Price is high so that customers who would leave under failure do not participate. That is, every customer who prepays stays under failure. In this case, Equation (3) is negative, which implies $P>(1-q)V-qE$, and only consumers with $D\leq (V-P)/q$ prepay for the service. Because the damage cost is uniformly distributed on [0, d], the fraction of consumers who participate is $(V-P)/(qd)\leq 1$, which implies $P\geq V-qd$. Note that when V is sufficiently high, the entire market enrolls, and no one leaves under failure; i.e., $P=V-qd$. The service provider's profit is $\pi = P(V-P)/(qd)$, where

$$P>(1-q)V-qE, \quad \text{and} \quad P\geq V-qd. \tag{5}$$

Thus, the service provider's profit function can be written as

$$\pi = \begin{cases} P & \text{(Case 1)}, \\ \dfrac{P(V-P)}{dq} & \text{(Case 2)}. \end{cases} \tag{6}$$

The equilibrium price P^* maximizes the expected profit in (6) subject to the respective constraint (4) and (5) (see the appendix for details). The optimal profit is obtained by plugging P^* back into the profit function (6). Comparing profits for Cases 1 and 2, we obtain a threshold level E_0 so that Case 1 is optimal when $E\leq E_0$. In particular, $E_0 = ((1-q)/q)V - V^2/(4dq^2)$ if $V\leq 2dq$ and $E_0 = d-V$ if $V>2dq$. Table 1 summarizes the results.

Table 1 shows that when escape cost is below the threshold ($E\leq E_0$), it is optimal for the provider to enroll all customers. Because of the relatively low escape cost, customers subject to high pain and suffering leave under failure, so they are not confined in equilibrium. In this region, a higher escape cost E or a higher probability of failure q leads to a lower expected consumer surplus. Therefore, the service provider must offer a lower price to keep customers, leading to a lower profit. When escape cost is above the threshold ($E>E_0$), there could be full or partial enrollment. Because it is now too costly to leave, no one escapes and customers are confined in equilibrium. In particular, when customer's valuation is sufficiently high, i.e., $V>2dq$, the entire market prepays for the service and stays under failure. Because no one incurs the escape cost, an increase in E has no effect on price or profit. However, consumers respond to

Table 1 Equilibrium With or Without Confinement

	Equilibrium without confinement ($E \le E_0$)	Equilibrium with confinement ($E > E_0$)	
		$V \le 2dq$	$V > 2dq$
Price	$(1-q)V - qE$	$\frac{V}{2}$	$V - qd$
Profit	$(1-q)V - qE$	$\frac{V^2}{4dq}$	$V - qd$
Fraction of customers who participate	1	$\frac{V}{2dq}$	1
Fraction of customers who stay under failure	$\frac{V+E}{d}$	$\frac{V}{2dq}$	1

a higher probability of failure with a lower expected utility or enrollment, so the profit decreases with q.

Lengthy confinements, however, can violate customer rights and the law. Investing in resources to lower escape costs can help customers escape under failure. For example, airlines can make arrangements to deplane customers stuck in tarmac delays. Nevertheless, such arrangements can be expensive to implement, so providers choose to confine customers instead.

The dichotomy described in Table 1 is empirically relevant to sectors in the service industry such as cruises, trains, and airlines. Under service failures, service recovery is very costly for these operators, and therefore they are reluctant to move out of the confinement equilibrium. For example, major airlines tend to operate in congested hub airports, and therefore it is very costly for them to secure gates for passengers to deplane during delays. They also use large airplanes that take longer to board and deplane. These operational constraints help explain why major airlines had repeatedly fought against the legislation until the serious Minnesota overnight stranding in 2009. In contrast, it is rare to hear about customers being confined in buses or movie theaters, where the cost of letting customers escape is not an issue.

Interestingly, although customers have taken the possible confinement into account when prepurchasing the service, there will be an outcry for the pain and suffering under failure. This is because ex ante consumers act upon expected surplus that is negatively affected by the *expected damage qD*. When the service indeed fails, a customer realizes his damage D, which may result in a negative surplus ex post. Because escape costs can be prohibitively high, customers willing to abort the failed service are unable to do so. Instead, they are held against their will, because the provider prefers not to incur the cost for reducing escape costs. The confinement equilibrium is summarized in the following proposition.

Proposition 1 (Confinement Equilibrium). *The service provider confines customers under failure if it is very costly to reduce escape costs, so customers who prepurchase the service at will may find themselves being confined against their will.*

The confinement equilibrium captures the conflict between the customers and the service provider. It explains why despite the public outrage, airlines are reluctant to adopt any recovery plans that allow customers to discontinue their services under failure. Even after JetBlue introduced its own CBR in 2007, no other airlines followed suit. However, customers who suffer the most under confinements are likely to voice their complaints, leading to government intervention, as examined next.

3.2. Government Intervention and Social Welfare

The confinement equilibrium is legally unsustainable. For example, the U.S. Department of Transportation (DOT) recently announced the first customer bill of rights that imposes a heavy fine for keeping customers on board a plane for more than three hours. As a result, most airlines have planes return to the gate after waiting 2 or 2.5 hours on a tarmac, which can result in more flight cancellations and airport congestion (Lowy 2009). Passengers can change tickets or cancel their trips while waiting at the boarding gate for the service to be restored. Because airlines operate under costly restrictions (e.g., the maximum length of a tarmac delay) and incur an additional cost for deplaning and reboarding passengers, profits will suffer under the new regulation.

Under a government CBR, a law will require escape cost lower than E_0 (so that confinements no longer occur), preferably at the level E_G that maximizes social welfare. For simplicity, we assume that the service provider incurs a total cost of $f_1 + f_2(E_0 - E_G)$ reducing the escape cost from E to E_G, where f_1 corresponds to the substantial fixed cost lowering E to E_0 so that escape becomes possible (e.g., spending on equipment that helps passengers deplane an aircraft), and $f_2(E_0 - E_G)$ represents the additional cost that facilitates leaving to further reduce the escape cost to E_G (e.g., providing free shuttle or luggage assistance). As it becomes incrementally more costly to lower escape cost, it is reasonable to assume that $f_2(E_0 - E_G)$ is a convex and increasing function of the reduction in escape cost, $E_0 - E_G$.

In addition to regulating escape cost, the government can specify certain levels of compensations for customers. Two types of compensations are possible: (a) compensation $R_S \geq 0$ to consumers who decide to use the service under failure (*compensation for staying*) and (b) compensation $R_L \geq 0$ to customers who escape the failed service (*compensation for leaving*). The preferred escape cost level and compensations for the government CBR are given in Proposition 2.

Proposition 2 (Government CBR). *To ban confinement and maximize social welfare, the escape cost must be lowered to $E_G \leq E_0$ with compensation for service failures set at $R_S = R_L$.*

The exact level of E_G depends on the function $f_2(E_0 - E_G)$; see the proof in the appendix for details. Thus, the government prefers offering the same amount of compensation to those who stay and leave, which is consistent with the practice. Note that alternative compensations exist to maximize social welfare (including no compensation at all; i.e., $R_S = R_L = 0$). Such compensations are transfer payments and therefore are not essential for enhancing social welfare.

Because government intervention is aimed at protecting customers' rights, it may hurt the profit of the provider. Assuming that government intervention is imminent, the service provider can act proactively to preempt the law by introducing a self-imposed CBR, as examined next.

3.3. Self-Imposed CBR: Let Customers Go and Compensate for Failure

Under a self-imposed CBR (self CBR), the service provider reduces the escape cost to a level that allows customers to escape, with two types of compensations for failure. Given the escape cost E, the sequence of events under a self CBR is similar to that in §3.1. In Stage 1, the provider announces price P and commits to offering compensation R_S to customers who decide to stay and R_L to those who leave in case of a service failure. A customer prepurchases the service if the expected surplus is nonnegative. In Stage 2, customers who have prepaid arrive and observe whether there is a failure. Under no failure, all customers consume the service. Otherwise, each customer self-selects whether to stay or abort the service based on his damage D, the compensations R_S and R_L, and the escape cost E.

Table 2 presents the equilibrium under self CBR (see the appendix for details), where the profit depends on the *difference* in compensations, $\Delta R = R_L - R_S$, rather than on the specific compensation levels. Similar to Table 1, the equilibrium solution depends on a threshold level $E_R = \min\{((1-q)/q)V, 2d - V\}$. Note that $E_R \geq E_0$.

As can be seen from Table 2, customers are again confined under a sufficiently high escape cost ($E > E_R$), where there is no advantage of offering compensation. The lemma below allows us to restrict the analysis to the range [0, E_R].

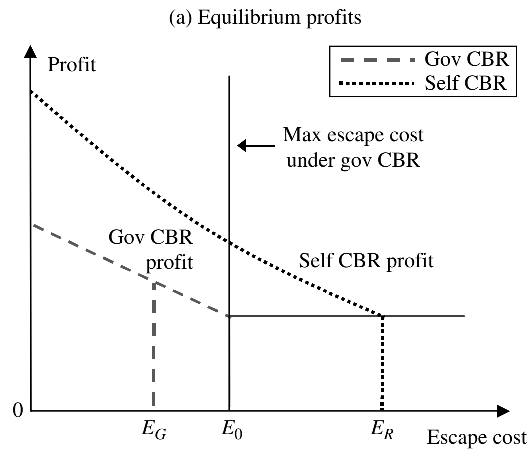
Lemma 1. *The self CBR is sustainable when the escape cost is below the threshold level E_R.*

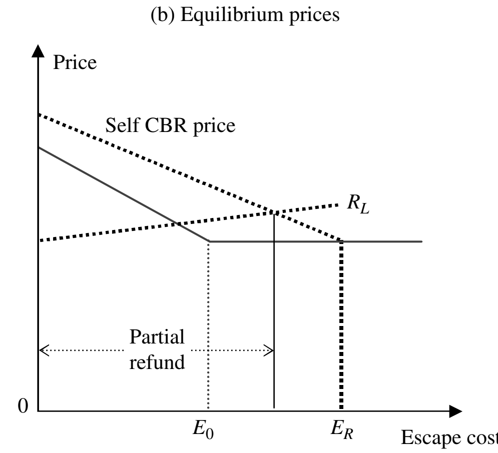
By Lemma 1, the provider must reduce the escape cost below E_R to avoid potential government intervention. According to Table 2, it is optimal to offer higher compensation for leaving in this region, as shown in the next proposition (see the appendix for the proof).

Table 2 Self CBR Equilibrium Given Escape Cost

	Equilibrium with compensation ($E \leq E_R$)	Equilibrium without compensation ($E > E_R$)
Price	$V - \dfrac{q[V+E]}{2} + qR_S$	The equilibrium values are identical to those under $E > E_0$ in Table I (i.e., confinement).
Compensation ΔR	$\dfrac{V+E}{2} > 0$	
Profit	$(1-q)V - qE + \dfrac{q[V+E]^2}{4d}$	No advantage of offering compensations ($R_S = R_L = 0$).
Fraction of customers who participate	1	
Fraction of customers who stay under failure	$\dfrac{V+E}{2d}$	

Figure 1 Government CBR vs. Self CBR: Equilibrium Profits and Prices





Proposition 3 (A CBR with Compensation for Leaving Under Failure). *Allowing customers to escape a service failure with targeted compensation leads to a higher profit compared to the profit under the government CBR.*

This result is intriguing. Why should compensation be offered when (a) the provider is not at fault for the failure and (b) payment for the service has already been collected? By offering targeted compensation with $\Delta R = R_L - R_S = (V + E)/2$, the provider can increase price by $q[V + E]/2 = q\Delta R$ to all customers and earn a higher profit than that under the government CBR. Because $R_L - R_S = (V + E)/2 > 0$, more customers are encouraged to leave and escape the pain and suffering under confinement. The extra profit comes from those customers who prepay for the service and stay under failure.

Note that there exist alternative compensation schedules that maximize the provider's profit as long as $\Delta R = (V+E)/2$. A simple case is $R_S = 0$, where only compensation for leaving is offered. In general, R_S can be positive so that customers who escape under failure receive higher compensation than those who stay. However, the positive compensation to those who stay leads to a price increase of qR_S, so social welfare and profits remain the same.

Figure 1 compares the equilibrium profits and prices under the government CBR and the self CBR for the simple case of $R_S = 0$.[5] As discussed previously, under the government CBR the maximum allowable escape cost is E_0, whereas the preferred level satisfies $E_G \leq E_0$. According to Table 2, the self CBR profit declines with the escape cost and truncates at E_R. Because compensation motivates customers to escape under failure, the confinement region shrinks with $E_R \geq E_0$, and thus, $E_R \geq E_G$.

As shown in Figure 1(a), adopting a self CBR allows the service provider to operate over a wider range on $[0, E_R]$, where customers with severe pain and suffering can escape at will. Therefore, by introducing the right incentive, the service provider could preempt a government CBR that imposes costly restrictions on service delivery. Moreover, the profit under self CBR dominates the profit under government regulation. This suggests that even if the provider did not take the initiative to preempt the law, it can still benefit from offering targeted compensation while operating at an escape cost level below E_0. The profit advantage here does not necessarily come from a higher enrollment. Rather, it comes from "excluding" those high-damage-cost customers when the service fails. In other words, under the targeted compensation policy, the service provider essentially "pays" those troubled customers to leave, who would otherwise suffer the most and push the legislator for intervention.

As shown in Proposition 2, the government CBR may also mandate a certain level of compensation for every customer regardless of his or her decision to leave or stay. Thus, it fails to function as an incentive that encourages customers to choose the recovery plan that favors the service provider. In fact, offering the same amount of compensation to every customer has no impact on customers' welfare, as the service provider would simply raise the price accordingly and customers ultimately bear all the cost for offering the compensation. In contrast, a targeted compensation improves the seller's profit while reducing the welfare of customers.

The discussion so far focuses on industries with high escape costs. Nevertheless, the result in Table 2 is also applicable to services operating under low escape costs. These service providers may allow a partial or full refund if a customer cancels the service and seeks

[5] For comparison purposes, we assumed that the provider incurs the same cost under government CBR and self CBR when investing in resources that lowers the escape cost.

better alternatives. For example, after check-in, airline passengers typically wait at the boarding gate if the flight is delayed. In this case, some airlines such as Southwest will fully refund passengers who give up the flight. For vacation tours that are delayed because of traffic congestion, customers who struggle to escape might get a partial or full refund. For the simple case of $R_S = 0$, the next proposition concerns how the compensation level depends on the escape cost.

Proposition 4 (Optimal Level of Compensation). *Under homogeneous escape cost, the optimal compensation is a partial refund for relatively low levels of escape cost. As E increases, the optimal refund increases and eventually exceeds the prepaid price.*

See the appendix for the proof. When the escape cost increases, a higher compensation for leaving is needed. On the other hand, the price under compensation decreases with E. Thus a partial refund is offered when E is relatively low, as shown in Figure 1(b). Interestingly, the optimal compensation does not change with the mean or variance of the damage cost (because it is independent of d). This is because the compensation is not offered to comfort customers for their suffering. Instead, it is used to induce customer behavior that helps the service provider.

3.4. Self-Imposed CBR: Heterogeneous Escape Costs

The results above were obtained under the simplifying assumption that consumers face the same escape cost. In this section, we show that under heterogeneous escape costs, targeted compensation still helps improve profit, although the compensation level is different.

For model tractability, we assume that there are two consumer segments with different escape costs. A proportion α of the customers has high escape cost E_h, and the other proportion has low escape cost E_l. In the airline setting, these two segments correspond to business and leisure travelers who differ significantly in their losses from giving up the service. Define $\Delta E = E_h - E_l > 0$, which reflects the level of heterogeneity between the two segments. When the service provider lowers the escape cost of every customer (e.g., by providing transportation for leaving), E_l and E_h are likely to be lowered by the same amount so that ΔE stays unchanged. The derivation shares the same logic as that for Table 2, and the equilibrium solution depends on some threshold levels of E_1 and E_2, as summarized in Table 3 (see the appendix for details).

The equilibrium profit, again, depends on the difference in compensations ($\Delta R = R_L - R_S$) only. A positive difference ($\Delta R > 0$) encourages more customers to leave under failure, whereas a negative difference ($\Delta R < 0$) induces more customers to stay when failure occurs. As can be seen from Table 3, it is optimal to offer a higher compensation for staying (i.e., $R_S > R_L$) when $E_1 \le E_l \le E_3$, where $E_3 = \alpha V/(1+\alpha)q - V$ (derived from $\Delta R^* \le 0$). Depending on parameters, it is possible to have $E_1 = 0$ (i.e., no region for full participation), $E_1 = E_2$ (i.e., no region for partial participation), or $E_3 < E_1$ (i.e., always offer a higher compensation to those who leave).

Figure 2 shows how the optimal compensation policy depends on E_l and ΔE for low and high valuations,

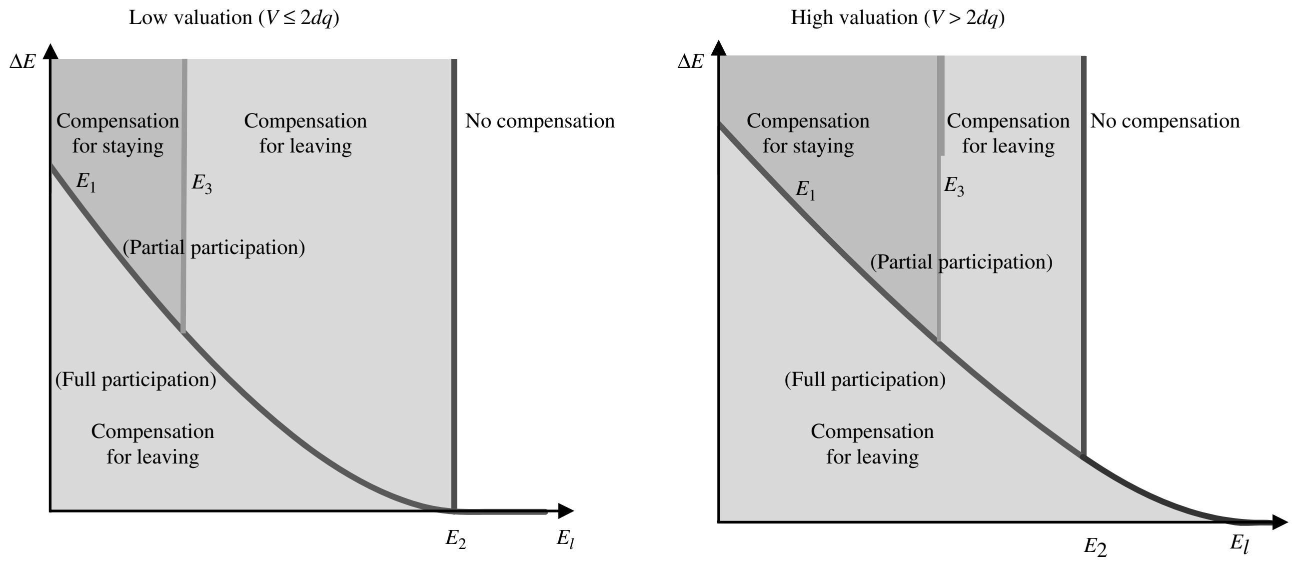
Table 3 Self CBR Equilibrium with Heterogeneous Escape Costs

	Full participation ($0 \le E_l \le E_1$)	Partial participation[a] ($E_1 \le E_l \le E_2$)
Price	$(1-q)V + q(R_L - E_h)$	$(1-q)V + q(R_L - E_l)$
Compensation ΔR	$\frac{1}{2}[V + \alpha E_h + (1-\alpha)E_l] > 0$	$\frac{(1+\alpha)(V+E_l)}{2} - \frac{\alpha V}{2q}$
Profit	$(1-q)V - qE_h + \frac{q}{4d}[V + \alpha E_h + (1-\alpha)E_l]^2$	$(1-\alpha)[(1-q)V - qE_l] + \frac{q}{4d}\left[\frac{V\alpha}{q} + (1-\alpha)(V+E_l)\right]^2$
Fraction of customers who participate	1	$1 - \alpha + \frac{\alpha}{2d}\left[\frac{V\alpha}{q} + (1-\alpha)(V+E_l)\right]$
Fraction of customers who stay under failure	$\frac{1}{2d}[V + \alpha E_h + (1-\alpha)E_l]$	$\frac{1}{2d}\left[\frac{V\alpha}{q} + (1-\alpha)(V+E_l)\right]$

Notes. The specific values of E_1 and E_2 are complex and can be found in the appendix. The equilibrium with confinement under high escape cost (i.e., $E_l > E_2$) is not sustainable and thus is omitted.

[a]Another solution is possible under partial participation, which is valid if $d/\alpha + E_l \le (1-q)V/q < d/\alpha + 2E_h - E_l$. A careful examination reveals that this condition is often violated for reasonable parameters of α and q. This solution does not change our insights qualitatively but significantly complicates the presentation of results, so it is not included in Table 3 (see Case 2.1 under §A.3).

Figure 2 **Compensation Policies Regions**



respectively. Given ΔE, it is optimal to enroll the entire market (i.e., full participation) for very low E_l ($0 \leq E_l \leq E_1$) when offering a higher compensation for leaving is optimal. Offering a higher compensation for staying is optimal only when E_l is low and ΔE is sufficiently high (so that E_h is high). In this case, it is optimal to enroll the entire E_l segment, as well as the low-damage-cost customers from the E_h segment (i.e., partial participation). Because E_l is low ($E_1 \leq E_l \leq E_3$), customers from the E_l segment who have high damage cost still escape, despite the incentive for staying under failure. On the other hand, the low-damage-cost customers from the E_h segment are motivated to stay rather than give up the service. Otherwise, if E_l is relatively high ($E_3 \leq E_l \leq E_2$), most customers from both segments will stay even without any incentive. In this case, offering a higher compensation for leaving again becomes optimal because the total pain and suffering incurred is too costly.

Figure 2 also shows that compensation for staying is more likely to be optimal under high valuation V (because E_3 increases with V). Intuitively, it makes more economic sense to let customers stay and realize their valuations if V is relatively high. Proposition 5 summarizes our results (see the appendix for the proof).

Proposition 5 (Compensation Under Heterogeneous Escape Costs). *Targeted compensation for service failure leads to higher profit than government CBR even when the service is offered to two consumer segments with different escape costs. However, it can sometimes be optimal to offer higher compensation to customers who stay than to customers who leave.*

Proposition 5 shows that allowing customers to leave with targeted compensation improves profit compared to the government CBR, even when escape costs differ across consumer segments. However, the optimal compensation level depends on the trade-off between having fewer customers realize the discomfort from staying and having fewer of them incur their escape costs. Again, the compensation serves as an incentive to induce customer behavior that favors the service provider.

4. Discussion and Conclusion

Service failures are often caused by exogenous factors that are hard to predict and are therefore hard to control (for example, bad weather or labor strikes). Because service providers do not see themselves as responsible for such failures, too often they are reluctant to implement customer-friendly solutions. When such a failure occurs in a confined zone, customers can be held against their will for long hours if it is costly to make arrangements for them to leave. However, lengthy confinements cause severe pain and suffering, and customer complaints put regulators under pressure to pass a customer bill of rights requiring airlines to allow passengers to leave the plane if the service fails. A case in point is the Airline Passenger Bill of Rights approved by the DOT in 2009, which fines airlines up to $27,500 per passenger for tarmac delays of three hours or more on domestic flights (Bomkamp 2010). In 2011, DOT extended the rule, restricting tarmac delays by international flights to no more than four hours (Chen 2011).

This paper shows that service providers may find it profitable to confine customers under failure as long as they can successfully fend off government intervention. However, this policy is legally unsustainable, as the airline industry case shows. Our analysis suggests that the service provider should preempt the government intervention by designing flexible service recovery strategies, such as a self-imposed CBR that allows customers to escape and compensates for failure. When customers are not confined, profits can be enhanced by targeting compensations based on customers' decisions to leave or stay. This scheme recognizes the heterogeneity in customers' discomfort from staying and in their losses of giving up the service. Because consuming the service under failure causes pain and suffering, allowing customers to leave with compensation leads to higher prices and profits compared with the government CBR. Such a policy is likely to be perceived as socially responsible because it promotes customer satisfaction and reduces complaints by those who suffer the most from captivity. When escaping failure leaves some customers with significant losses, compensating customers who stay and consume the service under failure sometimes is more profitable.

Although we have focused on service operators with high escape costs such as airlines, cruises, trains, and vacation tours, a targeted compensation scheme is still relevant for services currently operating under low escape costs. By offering compensation to customers who leave or stay, the service provider motivates customers to act in a way that lowers damages from failure. This compensation scheme essentially applies contingent pricing based on customer's tolerance to inconveniences under failure.

The use of a bill of rights to protect customers who are caught in confined zones under failure is gaining momentum around the world. For example, Europe passed its air passenger rights in 2004. Following that, the European Commission adopted similar legislation in the rail industry and is considering proposals on passenger rights in sea and inland waterway transport as well as international coach/bus transport. In September 2008, Canada passed Flight Rights, which allows passengers to deplane after a 90-minute tarmac delay with the option of reboarding (*EturboNews* 2008). Other countries including Australia are debating on whether to pass a CBR. The recently implemented government CBR in the United States provides excellent opportunities for empirical research. Under the heavy fine for confinement, many airlines are making arrangements in order to avoid holding passengers beyond the three-hour limit. It will be interesting to examine the impact of this policy on airlines' pricing and operational efficiency.

Our paper models the long-term equilibrium where customers have complete information about the possible damage caused by service failure. Therefore, customers respond to poor service recovery schemes with lower expected utility and/or a reduction in enrollment. In this case, a compensation policy can help improve profit. Apart from a lower expected utility or enrollment, customers' negative experience from confinement can result in additional damages to the provider's profit. For instance, customers who suffer the most under failure may drastically lower their valuations for any future service. Moreover, poor management of service failure can be quickly communicated over the social network, resulting in additional damages to brand image and customer loyalty. Future research can explicitly explore how reputation effects of service failures affect profit using a multiperiod dynamic model.

To make the analysis tractable, we assumed that the valuation for the service is the same across consumers.[6] Under heterogeneous valuations, the service provider can segment the market and design different compensations for each segment. For example, airlines that offer different airfare classes could sell tickets with different compensation policies. When it is difficult to segment consumers into relatively homogeneous classes, a CBR that compensates customers for aborting the service under failure would be more attractive to customers who have relatively low valuation but experience great discomfort from failure. Consumers with high valuation for the service would prefer to stay onboard despite the pain and suffering involved. Letting customers with high damage cost relative to their service valuation leave might still improve profits. Empirical and simulation study can help configure the compensation schemes under multiple segmentations with respect to customer valuations, along with heterogeneity in escape cost and in the discomfort from consuming the service under failure.

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Appendix

This appendix presents the derivation of the confinement equilibrium and the equilibrium under self CBR, followed by proofs of the propositions.

A.1. Derivation of Table 1 (The Confinement Equilibrium)

By Equation (6), the service provider's problem can be written as

$$\max \pi = \begin{cases} P & \text{if } 0 \le P \le (1-q)V - qE, \quad (7) \\ \dfrac{P(V-P)}{qd} & \text{if } P > (1-q)V - qE \\ & \quad \text{and } P \ge V - qd. \quad (8) \end{cases}$$

Maximizing π in (7) yields $\pi = P = (1-q)V - qE$, which is valid for $E \le ((1-q)/q)V$. In this case, all the consumers

[6] We analyzed the extension of heterogeneous discomfort of staying and customer valuations assuming the same escape cost for customers, and we obtain similar insights regarding the benefit of offering targeted compensation.

will participate and the fraction of customers who stay is $(V+E)/d$.

Maximizing π in (8) yields $P=V/2$ and $\pi=V^2/(4dq)$ if $E>((1-2q)/(2q))V$ and $V\le 2dq$, where the fraction of customers who participate and stay is $V/(2dq)$. Otherwise, if $E>d-V$ and $V>2dq$, then $\pi=P=V-qd$, and the fraction of customers who participate and stay is 1. (The boundary solution $P=(1-q)V-qE$ will be dominated by the solution to (7) and hence is omitted.)

Define the threshold level

$$E_0=\begin{cases}\dfrac{1-q}{q}V-\dfrac{V^2}{4dq^2} & \text{if } V\le 2dq,\\ d-V & \text{if } V>2dq.\end{cases}\tag{9}$$

When $V\le 2dq$, we have $(1-q)V-qE\ge V^2/(4dq)$ if $E\le E_0$. Also, $((1-2q)/(2q))V\le E_0<((1-q)/q)V$ so that the equilibrium solution is $\pi=(1-q)V-qE$ for $E\le E_0$ and $\pi=V^2/(4dq)$ for $E>E_0$.

When $V>2dq$, we have $(1-q)V-qE\ge V-qd$ if $E\le E_0$. Also, $E_0=d-V<((1-q)/q)V$ so that the equilibrium solution is $\pi=(1-q)V-qE$ for $E\le E_0$ and $\pi=V-qd$ for $E>E_0$.

A.2. Derivation for Table 2 (Equilibrium Under Both Types of Compensation)

In Stage 2, a customer with damage cost $D\le V+E+R_S-R_L$ will stay under failure.

In Stage 1, there are again two possible cases.

Case 1. $P\le(1-q)V+q(R_L-E)$: If the number of customers who leave, $(d-(V+E+R_S-R_L))/d$, is between 0 and 1, i.e., $0\le V+E+R_S-R_L\le d$, then the seller's profit function is $\pi=P-qR_L[(d-(V+E+R_S-R_L))/d]-qR_S[(V+E+R_S-R_L)/d]$. Otherwise, if $V+E+R_S-R_L>d$, all the customers stay under failure, and the seller's profit function is $\pi=P-qR_S$.

Case 2. $P>(1-q)V+q(R_L-E)$: Price high so that only consumers with damage cost below $(V-P)/q+R_S$ participate (and stay under failure). If the fraction of customers who stay, $(V-P+qR_S)/(qd)$, is between 0 and 1, i.e., $P-qR_S\ge V-qd$, then the seller's profit function is $\pi=[P-qR_S]((V-P+qR_S)/(qd))$. Otherwise, if $P-qR_S<V-qd$, all the customers participate and stay under failure so that $\pi=P-qR_S$.

To summarize, the service provider's problem can be written as

$$\max\pi=\begin{cases}P-qR_L\left[\dfrac{d-(V+E+R_S-R_L)}{d}\right]-qR_S\left[\dfrac{V+E+R_S-R_L}{d}\right] & \text{if } 0\le P\le(1-q)V+q(R_L-E) \text{ and } 0\le V+E+R_S-R_L\le d, \quad (10)\\ P-qR_S & \text{if } 0\le P\le(1-q)V+q(R_L-E) \text{ and } V+E+R_S-R_L\ge d, \quad (11)\\ [P-qR_S]\left(\dfrac{V-P+qR_S}{qd}\right) & \text{if } P>(1-q)V+q(R_L-E) \text{ and } P-qR_S\ge V-qd, \quad (12)\\ P-qR_S & \text{if } P>(1-q)V+q(R_L-E) \text{ and } P-qR_S\le V-qd. \quad (13)\end{cases}$$

For (10), all consumers participate and some stay upon failure. The optimal price is achieved at the maximum level, $P=(1-q)V+q(R_L-E)$, so that profit is maximized at $P=V-q((V+E)/2)+qR_S$ and $R_L-R_S=(V+E)/2$ with $\pi=(1-q)V-qE+q[V+E]^2/(4d)$. Enrollment is 1 and the fraction of customers who stay is $(V+E)/(2d)$. This solution satisfies the conditions in (10) if $E\le\min\{((2-q)/q)V+2R_S, 2d-V\}$.

For (11), all consumers participate and stay upon failure. The optimal $\pi=V-qd$, with $R_L-R_S=V+E-d$ and $P=(1-q)V+q(R_L-E)$. This solution is dominated by (12).

For (12), consumers with damage cost below $(V-P)/q+R_S$ will participate and stay upon failure. Maximizing π in (12) yields the interior solution $P=V/2+qR_S$, which is valid when $R_L-R_S<V+E-V/(2q)$. If $V\le 2qd$, we can choose $R_L-R_S<V+E-V/(2q)$ so that $P=V/2+qR_S>(1-q)V+q(R_L-E)$ and $\pi=V^2/(4dq)$. Otherwise, if $V>2qd$, the solution is achieved at the boundary with $R_L-R_S<V+E-d$, price $P=V-qd+qR_S$, and profit $\pi=V-qd$.

For (13), all consumers participate and stay upon failure. The solution is achieved at the boundary with $R_L-R_S<V+E-d$, price $P=V-qd+qR_S$, and profit $\pi=V-qd$. Because $V^2/(4dq)\ge V-qd$ always holds, (13) is dominated by (12), so we ignore (13) from now on.

Define the threshold level $E_R=\min\{((1-q)/q)V, 2d-V\}$. Because $E_R\le\min\{((2-q)/q)V, 2d-V\}$, the profit in (10) is valid on [0, E_R].

1. When $V\le 2dq$, $E_R=((1-q)/q)V\le 2d-V$. Comparing profits in (10) and (12), we have

$$(1-q)V-qE+q[V+E]^2/(4d)\ge V^2/(4dq)\quad\text{if}$$
$$E\le((1-q)/q)V\quad\text{or}\quad E\ge 4d-((1+q)/q)V,$$

whereas $4d-((1+q)/q)V>2d-V$ when $V\le 2qd$. Thus, $\pi=(1-q)V-qE+q[V+E]^2/(4d)$ for $E\le E_R$. For $E\ge E_R=((1-q)/q)V$, the profit in (10) is dominated by that in (12) so that $\pi=V^2/(4dq)$.

2. When $V>2dq$, $E_R=2d-V\le((1-q)/q)V$. Comparing profits in (10) and (12), we have

$$(1-q)V-qE+q[V+E]^2/(4d)>V-qd\quad\text{if } E\le 2d-V.$$

Thus, $\pi=(1-q)V-qE+q[V+E]^2/(4d)$ for $E\le E_R$. When $E\ge E_R=2d-V$, $V-qd\ge(1-q)V-qE$, so $\pi=V-qd$.

A.3. Derivation for Table 3 (Equilibrium Under Heterogeneous Escape Cost)

The derivation for Table 3 follows the same logic as that for Table 2, so we just provide a sketch of the analysis here. In Stage 2, a customer with escape cost E_i will stay if his damage cost D satisfies $D\le V+E_i+R_S-R_L$, $i=h,l$. In Stage 1, a customer's expected surplus is $CS_{\text{stay}}=q(V-D+R_S)+(1-q)V-P$ if he stays, and $CS_{\text{leave}}=q(R_L-E_i)+(1-q)V-P$ if he decides to leave under failure. With heterogeneity in the escape cost, we will have three cases.

Case 1. *Full participation of both segments*: Price low so that everyone participates; i.e., $P\le(1-q)V+q(R_L-E_h)$. Enrollment is 1. The number of customers who stay is $(1/d)[V+R_S-R_L+\alpha E_h+(1-\alpha)E_l]$. The seller's profit is

$$\pi=P-qR_L(1-[V+R_S-R_L+\alpha E_h+(1-\alpha)E_l]/d)$$
$$-qR_S([V+R_S-R_L+\alpha E_h+(1-\alpha)E_l]/d).$$

The optimal price is $P=(1-q)V+q(R_L-E_h)$. The profit is maximized at $R_L-R_S=V+\alpha E_h+(1-\alpha)E_l/2$ with $\pi=(1-q)V-qE_h+q[V+\alpha E_h+(1-\alpha)E_l]^2/(4d)$. This solution is valid when $(1/d)[V+R_S-R_L+\alpha E_h+(1-\alpha)E_l]\le 1$; i.e., $V+\alpha E_h+(1-\alpha)E_l/(2d)\le 1$.

Case 2. *Full participation of E_l segment and partial participation of E_h segment*: This happens when $(1-q)V+q(R_L-E_h)<P\le(1-q)V+q(R_L-E_l)$. The number of customers who enroll (#*enrollment*) is $1-\alpha+(\alpha/d)((V-P)/q+R_S)$, the number who stay (#*stay under failure*) is $((1-\alpha)/d)[V+E_l+R_S-R_L]+(\alpha/d)[(V-P)/q+R_S]$, and the number who leave (#*leave under failure*) is $(1-\alpha)[1-V+E_l+R_S-R_L/d]$. Then profit is

$$\pi=P(\#\textit{enrollment})-qR_L(\#\textit{leave under failure})-qR_S(\#\textit{stay under failure}).$$

Depending on whether the price satisfies the participating constraint, there are three subcases.

Case 2.1. Profit maximization leads to the interior solution $P=\alpha V+(1-\alpha)dq/(2\alpha)+qR_S$, $R_L-R_S=(V+E_l-d)/2$, which is valid if $d/\alpha+E_l\le(1-q)V/q<d/\alpha+2E_h-E_l$. This condition is easily violated when either α or q is reasonably small. Also, this case does not change our results qualitatively. For ease of exposition, we decide to focus on more viable cases and not include this solution in Table 3.

Case 2.2. The optimal solution is at the boundary with $P=(1-q)V+q(R_L-E_l)$. The corresponding $R_L-R_S=(1+\alpha)(V+E_l)/2-V\alpha/(2q)$, and $\pi=(1-\alpha)[(1-q)V-qE_l]+q/(4d)[V\alpha/q+(1-\alpha)(V+E_l)]^2$.

Case 2.3. The optimal solution is at the boundary with $P=(1-q)V+q(R_L-E_h)$. It is straightforward to verify that this case is dominated by Case 1.

Case 3. **Partial participation of both segments**: This case requires $P>(1-q)V+q(R_L-E_l)$; i.e., price high so that only consumers with damage cost below $(V-P)/q+R_S$ will participate and stay under failure. Similar to the problem under homogeneous escape cost, the profit function is given by $\pi=[P-qR_S](V-P+qR_S/(qd))$. Thus $P=V/2+qR_S$, $R_L-R_S<V+E_l-V/(2q)$, and $\pi=V^2/(4dq)$ when $V\le 2qd$. When $V>2qd$, we have $P=V-qd+qR_S$, $R_L-R_S<V+E_l-V/(2q)$ and $\pi=V-qd$. Note that this case implies no customer will be able to escape under failure, which is not viable under a self CBR.

Comparisons. Recall that $\Delta E=E_h-E_l$. We can rewrite the profit as a function of E_l and ΔE for each case. Comparing the profits under Cases 1 and 2.2, we know that the profit under Case 1 is higher if and only if $E_l<E_{1,2}$, where

$$E_{1,2}=\frac{1}{(2-\alpha)}\left[2d+\frac{V(1-\alpha)}{q}-\Delta E-\sqrt{\left(2d+\frac{V(1-\alpha)}{q}-\Delta E\right)^2-(2-\alpha)\left(\alpha\Delta E^2-\alpha\frac{V^2}{q^2}-\frac{4d\Delta E}{\alpha}+\frac{4dV}{q}\right)}\right]-V.$$

$E_{1,2}$ is decreasing in ΔE with $E_{1,2}(\Delta E=0)=((1-q)/q)V$.

When $V\le 2qd$, comparing the profit under Case 2 with that under Case 3, we have

$$(1-\alpha)[(1-q)V-qE_l]+(q/(4d))[V\alpha/q+(1-\alpha)(V+E_l)]^2\ge V^2/(4dq)\quad\text{iff } E_l\le((1-q)/q)V.$$

When $V>2qd$, comparing the profit under Case 2 with that under Case 3, we have

$$(1-\alpha)[(1-q)V-qE_l]+(q/(4d))[V\alpha/q+(1-\alpha)(V+E_l)]^2\ge V-qd\quad\text{iff } E_l\le(2dq-V\alpha)/(q(1-\alpha))-V.$$

Therefore, for $E_l>(2dq-V\alpha)/(q(1-\alpha))-V$, Case 2 is dominated by Case 3. Comparing Case 1 with Case 3, we have

$$(1-q)V-qE_h+q[V+\alpha E_h+(1-\alpha)E_l]^2/(4d)\ge V-qd\quad\text{if } E_l<E_{1,3},$$

where $E_{1,3}=2d-\alpha\Delta E-2\sqrt{d(1-\alpha)\Delta E}-V$. Note that $E_{1,3}$ is decreasing in E with $E_{1,3}(\Delta E=0)=2d-V$. We can verify that $E_{1,2}\le E_{1,3}$ iff $E_l\le(2dq-V\alpha)/(q(1-\alpha))-V$.

Note that $(2dq-V\alpha)/(q(1-\alpha))-V<((1-q)/q)V$ iff $V>2qd$. Define $E_1=\max\{0,\min\{E_{1,2},E_{1,3}\}\}$, and $E_2=\max\{E_{1,3},\min\{((1-q)/q)V,(2dq-V\alpha)/(q(1-\alpha))-V\}\}$. By construction, it is possible to have $E_1=0$ or $E_1=E_2$. Also, Case 1 is optimal when $0\le E_l\le E_1$, Case 2.2 is optimal when $E_1\le E_l\le E_2$, and Case 3 is optimal when $E_l>E_2$.

A.4. Proofs

Proof of Proposition 2. The provider incurs a total cost $f_1+f_2(E_0-E_G)$, reducing escape cost to E_G, where f_1 corresponds to the fixed cost of lowering escape cost to E_0 and $f_2(E_0-E_G)$ represents the additional cost that reduces escape cost to $E_G\le E_0$. The government also specifies compensation $R_S\ge 0$ to customers who use the service under failure and compensation $R_L\ge 0$ to customers who escape the failed service. Given mandated escape cost level E_G and compensations (R_S,R_L), there are two possible cases.

Case 1. $P\le(1-q)V+q(R_L-E_G)$: Because no confinement is allowed under the government CBR, we have $V+E_G+R_S-R_L<d$ (otherwise, all customers stay under failure, i.e., confinement again occurs). The seller's profit is $\pi=P-qR_L[d-(V+E_G+R_S-R_L)/d]-qR_S[V+E_G+R_S-R_L/d]$.

Case 2. $P>(1-q)V+q(R_L-E_G)$: Price high so that only consumers with damage cost below $((V-P)/q)+R_S$ participate (and stay under failure). This implies that confinement occurs. However, the government will set E_G low so that Case 2 never happens.

Under Case 1, the social welfare is

$$\begin{aligned}&\frac{q}{d}\left[\int_0^{V+E_G+R_S-R_L}(V+R_S-x)\,dx+[d-(V+E_G+R_S-R_L)]\cdot[R_L-E_G]\right]+(1-q)V-qR_L\left[\frac{d-(V+E_G+R_S-R_L)}{d}\right]\\&\quad-qR_S\left[\frac{V+E_G+R_S-R_L}{d}\right]-f_1-f_2(E_0-E_G)\\&=(1-q)V-qE_G-f_1-f_2(E_0-E_G)+\frac{q}{2d}[(V+E_G)^2-(R_L-R_S)^2].\end{aligned}$$

Thus, the social welfare is maximized at $R_S=R_L$. Recall that $f_2(E_0-E_G)$ is a function convex and increasing in E_0-E_G; i.e., $f_2'(E_0-E_G)\ge 0$, $f_2''(E_0-E_G)\ge 0$. As q is small compared to d, for simplicity we assume $f_2''(E_0-E_G)>q/d$ always holds. Thus, the social welfare function is concave in E_G.

Taking the first-order derivative with respect to E and setting it to 0 yields

$$f_2'(E_0 - E_G) = q[1-(V+E_G)/d].$$

Because $f_2'(E_0 - E_G)$ is monotonically increasing, if $f_2'(E_0 - E) > q[1-(V+E)/d]$ for all E on $[0, E_0]$, then $E_G = E_0$. If $f_2'(E_0 - E) < q[1-(V+E)/d]$ for all E on $[0, E_0]$, then $E_G = 0$. Otherwise, social welfare is maximized at E_G, which satisfies the condition above. □

Proof of Proposition 3. We first consider the case $V \le 2qd$. It is easy to verify that $E_0 \le E_R$. By Table 2, the profit under compensation is $(1-q)V - qE + q[V+E]^2/(4d)$ when $E \le E_R$, which is quadratic in E and achieves minimum at $E = 2d - V$. The profit under no compensation is $(1-q)V - qE$ for $E \le E_0$ and $V^2/(4dq)$ for $E > E_0$. For $E \le E_0$, profit is higher under compensation as $q[V+E]^2/(4d) > 0$. For $E_0 \le E \le E_R$, the profit difference is $[(1-q)V - qE][1-(1+q)V + qE/(4dq)]$, which is nonnegative for $E \le E_R$. The proof for $V > 2qd$ is similar and is omitted here. □

Proof of Proposition 4. By Table 2, the difference between the price and the compensation, $V - (1+q)(V+E)/2$, is monotonically decreasing with E. Therefore, the optimal compensation is below the prepaid price (i.e., partial refund) if $E \le (1-q)/(1+q)V$ and above it otherwise. □

Proof of Proposition 5. By Table 3, in the viable region where customers are able to escape, the difference in compensations in general is not 0; i.e., $R_L - R_S \neq 0$. This implies that the profit under self CBR is higher than that under government CBR. A careful examination of Table 3 reveals that $R_L - R_S > 0$ always holds for Case 1. For Case 2, compensation for staying is optimal when $E_1 \le E_l \le E_2$ and $R_L - R_S = (1+\alpha)(V+E_l)/2 - V\alpha/(2q) < 0$.

Table A.1 Summary of Notation

q	Probability of service failure
V	Valuation of the service
D	The damage a customer incurs from consuming the failed service, uniformly distributed on $[0, d]$
D_0	The damage of the marginal consumer who is indifferent between staying and leaving under failure
E	Escape cost (in the model of homogeneous escape cost)
P	Service provider's price
π	Service provider's profit
E_0	Threshold escape cost level, beyond which confinement occurs
E_G	Government-preferred escape cost level
f_1	Fixed cost of lowering the escape cost from E to E_0
f_2	Variable cost for further lowering the escape cost below E_0
R_S	Compensation for customers who stay and consume the failed service
R_L	Compensation for customers who escape the failed service
ΔR	$\Delta R = R_L - R_S$
E_R	Threshold escape cost level under self CBR
	Model of heterogeneous escape costs
E_h	High escape cost of customers who face significant loss from giving up the service
E_l	Low escape cost
ΔE	$\Delta E = E_h - E_l$
α	The proportion of customers who have high escape cost E_h

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