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Reputation and liability in experience goods markets with imperfect monitoring

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ABSTRACT

This paper investigates the interaction of reputation and product liabilities from a new perspective. We introduce a reputation model in an experience good market with imperfect monitoring, in which reputation incentives without product liability are not sufficient for inducing a desired outcome. Even a firm with high market reputation will cheat consumers, and the reputation will eventually collapse. We then introduce two product liabilities into the reputation model: *strict liability* and *negligence rule*. It is shown that under certain conditions, these two liabilities can both improve firms' incentives and final outcomes. What is the best product liability depends on the costs of firms and courts as well as courts' professional level. The paper also sheds light on which liability regime is optimal in this reputational setting.

1. Introduction

Reputation and product liability are two major mechanisms that affect firms' incentives to increase product quality and prevent product harm to consumers. Literature on the interaction of reputation and product liabilities includes Polinsky and Shavell (2010), Cooter and Ulen (2011), Ganuza et al. (2016), Chen et al. (2017), Fong and Liu (2018), Baker and Choi (2018), and so on. Polinsky and Shavell (2010) compared the benefits and costs of product liability, and showed that reputation and product liability are substitutes for each other in improving product quality. Especially, Ganuza et al. (2016) and Baker and Choi (2018) both revealed that there is complementarity between reputation and product liability using a relational contract approach. However, relational contracts are typically long term agreements involving substantial mutual commitment and extensive cooperation and communication between the parties. Indeed, the equilibrium strategy they used has cooperation phases and punishment phases, which needs a high degree of coordination between firm behaviour and consumer beliefs about firm behaviour. In other literature, Chen et al. (2017) and Fong and Liu (2018) studied the interaction of reputation and product liabilities in credence goods markets.

This paper extends the results of Ganuza et al. (2016) and Baker and Choi (2018) to a reputation setting without full commitment, cooperation and communication between the parties. We investigate the impact of liability on firms' incentives to exert high effort to increase product quality in an experience good market with imperfect monitoring. In such a market, a "normal" firm can maintain its reputation and then gain "reputation premiums" by mimicking a "commitment" type.[1] Reputation is regarded as the probability that the firm is commitment-type in consumers' beliefs. The higher the probability, the higher the reputation of the firm. If the probability goes to zero, then the firm's reputation collapses. Imperfect monitoring means that even if consumers find that the product generates a bad outcome, they cannot accurately identify the effort of the firm, which gives the normal firm an opportunity to cheat consumers. By the results of Benabou and Laroque (1992), Mailath and Samuelson (2001), and Cripps et al. (2004), a normal firm will not always exert high effort, even a normal firm with high market reputation will cheat consumers,

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[1] In a reputation model with incomplete information, there are usually two types of firms, "commitment" and "normal". A commitment type always exerts high effort, while a normal type may exert high or low effort.

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and it cannot maintain a permanent reputation. Reputation will eventually collapse.

We then introduce two product liabilities into our reputation model, called *strict liability* and *negligence rule*. We study and discuss the interaction of reputation and these two liabilities. We find that the introduction of these two liabilities may improve firms' incentives and final outcomes under certain conditions. That is, in such a market, strict liability and negligence rule can both force firms to always exert high effort under certain conditions, and then we can get a better outcome than relying on reputation alone. Moreover, what is the best product liability depends on the costs of firms and courts as well as courts' professional level. We give the critical conditions for the application of these two liabilities.

2. The benchmark model

We begin with an infinite time horizon reputation model with imperfect monitoring close to Mailath and Samuelson (2001). We consider a risk-neutral, long-lived firm that produces experience goods. There is a continuum of identical consumers of unit mass. Consumers are short-lived.[2] They purchase an experience good from the firm repeatedly. The experience good generates two utility levels, normalized to 0 and 1. A utility of 1 as a good outcome is denoted by g and a utility of 0 as a bad outcome is denoted by b. The probability of being a good outcome depends on effort level of the firm in each period. There are two possible effort levels, high (H) and low (L), and two types of firms, "commitment" (C) and "normal" (N). A commitment type always exerts high effort, and a normal type may exert high or low effort.

High effort generates a good outcome for consumers with probability ρ_H, and low effort generates a good outcome with probability ρ_L ($0 < \rho_L < \rho_H < 1$). Low effort entails no cost, while high effort incurs a cost of c, where $0 < c < \rho_H - \rho_L$. The latter inequality ensures that the firm always exerting high effort is the socially optimal outcome.[3]

The prior probability for the firm to be commitment at time zero is given by $\phi_0 \in (0, 1]$. In each period, a consumer assigns a probability for the product to induce a good outcome in that period. Each consumer pays his expected utility given that probability. Firm's revenue in a period is increasing in consumers' beliefs over the firm's effort choice in that period, regardless of the true effort choice.

At the beginning of period t, consumers assign a posterior probability ϕ_t to the firm being commitment-type, and have an expected utility p_t from consuming the good. If the firm is normal, it makes an unobserved effort choice, and then receives revenues of p_t, regardless of its type and the realized utility in that period. Consumers, the firm, and the market then observe the realized utility of the good and update beliefs about the type of the firm and their expected utility. Assume that all consumers receive the same realization of utility outcomes, which is public (so that ϕ_t and p_t are identical for all consumers). At the end of the period, the firm and the market both observe the outcome. Moreover, we assume the firm's discount factor is δ.

The normal firm's strategy is assumed to be a Markov strategy, which is a mapping

$$\tau : [0, 1] \to [0, 1],$$

[4] where $\tau(\phi)$ is the probability of high effort when consumers' posterior probability that the firm is commitment-type is ϕ. The commitment type makes no choice, and hence has a trivial strategy.

Consumer behaviour is described by the Markov belief function

$$p : [0, 1] \to [0, 1],$$

where $p(\phi)$ is the probability consumers assign to receive a good outcome, given posterior probability ϕ. Revenues for the firm are then $p(\phi)$.

The posterior probability that the firm is commitment-type is denoted by $\varphi(\phi|x)$ or ϕ_x, given a realized outcome $x \in \{g, b\}$ and a prior probability ϕ.

In a Markov perfect equilibrium, the normal firm maximizes profit, consumers' expectations are correct, and consumers follow Bayes' rule to update their posterior probabilities:

Definition 1. A Markov perfect equilibrium is the triple (τ, p, φ) such that

(a) $\tau(\phi)$ is maximizing for all ϕ,
(b) $p(\phi) = \phi\rho_H + (1-\phi)[\tau(\phi)\rho_H + (1-\tau(\phi))\rho_L]$,
(c) $\varphi(\phi|g) \equiv \phi_g = \frac{\phi\rho_H}{\phi\rho_H + (1-\phi)[\tau(\phi)\rho_H + (1-\tau(\phi))\rho_L]}$,
(d) $\varphi(\phi|b) \equiv \phi_b = \frac{\phi(1-\rho_H)}{\phi(1-\rho_H) + (1-\phi)[\tau(\phi)(1-\rho_H) + (1-\tau(\phi))(1-\rho_L)]}$.

A firm's strategy uniquely determines the equilibrium pricing rule and the equilibrium updating rule that consumers must use if their beliefs are to be correct.

Proposition 1. *In a market without liability rule, the normal firm always exerting high effort is not a Markov perfect equilibrium. Moreover, for any $\phi \in [0, 1)$, we have $\tau(\phi) < 1$ in a Markov perfect equilibrium.*

The reason for this result is that the market is an experience good market with imperfect monitoring. That is, even if consumers find that the product generates a bad outcome, they cannot accurately identify the effort of the firm, which gives the normal firm an opportunity to cheat consumers. Even a normal firm with high market reputation will cheat consumers since the marginal revenue brought by its high effort is less than the marginal cost.

By the results of Benabou and Laroque (1992), Mailath and Samuelson (2001), and Cripps et al. (2004), it is impossible for a normal firm to maintain a permanent reputation in the presence of imperfect monitoring. Consumers will eventually learn about the firm's type, and the equilibrium will converge to the case of complete information (the equilibrium in which a normal firm will always exert low effort and get a revenue of ρ_L in each period). That is, reputation will eventually collapse.

3. Market reputation with product liability

Now we introduce product liability into our reputation model. We assume a court can verify the firm's effort level and impose some degree of product liability after a bad outcome is realized. We consider a family of rules used by the court. After a bad outcome is realized, the firm should pay a forfeit. More specifically, the firm should pay:

(a) αF if there is a bad outcome and the firm exerted high effort, where $\alpha \in [0, 1]$ and F will be determined by the solution.

(b) βF if there is a bad outcome and the firm exerted low effort, where $\beta \geq \alpha$ and $\beta \in [0, 1]$.

[2] This means in each period there is a continuum of new consumers of unit mass, and consumers are myopic. Moreover, no single consumer can affect the future play of the game.

[3] In each period, if the firm exerts high effort, then the expected social welfare is $\rho_H - c$. If it exerts low effort, the expected social welfare is ρ_L.

[4] This game has many equilibria. Some equilibria may not only fail to capture the asset-like features of reputations, but also depend upon an implausible degree of coordination between firm behaviour and consumer beliefs about firm behaviour. We can eliminate these equilibria by requiring behaviour to be Markov.

Thus, every liability rule is a specification (α, β). We consider four product liabilities:

(1) Strict liability: firm must pay F whether it exerted high effort or not, that is, $\alpha = \beta = 1$.

(2) Negligence rule: firm must pay F if and only if it exerted low effort, that is, $\alpha = 0$ and $\beta = 1$.

(3) Negligence rule with errors in determining liability: this liability rule includes the realistic complication that a court could incur two possible errors when determining liability based on the true level of effort exerted by the firm. Type I error implies convicting an "innocent" firm (a firm who exerted high effort), that is, $\alpha > 0$. Type II error takes place when a "guilty" firm (a firm who exerted low effort) is not found liable, that is, $\beta < 1$.

(4) No liability: $\alpha = \beta = 0$.

Next, we will discuss the interaction between these product liabilities and the market reputation in our model.

3.1. Strict liability

Under strict liability, we assume that the cost of implementing strict liability is c_1 in each period. Then, if strict liability is better than no liability, we need $\rho_H - c - c_1 > \rho_L$. We assume the average social welfare function is:

$$W = \lim_{n\to\infty} \frac{1}{n} \sum_{t=1}^{n} W_t,$$

where W_t is the expected social welfare in period t $(t = 1, \ldots)$.[5] Then we have the following proposition.

Proposition 2. *In a market with strict liability, if* $c \le \frac{\rho_H(\rho_H-\rho_L)}{1-\rho_L}$ *and* $\rho_H - c - c_1 > \rho_L$, *then* $F = \frac{c}{\rho_H-\rho_L}$. *In this case, strict liability is better than no liability, and we can get a Markov perfect equilibrium in which the normal firm always exerts high effort, and consumers always pay* ρ_H.

When the two conditions of Proposition 2 are satisfied, we can get a better outcome under strict liability than no liability. If the condition $c \le \frac{\rho_H(\rho_H-\rho_L)}{1-\rho_L}$ is not satisfied, we cannot get the desired equilibrium. A normal firm will still choose low effort in some periods, and it cannot maintain a permanent reputation. Reputation will still collapse eventually. This means we cannot obtain a better outcome than no liability, but have to pay an extra cost to implement the strict liability. (That is, no liability is better than the strict liability.)[6] If the condition $\rho_H - c - c_1 > \rho_L$ is not satisfied, then the cost of implementing strict liability is too high so that it is better for the society to choose no liability rather than strict liability.

3.2. Negligence rule

Now we discuss negligence rule. We only consider negligence rule with errors in determining liability. Negligence rule without errors can be seen as a special case. We assume that the cost of implementing negligence rule is c_2 $(c_2 > c_1)$[7] in each period. Then, if negligence rule is better than no liability, we need $\rho_H - c - c_2 > \rho_L$. We have the following proposition.

Proposition 3. *In a market with negligence rule, if* $c \le \frac{\rho_H[\beta(1-\rho_L)-\alpha(1-\rho_H)]}{\beta(1-\rho_L)}$ *and* $\rho_H - c - c_2 > \rho_L$, *then* $F = \frac{c}{\beta(1-\rho_L)-\alpha(1-\rho_H)}$. *In this case, negligence rule is better than no liability, and we can get a Markov perfect equilibrium in which the normal firm always exerts high effort, and consumers always pay* ρ_H.

Like Proposition 2, Proposition 3 also requires satisfying the two conditions $c \le \frac{\rho_H[\beta(1-\rho_L)-\alpha(1-\rho_H)]}{\beta(1-\rho_L)}$ and $\rho_H - c - c_2 > \rho_L$. Otherwise, negligence rule cannot yield a better outcome than no liability.

Propositions 2–3 also give the critical conditions for determining which liability regime is the optimal in this reputational setting. If $c \le \frac{\rho_H(\rho_H-\rho_L)}{1-\rho_L}$ and $\rho_H - c - c_1 > \rho_L$, then strict liability is the best product liability since the cost of strict liability is less than that of negligence rule. If $\frac{\rho_H(\rho_H-\rho_L)}{1-\rho_L} < c \le \frac{\rho_H[\beta(1-\rho_L)-\alpha(1-\rho_H)]}{\beta(1-\rho_L)}$ and $\rho_H - c - c_2 > \rho_L$, then negligence rule is the best product liability since we cannot obtain the desired equilibrium by strict liability. Otherwise, no liability is the best.

3.3. Discussions

The economic intuition behind this paper is clear. In an experience good market with imperfect monitoring under no liability, even if consumers find that the product generates a bad outcome, they cannot accurately identify the effort of the firm, which gives the normal firm an opportunity to cheat consumers. Then a normal firm will cheat consumers if the marginal revenue brought by its high effort is less than the marginal cost. Eventually, consumers will learn the firm's type from the outcomes in the past if the firm does not always exert high effort, and then reputation will collapse.

Product liabilities can help eliminate the gap between the firm's marginal cost and the marginal revenue it earns through high effort, and can force the normal firm to always exert high effort when the firm's individually rational constraint is satisfied. Then, we can get an equilibrium in which the normal firm always exerts high effort, and consumers always pay ρ_H. Since negligence rule often requires the court to have higher professional verifying ability than that under strict liability, strict liability often incurs a lower implementation cost than negligence rule. Thus, if we can get the desired equilibrium (that is, eliminating the above gap and satisfying the firm's individually rational constraint at the same time), and the cost of implementing strict liability is not so high that it is better for the society to use no liability, strict liability is the best.[8] If we cannot get a desired equilibrium by strict liability, and the conditions of Proposition 3 are satisfied, then negligence rule is the optimal since we can get a desired equilibrium only by negligence rule.

Otherwise, no liability scheme should be adopted because the costs of implementing product liabilities may be too high so that it is better for the society to use no liability, or because we cannot get the desired equilibrium. In the latter case, the firm's cost to exert high effort is too high, so that we cannot eliminate the above gap and satisfy the firm's individually rational constraint at the same time under any product liability. A normal firm will still choose low effort in some periods, and it cannot maintain a permanent reputation. Reputation will still collapse eventually.

[5] In this paper, we use average social welfare function to compare different product liabilities. The average social welfare under no liability is ρ_L since reputation will eventually collapse.

[6] If $c > \frac{\rho_H(\rho_H-\rho_L)}{1-\rho_L}$, then we should set a forfeit $F < \frac{c}{\rho_H-\rho_L}$ to satisfy the firm's individually rational constraint. Similar to Proposition 1, for any $\phi \in [0, 1)$, we have $\tau(\phi) < 1$ in a Markov perfect equilibrium. Then, reputation will still collapse eventually, and the average social welfare is $\rho_L - c_1 < \rho_L$.

[7] Considering that negligence rule often requires the court to have higher professional verifying ability than that under strict liability, it is reasonable to assume that the cost of negligence rule is higher than that of strict liability.

[8] Ganuza et al. (2016) showed that negligence rule reduces reputational costs more intensely than strict liability. Their result is based on the subgame-perfect equilibrium strategy inspired by Green and Porter (1984). We consider Markov strategy in this paper. From our perspective, if we can get the desired equilibrium, then strict liability is better than negligence rule since it has a lower implementation cost.

That is, we cannot get a better outcome under any product liability than no liability, but we have to pay an extra cost to implement these liabilities.

Therefore, in such a market, reputation may not fully substitute for product liabilities from our perspective in this paper. When strict liability or negligence rule is the best product liability, we can obtain a better outcome under these liabilities than relying on reputation alone. In this case, reputation alone cannot encourage normal firms to always exert high effort, and only the one with product liability generates a desired outcome. Hence reputation cannot fully substitute for product liabilities for the problem under discussion in this paper.

4. Conclusion

In experience goods markets with imperfect monitoring, market reputation alone will fail. Even a normal firm with high market reputation will cheat consumers, and reputation will collapse eventually. The introduction of product liabilities can help solve this problem. Under certain conditions, strict liability and negligence rule can both be better than no liability. What is the best product liability depends on the costs of firms and courts as well as courts' professional level. In reality, all these factors need to be taken into consideration to determine the most appropriate product liability.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Appendix. Proofs

Proof of Proposition 1. By the definition of Markov perfect equilibrium, for any $\phi \in (0,1)$ and $0 \le \tau(\phi) < 1$, we have:

$$\phi_g = \frac{\phi\rho_H}{\phi\rho_H + (1-\phi)[\tau(\phi)\rho_H + (1-\tau(\phi))\rho_L]} > \frac{\phi\rho_H}{\phi\rho_H + (1-\phi)\rho_H} = \phi,$$

and

$$\phi_b = \frac{\phi(1-\rho_H)}{\phi(1-\rho_H) + (1-\phi)[\tau(\phi)(1-\rho_H) + (1-\tau(\phi))(1-\rho_L)]} < \frac{\phi(1-\rho_H)}{\phi(1-\rho_H) + (1-\phi)(1-\rho_H)} = \phi.$$

Thus, $\phi_b < \phi < \phi_g$.

If $\phi = 1$, then $\phi_g = \phi_b = \phi = 1$.

If $\phi = 0$, then $\phi_g = \phi_b = \phi = 0$. The only Markov perfect equilibrium is that the normal firm always exerts low effort, and consumers always pay ρ_L. That is, $\tau(0) = 0$ in a Markov perfect equilibrium.

Next we only need to show that for any $\phi \in (0,1)$, $\tau(\phi) < 1$ in a Markov perfect equilibrium. Suppose by way of contradiction that there is a $\widehat{\phi} \in (0,1)$ such that $\tau(\widehat{\phi}) = 1$, then $\widehat{\phi}_g = \widehat{\phi}_b = \widehat{\phi}$.

Given $\phi \in (0,1)$, the value function of the normal firm in a Markov perfect equilibrium is:

$$V_N^e(\phi) = p(\phi) - c\tau(\phi) + \delta\{[\tau(\phi)\rho_H + (1-\tau(\phi))\rho_L]V_N^e(\phi_g) + [\tau(\phi)(1-\rho_H) + (1-\tau(\phi))(1-\rho_L)]V_N^e(\phi_b)\}.$$

The payoff from exerting low effort and thereafter adhering to the equilibrium strategy is:

$$V_N(\phi, L) = p(\phi) + \delta[\rho_L V_N^e(\phi_g) + (1-\rho_L)V_N^e(\phi_b)].$$

Since $\tau(\widehat{\phi}) = 1$, we have

$$V_N^e(\widehat{\phi}) = p(\widehat{\phi}) - c + \delta[\rho_H V_N^e(\widehat{\phi}_g) + (1-\rho_H)V_N^e(\widehat{\phi}_b)].$$

In a Markov perfect equilibrium, $\tau(\widehat{\phi}) = 1$ means $V_N^e(\widehat{\phi}) - V_N(\widehat{\phi}, L) = \delta(\rho_H - \rho_L)[V_N^e(\widehat{\phi}_g) - V_N^e(\widehat{\phi}_b)] - c \ge 0$. Since $\widehat{\phi}_g = \widehat{\phi}_b = \widehat{\phi}$, then $V_N^e(\widehat{\phi}_g) - V_N^e(\widehat{\phi}_b) = 0$. Thus $V_N^e(\widehat{\phi}) - V_N(\widehat{\phi}, L) = -c < 0$, a contradiction. Hence for any $\phi \in [0,1)$, $\tau(\phi) < 1$ in a Markov perfect equilibrium. This means the normal firm always exerting high effort is not a Markov perfect equilibrium.

Proof of Proposition 2. Under strict liability, given ϕ, the value function of the normal firm in a Markov perfect equilibrium is:

$$V_{N1}^e(\phi) = p(\phi) - c\tau(\phi) - [\tau(\phi)(1-\rho_H) + (1-\tau(\phi))(1-\rho_L)]F + \delta\{[\tau(\phi)\rho_H + (1-\tau(\phi))\rho_L]V_{N1}^e(\phi_g) + [\tau(\phi)(1-\rho_H) + (1-\tau(\phi))(1-\rho_L)]V_{N1}^e(\phi_b)\}.$$

The payoff from exerting low effort and thereafter adhering to the equilibrium strategy is:

$$V_{N1}(\phi, L) = p(\phi) - (1-\rho_L)F + \delta[\rho_L V_{N1}^e(\phi_g) + (1-\rho_L)V_{N1}^e(\phi_b)].$$

Suppose that the normal firm always exerting high effort is a Markov perfect equilibrium. That is, for any $\phi \in [0,1)$, we have $\tau(\phi) = 1$. Then, for any $\phi \in [0,1)$, we have $\phi_g = \phi_b = \phi$, and

$$V_{N1}^e(\phi) = p(\phi) - c - (1-\rho_H)F + \delta[\rho_H V_{N1}^e(\phi_g) + (1-\rho_H)V_{N1}^e(\phi_b)].$$

Since the normal firm always exerting high effort is a Markov perfect equilibrium, then for any $\phi \in [0,1)$, we have

$$V_{N1}^e(\phi) - V_{N1}(\phi, L) = \delta(\rho_H - \rho_L)[V_{N1}^e(\phi_g) - V_{N1}^e(\phi_b)] + (\rho_H - \rho_L)F - c \ge 0. \quad (1)$$

$\phi_g = \phi_b = \phi$ means $V_{N1}^e(\phi_g) = V_{N1}^e(\phi_b)$. Then, we must have $(\rho_H - \rho_L)F - c \ge 0$.

If we want (1) to be always satisfied, we need to set $F = \frac{c}{\rho_H - \rho_L}$.

Moreover, if we want to get a Markov perfect equilibrium in which the normal firm always exerts high effort, and consumers always pay ρ_H, we also need to satisfy the firm's individually rational constraint. This means

$$\rho_H - c - (1-\rho_H)F = \rho_H - c - (1-\rho_H)\frac{c}{\rho_H - \rho_L} \ge 0.$$

That is, $c \le \frac{\rho_H(\rho_H - \rho_L)}{1-\rho_L}$.

In this case, the average social welfare is $\rho_H - c - c_1$. As mentioned above, if strict liability is better than no liability, we also need $\rho_H - c - c_1 > \rho_L$.

Summarizing the above discussion, the proof is completed.

Proof of Proposition 3. Under negligence rule, given ϕ, the value function of the normal firm in a Markov perfect equilibrium is:

$$V_{N2}^e(\phi) = p(\phi) - c\tau(\phi) - [\alpha\tau(\phi) + \beta(1-\tau(\phi))][\tau(\phi)(1-\rho_H) + (1-\tau(\phi))(1-\rho_L)]F + \delta\{[\tau(\phi)\rho_H + (1-\tau(\phi))\rho_L]V_{N2}^e(\phi_g) + [\tau(\phi)(1-\rho_H) + (1-\tau(\phi))(1-\rho_L)]V_{N2}^e(\phi_b)\}.$$

The payoff from exerting low effort and thereafter adhering to the equilibrium strategy is:

$$V_{N2}(\phi, L) = p(\phi) - \beta(1-\rho_L)F + \delta[\rho_L V_{N2}^e(\phi_g) + (1-\rho_L)V_{N2}^e(\phi_b)].$$

Suppose that the normal firm always exerting high effort is a Markov perfect equilibrium. That is, for any $\phi \in [0, 1)$, we have $\tau(\phi) = 1$. Then, for any $\phi \in [0, 1)$, we have $\phi_g = \phi_b = \phi$, and

$$V^e_{N2}(\phi) = p(\phi) - c - \alpha(1 - \rho_H)F + \delta[\rho_H V^e_{N2}(\phi_g) + (1 - \rho_H)V^e_{N2}(\phi_b)].$$

Since the normal firm always exerting high effort is a Markov perfect equilibrium, then for any $\phi \in [0, 1)$, we have

$$V^e_{N2}(\phi) - V_{N2}(\phi, L) = \delta(\rho_H - \rho_L)[V^e_{N2}(\phi_g) - V^e_{N2}(\phi_b)] + [\beta(1 - \rho_L) - \alpha(1 - \rho_H)]F - c \geq 0. \quad (2)$$

$\phi_g = \phi_b = \phi$ means $V^e_{N2}(\phi_g) = V^e_{N2}(\phi_b)$. Then, we must have $[\beta(1 - \rho_L) - \alpha(1 - \rho_H)]F - c \geq 0$.

If we want (2) to be always satisfied, we need to set $F = \frac{c}{\beta(1-\rho_L)-\alpha(1-\rho_H)}$.

Moreover, if we want to get a Markov perfect equilibrium in which the normal firm always exerts high effort, and consumers always pay ρ_H, we also need to satisfy the firm's individually rational constraint. This means

$$\rho_H - c - \alpha(1 - \rho_H)F = \rho_H - c - \alpha(1 - \rho_H)\frac{c}{\beta(1 - \rho_L) - \alpha(1 - \rho_H)} \geq 0.$$

That is, $c \leq \frac{\rho_H[\beta(1-\rho_L)-\alpha(1-\rho_H)]}{\beta(1-\rho_L)}$.

In this case, the average social welfare is $\rho_H - c - c_2$. As mentioned above, if negligence rule is better than no liability, we also need $\rho_H - c - c_2 > \rho_L$.

Summarizing the above discussion, the proof is completed.

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