ECONSTOR
Make Your Publications Visible.

A Service of
ZBW
Leibniz-Informationszentrum Wirtschaft
Leibniz Information Centre for Economics

Kim, KyungMin

Article

The Coase conjecture with incomplete information on the monopolist's commitment

Theoretical Economics

Provided in Cooperation with:
The Econometric Society

Suggested Citation: Kim, KyungMin (2009) : The Coase conjecture with incomplete information on the monopolist's commitment, Theoretical Economics, ISSN 1555-7561, The Econometric Society, New York, NY, Vol. 4, Iss. 1, pp. 17-44

This Version is available at:
https://hdl.handle.net/10419/150123

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

https://creativecommons.org/licenses/by-nc/3.0

WWW.ECONSTOR.EU

Mitglied der Leibniz-Gemeinschaft

Theoretical Economics 4 (2009), 17–44 1555-7561/20090017

The Coase conjecture with incomplete information on the monopolist's commitment

KyungMin Kim
Department of Economics, University of Pennsylvania

A key to the Coase conjecture is the monopolist's inability to commit to a price, which leads consumers to believe that a high current price will be followed by low future prices. This paper studies the robustness of the Coase conjecture with respect to these beliefs of consumers. In particular, there is uncertainty over whether the monopolist is committed to a price (i.e. she may be a commitment type). Consequently, consumers are no longer certain that the price will change over time. I consider two kinds of commitment types. A behavioral commitment type charges an exogenously given price, while the rational commitment type optimally chooses a price. I show that the Coase conjecture is robust with regard to uncertainty over the monopolist's commitment. When the probability of behavioral types is sufficiently small, as in the original Coase conjecture, the monopolist earns the competitive profit. When the probability of behavioral types is positive, unlike in the original Coase conjecture, there is positive delay. But the delay disappears as the probability approaches zero. When the commitment type is rational, unless the probability of the commitment type is sufficiently high, both normal and committed monopolists charge the competitive price, and thus there is no delay.

Keywords. Coase conjecture, reputational bargaining, rational commitment.
JEL classification. C72, C78, D82.

1. Introduction

A durable goods monopolist has an incentive to lower her price over time to make further sales. But consumers, anticipating lower prices in the future, delay purchases unless the monopolist offers a reasonable price. When consumers are patient, the monopolist charges the competitive price immediately, and thus there is no delay. In a dynamic environment, the presence of monopoly creates no distortion in allocations. This is the well-known *Coase conjecture*.

KyungMin Kim: kim37@econ.upenn.edu

This is a revised version of my third-year paper submitted to the University of Pennsylvania. I am deeply indebted to my advisors, George Mailath and Andrew Postlewaite, for their constant support and guidance. I thank Barton Lipman and two anonymous referees for insightful and detailed suggestions that have led to substantial improvements in the paper. I am also grateful to Aureo de Paula, Jan Eeckhout, Eduardo Faingold, Karam Kang, Soojin Kim, Phillip Kircher, Jing Li, Steven Matthews, Antonio Merlo, Jonathan Pogach, Mark Satterthwaite, and seminar participants in the Penn economic theory workshop and lunch club for many helpful comments.

Copyright © 2009 KyungMin Kim. Licensed under the Creative Commons Attribution-NonCommercial License 3.0. Available at http://econtheory.org.

A key to this result is that consumers believe that the price is falling toward the competitive price sufficiently quickly. These beliefs are generated by a lack of commitment by the monopolist to price and make consumers reluctant to accept a high price. In contrast, if consumers could be convinced that the price would not change, they would accept a high price immediately. The monopolist would charge the static monopoly price and earn the static monopoly profit.

This paper studies the robustness of the Coase conjecture with respect to consumers' beliefs about a lack of commitment by the monopolist to price. I perturb the standard durable goods monopoly environment so that consumers are no longer certain that the price will change over time. Formally, I introduce incomplete information on the monopolist's commitment to price. A *commitment type* of the monopolist is one who is committed to a price, that is, who cannot adjust the price over time. In the presence of commitment types, consumers face non-trivial decision problems. Without uncertainty, they are certain that the price will drop soon. With uncertainty, the price may not fall, in which case consumers prefer an early purchase. Consumers' decision problems are complicated more by the fact that the normal monopolist has an incentive to build a reputation as a commitment type.

I consider two kinds of commitment types. A *behavioral commitment* type (in short, behavioral type) has no payoff concerns and always offers an exogenously given price. The *rational commitment* type optimally chooses a price, knowing that she cannot adjust it later. The former type corresponds to a simple commitment type in the reputation literature, while the latter type is new.[1] The introduction of behavioral types highlights the normal type's incentive to build a reputation as a commitment type, while studying the model with the rational commitment type is of interest for the following reasons. First, the rational commitment type is the monopolist who, if her type is known to consumers, charges the static monopoly price and achieves the static monopoly profit. In this sense, the rational commitment type can be thought of as the monopolist with commitment power, whose behavior has long been studied in the literature. Second, the rational commitment type provides a way to endogenize the behavior of the commitment type. It captures the following beliefs of consumers: if the monopolist is committed to a price, the price maximizes her expected payoff conditional on her not being able to adjust the price. Last, some institutional features may induce bargainers to behave like the rational commitment type. For instance, a monopolist may hire a salesman without giving him the authority to bargain over the price. In addition, in wage bargaining (international trade negotiation), the firm (opposite party) may be uncertain over the union leader's (bargaining official's) level of delegation from the rank and file (government or voters).

I find that the Coase conjecture is robust with regard to uncertainty over the monopolist's commitment. I distinguish between two implications of the Coase conjecture: (1) the monopolist earns the competitive profit (profit implication), and (2) there is no delay (efficiency implication). While these two are indistinguishable in the original Coase conjecture, the current setting shows that they are distinct.

[1] To the best of my knowledge, Kambe (1999) is the only paper that considers this type and studies a related strategic problem in a dynamic environment.

When the probability of behavioral types is small, the normal monopolist charges more than the competitive price, but earns only the competitive profit. Therefore, the profit implication of the Coase conjecture is robust in a strong sense, while the efficiency result (no delay) does not hold whenever the probability of behavioral types is positive. Since delay becomes negligible as the probability of behavioral types vanishes, the efficiency implication is also robust, though not as strong as the profit implication. To see how this happens, suppose there is a single behavioral type who charges more than the competitive price. The normal monopolist offers the same price because she has an incentive to build a reputation as the commitment type. When the probability of the behavioral type is small, consumers believe that the price is likely to drop in the future and, therefore, delay purchases. If the seller keeps offering the high price, some consumers accept the price, but a majority of consumers wait, hoping for the price to fall. When the probability of the behavioral type is small and consequently consumers have a strong incentive to wait, the loss of profit from delayed purchases completely offsets the gain from selling to some consumers at the high price.[2] The conclusions carry over to the case with multiple behavioral types. This is because in equilibrium consumers' beliefs over the seller's type are determined so that the normal monopolist is indifferent between all prices she may offer. This ensures that when the unconditional probability of behavioral types is small, the probability of the behavioral type (consumers' beliefs over the seller's type) conditional on a price is small uniformly over all prices.

When the commitment type is rational, unless the probability of the commitment type is sufficiently high, both the normal and committed monopolists offer the competitive price immediately and earn the competitive profit. Therefore, both implications of the Coase conjecture are robust in a strong sense. Though the rational commitment type chooses a price, conditional on her choosing any given price the situation amounts to the one with a single behavioral type. Consequently, when the probability of the commitment type is small, both the rational commitment type and the normal type earn only the competitive profit. The reason why the efficiency implication is also strongly robust is as follows. A monopolist generally has an incentive to avoid the delay cost by lowering the price. This incentive is particularly large to the rational commitment type who must endure all delay cost. When the rational commitment type expects no more than the competitive profit, it is optimal for her to offer the competitive price. Then the normal type has no choice but to offer the competitive price as well.

Stokey (1981), Bulow (1982), Fudenberg et al. (1985), Gul et al. (1986), and Ausubel and Deneckere (1989) are classic papers on the Coase conjecture. They are concerned with the conjecture itself, while the interest of this paper is its robustness. McAfee and Wiseman (2008) consider the Coase conjecture with a capacity constraint. They show that, no matter how small is the capacity cost, the monopolist achieves at least 29.8%

[2]Another way to understand this result is to consider the problem in the reputation context. The normal monopolist establishes a reputation as the commitment type, while consumers pretend to have lower valuations. Since this is a two-sided reputation game, who is better off depends on each player's degree of uncertainty over the opponent's type. The monopolist is better off only when the possibility of commitment (the seller's bargaining power) outweighs the natural tendency of consumers to pretend to have lower valuations (the buyer's bargaining power).

of the static monopoly profit, and thus the Coase conjecture does not hold. The crucial idea is that, with a capacity constraint that is observable to consumers, the monopolist can effectively commit to quantity instead of price.

Another branch of the literature upon which this paper builds studies reputational bargaining. Chatterjee and Samuelson (1988) study a bilateral bargaining game with two-sided incomplete information over fundamentals (the buyer's valuation and the seller's production cost) and characterize the equilibrium, which features a war of attrition.[3] Myerson (1991) was the first to introduce into the bargaining context the commitment (irrational or obstinate) type, which had been widely studied in repeated games following the seminal works of Kreps and Wilson (1982) and Milgrom and Roberts (1982). He shows that in an alternating offer bargaining game with one-sided incomplete information, as bargaining friction becomes negligible, agreement occurs immediately on the outcome that would prevail when a party is known to be stubborn. Abreu and Gul (2000) generalize Myerson's insight and study a two-sided reputational bargaining game. In their setting, there are multiple behavioral types and each normal type chooses a behavioral type to mimic. They demonstrate that the equilibrium in continuous time is unique and has a war-of-attrition structure. Furthermore, they show that the equilibrium in discrete time converges to the unique equilibrium in continuous time, independent of the exact bargaining protocol so long as both players make offers frequently. Kambe (1999) considers the setting in which players become stubborn with positive probability after making their initial demands. He also analyzes the case in which players know their types before making their demands. The second case is analogous to the rational commitment type in this paper. Compte and Jehiel (2002) investigate the role of outside options in the reputational bargaining environment. They show that outside options may cancel out the effect of obstinacy, in the sense that players reveal their rationality as soon as possible.

The closest paper to this one is Inderst (2005). He studies the case in which there is a single behavioral type. This case serves as the building block in this paper, but has the following limitations. First, with a single behavioral type, all prices other than the competitive price and the price offered by the behavioral type are irrelevant. My model with multiple behavioral types endogenizes the set of equilibrium prices and yields results that do not rely on the specific price offer. Second, in the model with a single behavioral type, the probability that the seller is the commitment type conditional on the price offer is equal to its unconditional probability, which is exogenously given. My model with multiple behavioral types endogenizes the conditional probabilities and allows me to address an interesting question in the presence of commitment types: which price is more credible? Do consumers believe that the price is more likely to drop when the initial price is higher or lower? Last, it turns out that many equilibria in the game with the rational commitment type are not robust to the introduction of a small probability of multiple behavioral types. This equilibrium selection is not possible with a single behavioral type.

[3] A war-of-attrition structure is assumed in Chatterjee and Samuelson (1987), while it is derived as an equilibrium property in their 1988 paper.

The remainder of the paper is organized as follows. The next section studies the game with a single behavioral type. In addition, I provide some definitions and facts that are useful in the subsequent sections. Sections 3 and 4 examine the game with multiple behavioral types and the game with the rational commitment type, respectively. I conclude by discussing some relevant issues in Section 5. I also analyze the full-fledged game in which both behavioral types and the rational commitment type are active. The full-fledged game is necessary for the equilibrium selection in Section 4, but rather complicated. I provide an intuition for the selection in Section 4 and defer the analysis of the full-fledged game to the Appendix.

2. Single behavioral type: the building block

2.1 *Setup*

The basic setup is the standard durable goods monopoly problem. This problem is identical to the bilateral sequential bargaining game in which the buyer has private information about his valuation and the seller makes all the offers. The seller's production cost is known and normalized to 0. The buyer's valuation, v, is drawn from a distribution function F with support $[\underline{v}, \overline{v}]$, $0 < \underline{v} < \overline{v} < \infty$.[4] The distribution function F has a positive and continuously differentiable density f. At each date $t \geq 0$, the seller makes an offer and the buyer decides whether to accept the offer. The common discount factor is $\delta = e^{-r\Delta}$, where Δ is the offer interval and r is the discount rate. This game has a unique sequential equilibrium in which the price falls to $\underline{v}$ in a finite time (see Fudenberg et al. 1985 or Gul et al. 1986). As δ approaches 1, the seller offers a price close to $\underline{v}$ and delay disappears in the limit.

I study a perturbation of this game in which the seller is committed to a price $p \in (\underline{v}, \overline{v})$ with probability μ. With the complementary probability, the seller is the same type as in the original game (the normal type). For analytical tractability, I focus on the continuous-time game. In continuous time, the Coasian dynamics force the seller to immediately lower the price to $\underline{v}$ in case her type is revealed to be normal. Since any price revision reveals the seller's type to be normal, I can assume that at each time and history, the normal type has only two options: continuing to offer the same price as the commitment type and offering the competitive price, $\underline{v}$. For completeness, I assume that once the seller offers $\underline{v}$, she keeps offering $\underline{v}$ after any history. For the convergence of the discrete-time game to the continuous-time game, see Inderst (2005).

2.2 *Characterization*

To understand the equilibrium structure, suppose there is a completely separating equilibrium. In such an equilibrium, the buyer accepts p immediately whenever his

[4]The "gap" assumption $\underline{v} > 0$ makes the seller immediately lower the price to $\underline{v}$ once the buyer's valuation is known to be close to $\underline{v}$. With no gap ($\underline{v} = 0$), the Coase conjecture may not hold (see Ausubel and Deneckere 1989). The gap assumption plays another role in my model, which is to make the normal type exhaust her reputation. The latter role is clarified in the last section, when I examine the limit equilibrium as $\underline{v} \to 0$.

valuation is higher than p. Since the normal type achieves only $\underline{v}$, it is a profitable deviation for the normal type to offer p first and lower to $\underline{v}$ an instant later. Now suppose there is a completely pooling equilibrium. The buyer again accepts p immediately whenever his valuation is higher than p. Then the normal type lowers the price to $\underline{v}$ an instant later. Therefore, as is common in many reputation games, the normal type plays a mixed strategy in equilibrium.

Characterizing equilibrium in this type of reputation game is difficult in general. Abreu and Gul (2000), however, show that the equilibrium analysis is tractable in the bargaining context. Their analysis builds on the following two observations. First, once a party is revealed to be normal, the Coasian dynamics force him to accept the opponent's demand immediately in continuous time. Second, given the first observation, the only strategic issue is to find the optimal concession times for the players to reveal their rationality, and the underlying structure of this concession game is a war of attrition.

Though Abreu and Gul study a variant of the Rubinstein bargaining game, this paper and their paper have similar equilibrium structures. Indeed, if the buyer's valuation is drawn from a binary distribution in my problem, the equilibrium characterization is straightforward from Abreu and Gul. Given a price higher than the low valuation, the normal type seller and the high valuation buyer mix between conceding and waiting over a time interval. Their concession probabilities are determined so that the opponent is indifferent between conceding and waiting at each time.

With a continuum of buyer valuations, the analysis is not immediate from Abreu and Gul. Before presenting the results, I note that this extension is different from an extension to the case with multiple behavioral types. With multiple behavioral types, an additional issue is which behavioral type each player chooses to mimic. Conditional on those choices, the game reduces to the one with a single behavioral type. With a continuum of buyer valuations, a different type of war of attrition arises.

An equilibrium is characterized by (G_S, τ) where $G_S : \mathbb{R}_+ \to [0,1]$ is the seller's unconditional concession probability distribution and $\tau : [\underline{v}, \overline{v}] \to \mathbb{R}_+ \cup \{\infty\}$ is the buyer's concession function. The number $G_S(t)$ is the cumulative probability that the seller concedes (offers $\underline{v}$) by time t, conditional on the buyer not having accepted the previous offers. The number $\tau(v)$ is the optimal concession time of the type v buyer, conditional on the seller not having lowered the price. Since the commitment type seller and the buyer with a valuation lower than p never concede, $G_S(t) \leq 1-\mu, \forall t$ and $\tau(v) = \infty, \forall v < p$. In addition, define $G_B : \mathbb{R}_+ \to [0,1]$ by $G_B(t) = \Pr\{v : \tau(v) \leq t\}$. The function G_B is the buyer's unconditional concession probability distribution.

The following measure can be interpreted as the buyer's bargaining power and plays an important role in this paper. Given a distribution function F and $p \in [\underline{v}, \overline{v}]$, let

$$\phi(F,p) = \exp\left(-\frac{1}{\underline{v}}\int_p^{\overline{v}} \frac{(v-p)f(v)}{F(v)}\,dv\right).$$

This is one way to measure how left-skewed the distribution is relative to p. If F first-

order stochastically dominates F', then $\phi(F,p) \leq \phi(F',p)$.[5] Intuitively, the more likely the buyer has a valuation lower than p, the more easily he can pretend to have a valuation lower than p, and consequently, the stronger his bargaining power. The function ϕ is strictly increasing in p because the buyer has a greater incentive to wait when facing a higher price.

The characterization results are summarized in the following proposition, which is a rewriting of Proposition 1 in Inderst (2005).

Proposition 1. *There exists a unique sequential equilibrium* (G_S, τ)*, which is characterized by*

$$\tau(v) = \begin{cases} 0 & \text{if } v > F^{-1}(c_B) \\ -\dfrac{p-\underline{v}}{\underline{v}r} \ln\left(\dfrac{F(v)}{c_B}\right) & \text{if } p \leq v \leq F^{-1}(c_B) \\ \infty & \text{if } v < p \end{cases}$$

$$G_B(t) = \begin{cases} 1 - c_B \exp\left(-\frac{\underline{v}}{p-\underline{v}} r t\right) & \text{if } t \leq -\frac{p-\underline{v}}{\underline{v}r} \ln\left(\frac{F(p)}{c_B}\right) \\ 1 - F(p) & \text{otherwise} \end{cases}$$

$$G_S(t) = \min\left\{1 - \mu \exp\left(\frac{1}{\underline{v}} \int_p^{F^{-1}\left(c_B \exp\left\{-\frac{\underline{v}}{p} r t\right\}\right)} \frac{(v-p)f(v)}{F(v)}\, dv\right), 1-\mu\right\},$$

where $c_B = 1$ *if* $\mu \leq \phi(F,p)$ *and*

$$\frac{1}{\underline{v}} \int_p^{F^{-1}(c_B)} \frac{(v-p)f(v)}{F(v)}\, dv + \ln\mu = 0 \quad \text{if } \mu > \phi(F,p).$$

The equilibrium changes qualitatively at $\mu = \phi(F,p)$. If $\mu > \phi(F,p)$, then the buyer concedes (accepts the offer p) with positive probability at date 0. If $\mu < \phi(F,p)$, then the seller concedes (offers $\underline{v}$) with positive probability at date 0. If $\mu = \phi(F,p)$, then no player immediately concedes with positive probability.

I provide the idea of the proof, highlighting similarities and differences between the two-type case (Abreu and Gul) and the continuum type case (Inderst and this paper).

As in Abreu and Gul, the normal type randomizes over a time interval. Therefore, she is indifferent between waiting and conceding at time t such that $0 < G_S(t) < 1-\mu$. From this indifference,

$$r\underline{v} = \frac{dG_B(t)/dt}{1-G_B(t)}(p-\underline{v}).$$

The left-hand side is the marginal cost of waiting an instant more, while the right-hand side is the corresponding marginal benefit. The latter consists of the conditional concession rate of the buyer at time t and the seller's additional benefit by selling at p

[5]Notice that

$$\phi(F,p) = \exp\left(-\frac{1}{\underline{v}} \int_p^{\overline{v}} \frac{(v-p)f(v)}{F(v)}\, dv\right) = \exp\left(\frac{1}{\underline{v}} \int_p^{\overline{v}} \ln F(v)\, dv\right).$$

Since $F(v) \leq F'(v)$ for all v, $\phi(F,p) \leq \phi(F',p)$.

instead of $\underline{v}$. This ordinary differential equation has a closed-form solution, $G_B(t) = 1 - c_B \exp(-\underline{v} r t/(p-\underline{v}))$ where $c_B \in [F(p), 1]$ is a constant.

Unlike in Abreu and Gul, each buyer type has his own optimal concession time. Since $\tau(v)$ is the optimal concession time of the type v buyer,

$$r(v-p) = \frac{dG_S(\tau(v))/dt}{1-G_S(\tau(v))}(p-\underline{v}) \text{ for } v > p \text{ and } \tau(v) > 0.$$

That is, the marginal cost (the left-hand side) and the marginal benefit (the right-hand side) of delay for the type v buyer are equated at his optimal concession time, $\tau(v)$. By the skimming property ($v > v' \Rightarrow \tau(v) < \tau(v')$),[6] τ^{-1} is well-defined in the interior. Then,

$$r(\tau^{-1}(t)-p) = \frac{dG_S(t)/dt}{1-G_S(t)}(p-\underline{v}).$$

The solution to this ordinary differential equation is

$$G_S(t) = 1 - c_S \exp\left(-\int_0^t \frac{r(\tau^{-1}(s)-p)}{p-\underline{v}}\, ds\right),$$

where $c_S \in [\mu, 1]$ is another constant. Using

$$1 - F(\tau^{-1}(t)) = G_B(t) = 1 - c_B \exp\left(-\frac{\underline{v}}{p-\underline{v}} r t\right),$$

I can substitute for $\tau^{-1}(s)$. After arranging terms,

$$G_S(t) = 1 - c_S \exp\left(-\frac{1}{\underline{v}} \int_{F^{-1}\left(c_B \exp\left\{-\frac{\underline{v}}{p-\underline{v}} r t\right\}\right)}^{F^{-1}(c_B)} \frac{(v-p)f(v)}{F(v)}\, dv\right).$$

The two unknowns, c_B and c_S, are found in the same way as in Abreu and Gul. First, a player prefers waiting an instant to conceding immediately, if the opponent concedes with positive probability. Therefore, either $c_B = 1$ or $c_S = 1$. Second, once the opponent turns out to be the strong type (the commitment type and the buyer with a valuation lower than p), a player concedes immediately. Therefore, $G_S(t^*) = 1-\mu \Leftrightarrow G_B(t^*) = 1 - F(p)$. These two facts uniquely pin down c_B and c_S.

One apparent difference from Abreu and Gul is the concession rate of the seller. In Abreu and Gul, both players have constant concession rates. In my model, the buyer has a constant concession rate, while the concession rate of the seller decreases over time. The constant concession rate of the buyer is due to the fact that there is a single seller type who needs to be provided with an incentive. The reason for the decreasing concession rate of the seller is that each buyer type has a different marginal cost of waiting. The intuition is as follows. By the skimming property, a buyer with a higher valuation concedes earlier. But a buyer with a higher valuation has a higher marginal cost of waiting and, therefore, must be provided with a higher marginal benefit. This can be created only through a higher concession rate of the seller.

[6]The marginal benefit of waiting more is independent of the buyer's valuation and decreases over time, while the marginal cost is strictly increasing in the buyer's valuation and is constant over time.

2.3 *The Coase conjecture with a single behavioral type*

Given p and μ, there exists a unique sequential equilibrium. Hence the indirect expected utility of the normal type is well-defined as a function of p and μ. I denote by $U_N(p,\mu)$ the normal type's indirect expected utility.

Corollary 1 (The normal type's indirect expected utility).

$$U_N(p,\mu) = (1-c_B)p + c_B\underline{v},$$

where $c_B = 1$ *if* $\mu \le \phi(F,p)$, *and*

$$\frac{1}{\underline{v}}\int_p^{F^{-1}(c_B)} \frac{(v-p)f(v)}{F(v)}\,dv + \ln\mu = 0 \quad \text{if } \mu > \phi(F,p).$$

Once a war of attrition starts, the normal type is indifferent between waiting and conceding, and thus her expected payoff is equal to $\underline{v}$. The normal type achieves more than $\underline{v}$ only when the buyer concedes with positive probability at date 0. The term $(1-c_B)p$ reflects that possibility.[7]

What is the probability that delay occurs? Suppose $\mu < \phi(F,p)$. Then the probability that the seller offers p is

$$\mu + (1-\mu)\left(1 - \frac{1-\mu/\phi(F,p)}{(1-\mu)}\right) = \frac{\mu}{\phi(F,p)}.$$

The first term is the probability that the seller is the behavioral type, while the second term is the probability that the seller is the normal type and offers p.[8] It is immediate that delay occurs whenever μ is positive, but disappears as μ vanishes.

Corollary 2 (The Coase conjecture with a single behavioral type). *When there is a single behavioral type, the profit implication of the Coase conjecture is robust in a strong sense (it holds for* μ *small but positive), while the efficiency implication is robust in a weak sense (it holds only when* μ *tends to* 0*).*

2.4 *Some useful facts and isoprofit curves*

Suppose $\mu < \phi(F,p)$, but the seller offered p. What is the buyer's posterior belief that the seller is the commitment type? Since the normal type concedes with probability $(1-\mu/\phi(F,p))/(1-\mu)$ at date 0, conditional on the seller not having offered $\underline{v}$ (having offered p), the buyer's posterior belief is

$$\frac{\mu}{\mu + (1-\mu)\left(1 - \frac{1-\mu/\phi(F,p)}{1-\mu}\right)} = \phi(F,p).$$

[7]As μ tends to 1, c_B approaches $F(p)$, and thus the first term in $U_N(p,\mu)$ converges to the expected payoff of the static monopolist who charges p. Intuitively, if the seller is the commitment type almost for sure, the buyer accepts p immediately whenever his valuation is greater than p.

[8]The probability that the seller offers $\underline{v}$ at date 0 is $1-\mu/\phi(F,p)$. Since the behavioral type does not concede, the normal type concedes with probability $(1-\mu/\phi(F,p))/(1-\mu)$.

Intuitively, at the time when a war of attrition starts, the players' bargaining powers must be balanced. When $\mu < \phi(F,p)$, the only way to establish the balance is that the normal type concedes with positive probability so that the buyer's posterior belief (the seller's bargaining power) increases to $\phi(F,p)$.

Corollary 3. *When $\mu < \phi(F,p)$, the buyer's belief conditional on the seller having offered p at date 0 is equal to $\phi(F,p)$. Therefore, the buyer's posterior belief conditional on p is bounded below by $\phi(F,p)$.*

Next, consider the game with the rational commitment type. Suppose the rational commitment type offers p and the buyer's belief is given by μ after observing p. Then the subsequent game proceeds exactly in the same way as the one with a single behavioral type. Therefore, I can interpret the behavioral type in the previous game as the rational commitment type and calculate the indirect expected utility of the rational commitment type as a function of p and μ. I denote by $U_R(p,\mu)$ the rational commitment type's indirect expected utility. From now on, subscripts N and R refer to the normal type and the rational commitment type, respectively.

Corollary 4 (The rational commitment type's indirect expected utility).

$$U_R(p,\mu) = (1-c_B)p + c_B\underline{v}\Big(1-\Big(\frac{F(p)}{c_B}\Big)^{p/\underline{v}}\Big)$$

where $c_B = 1$ if $\mu \le \phi(F,p)$, and

$$\frac{1}{\underline{v}}\int_p^{F^{-1}(c_B)} \frac{(v-p)f(v)}{F(v)}\,dv + \ln\mu = 0 \quad \text{if } \mu > \phi(F,p).$$

Relative to the normal type's indirect expected utility, $U_R(p,\mu)$ contains an additional term. This can be interpreted as the cost to the rational commitment type of not being able to adjust the price.

I maintain the following assumption from now on, where p_i^* is the price that maximizes $U_i(p,1)$.

Assumption 1. $p_R^* > \underline{v}$ and

$$\frac{1-F(p)}{f(p)} \gtreqless p \quad \text{if } p \lesseqgtr p_R^*$$
$$\underline{v} + \frac{1-F(p)}{f(p)} \gtreqless p \quad \text{if } p \lesseqgtr p_N^*.$$

This assumption states that the functions $U_R(p,1) = (1-F(p))p$ and $U_N(p,1) = (1-F(p))p + F(p)\underline{v}$ are single-peaked. A sufficient condition is that the inverse hazard ratio $(1-F(p))/f(p)$ is decreasing, which is frequently employed in the mechanism design literature.

The following results are immediate from Proposition 1.

Lemma 1. *Suppose $\mu > \phi(F,p)$. Then*

(i) $\lim_{\mu\to 1} c_B(p,\mu) = F(p)$

(ii) $\partial c_B(p,\mu)/\partial p > 0$, $\partial c_B(p,\mu)/\partial \mu < 0$

(iii) $\partial U_i(p,\mu)/\partial \mu > 0$.

For each $p' \in [\underline{v}, p_i^*]$, let $\rho_i(p') \in [p_i^*, \overline{v}]$ be the value such that $U_i(\rho_i(p'),1) = U_i(p',1)$. The function $\rho_i, i = N, R$ is well-defined under Assumption 1. Now let $I_i^{p'}$ be the level set on which the type i seller is indifferent. Formally, for $p' \in (\underline{v}, p_i^*]$,

$$I_i^{p'} = \{(p,\mu) \in (\underline{v}, \overline{v}) \times (0,1] : U_i(p,\mu) = U_i(p',1)\}.$$

Lemma 2. *Given $p' \in (\underline{v}, p_i^*]$, for each $p \in (p', \rho_i(p'))$ there exists a unique $\mu_i \in (\phi(F,p),1)$ such that $(p,\mu_i) \in I_i^{p'}$.*

Proof. Suppose $p \in (p', \rho_i(p'))$. Since $U_i(p,\phi(F,p)) \le \underline{v} < U_i(p',1) < U_i(p,1)$ and $U_i(p,\cdot)$ is continuous, there exists $\mu_i \in (\phi(F,p),1)$ such that $(p,\mu_i) \in I_i^{p'}$. It is also unique because $U_i(p,\cdot)$ is strictly increasing when $\mu > \phi(F,p)$. □

Given Lemma 2, for each $p' \in (\underline{v}, p_i^*]$, the associated isoprofit curve is represented by a function $\psi_i^{p'} : [p', \rho_i(p')] \to [0,1]$ where $(p, \psi_i^{p'}(p)) \in I_i^{p'}$ $\forall p \in [p', \rho_i(p')]$. The continuity of $\psi_i^{p'}$ is implied by the continuity of $U_i(\cdot,\cdot)$.

The isoprofit curves on which each type gets $\underline{v}$ play crucial roles later. For the normal type, it is straightforward to show that as p' tends to $\underline{v}$, $\psi_N^{p'}(p)$ converges to $\phi(F,p)$ for all p (see Figure 1). For the rational commitment type, define $\psi_R^{\underline{v}}(p) = \lim_{p'\to\underline{v}} \psi_R^{p'}(p)\ \forall p \in (\underline{v}, \overline{v})$. Then $\psi_R^{\underline{v}}(p) \in (\phi(F,p),1)$, because $U_R(p,\phi(F,p)) = \underline{v}(1-F(p)^{p/\underline{v}}) < \underline{v} < U_R(p,1)$ for $p > \underline{v}$. In addition, as p tends to $\underline{v}$, for the rational commitment type to achieve $\underline{v}$, c_B must be close to $F(p)$ (see Figure 2), and thus $\psi_R^{\underline{v}}(p)$ approaches 1. Intuitively, for the rational commitment type to achieve $\underline{v}$ by offering a price close to $\underline{v}$, there cannot be significant delay, which happens only when the probability of the commitment type is sufficiently large.

3. Multiple behavioral types

This section studies the game with multiple behavioral types. Let $\Xi_B \subseteq [\underline{v}, \overline{v}]$ be the set of behavioral types.[9] The seller is behavioral with probability μ_B. Conditional on the seller's being behavioral, the probability measure over the Borel σ-field, $\mathscr{F}$, of Ξ_B is given by λ. For notational simplicity, I assume that λ has no mass at $\underline{v}$.

Given the results in Section 2, the analysis for multiple behavioral types reduces to the following simple problem. The normal type plays a mixed strategy, denoted by a cumulative distribution function H_N over $[\underline{v}, \overline{v}]$. Consumers assign beliefs to prices; that

[9] I denote each behavioral type by the price to which she is committed.

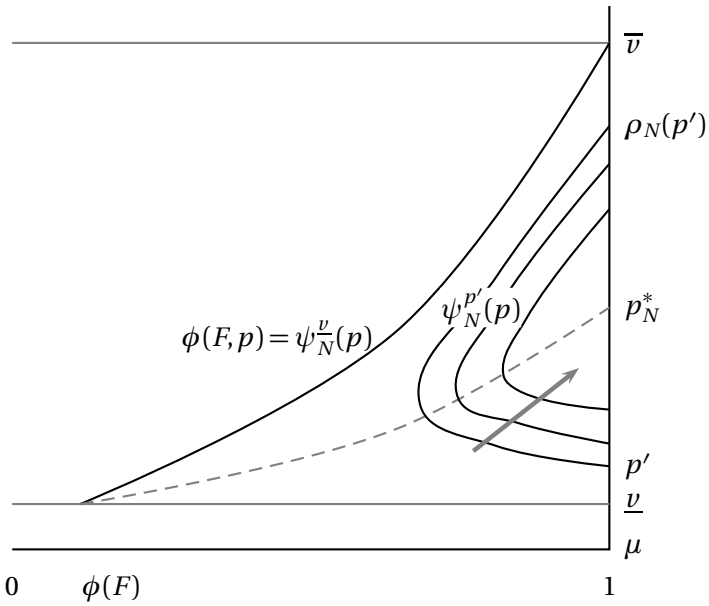

FIGURE 1. Isoprofit curves of the normal type.

is, consumers determine $\mu : [\underline{v}, \overline{v}] \to [0,1]$. The solution (equilibrium) to this reduced-form problem is (H_N^*, μ^*) such that (i) given μ^*, for any $p' \in \Xi_N^* \equiv \text{supp} H_N^*$,

$$U_N(p', \mu^*(p')) = \max_{p \in [\underline{v}, \overline{v}]} U_N(p, \mu^*(p)),$$

and (ii) given H_N^* (and λ), μ^* is the conditional probability that the seller is a commitment type. This reduction is possible because once the seller offers a price p and consumers' beliefs are given by μ, the subsequent dynamics amount to those with a single behavioral type. Furthermore, as shown in the previous section, the dynamics have a unique sequential equilibrium and the normal type's indirect expected utility is available.

I assume that whatever price is offered by the seller, there is a chance that the seller is a commitment type. This is an extreme case of a "rich" set of behavioral types.

ASSUMPTION 2. $\lambda([\underline{v}, p])$ is strictly increasing in $p \in (\underline{v}, \overline{v})$.

One important consequence of this assumption is that there is no off-the-equilibrium-path price in $[\underline{v}, \overline{v}]$, and therefore, μ^* is completely determined by Bayes' rule. Once either μ^* or H_N^* is determined, the other follows. Relying on this observation, I focus on μ^* and do not explicitly derive H_N^*.

LEMMA 3. *The set of prices the normal type offers in equilibrium (Ξ_N^*) is $[p', \rho_N(p')]$ for some $p' \in [\underline{v}, p_N^*]$. In addition, if $p' > \underline{v}$, then $\mu^*(p') = \mu^*(\rho_N(p')) = 1$.*

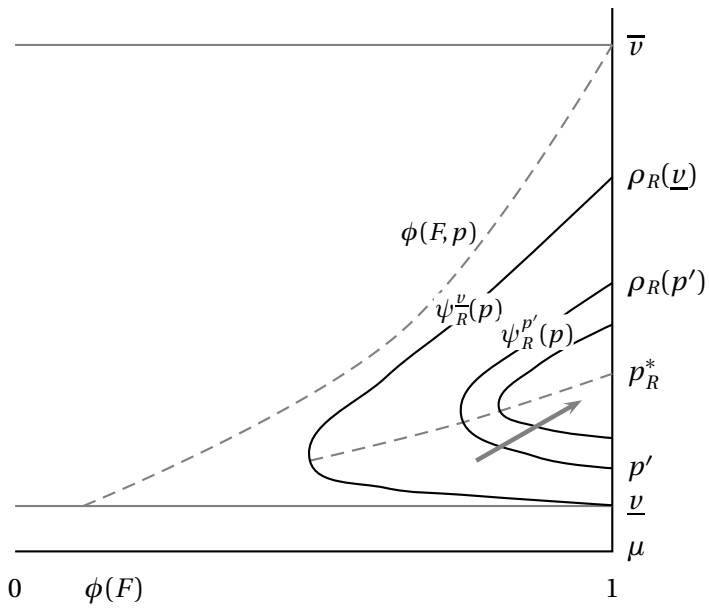

FIGURE 2. Isoprofit curves of the rational commitment type.

PROOF. Suppose $p' \in \Xi_N^*$, but $p \notin \Xi_N^*$ for some $p \in (p', \rho_N(p'))$. Then the normal type deviates to p, because $U_N(p,1) > U_N(p',1) \geq U_N(p',\mu^*(p'))$. Therefore, $[p',\rho_N(p')] \subseteq \Xi_N^*$. This establishes the first result.

Now suppose $\Xi_N^* = [p',\rho_N(p')]$ for some $p' > \underline{v}$, but $\mu^*(p') < 1$. Then for $\varepsilon > 0$ sufficiently small, $U_N(p'-\varepsilon,1) > U_N(p',\mu^*(p'))$, which cannot be the case in equilibrium. An analogous proof applies to $\rho_N(p')$. □

Suppose that in equilibrium $\Xi_N^* = [p',\rho_N(p')]$ for some $p' \in (\underline{v}, p_N^*]$. A straightforward but crucial consequence is that $\mu^*(p) = \psi_N^{p'}(p)$ on Ξ_N^*. That is, for Ξ_N^* to be the equilibrium support, the equilibrium beliefs must coincide with the isoprofit curve of the normal type starting from $(p',1)$ (see Figure 3). This is simply a restatement that in equilibrium a player is indifferent over all actions in the support of his mixed strategy.

The appropriate p' is found as follows. Given μ_B and λ, start from p_N^* and continuously lower the price. As p' decreases, the corresponding isoprofit curve expands to the left, encompassing previous isoprofit curves (see Figure 1). In order to make μ^* follow $\psi_N^{p'}$, the normal type must play each price with a specific probability. Integrating over the probabilities that the normal type assigns to each price, the integral continuously increases as p' decreases. The integral becomes equal to 1 at the proper p' (the normal type must exhaust probability 1). Such p' is unique because isoprofit curves do not cross each other.

If there does not exist such $p' > \underline{v}$, then $\Xi_N^* = [\underline{v},\overline{v}]$. That is, the normal type mixes over all prices in $[\underline{v},\overline{v}]$. In this case, the equilibrium beliefs are given by $\mu^*(p) = \phi(F,p)$ $\forall p > \underline{v}$. This is because consumers' posterior beliefs conditional on the initial offer $p > \underline{v}$

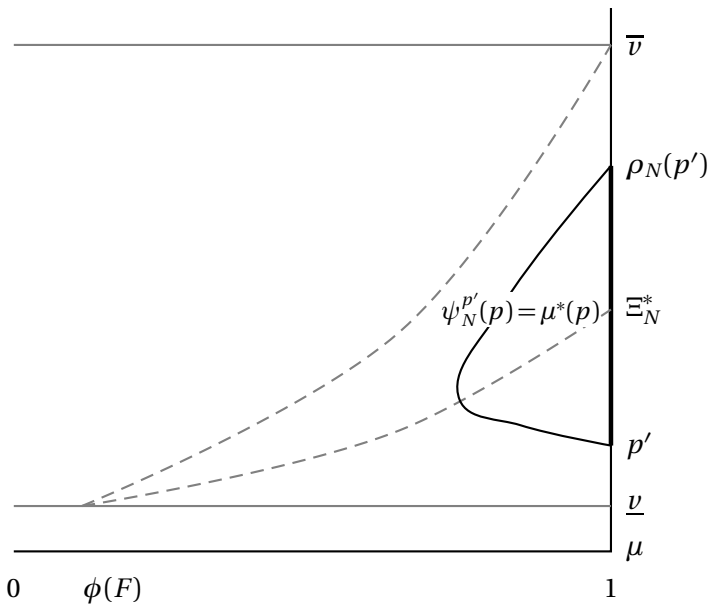

FIGURE 3. A typical equilibrium when $\mu_B > \varphi(F,\lambda)$ in the model with multiple behavioral types.

are at least $\phi(F,p)$ (see Corollary 3). When $\Xi_N^* = [\underline{v},\overline{v}]$, the integral over the probabilities the normal type assigns to each price in $(\underline{v},\overline{v}]$ is less than 1. With the remaining probability, she offers $\underline{v}$.

The following quantity plays a role similar to the role played by $\phi(F,p)$ in the previous section. Given λ and F, let $\varphi(F,\lambda)$ be the value that satisfies

$$\frac{1-\varphi(F,\lambda)}{\varphi(F,\lambda)} = \int_{(\underline{v},\overline{v})} \frac{1-\phi(F,p)}{\phi(F,p)}\, d\lambda.$$

Roughly, $\varphi(F,\lambda)$ is an average value of $\phi(F,p)$ with respect to λ. It can be interpreted as the bargaining power of the buyer facing behavioral commitment types distributed according to λ. As in $\phi(F,p)$, if F first-order stochastically dominates F', then $\varphi(F,\lambda) \leq \varphi(F',\lambda)$. Intuitively, the seller is relatively stronger when she faces a more favorable distribution of buyer valuations.

PROPOSITION 2. *(i) If $\mu_B \leq \varphi(F,\lambda)$, then there exists a unique sequential equilibrium in which the normal type mixes over all prices in $[\underline{v},\overline{v}]$ and consumers' beliefs are given by $\mu^*(p) = \phi(F,p)\ \forall p > \underline{v}$. In this case, the normal type earns the competitive profit.*

(ii) If $\mu_B > \varphi(F,\lambda)$, then there exists a unique sequential equilibrium in which the normal type mixes over prices in the interval $[p',\rho_N(p')]$ for some $p' \in (\underline{v},p_N^*)$ and consumers' beliefs coincide with the isoprofit curve of the normal type that starts from p'. In this case, the normal type achieves more than the competitive profit.

Proof. The proof uses the fact that the likelihood ratio of the seller's being the normal type to her being a commitment type is a martingale with respect to the distribution of commitment types (see Doob 1953). Formally,

$$\frac{1-\mu_B}{\mu_B} = \int_{(\underline{v},\overline{v})} \frac{1-\mu^*}{\mu^*}\, d\lambda = \int_{\Xi_N^*} \frac{1-\mu^*}{\mu^*}\, d\lambda.$$

In words, the aggregate ratio of the normal type to behavioral types (the left-hand side) must be equal to the expectation of the conditional ratio (the right-hand side).[10]

Suppose $\mu^*(p) > \phi(F,p)$ for some $p > \underline{v}$. Since $U_N(p,\mu^*(p)) > \underline{v}$, for any $p'' \in \Xi_N^*$, $\mu^*(p'') > \phi(F,p'')$ and $\underline{v} \notin \Xi_N^*$. For μ^* to be the equilibrium beliefs,

$$\frac{1-\mu_B}{\mu_B} = \int_{\Xi_N^*} \frac{1-\mu^*}{\mu^*}\, d\lambda < \int_{(\underline{v},\overline{v})} \frac{1-\phi(F,p)}{\phi(F,p)}\, d\lambda = \frac{1-\varphi(F,\lambda)}{\varphi(F,\lambda)}.$$

Hence, if $\mu_B \leq \varphi(F,\lambda)$, then $\mu^*(p) = \phi(F,p)\ \forall p > \underline{v}$ and $\Xi_N^* = [\underline{v},\overline{v}]$.

Now suppose $\mu_B > \varphi(F,\lambda)$. Define $J : (\underline{v}, p_N^*] \to \mathbb{R}_+$ by

$$J(p') = \int_{(p',\rho_N(p'))} \frac{1-\psi_N^{p'}(p)}{\psi_N^{p'}(p)}\, d\lambda.$$

The function J is strictly decreasing, because if $p' < p''$ then $\psi_N^{p'}(p) < \psi_N^{p''}(p)$. In addition, as p' tends to $\underline{v}$, $\psi_N^{p'}(p)$ converges to $\phi(F,p)$ for all $p > \underline{v}$. Therefore, the image of J is $[0,(1-\varphi(F,\lambda))/\varphi(F,\lambda))$. Hence, for each $\mu_B > \varphi(F,\lambda)$, there exists a unique corresponding $p' \in (\underline{v}, p_N^*]$ such that $(1-\mu_B)/\mu_B = J(p')$. By Lemma 3, this is the unique equilibrium. □

If $\mu_B \leq \varphi(F,\lambda)$, the probability that delay occurs is

$$\mu_B + (1-\mu_B)\int_{(\underline{v},\overline{v})} \frac{\mu_B}{1-\mu_B}\frac{1-\phi(F,p)}{\phi(F,p)}\, d\lambda = \frac{\mu_B}{\varphi(F,\lambda)}.$$

The first term is the probability that the seller is behavioral, while the second term comes from the mimicking behavior of the normal type. The integrand is the probability that the normal type assigns to p so that consumers' conditional beliefs are equal to $\phi(F,p)$. Hence, the integral is the probability that the normal type offers a price higher than $\underline{v}$ at date 0. It is immediate that delay occurs whenever $\mu_B > 0$, but disappears as μ_B approaches 0.

[10]The case where both H_N and λ have densities is particularly easy. Suppose h_N and g are the density functions of H_N and λ, respectively. Then

$$\mu^*(p) = \frac{\mu_B g(p)}{(1-\mu_B)h_N(p) + \mu_B g(p)} \Leftrightarrow \frac{1-\mu_B}{\mu_B} h_N(p) = \frac{1-\mu^*(p)}{\mu^*(p)} g(p).$$

Since h_N is a density function and its support is Ξ_N^*,

$$\frac{1-\mu_B}{\mu_B} = \frac{1-\mu_B}{\mu_B}\int_{\Xi_N^*} h_N(p)\, dp = \int_{\Xi_N^*} \frac{1-\mu^*(p)}{\mu^*(p)} g(p)\, dp = \int_{\Xi_N^*} \frac{1-\mu^*}{\mu^*}\, d\lambda.$$

Corollary 5 (The Coase conjecture with multiple behavioral types). *When there are multiple behavioral types, the profit implication of the Coase conjecture is robust in a strong sense, while the efficiency implication is robust in a weak sense.*

The reason why the conclusions in the previous section carry over to the case with multiple behavioral types is that when the unconditional probability of behavioral types, μ_B, is small, the probabilities conditional on the seller's initial offer are small uniformly over all prices. This relationship is generated by the fact that in equilibrium the normal type is indifferent over all prices she may offer. Intuitively, if the normal type prefers one price to other prices, consumers believe that the seller who offers the price is the normal type with a high probability. This reduces the normal type's expected payoff and, therefore, nullifies her preference for the price.

Now suppose the seller is likely to be committed ($\mu_B > \varphi(F,\lambda)$). Which prices do consumers believe are more likely to drop? Consumers are most suspicious when the seller offers a price that is neither low nor high (see Figure 3). Only a few consumers may accept a high price. Therefore, if the price is too high, it is unlikely that the seller rationally set the price. The seller does not benefit a lot from offering a low price. Consumers believe that the opportunistic seller must have tried a higher price, and consequently, the seller offering a low price is indeed committed to the price.

Lastly, observe that if μ_B is sufficiently high, then the normal type always offers a price higher than the static monopoly price (and earns more than the static monopoly profit). Formally, if

$$\frac{1-\mu_B}{\mu_B} < C(F,\lambda) \equiv \int_{(p_R^*,\rho_N(p_R^*))} \frac{1-\psi_N^{p_R^*}(p)}{\psi_N^{p_R^*}(p)}\, d\lambda,$$

then any price the normal type offers in equilibrium is higher than the static monopoly price. To see this, suppose μ_B is arbitrarily close to 1. Then, whatever price was offered, consumers believe that the seller is committed almost for sure and, therefore, accept the price as long as their valuations are greater than the price. An instant later, the normal type can lower the price and earn an additional profit. In this scenario, the effective objective function of the normal type is $U_N(p,1) = (1-F(p))p + F(p)\underline{v}$, whose maximum p_N^* is strictly greater than p_R^*. Without uncertainty, her flexibility is a curse. With uncertainty, it may be a blessing.

4. The rational commitment type

In this section, the seller is the rational commitment type with probability μ_R and the normal type with the complementary probability. Again, I focus on the determination of equilibrium prices and beliefs. This is possible because the indirect expected utility of the rational commitment type is available as well (see Corollary 4).

It is always an equilibrium that both types offer the competitive price. This equilibrium is induced by the most skeptical beliefs of consumers that $\mu^*(p) = \phi(F,p)$ for $p > \underline{v}$. Under these beliefs, it is optimal for the rational commitment type to offer $\underline{v}$. The

normal type is indifferent over all prices in $[\underline{v}, \overline{v}]$, and thus it is rational for her to offer $\underline{v}$. Given these choices, consumers' beliefs are consistent because any price higher than $\underline{v}$ is off the equilibrium path.

For μ_R small, this equilibrium is the unique equilibrium. Suppose $\mu_R \leq \phi(F)$ ($\equiv \phi(F, \underline{v})$), but the rational commitment type offers $p > \underline{v}$. Then consumers' beliefs conditional on p, $\mu(p)$, must be greater than $\phi(F, p)$, because $\underline{v}$ is the lower bound of the seller's payoff (she can always offer $\underline{v}$), while $U_R(p, \phi(F, p)) < \underline{v}$. But this is a contradiction for the following reason. On the one hand, for consumers' beliefs to be greater than $\phi(F, p)$, the normal type must offer $\underline{v}$ with positive probability, because $\mu(p) > \phi(F, p) \geq \phi(F) \geq \mu_R$. This implies that the equilibrium expected payoff of the normal type is $\underline{v}$. On the other hand, the normal type can achieve more than $\underline{v}$ by offering p, because $U(p, \mu(p)) > U(p, \phi(F, p)) = \underline{v}$. Consequently, when $\mu_R \leq \phi(F)$, the rational commitment type offers $\underline{v}$ in equilibrium. Given this, the normal type has no choice but to offer $\underline{v}$ as well.

The cutoff value for μ_R below which it is the unique equilibrium that both types offer $\underline{v}$ is greater than $\phi(F)$. When μ_R is slightly greater than $\phi(F)$, the normal type prefers a price slightly higher than $\underline{v}$. On the contrary, the rational commitment type is not better off by offering a price higher than $\underline{v}$. The normal type's flexibility ensures her $\underline{v}$ under any circumstance, while the rational commitment type must endure all delay cost from a war of attrition. Let $\widetilde{\phi}(F)$ be the minimum value of μ above which the rational commitment type can achieve at least $\underline{v}$ by offering some price higher than $\underline{v}$. Formally,

$$\widetilde{\phi}(F) = \min_p \psi_R^{\underline{v}}(p) = \min_p \lim_{p' \to \underline{v}} \psi_R^{p'}(p).$$

Then, by the same reasoning as in the previous paragraph, the Coase conjecture holds up to $\widetilde{\phi}(F)$.

If $\mu_R \geq \widetilde{\phi}(F)$, then there exists another equilibrium. Let $P(\mu_R)$ be the set of prices such that if $p \in P(\mu_R)$ then $p > \underline{v}$ and $U_R(p, \mu_R) \geq \underline{v}$. Fix $p \in P(\mu_R)$ and find $p_N \in (\underline{v}, p_N^*)$ and $p_R \in (\underline{v}, p_R^*)$ such that $\mu_R = \psi_R^{p_R}(p) = \psi_N^{p_N}(p)$. Then take off-the-equilibrium-path beliefs so that $\mu^*(p') \leq \min\{\psi_R^{p_R}(p'), \psi_N^{p_N}(p')\}$ $\forall p' \neq p$ (for example, $\mu^*(p') = \phi(F, p)$ $\forall p' \neq p$). Under these beliefs, by construction, p is the optimal price for both types. Therefore, for any $p \in P(\mu_R)$, there exists a corresponding sequential equilibrium (see Figure 4).

Proposition 3. *(i) It is always an equilibrium that both types offer the competitive price. For $\mu_R < \widetilde{\phi}(F)$, this is the unique sequential equilibrium.*

(ii) If $\mu_R \geq \widetilde{\phi}(F)$, then for any $p \in P(\mu_R)$, there exists a corresponding sequential equilibrium in which both types offer p.

The following result is immediate.

Corollary 6 (The Coase conjecture with the rational commitment type). *When the commitment type is rational, both the profit implication and the efficiency implication of the Coase conjecture are robust in a strong sense.*

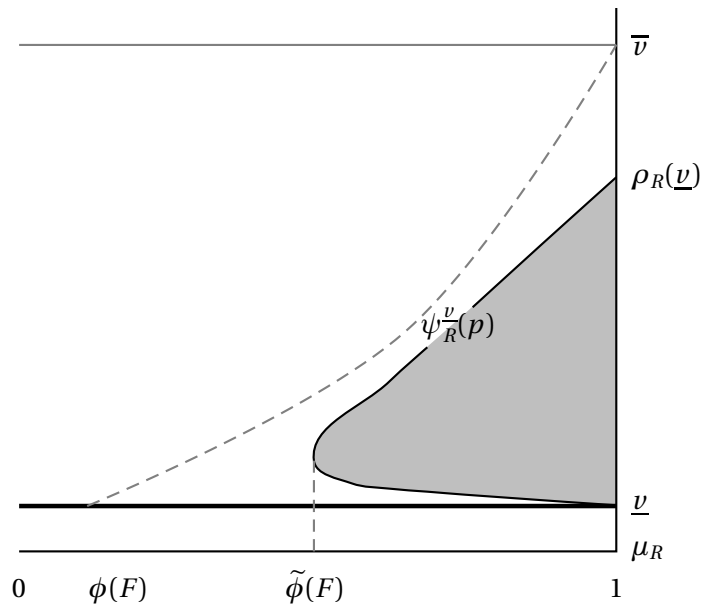

FIGURE 4. The set of equilibria in the model with the rational commitment type.

4.1 *Equilibrium selection*

The multiplicity of equilibria is driven by the signaling structure of the game at the stage when the seller decides her initial offer. While the common equilibrium refinements do not have any power (for example, the intuitive criterion does not exclude any equilibrium),[11] a selection method using behavioral types is quite effective in this game. The procedure is (1) perturb the game by allowing a small probability of behavioral types, (2) let the probability approach zero, and (3) evaluate what equilibria survive the process.

In the full-fledged game, given the equilibrium beliefs μ^*, each payoff type finds her own optimal price. Hence, the isoprofit curve of each type is tangent to the equilibrium belief function μ^* at her own optimal price (if the optimal price is greater than $\underline{v}$). But when the probability of behavioral types, μ_B, is positive, the equilibrium beliefs coincide with an isoprofit curve of the normal type (see Lemma 3 and the subsequent discussion). Therefore, at the optimal price of the rational commitment type, the isoprofit curve of the rational commitment type is tangent to that of the normal type. This property holds whenever $\mu_B > 0$ and, therefore, holds in the limit as μ_B tends to 0.

Figure 5 shows the set of equilibria that survive as μ_B approaches zero. It consists of two kinds of equilibria. The first type is the degenerate one in which both the normal

[11] A criterion that has some selection power is that of "undefeated" equilibrium as defined by Mailath et al. (1993). Undefeated is equivalent to Pareto domination in the current game. When there are two equilibria in which p and p' are played, the equilibrium with p defeats that with p' if both types are better off in the former. If one type is better off but the other type is worse off, the two equilibria are incomparable.

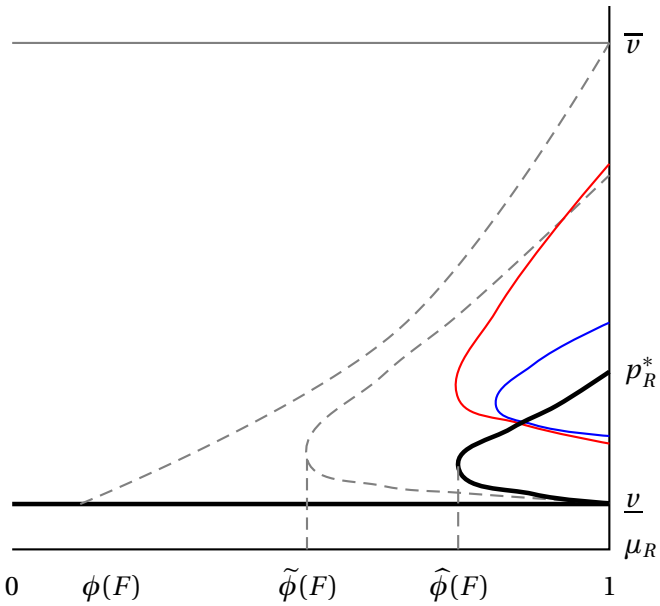

FIGURE 5. The thick black line is the set of equilibria that survive the selection process.

type and the rational commitment type offer the competitive price. This equilibrium survives the selection process, because for μ_B small, the most skeptical beliefs of consumers, $\mu^*(p) = \phi(F, p), p > \underline{v}$, induce the rational commitment type to offer $\underline{v}$, which in turn makes the beliefs consistent. The second type is the one in which both types offer $p > \underline{v}$ and the isoprofit curves of the two types are tangent to each other. These are the equilibria that are limits of the equilibria in the full-fledged game in which the two payoff types pool at prices higher than $\underline{v}$. As discussed before, the property that the isoprofit curves of the two payoff types are tangent to each other is preserved in the limit.

Let $\widehat{\phi}(F)$ be the largest value of μ_R below which the isoprofit curves of the two payoff types are never tangent to each other. In other words, $\widehat{\phi}(F)$ is the leftmost value of the contract curve between U_N and U_R.

PROPOSITION 4. *(i) If $\mu_R < \widehat{\phi}(F)$, then the only equilibrium that survives the selection process is the one in which both the normal type and the rational commitment type offer $\underline{v}$. This remains an equilibrium even for $\mu_R \geq \widehat{\phi}(F)$.*

(ii) If $\mu_R \geq \widehat{\phi}(F)$, then there exists another equilibrium that survives the selection process, in which both types offer a higher price than $\underline{v}$.

The cutoff value $\widehat{\phi}(F)$ is greater than $\widetilde{\phi}(F)$. Therefore, restricting attention to the set of equilibria that survive the selection process, the Coase conjecture is even more robust. The mathematical reason why $\widehat{\phi}(F) > \widetilde{\phi}(F)$ is that the contract curve of U_N and U_R lies in the interior of $\psi_R^{\underline{v}}$. The intuitive reason is that off-the-equilibrium-path beliefs are more restricted when there are behavioral types. Without behavioral types, the only

requirement on off-the-equilibrium-path beliefs is that the equilibrium beliefs must be to the left of the minimum of the isoprofit curves of the two payoff types. This allows the seller to have rather pessimistic off-the-equilibrium-path beliefs and, consequently, yields a large set of equilibria. With behavioral types, the seller loses this latitude. Now μ^* must coincide with an isoprofit curve of the normal type and the isoprofit curve of the rational commitment type must be tangent to that of the normal type. This makes it harder for the two payoff types to coordinate on a price higher than $\underline{v}$ and, ultimately, increases the cutoff value.

5. Discussion

5.1 *Acquired stubbornness vs. inborn stubbornness*

Kambe (1999) introduces two kinds of stubbornness. With "inborn" stubbornness an agent knows her type before deciding the initial offer, while with "acquired" stubbornness she does not know whether she will be stuck with the initial offer. Kambe argues that acquired stubbornness can arise either psychologically or economically (reputationally).

This paper studies inborn stubbornness. Extending the model to incorporate acquired stubbornness is straightforward. The only difference is that the relevant indirect expected utility of the seller is the weighted sum of the two indirect utility functions. One feature of acquired stubbornness is that equilibrium is always unique, which is a trivial consequence of the fact that there is a single decision maker.

5.2 *The no gap case*

With no gap ($\underline{v}=0$), there are multiple equilibria in the standard problem (see Ausubel and Deneckere 1989). Therefore, in order to analyze the no gap case, the equilibrium behavior in case the seller's type is revealed to be normal needs to be specified. I focus on the weak-Markov equilibrium. This case is particularly tractable, because it is the limit of the unique equilibrium in the gap case, and thus the limit argument can be used in my problem as well.

Given p and μ, as $\underline{v} \to 0$, $\tau(v)=0$ for $v<p$, and $G_S(t)=0\ \forall t$. That is, the seller never lowers the price and all consumers with higher valuations than p purchase immediately. The driving force of this result is that the normal type becomes more reluctant to concede as the gain from doing so ($\underline{v}$) becomes smaller and she has no reason to reveal her type in the limit. In the limit as $\underline{v} \to 0$, the seller always (whether she is the normal type or the rational commitment type and whether there are behavioral types or not) offers the static monopoly price and achieves the static monopoly profit.

5.3 *Different discount factors: relation with the standard reputation result*

Suppose the buyer and the seller have different discount factors, r_B and r_S, respectively. Then for all p,

$$\phi(F,p)=\exp\left(-\frac{1}{\underline{v}}\frac{r_B}{r_S}\int_p^{\overline{v}}\frac{(v-p)f(v)}{F(v)}\,dv\right).$$

All other results have straightforward extensions. For fixed r_B, as r_S becomes smaller, $\phi(F,p)$ decreases, and thus the buyer concedes faster. The robustness results for the Coase conjecture still hold, but less strongly.

This analysis shows that the standard reputation result still holds in my problem in terms of discount rates: in the game with behavioral types, for fixed $\mu_B > 0$, there exists $\overline{r}_S > 0$ such that if $r_S \leq \overline{r}_S$ then the expected payoff of the normal type is ε-close to her maximum expected payoff $U_N(p_N^*, 1)$.

Appendix: The full-fledged game

This appendix studies the game in which both the rational commitment type and behavioral types are active. Let μ_N, μ_R, and μ_B be the probabilities that the seller is the normal type, the rational commitment type, and one of the behavioral types, respectively. I keep the notation and assumptions in Section 2 and 3.

Again I focus on the determination of equilibrium prices and beliefs. A mixed strategy of the type i seller is represented by a cumulative distribution function H_i over $[\underline{v}, \overline{v}]$, $i = N, R$.

Definition 1. A triple (H_N^*, H_R^*, μ^*) constitutes a sequential equilibrium in the full-fledged game if (i) given μ^*, for any $p' \in \Xi_i^* \equiv \operatorname{supp} H_i^*$, $i = N, R$,

$$U_i(p', \mu^*(p')) = \max_{p \in [\underline{v}, \overline{v}]} U_i(p, \mu^*(p)),$$

and (ii) given H_N^* and H_R^* (and λ), μ^* is the conditional probability that the seller is a commitment type.

Since Lemma 3 applies whenever $\mu_B > 0$, once Ξ_N^* is given, μ^* is uniquely identified, and Ξ_R^* satisfies one of the conditions in the following result.

Lemma 4. *Either* $\Xi_R^* \subseteq \Xi_N^*$ *or* $\Xi_R^* = \{p_R^*\}$.

Proof. Suppose there exists $p \in \Xi_R^* - \Xi_N^*$. If $p \neq p_R^*$, for ε small enough, the rational commitment type has a profitable deviation to either $p - \varepsilon$ or $p + \varepsilon$, because $U_R(p, 1)$ is single-peaked. □

There are three types of equilibria according to Ξ_N^*: (1) $\Xi_N^* = [\underline{v}, \overline{v}]$, (2) $\Xi_R^* = \{p_R^*\} \not\subset \Xi_N^*$, and (3) $\Xi_R^* \subseteq \Xi_N^* \neq [\underline{v}, \overline{v}]$.

Case 1: $\Xi_N^* = [\underline{v}, \overline{v}]$ By the discussion in Section 3, if $\Xi_N^* = [\underline{v}, \overline{v}]$, then $\mu^*(p) = \phi(F,p)$ $\forall p > \underline{v}$. In this case, the rational commitment type offers $\underline{v}$. Given this, the game is essentially equivalent to the one without the rational commitment type. The normal type plays each price $p > \underline{v}$ to the extent that $\mu^*(p) = \phi(F,p)$ and plays $\underline{v}$ with the remaining probability. As in Section 3, this equilibrium exists if and only if

$$\frac{\mu_N}{\mu_B} \geq \int_{(\underline{v}, \overline{v})} \frac{1 - \phi(F,p)}{\phi(F,p)} \, d\lambda = \frac{1 - \varphi(F,\lambda)}{\varphi(F,\lambda)}.$$

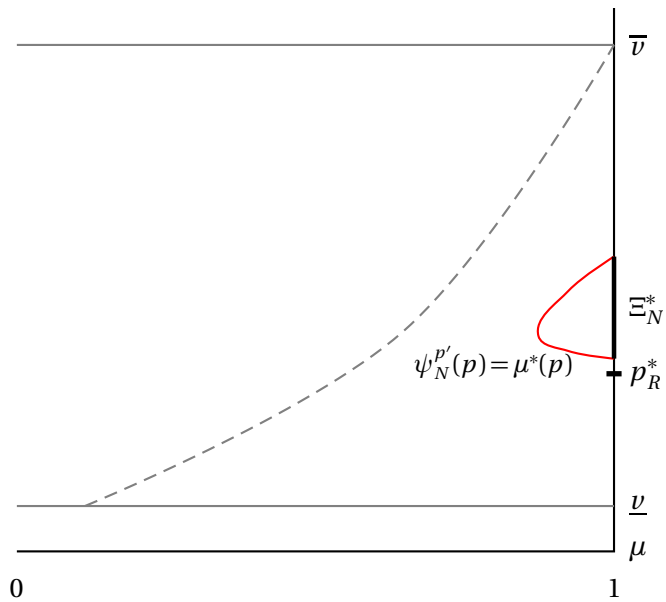

FIGURE 6. Case 2 equilibrium.

Case 2: $\Xi_R^* = \{p_R^*\} \not\subset \Xi_N^*$ At the end of Section 3, I discuss the possibility that the normal type always offers a price higher than the static monopoly price, p_R^*. This happens when the probability of behavioral types is sufficiently greater than that of the normal type. The same phenomenon happens in the full-fledged game. If μ_B is sufficiently larger than μ_N, then any price the normal type offers in equilibrium is greater than p_R^* (see Figure 6). Then $\mu^*(p_R^*) = 1$ and the rational commitment type obviously chooses p_R^*. In turn, the normal type does not offer p_R^* because she is achieving more than $U_N(p_R^*, 1)$ already. As in Section 3, this equilibrium exists if and only if

$$\frac{\mu_N}{\mu_B} < C(F,\lambda) \equiv \int_{(p_R^*, \rho_N(p_R^*))} \frac{1-\psi_N^{p_R^*}(p)}{\psi_N^{p_R^*}(p)}\, d\lambda.$$

Case 3: $\Xi_R^* \subseteq \Xi_N^* \neq [\underline{v}, \overline{v}]$ Suppose $\Xi_N^* = [p', \rho_N(p')]$ for some $p' \in (\underline{v}, p_R^*]$. Since $\mu^*(p) = \psi_N^{p'}(p)$, for any $p'' \in \Xi_R^*$

$$p'' \in \arg\max_p U_R(p, \mu^*(p)) = \arg\max_p U_R(p, \psi_N^{p'}(p)).$$

Since $\psi_N^{p'}(\cdot)$ is an isoprofit curve of the normal type, this implies that for $p'' \in \Xi_R^*$, the isoprofit curve of the rational commitment type is tangent to that of the normal type at $(p'', \psi_N^{p'}(p''))$ (see Figure 7). Let $\Upsilon(p')$ be the set of optimal prices of the rational commitment type given $\mu^*(p) = \psi_N^{p'}(p)$. The set $\Upsilon(p')$ is well-defined because $\psi_N^{p'}(\cdot)$ is closed

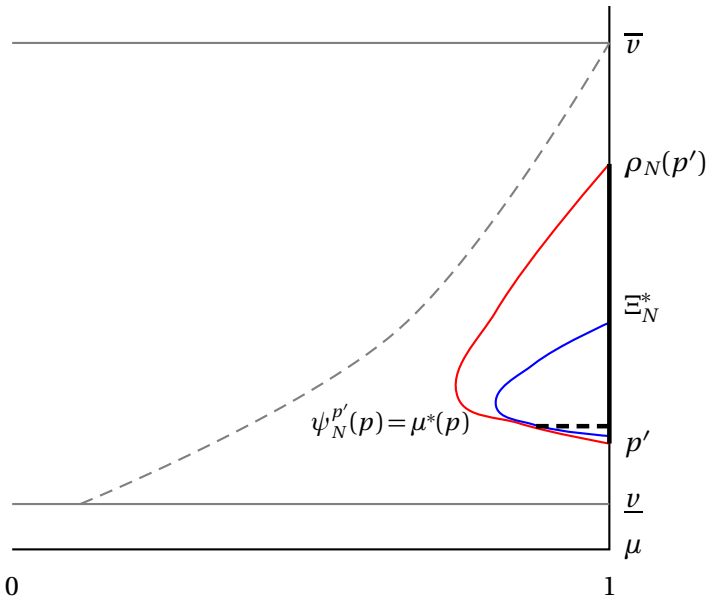

FIGURE 7. Case 3 equilibrium.

and connected and U_R is continuous. The following lemma provides some necessary conditions on $\Upsilon(p')$.

LEMMA 5. *For any $p' \in (\underline{v}, p_R^*]$, if $p'' \in \Upsilon(p')$, then $p'' \leq p_R^*$. That is, the rational commitment type never chooses a price higher than p_R^*. In addition, as p' tends to p_R^* or $\underline{v}$, for any $p'' \in \Upsilon(p')$, $\psi_N^{p'}(p'')$ converges to 1. That is, the beliefs associated with prices in $\Upsilon(p')$ are close to 1 if p' is sufficiently close to p_R^* or $\underline{v}$.*

PROOF. For $p \in (\underline{v}, \overline{v})$ and $\mu \in (\phi(F,p), 1)$, let

$$\begin{aligned} K(p,\mu) &= \frac{\partial U_R(p,\mu)}{\partial p}\frac{\partial U_N(p,\mu)}{\partial \mu} - \frac{\partial U_R(p,\mu)}{\partial \mu}\frac{\partial U_N(p,\mu)}{\partial p} \\ &= \left(\frac{F(p)}{c_B}\right)^{p/\underline{v}} \frac{\partial c_B}{\partial \mu}(p-\underline{v})\left(c_B\left(1+\ln\left(\frac{F(p)}{c_B}\right)+p\frac{f(p)}{F(p)}\right)-1\right). \end{aligned}$$

We have $K(p,\mu)=0$ if and only if

$$k(p,\mu) = c_B\left(1+\ln\left(\frac{F(p)}{c_B}\right)+p\frac{f(p)}{F(p)}\right)-1=0.$$

Since $c_B < 1$,

$$\ln\left(\frac{F(p)}{c_B}\right)+p\frac{f(p)}{F(p)} > 0.$$

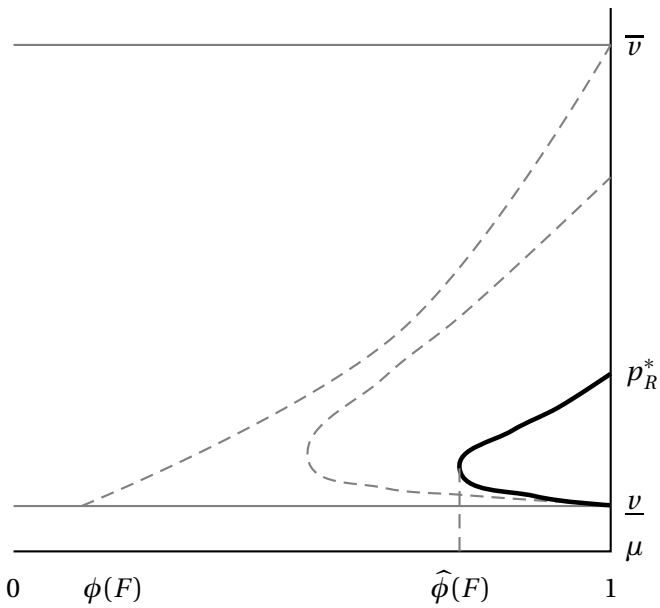

FIGURE 8. A typical shape of the contract curve.

In addition, at pairs (p,μ) that satisfies the above inequality,

$$\frac{\partial k(p,\mu)}{\partial \mu} = \frac{\partial c_B}{\partial \mu}\left(\ln\left(\frac{F(p)}{c_B}\right) + p\frac{f(p)}{F(p)}\right) < 0.$$

This implies that for each p, if there exists μ such that $k(p,\mu)=0$, this μ is unique. Now notice that

$$\lim_{\mu\to 1} k(p,\mu) = pf(p) - (1-F(p)) \lesseqgtr 0 \text{ if } p \lesseqgtr p_R^*.$$

Hence for $K(p,\mu)=0$, p is less than p_R^*. This establishes the first result.

If p' is sufficiently close to p_R^*, the rational commitment type chooses (p,μ) sufficiently close to the global maximizer $(p_R^*,1)$, and thus μ is close to 1 (see Figure 8). (If p' is equal to p_R^*, then the rational commitment type obviously chooses $(p_R^*,1)$.)

Now suppose p' is close to $\underline{v}$. Since $U_R(p,\mu) < \underline{v}$ for $\mu < 1$ and p close to $\underline{v}$ (see Figure 2), the rational commitment type chooses p such that the associated belief $\psi_N^{p'}(p)$ is sufficiently close to 1 (see Figure 8). □

The argument from this point proceeds as follows. First, I suppose $\Xi_N^* = [p', \rho_N(p')]$ and the rational commitment type chooses prices in $\Upsilon(p')$. This produces the distribution of commitment types, including both behavioral types and the rational commitment type. Given this distribution, the problem is equivalent to the one with only behavioral types. As in the proof of Proposition 2, it suffices to check whether the ratio of the normal type to the commitment types is equal to the expectation of the conditional ratio under the new distribution.

Let $p^{\Upsilon(p')} = \arg\min_{p\in\Upsilon(p')}\{\psi_N^{p'}(p)\}$ and $p_{\Upsilon(p')} = \arg\max_{p\in\Upsilon(p')}\{\psi_N^{p'}(p)\}$. For each $p' \in (\underline{v}, p_R^*]$ define $\overline{\lambda}^{\mu_B,\mu_R,p'} : \mathscr{F} \to [0,1]$ and $\underline{\lambda}^{\mu_B,\mu_R,p'} : \mathscr{F} \to [0,1]$ by

$$\overline{\lambda}^{\mu_B,\mu_R,p'}(P) = \frac{\mu_R 1_{\{p^{\Upsilon(p')}\in P\}} + \mu_B \lambda(P)}{\mu_R + \mu_B}$$

and

$$\underline{\lambda}^{\mu_B,\mu_R,p'}(P) = \frac{\mu_R 1_{\{p_{\Upsilon(p')}\in P\}} + \mu_B \lambda(P)}{\mu_R + \mu_B}$$

for $P \in \mathscr{F}$. These are mixed distributions of commitment types, conditional on the rational commitment type playing $p^{\Upsilon(p')}$ and $p_{\Upsilon(p')}$, respectively.

As in the proof of Proposition 2, define $\overline{J}^{\mu_B,\mu_R}, \underline{J}^{\mu_B,\mu_R} : (\underline{v}, p_R^*] \to \mathbb{R}_+$ by

$$\begin{aligned}
\overline{J}^{\mu_B,\mu_R}(p') &= \int_{(p',\rho_N(p'))} \frac{1-\psi_N^{p'}(p)}{\psi_N^{p'}(p)}\, d\overline{\lambda}^{\mu_B,\mu_R,p'} \\
&= \frac{\mu_R}{\mu_R+\mu_B}\frac{1-\psi_N^{p'}(p^{\Upsilon(p')})}{\psi_N^{p'}(p^{\Upsilon(p')})} + \frac{\mu_B}{\mu_R+\mu_B}\int_{(p',\rho_N(p'))} \frac{1-\psi_N^{p'}(p)}{\psi_N^{p'}(p)}\, d\lambda \\
\underline{J}^{\mu_B,\mu_R}(p') &= \int_{(p',\rho_N(p'))} \frac{1-\psi_N^{p'}(p)}{\psi_N^{p'}(p)}\, d\underline{\lambda}^{\mu_B,\mu_R,p'} \\
&= \frac{\mu_R}{\mu_R+\mu_B}\frac{1-\psi_N^{p'}(p_{\Upsilon(p')})}{\psi_N^{p'}(p_{\Upsilon(p')})} + \frac{\mu_B}{\mu_R+\mu_B}\int_{(p',\rho_N(p'))} \frac{1-\psi_N^{p'}(p)}{\psi_N^{p'}(p)}\, d\lambda.
\end{aligned}$$

By definition, $\psi_R^{p'}(p^{\Upsilon(p')}) \le \psi_R^{p'}(p_{\Upsilon(p')})$, and thus $\overline{J}^{\mu_B,\mu_R}(p') \ge \underline{J}^{\mu_B,\mu_R}(p')$. The minimum of both $\overline{J}^{\mu_B,\mu_R}(p')$ and $\underline{J}^{\mu_B,\mu_R}(p')$ is achieved at p_R^* because, by Lemma 5,

$$\frac{1-\psi_N^{p_R^*}(p_R^*)}{\psi_N^{p_R^*}(p_R^*)} = 0 \le \frac{1-\psi_N^{p'}(p_{\Upsilon(p')})}{\psi_N^{p'}(p_{\Upsilon(p')})} \le \frac{1-\psi_N^{p'}(p^{\Upsilon(p')})}{\psi_N^{p'}(p^{\Upsilon(p')})},$$

and $\psi_N^{p'}(p)$ is strictly increasing in p' (so $(1-\psi_N^{p'}(p))/\psi_N^{p'}(p)$ is strictly decreasing in p'). In addition, its value is $\mu_B C(F,\lambda)/(\mu_R+\mu_B)$ (see the definition of $C(F,\lambda)$ in Case 2). Now define a correspondence $J^{\mu_B,\mu_R} : (\underline{v}, p_R^*] \to \mathbb{R}_+$ by

$$J^{\mu_B,\mu_R}(p') = [\underline{J}^{\mu_B,\mu_R}(p'), \overline{J}^{\mu_B,\mu_R}(p')].$$

Every value in $J^{\mu_B,\mu_R}(p')$ can be achieved by putting appropriate weights on $p^{\Upsilon(p')}$ and $p_{\Upsilon(p')}$. In addition, by the Theorem of the Maximum, J^{μ_B,μ_R} is upper hemicontinuous.

A Case 3 equilibrium exists when the ratio of the normal type to the commitment types is in the range of the correspondence J^{μ_B,μ_R}, that is, when

$$\frac{\mu_B}{(\mu_R+\mu_B)}C(F,\lambda) \le \frac{\mu_N}{(\mu_R+\mu_B)} < M^{\mu_1,\mu_2} \equiv \sup\{\overline{J}^{\mu_B,\mu_R}(p') : p' \in (\underline{v}, p_R^*]\}.$$

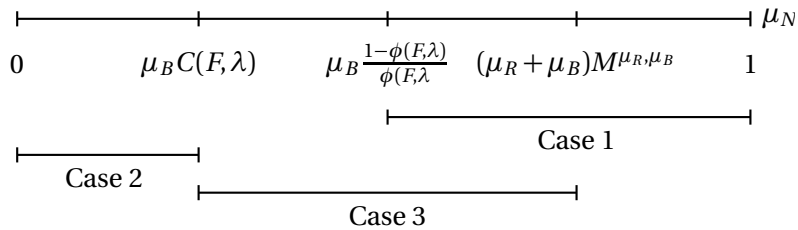

FIGURE 9. The summary of the full-fledged game.

PROPOSITION 5. *(i) (Case 1: degenerate) If $\mu_N/\mu_B \geq (1-\varphi(F,\lambda))/\varphi(F,\lambda)$, then there exists an equilibrium in which $\Xi_N^* = [\underline{v}, \overline{v}]$, $\mu^*(p) = \phi(F,p)\,\forall p > \underline{v}$, and $\Xi_R^* = \{\underline{v}\}$.*

(ii) (Case 2: separating) If $\mu_N/\mu_B < C(F,\lambda)$, then there exists an equilibrium in which $\Xi_N^* = [p', \rho_N(p')]$ for some $p' \in (p_R^*, p_N^*)$, $\Xi_R^* = \{p_R^*\}$, and

$$\mu^*(p) = \begin{cases} 1 & \text{if } p \notin \Xi_N^* \\ \psi_N^{p'}(p) & \text{if } p \in \Xi_N^*. \end{cases}$$

(iii) (Case 3: pooling) If $\mu_B C(F,\lambda) \leq \mu_N < (\mu_R+\mu_B)M^{\mu_1,\mu_2}$ then there exists an equilibrium in which $\Xi_R^* \subset \Xi_N^* = [p', \rho_N(p')]$ for some $p' \in (\underline{v}, p_R^*]$ and

$$\mu^*(p) = \begin{cases} 1 & \text{if } p \notin \Xi_N^* \\ \psi_N^{p'}(p) & \text{if } p \in \Xi_N^*. \end{cases}$$

Figure 9 summarizes all the results. When μ_N is sufficiently small, the normal type and the rational commitment type separate. The normal type offers only prices that are higher than the static monopoly price and the rational commitment type offers the static monopoly price. When μ_N is sufficiently large, the normal type mixes over all prices in $[\underline{v}, \overline{v}]$ and the rational commitment type offers the competitive price. In between, the two payoff types pool at prices higher than the competitive price.

When $\mu_B(1-\varphi(F,\lambda))/\varphi(F,\lambda) \leq \mu_N < (\mu_R+\mu_B)M^{\mu_1,\mu_2}$, there are multiple equilibria. This is when the probability of behavioral types is not sufficiently high, and thus the normal type has an incentive to mimic the rational commitment type, while the probability of the rational commitment type is not sufficiently low so that both types can be better off by coordination. If the rational commitment type offers prices higher than $\underline{v}$, then the normal type achieves more than $\underline{v}$ by mimicking the rational commitment type as well as the behavioral types. The rational commitment type also earns more than $\underline{v}$. If the rational commitment type offers $\underline{v}$, the normal type randomizes over $[\underline{v}, \overline{v}]$ and $\mu^*(p) = \phi(F,p)$. This in turn makes $\underline{v}$ the optimal price for the rational commitment type.

For the equilibrium selection in Section 4, let $\widehat{\phi}(F)$ be the largest value of μ below which the isoprofit curves of the two payoff types are never tangent to each other (see Figure 5). This value is not less than $\widetilde{\phi}(F)$ because U_R is tangent to U_N only in the upper

contour set of $U_R(p, \psi_N^{\underline{v}}(p))$. In fact, this value is strictly greater than $\widetilde{\phi}(F)$, because if p' is sufficiently close to $\underline{v}$, then the associated beliefs for prices in $\Upsilon(p')$ are close to 1 (Lemma 5).

As μ_B tends to 0,

$$\overline{J}^{\mu_B,\mu_R}(p') = \frac{\mu_R}{\mu_R+\mu_B}\frac{1-\psi_N^{p'}(p^{\Upsilon(p')})}{\psi_N^{p'}(p^{\Upsilon(p')})} + \frac{\mu_B}{\mu_R+\mu_B}\int_{(p',\rho_N(p'))}\frac{1-\psi_N^{p'}(p)}{\psi_N^{p'}(p)}\,d\lambda$$
$$\to \frac{1-\psi_N^{p'}(p^{\Upsilon(p')})}{\psi_N^{p'}(p^{\Upsilon(p')})},$$

and thus M^{μ_R,μ_B} converges to $(1-\widehat{\phi}(F))/\widehat{\phi}(F)$. In addition, as μ_B tends to 0, Case 2 becomes empty, while Case 1 covers the interval $(0,1]$. Given this, the equilibrium selection exercise in Section 4 is straightforward. Case 1 corresponds to the Coase conjecture outcome, while Case 3 corresponds to the outcome in which the isoprofit curves of the two payoff types are tangent to each other.

References

Abreu, Dilip and Faruk Gul (2000), "Bargaining and reputation." *Econometrica*, 68, 85–117. [20, 22]

Ausubel, Lawrence M. and Raymond J. Deneckere (1989), "Reputation in bargaining and durable goods monopoly." *Econometrica*, 57, 511–531. [19, 21, 36]

Bulow, Jeremy I. (1982), "Durable-goods monopolists." *Journal of Political Economy*, 90, 314–332. [19]

Chatterjee, Kalyan and Larry Samuelson (1987), "Bargaining with two-sided incomplete information: An infinite horizon model with alternating offers." *Review of Economic Studies*, 54, 175–192. [20]

Chatterjee, Kalyan and Larry Samuelson (1988), "Bargaining under two-sided incomplete information: The unrestricted offers case." *Operations Research*, 36, 605–618. [20]

Compte, Olivier and Philippe Jehiel (2002), "On the role of outside options in bargaining with obstinate parties." *Econometrica*, 70, 1477–1517. [20]

Doob, Joseph L. (1953), *Stochastic Processes*. Wiley, New York. [31]

Fudenberg, Drew, David K. Levine, and Jean Tirole (1985), "Infinite-horizon models of bargaining with one-sided incomplete information." In *Game-Theoretic Models of Bargaining* (Alvin E. Roth, ed.), 73–98, Cambridge University Press, Cambridge. [19, 21]

Gul, Faruk, Hugo Sonnenschein, and Robert Wilson (1986), "Foundations of dynamic monopoly and the Coase conjecture." *Journal of Economic Theory*, 39, 155–190. [19, 21]

Inderst, Roman (2005), "Bargaining with a possibly committed seller." *Review of Economic Dynamics*, 8, 927–944. [20, 21, 23]

Kambe, Shinsuke (1999), "Bargaining with imperfect commitment." *Games and Economic Behavior*, 28, 217–237. [18, 20, 36]

Kreps, David M. and Robert Wilson (1982), "Reputation and imperfect information." *Journal of Economic Theory*, 27, 253–279. [20]

Mailath, George J., Masahiro Okuno-Fujiwara, and Andrew Postlewaite (1993), "Belief-based refinements in signalling games." *Journal of Economic Theory*, 60, 241–276. [34]

McAfee, R. Preston and Thomas Wiseman (2008), "Capacity choice counters the Coase conjecture." *Review of Economic Studies*, 75, 317–332. [19]

Milgrom, Paul and John Roberts (1982), "Predation, reputation, and entry deterrence." *Journal of Economic Theory*, 27, 280–312. [20]

Myerson, Roger B. (1991), *Game Theory: Analysis of Conflict*. Harvard University Press, Cambridge, Massachusetts. [20]

Stokey, Nancy L. (1981), "Rational expectations and durable goods pricing." *Bell Journal of Economics*, 12, 112–128. [19]

Submitted 2007-11-20. Final version accepted 2008-11-23. Available online 2008-11-23.