

Subsidize First And Profit Later: An Incomplete Information Analysis of Technology Subsidization

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ABSTRACT

To drive adoption, producers of new technologies frequently subsidize consumers, pricing below cost in early periods and recouping costs once an installed base is established. Regulating such subsidization requires distinguishing welfare-improving entrants building a customer base from inefficient firms exploiting investor subsidies to displace superior incumbents. This paper develops a two-period incomplete information model of technology adoption in which the entrant's net benefit of the new technology is private information. This model admits a unique pooling equilibrium in which all types of the entrant post identical first-period rental rates. This result delivers a stark challenge for antitrust regulators: both a welfare-improving entrant and a welfare-reducing predator play the same strategy, and no price-based regulatory test can distinguish them.

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1 Introduction

Leaked internal documents reveal that during its startup phase, Uber heavily subsidized riders to drive adoption and build market share¹. During this period, Uber burned through \$25 billion since its founding before recording its first cash-flow-positive quarter in 2022². Was this below-cost pricing the rational strategy of an efficient entrant building an installed base, or anticompetitive predation by an inefficient firm exploiting investor subsidies to crowd out superior incumbents? This paper argues the question may be unanswerable in principle. With a new generation of AI companies burning more cash than ever³, this question requires more effort from both the research and regulatory communities.

This paper develops a two-period model of technology adoption in which a new capital firm enters a market occupied by an incumbent. The entrant’s marginal cost is private information leading to uncertainty about the true benefit of adopting the new technology. Under a single participation condition, we prove the existence and uniqueness of a pooling perfect Bayesian equilibrium in which all types of the entrant post the same first-period rental rate. The central result is an identification problem for competition regulators: a welfare-improving entrant and a welfare-reducing predator employ identical pricing strategies. In many cases, both price below cost in period one and recoup through switching-cost lock-in in period two, satisfying both prongs of the Areeda and Turner (1975) predatory pricing test⁴.

This paper contributes to three strands of the industrial organization literature. The first strand is the role of information in technology adoption (Smith and Ulu (2017), Sendstad and Chronopoulos (2021), Ye, Paulson and Khanna (2024)). This is the first paper to examine how these forces interact with strategic competition and antitrust policy. The second is dynamic competition with switching costs (Klemperer (1987b), Klemperer (1987a), Farrell and Klemperer (2007), Biglaiser, Crémer and Dobos (2013)). This model departs from these benchmarks by introducing asymmetric switching costs and by making the entrant’s marginal cost private information. This generates novel equilibrium pricing dynamics absent from the complete-information literature. The third strand is limit pricing and signaling under asymmetric information (Milgrom and Roberts (1982a), Milgrom and Roberts (1982b), Kreps and Wilson (1982), Sweeting, Roberts and Gedge (2020)). In contrast to the existing literature, in this model, the entrant’s cost is private rather than the incumbent’s, and because costs are eventually revealed, beliefs formed in period one have no consequences for period-two payoffs. This eliminates the stan-

¹Lawrence (2022) reports that a January 2015 internal presentation shows the subsidy rate for Madrid and Berlin. In Madrid, Uber charged an average fare of \$9.10 per hour while paying drivers an average subsidy of \$17.50 per hour. In Berlin, the gross hourly fare was \$2.20 against a driver subsidy of \$10.20.

²Lee (2022)

³Muppidi (2025) reports that OpenAI plans to burn \$115B through 2029, representing an unprecedented level of pre-profitability cash burn for a private technology firm.

⁴This is an additional criticism of the Areeda and Turner (1975) tester beyond those previously noted by Bolton, Brodley and Riordan (2000) and Hovenkamp (2015)

standard signaling incentive and produces a unique pooling equilibrium in which no type of entrant can credibly separate.

2 Model

2.1 Environment

The economy consists of two types of agents: a unit mass of atomistic production firms and two capital firms indexed by $i \in \{O, N\}$. Capital firm i 's capital is characterized by its productivity y_i , its marginal cost c_i , and a switching cost κ_i that a production firm must pay prior to utilizing firm i 's capital for the first time. A production firm that has previously adopted firm i 's capital and wishes to switch to firm $j \neq i$ must pay κ_j .

There are two time periods $t = 1, 2$. The first represents a new technology being introduced to the market. All production firms enter period 1 having previously adopted capital firm O 's capital, so κ_O has already been paid. Capital firm N enters the market in period 1 with a new capital good. The productivity y_N and switching cost κ_N are common knowledge. The marginal cost c_N is private information of firm N ; production firms and firm O share a common prior F over c_N with support $[\underline{c}, \bar{c}]$. The second period represents the new technology reaching maturity: c_N is publicly revealed before any actions are taken.

At the start of each period, both capital firms simultaneously post rental rates $r_{O,t}$ and $r_{N,t}$. Production firms then choose which capital good to utilize, paying the relevant switching cost if choosing to switch.

Let $k_{i,t} \in \{0, 1\}$ denote whether a production firm utilizes capital i in period t , where $k_{O,t} + k_{N,t} = 1$. All production firms enter the model on capital O , so $k_{O,0} = 1$ and $k_{N,0} = 0$. The period t payoff for a production firm is

$$u_t(k_{N,t-1}) = \sum_{i \in \{O, N\}} k_{i,t} (y_i - r_{i,t} - \kappa_i \cdot \mathbf{1}\{k_{i,t-1} = 0\}). \quad (1)$$

The switching cost κ_i is paid whenever a production firm utilizes capital i for the first time, i.e., when $k_{i,t} = 1$ and $k_{i,t-1} = 0$. Production firms maximize expected lifetime utility

$$U = u_1(0) + \mathbb{E}_g [v(u_2(k_{N,1}))] \quad (2)$$

where v is strictly increasing and concave. Expectations are taken over the post-rent posting set of beliefs g . The period $t = 1$ payoff enters linearly because period $t = 1$'s rents are observed before the production firms' capital choice⁵. The concavity of v captures risk aversion over the uncertain period-two payoff, which depends on the privately known c_N through its effect on post-revelation rents.

⁵In principle, one could define U by $U = v(u_1(0)) + \mathbb{E}_g [v(u_2(k_{N,1}))]$. The resulting rents are implicitly defined as the solution of a nonlinear equation.

Let $s_{i,t}$ denote the market share of capital firm i in period t . The period payoff for capital firm i is

$$\pi_{i,t}(s_{N,t-1}) = (r_{i,t} - c_i) s_{i,t} \quad (3)$$

Definition 1. A *Perfect Bayesian Equilibrium* consists of a rental rate strategy $\{r_{N,t}(c_N), r_{O,t}\}$, a capital choice strategy $\{k_{i,t}(r_{N,t}, r_{O,t})\}$, and a belief system $g(c_N|r_{N,1})$ where

1. (*Belief Consistency*) For any $r_{N,1}$ posted with positive probability, after rents are posted, beliefs are updated via Bayes' rule. In period $t = 2$, $g(c_N|r_{N,1})$ is a point mass at the actual c_N .
2. (*Production Optimization*) Production firms set their capital choice strategy to maximize their expected lifetime utility (2).
3. (*Capital Optimization*) Each capital firm sets its rents to maximize its profits subject to its beliefs along with the production firms' and other capital firm's best response.

2.2 Equilibrium Results

Define technology gain δ by

$$\delta(c_N) = (y_N - c_N) - (y_O - c_O) \quad (4)$$

and define Λ by

$$\Lambda = \mathbb{E}_f [v(u_2(1)) - v(u_2(0))] - \mathbb{E}_f [u_2(1) - u_2(0)]. \quad (5)$$

This paper will focus on equilibrium where the new capital firm will enter into the market:

Assumption 1. *The primitives satisfy*

$$\delta(\bar{c}) \geq \begin{cases} \frac{1}{2}(\kappa_N - \Lambda) & : \kappa_O > -\delta(\bar{c}) \\ \kappa_N + \kappa_O - \Lambda & : \kappa_O \leq -\delta(\bar{c}) \end{cases} . \quad (6)$$

This assumption ensures that capital firm N finds it profitable to enter for all types $c_N \in [\underline{c}, \bar{c}]$. The two different cases result from capital firm N with costs \bar{c} forecasting the expected period two outcome. It is possible for a set of overly optimistic prior beliefs f to cause (6) to be satisfied even when $\delta < 0$. If Assumption 1 does not hold for \bar{c} but does hold for $c > \underline{c}$, then there exists a semi-pooling equilibrium on the support $[\underline{c}, c]$.

Lemma 1. Under Assumption 1, there exists a pooling perfect Bayesian equilibrium where

1. Rents are given by

$$r_{N,1}(c_N) = c_O + y_N - y_O - \kappa_N - \kappa_O + \Lambda \quad (7)$$

$$r_{O,1} = c_O - \mathbb{E}_f[\pi_{O,2}(0) - \pi_{O,2}(1)] \quad (8)$$

$$r_{N,2} = \begin{cases} c_O + y_N - y_O + \kappa_O & : s_{N,1} = 1 \text{ and } \kappa_O > -\delta \\ c_N & : s_{N,1} = 1 \text{ and } \kappa_O \leq -\delta \\ c_O + y_N - y_O - \kappa_N & : s_{N,1} = 0 \text{ and } \delta > \kappa_N \\ c_N & : s_{N,1} = 0 \text{ and } \delta \leq \kappa_N \end{cases}, \quad (9)$$

$$r_{O,2} = \begin{cases} c_O & : s_{N,1} = 1 \text{ and } \kappa_O \geq -\delta \\ c_N + y_O - y_N - \kappa_O & : s_{N,1} = 1 \text{ and } \kappa_O < -\delta \\ c_O & : s_{N,1} = 0 \text{ and } \delta \geq \kappa_N \\ c_N + y_O - y_N + \kappa_N & : s_{N,1} = 0 \text{ and } \delta < \kappa_N \end{cases}, \quad (10)$$

2. Production firms all pick capital firm N in period one, $k_{N,1} = 1$. In the second period, production firms revert to capital firm O if and only if $\kappa_O \leq -\delta(c_N)$.

3. The post rent beliefs are the same as the prior, $g = f$.

Furthermore, this is the unique equilibrium.

Proof. The proof of this lemma can be found in Appendix A. \square

The critical result is that the equilibrium is pooling meaning that, through rent posting behaviors alone, the production firms, capital firm O , or any outside observers are unable to gain any information about capital firm N 's true costs. This result also shows the necessity of risk aversion for beliefs to impact the model's outcome.

Corollary 1. *When v is the identity function, capital firm N rents are invariant to the prior beliefs. This rent is the same as the full information game.*

Proof. In this case, $\Lambda = 0$ meaning that (7) becomes $r_{N,1}(c_N) = c_O + y_N - y_O - \kappa_N - \kappa_O$. \square

Welfare Analysis: Focusing on the case where $\kappa_O > -\delta(c_N)$ ⁶, total welfare W is $W = 2(y_N - c_N) - \kappa_N$.

Proposition 1. *When $\kappa_O > -\delta(c_N)$, the entrance of capital firm N , compared to the case where capital firm O is an unrestricted monopoly, is welfare improving if and only if $2\delta(c_N) > \kappa_N$.*

Proof. The counterfactual welfare is $2(y_O - c_O)$. The difference is $2\delta - \kappa_N$. \square

When $\kappa_O \leq -\delta(c_N)$, the entrance of capital firm N is always welfare reducing. In this case, production firms pay κ_N to adopt an inferior technology in period one and κ_O to revert in period two, wasting both switching costs.

⁶In this case, production firms adopt capital N in period $t = 1$ and stick with it in period $t = 2$.

3 Implications For Antitrust Regulation

The pooling equilibrium delivers a stark identification problem for antitrust regulators. The legal framework governing predatory pricing in the United States, anchored by Areeda and Turner (1975), requires two elements: below-cost pricing and a dangerous probability of recoupment. With the model that means capital firm N prices below its marginal cost c_N in period one and recoups in the second period.

Corollary 2. *Capital firm N posts rents below its marginal cost c_N when*

$$\delta(c_N) < \kappa_N + \kappa_O - \Lambda. \quad (11)$$

Proof. Setting the rental rate (7) less than c_N results in (11). \square

The Areeda-Turner test is therefore triggered by any c_N satisfying (11). However, due to the pooling equilibrium, the regulator can not distinguish between below-cost and above-cost pricing from posted rents alone. This is particularly important when $\Lambda < \kappa_O$ since there exist types c_N such that $\kappa_N - \Lambda \leq 2\delta(c_N) < \kappa_N$ which are welfare reducing entrants who price below cost in the first period to gain market share.

The identification problem is fundamental rather than empirical. Because all types of capital firm N post the same first-period rent $r_{N,1}$ in the unique pooling equilibrium, a regulator observing only the rental rate cannot determine whether below-cost pricing reflects efficient penetration by a superior technology or anticompetitive subsidization by an inferior one. The recoupment mechanism compounds this difficulty: unlike classical predation models where recoupment requires driving the incumbent from the market, recoupment here occurs through switching-cost lock-in while capital firm O remains active. A regulator who correctly identifies below-cost pricing and plausible recoupment has satisfied both prongs of the Areeda and Turner (1975) test, yet has learned nothing about whether the entrant is welfare-improving or welfare-reducing. Conversely, blocking entry on the basis of below-cost pricing alone eliminates welfare-improving technologies and welfare-reducing ones in equal measure.

Since observed prices are uninformative, an alternative regulatory approach is needed. One candidate is to design a mechanism that induces costs revelation directly. For example, a menu of entry permits specifying combinations of subsidy allowances and recoupment price ceilings. The effectiveness of such a program and better alternatives is left for future research.

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A Proof of Lemma 1

This proof will begin by characterizing a candidate pooling equilibrium, showing no firm would deviate from this candidate equilibrium, and then show the uniqueness.

A.1 Period Two Optimal Rental Rates

For capital firm i , given its competitor's rental rate $r_{-i,2}$, there are two key rental thresholds: the maximum rental rate where the firm can retain all of its installed base, $r_{i,2}^{\text{retain}}$, and the maximum rental rate where the firm can cause its competitor's installed base to switch to it, $r_{i,2}^{\text{switch}}$. These are defined by the point the production firms are indifferent between switching and staying. That is

$$v(y_i - r_{i,2}^{\text{retain}}) = v(y_{-i} - r_{-i,2} - \kappa_{-i}), \quad (12)$$

$$v(y_i - r_{i,2}^{\text{switch}} - \kappa_i) = v(y_{-i} - r_{-i,2}). \quad (13)$$

Since v is strictly increasing

$$r_{i,2}^{\text{retain}} = r_{-i,2} + y_i - y_{-i} + \kappa_{-i}, \quad (14)$$

$$r_{i,2}^{\text{switch}} = r_{-i,2} + y_i - y_{-i} - \kappa_i. \quad (15)$$

The lowest rental rate a firm is willing to charge in the second period is their cost c_i . There are four possible cases.

Case 1: $s_{N,1} = 1$ and $\kappa_O > -\delta$. Capital firm N won the entire market share in the first period and capital firm O attempts to win the share back. If capital firm O post the lowest rental rate it can, $r_{O,2} = c_O$, the corresponding $r_{N,2}^{\text{retain}}$ is

$$r_{N,2}^{\text{retain}} = c_O - y_O + y_N + \kappa_O = c_N + \delta + \kappa_O > c_N \quad (16)$$

implying that capital firm N could slightly undercut capital firm O and retain the market share. Thus, the rents in this case are

$$r_{N,2} = c_O + y_N - y_O + \kappa_O \quad (17)$$

$$r_{O,2} = c_O. \quad (18)$$

Case 2: $s_{N,1} = 1$ and $\kappa_O \leq -\delta$. Capital firm N won the entire market share in the first period and is attempting to retain its market share. If it posts the lowest rental rate it can, $r_{N,2} = c_N$, the corresponding $r_{O,2}^{\text{switch}}$ is

$$r_{O,2}^{\text{switch}} = c_O - \delta - \kappa_O \geq c_O \quad (19)$$

implying that capital firm O can slightly undercut capital firm N and capture the market share⁷. The resulting rents are

$$r_{N,2} = c_N \quad (20)$$

$$r_{O,2} = c_N + y_O - y_N - \kappa_O. \quad (21)$$

Case 3: $s_{N,1} = 0$ and $\delta > \kappa_N$. Capital firm O won the entire market share in the first period and is attempting to retain its market share. If it posts the lowest rent it can $r_{O,2} = c_O$, the corresponding $r_{N,2}^{\text{switch}}$ is

$$r_{N,2}^{\text{switch}} = c_N + \delta - \kappa_N > c_N \quad (22)$$

implying that capital firm N could slightly undercut capital firm O and capture the market share. The resulting rents are

$$r_{N,2} = c_O + y_N - y_O - \kappa_N \quad (23)$$

$$r_{O,2} = c_O. \quad (24)$$

Case 4: $s_{N,1} = 0$ and $\delta \leq \kappa_N$. Capital firm O won the entire market share in the first period and capital firm N is attempting to capture its market share. If capital firm N posts the lowest rent it can $r_{N,2} = c_N$, the corresponding $r_{O,2}^{\text{retain}}$ is

$$r_{O,2}^{\text{retain}} = c_O - \delta + \kappa_N \geq c_O \quad (25)$$

implying that capital firm O could slightly undercut capital firm N and retain the market share. The resulting rents are

$$r_{N,2} = c_N \quad (26)$$

$$r_{O,2} = c_N + y_O - y_N + \kappa_N. \quad (27)$$

⁷In the case of equality, both capital firms post their lowest rent and the production firms are indifferent between switching and not.

A.2 Period Two Payoffs

The period-two market shares, profits, and production firm period utility in these four cases are

$$(s_{N,2}(s_{N,1}), s_{O,2}(s_{N,1})) = \begin{cases} (1, 0) & : s_{N,1} = 1 \text{ and } \kappa_O > -\delta \\ (0, 1) & : s_{N,1} = 1 \text{ and } \kappa_O \leq -\delta \\ (1, 0) & : s_{N,1} = 0 \text{ and } \delta > \kappa_N \\ (0, 1) & : s_{N,1} = 0 \text{ and } \delta \leq \kappa_N \end{cases}, \quad (28)$$

$$(\pi_{N,2}(s_{N,1}), \pi_{O,2}(s_{N,1})) = \begin{cases} (\delta + \kappa_O, 0) & : s_{N,1} = 1 \text{ and } \kappa_O > -\delta \\ (0, -\delta - \kappa_O) & : s_{N,1} = 1 \text{ and } \kappa_O \leq -\delta \\ (\delta - \kappa_N, 0) & : s_{N,1} = 0 \text{ and } \delta > \kappa_N \\ (0, \kappa_N - \delta) & : s_{N,1} = 0 \text{ and } \delta \leq \kappa_N \end{cases}, \quad (29)$$

$$u_2(k_{N,1}) = \begin{cases} y_O - c_O - \kappa_O & : k_{N,1} = 1 \text{ and } \kappa_O > -\delta \\ y_N - c_N & : k_{N,1} = 1 \text{ and } \kappa_O \leq -\delta \\ y_O - c_O & : k_{N,1} = 0 \text{ and } \delta > \kappa_N \\ y_N - c_N - \kappa_N & : k_{N,1} = 0 \text{ and } \delta \leq \kappa_N \end{cases}. \quad (30)$$

Note that $\delta > \kappa_N$ implies capital firm N supplants firm O in period 2 regardless of the period one outcome and $\kappa_O > -\delta$ implies inefficient lock-in.

A.3 Period One Candidate Rents

Assume capital firm N 's rental strategy is $r_{N,1}(c_N) = r_{N,1}^*$. This implies that the beliefs g are the same as the prior beliefs f . If capital firm N wants to charge the maximum rent while capturing the market in period 1, then $r_{N,1}^*$ is defined the point where the production firms are indifferent between adopting and not adopting:

$$y_N - r_{N,1}^* - \kappa_N + \mathbb{E}_f[v(u_2(1))] = y_O - r_{O,1} + \mathbb{E}_f[v(u_2(0))]. \quad (31)$$

Rearranging gives

$$r_{N,1}^* = r_{O,1} + y_N - y_O - \kappa_N + \mathbb{E}_f[v(u_2(1)) - v(u_2(0))]. \quad (32)$$

The minimum rent capital firm i is willing to post is the point where it is indifferent between losing and winning the market. For capital firm O , this is defined by

$$r_{O,1} - c_O + \mathbb{E}_f[\pi_{2,O}(0)] = \mathbb{E}_f[\pi_{2,O}(1)]. \quad (33)$$

Rearranging gives

$$r_{O,1} = c_O - \mathbb{E}_f[\pi_{2,O}(0) - \pi_{2,O}(1)]. \quad (34)$$

Assuming capital firm O posts its minimum rent, (32) becomes

$$\begin{aligned} r_{N,1}^* &= c_O + y_N - y_O - \kappa_N + \mathbb{E}_f[v(u_2(1)) - v(u_2(0))] - \mathbb{E}_f[\pi_{2,O}(0) - \pi_{2,O}(1)] \\ &= y_N - y_O + c_O - \kappa_N - \kappa_O + \Lambda \end{aligned} \quad (35)$$

The minimum rent capital firm N with costs c_N is willing to post, $\underline{r}_{N,1}(c_N)$, is defined by the rent the firm is indifferent between winning and losing the market:

$$\underline{r}_{N,1}(c_N) - c_N + \pi_{2,N}(1) = \pi_{2,N}(0). \quad (36)$$

Rearranging gives⁸

$$\underline{r}_{N,1}(c_N) = \begin{cases} c_N - \kappa_N - \kappa_O & : \delta > \kappa_N \\ c_N & : \delta \leq \kappa_N \text{ and } \kappa_O \leq -\delta \\ c_N - (\delta + \kappa_O) & : \delta \leq \kappa_N \text{ and } \kappa_O > -\delta \end{cases}. \quad (37)$$

The difference between $r_{N,1}^*$ and $\underline{r}_{N,1}(c_N)$ depends on which case the primitives fall in.

Case 1: $\delta(c_N) > \kappa_N$

$$r_{N,1}^* - \underline{r}_{N,1}(c_N) = \delta(c_N) + \Lambda. \quad (38)$$

Participation requires $\delta(c_N) > -\Lambda$.

Case 2: $\delta(c_N) \leq \kappa_N, \kappa_O \leq -\delta(c_N)$

$$r_{N,1}^* - \underline{r}_{N,1}(c_N) = \delta(c_N) - \kappa_N - \kappa_O + \Lambda. \quad (39)$$

Participation requires $\delta(c_N) > \kappa_N + \kappa_O - \Lambda$.

Case 3: $\delta(c_N) \leq \kappa_N, \kappa_O > -\delta(c_N)$

$$r_{N,1}^* - \underline{r}_{N,1}(c_N) = 2\delta(c_N) - \kappa_N + \Lambda. \quad (40)$$

Participation requires $2\delta(c_N) > \kappa_N - \Lambda$.

Since δ is decreasing in c_N , the binding type is \bar{c} . Assumption 1 requires the relevant condition for whichever case \bar{c} falls in. Thus, every type of capital firm N can adopt $r_{N,1}^*$ and, if capital firm O is able to match, slightly undercut this rent.

A.4 No Deviation

If capital firm N posts a rent higher than $r_{N,1}^*$, it loses the entire market share. So, its payoff would be $\pi_{2,N}(0)$. From (36), it follows that

$$\pi_{2,N}(0) = \underline{r}_{N,1}(c_N) - c_N + \pi_{2,N}(1) < r_{N,1}^* - c_N + \pi_{2,N}(1). \quad (41)$$

Thus, the deviation is less profitable. If, on the other hand, it posts a rent less than $r_{N,1}^*$ it is still retaining its market share but is losing profit with no gain.

If capital firm O posts a rent higher than $r_{O,1}$, it still would have zero market share. Thus, its profits are identical to the candidate rent. If capital firm O posts a rent lower than $r_{O,1}$, that would be lower than its zero profit rent. Even if it gains market share, it would be taking losses.

⁸ $\delta > \kappa_N$ implies $\delta + \kappa_O > 0$.

A.5 No Separating Equilibrium

Assume, for the purpose of contradiction, that there exists a separating equilibrium and corresponding $\hat{r}_{1,N}(c_N)$ where distinct types post distinct rents and beliefs update to point masses on the true c_N . Let $c_L < c_H$. The difference in payoffs for a type c_L firm deviating to the rents of a type c_H firm is

$$\hat{r}_{1,N}(c_H) - \hat{r}_{1,N}(c_L). \quad (42)$$

Thus, to prevent a firm of type c_L deviating to the different rent $\hat{r}_{1,N}(c_H) \leq \hat{r}_{1,N}(c_L)$. On the other hand, the difference in payoffs for a type c_H firm posting the rents of a type c_L firm is

$$\hat{r}_{1,N}(c_L) - \hat{r}_{1,N}(c_H) \quad (43)$$

meaning that, to prevent deviations, $\hat{r}_{1,N}(c_H) \geq \hat{r}_{1,N}(c_L)$. Thus,

$$\hat{r}_{1,N}(c_H) = \hat{r}_{1,N}(c_L) \quad (44)$$

contradicting the existence of a separating equilibrium. By an analogous argument, no semi-separating equilibrium exists.