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THE PROFITABLE SUPPRESSION OF INVENTIONS: TECHNOLOGY CHOICE AND ENTRY DETERRENCE

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The Profitable suppression of inventions:

Technology choice and entry deterrence§

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Abstract

AT&T was known for both funding a world-class research lab and delaying deployment of useful innovations from the lab. To explain this behavior we consider a model with an incumbent facing a potential entrant. The incumbent can choose from two technologies for production: old and new. The entrant's choice is limited to the old. We show that, under correlated production uncertainty, use of the common technology exposes the entrant to a greater risk. Therefore, the incumbent may suppress a newer, more efficient technology in favor of the old as a means to deter entry.

JEL: D83, L12, L13
Key words: technology choice, entry deterrence, production shocks, correlations of strategies

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Often a decade or more passed before new features, such as long-distance direct dialing and touch-tone phones, would finally percolate throughout the system…Perhaps the most egregious example of the company's technological conservatism was the languid introduction of electronic switching, conceived in the 1930s…. The noisy, clunky relays [of the old technology] opened and closed circuits to establish continuous physical connections between any two phones. A solid-state switch, on the other hand, would have no moving parts, making it smaller, faster, quieter, and more reliable. Although electronic switches based on solid-state components had been developed by 1959, AT&T didn't introduce the first digital switch into the Bell System until 1976. And electronic switching was still being gradually rolled out well into the 1980s…

- Historian M. Riordan (2005)

1. Introduction

During the 20th century, AT&T was known both for its development of new technologies and needless delay in deploying them. For example, AT&T waited for twenty years to introduce both the handset and dial system and the automatic phone (Dunford 1987). Delayed deployment of new technologies is surprising, given the fact that development costs had been sunk. Further, AT&T faced competitors and potential entrants in different markets all this time. From the very beginning Western Union was a rival in the long distance communications market though over time AT&T steadily gained domination.[1] However, once Western Union for all intents and purposes disappeared as a rival to AT&T, new ones began to appear in the long distance market: MCI (Microwave Communications, Inc.) followed by Datran (Data Transmission Company).

AT&T also faced competition at the local level from other phone service providers. "When Alexander Graham Bell's patents expired in 1893, AT&T was faced with the entry of competitors into its market. The newcomers, known collectively as the Independents, appeared first in small cities and towns in the Midwest, but quickly spread out across the nation and into

[1] "What tied the failure of Western Union to the success of Bell was a porous and shifting boundary between telegraphy and telephony, between what twentieth-century managers and regulators would later call the record and voice communications industries. Through the contract of 1879, Western Union attempted to keep Bell out of the long-distance communications market, which Western Union's managers viewed as the exclusive province of telegraphy….While regulators propped up Western Union as the only competitor to AT&T, by the 1960s it was offering only token competition." Hochfelder (2002)

larger cities" (Nix and Gabel 1993). The independents remained through the 20^{th} century, some outlasting AT&T itself. Interestingly, AT&T's main approach to deterring entry was by "developing its long-distance network and through patent litigation against its competitors" (Nix and Gabel 1993). Furthermore, the Kingsbury Commitment (1913) restricted AT&T from acquiring the independents and forced it to provide long-distance service to independents (Galambos 1992). Given that AT&T faced potentially entry from independents that it could not buy out, its delay in introducing superior, patented technology seems even more surprising.

Further, AT&T is not the only company that has allegedly delayed the introduction of a new technology. For example, GE delayed the introduction of fluorescent bulbs until a small rival (Sylvania) began producing them (Dunford 1987). IBM too had been accused of delaying introducing new main frames until rivals had finally entered the market with the old technology (Scherer 2007).

In this paper we examine the optimality of delayed introduction of new technology for AT&T's, IBM's or any incumbent monopolist. Given the choice between an old technology and a newly patented, lower cost technology, it is clear that a monopolist under normal circumstances would choose the new technology. We show however that, when facing a potential entrant having access only to the old technology, an incumbent may have an incentive to shelve the new technology even if it is more efficient.

Broadly, this phenomenon occurs when a new technology or product is distinct from the old one and there is technology-specific production uncertainty. In such a case, when the incumbent uses the old technology that is available to the entrant, both the incumbent and the entrant are exposed to common cost shocks. If instead the incumbent chooses a new, unconnected technology, then they are exposed to independent cost shocks. As a result, with the introduction of a new technology, an incumbent inadvertently shields an entrant from the shocks the incumbent faces. In duopolistic competition this shielding raises the expected profit for the entrant, thereby making entry more appealing.

To see why this is so intuitively, consider what occurs when an entrant happens to draw a low cost and increases its output. If the incumbent uses the old technology, the incumbent too draws the same low cost realization and increases output. On the other hand, if the incumbent uses the new technology its cost realization is uncorrelated to the entrant's, and so the incumbent is less likely to be increasing output. Thus, the use of the common technology correlates the firms' strategies. Further, as we show below, correlations of strategies make the profit function less convex, thereby reducing expected profits for the entrant. As a result, the incumbent may find it easier to deter entry with the old technology, even though it has access to a new and more efficient technology. Thus, while technology adoption as entry deterrence is not new in the literature (e.g., if the new technology has lower cost, the incumbent can undercut potential entrants), we bring a new perspective to it by emphasizing the role that cost uncertainty plays.[2]

Two points are worth emphasizing regarding suppression of innovations as a method of entry deterrence. First, what drives our result is not risk aversion but the correlations of strategies induced by a technology choice. To show this we assume risk neutrality of both firms. Secondly, unlike in previous work in strategic competition, our result holds whether the firms compete in quantities or in prices. We demonstrate this by showing that both Cournot and Hotelling price competition yield the same qualitative result.

In the next section, we briefly review the related literature. In section 3, we consider the standard model of quantity competition – Cournot competition – in a model in which the

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[2] In Ellison and Ellison (2007) entry costs for the potential entrant are stochastic, but this plays a role in making the effect of the incumbent's choice of investment continuous.

incumbent first chooses its technology and then the entrant chooses whether to enter with the old technology. In section 4, we consider price competition in the classic Hotelling model, finding that our result does not qualitatively change. Section 5 concludes.

2. Literature review

The literature on entry deterrence under cost uncertainty includes Maskin (1999), Waldman (1987) and Harrington (1987). Waldman (1987) considers the effect of uncertainty on non-cooperative entry deterrence and in particular its effect on the free rider problem. As we consider a lone incumbent the free rider issue does not arise here. Harrington (1987) examines the effects of uncertainty on entry deterrence when signaling is possible, while signaling cannot arise in our model. Closer to our work, Maskin (1999) studies the classic model of capacity choice by an incumbent facing a possible entrant, each facing a common cost shock, much as in our model when the incumbent chooses the old technology. He shows that cost uncertainty can lead to the incumbent choosing a larger level of capacity to deter entry. Since we consider technology choice instead of capacity choice, the role of cost uncertainty differs: in our analysis, by choosing the old technology the incumbent makes the strategies more correlated, lowering the entrant's expected profits. The incumbent thus benefits from the uncertainty. In Maskin (1999) there is only one technology for the incumbent and the uncertainty forces it to choose a greater capacity, making deterrence more costly. Thus, the uncertainty harms the incumbent.

Methodologically, our work is perhaps most closely related to that of Choi and Yi (2000), which examines vertical foreclosure and the choice of input specifications under cost uncertainty. In Choi and Yi (2000), there are two upstream firms selling inputs to two downstream firms. Each upstream firm can produce a specialized input for one downstream firm or a generalized input that can be used by the both downstream firms. The authors show that vertical integration is anticompetitive because an upstream firm would produce the generalized inputs in non-integrated vertical structure but, when integrated, it chooses to produce the specialized input for its downstream firm, thereby foreclosing the rival downstream firm. Although the environments differ, this result hinges, like ours, on the fact that the reduction of cost correlation can create a benefit. Specifically, in Choi and Yi (2000) the upstream firms observe cost realizations and then engage in Bertrand competition when producing the generalized inputs. As a result, an upstream firm earns zero profits if the rival firm draws the same or lower cost realization and captures all of the profit if it has the lower cost realization. Producing specialized inputs decreases the probability of both firms having the same cost realization and raises expected profits.[3] Thus the firms benefit from a reduction in correlation.

Our results could also be characterized as raising-the-rival's-costs strategy (Salop 1979, Salop and Shefffman 1983, 1987).[4] However, here the means is the choice of technology. By staying with the old technology the incumbent increases the correlation of the strategies, and decreases the expected profit to the potential entrant. As a result, the incumbent may choose an unpatented inferior technology over its patented new technology. Thus, the basic structure here is the reverse of the effect found in Gilbert and Newbery (1982) and Reinganum (1983), where the incumbent invents and patents an inferior technology to keep it from falling into the hand of the potential entrant. For the same reason our results are distinct from work on network compatibility and entry deterrence in several respects. For example, since the monopolist in our model has the new technology, our result is distinct from the one of the "excess inertia" found in Farrell and Saloner (1986) that can lead to predation. Likewise, there is no network externality

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[3] As Choi and Yi (2000) note this is also reminiscent of Dasgupta and Maksin's (1987) result that project portfolios are characterized by excessive correlation.

[4] Foreclosure in Choi and Yi (2000) also has the effect of raising the rival's cost and benefiting the integrated firms.

here so the incumbent does not remain with the old system because of the large customer base (Katz and Shapiro 1992).

3. Basic environment

Consider an incumbent monopolist (firm *i*) under the threat of entry (by firm *e*). Assume linear demand

$$p(Q) = 1 - Q$$

if $Q \leq 1$ and $p(Q) = 0$ otherwise. If there is entry, then the firms produce homogeneous products and compete in quantities (i.e., Cournot competition) with aggregate output $Q = q_i + q_e$, where q_k is firm *k*'s (= *i*, *e*) output. Otherwise, the incumbent retains its monopoly position and so $Q = q_i$.

There are two technologies available for production: an old technology (*O*), which can be used by either firm, and a new technology (*N*), which is available only to the incumbent. Firms adopting either technology are subject to technology-specific cost shocks, which can occur, e.g., when the new technology results in a drastically different production process from the one under the old technology. For simplicity, assume that marginal costs are stochastic but constant with respect to output. Let $\bar{c}_O$ denote the expected costs of the old technology and σ_O^2 its variance. Analogously, let $\bar{c}_N$ be the expected costs of the new technology and σ_N^2 its variance. The distributions are assumed independent and have support [0, 1), given the normalization on the demand function. We emphasize that it is not the cost variability itself that drives the result, but rather it is the variability combined with the fact that the firms compete strategically. To emphasize this point we assume that the cost variability is identical to the two technologies, i.e.,

$$\sigma_O{}^2 = \sigma_N{}^2 = \sigma^2.$$

We do assume however that the new technology is a superior technology in the following sense: the expected marginal cost of production is lower with the new technology: $\bar{c}_N \leq \bar{c}_O$. We say the technology is strictly superior when the inequality is strict.

We model the interaction between the firms in four stages. In the first stage, the incumbent chooses (and commits to) its technology, incurring fixed cost K_i. In the second stage, the entrant observes the incumbent's first-stage decision and chooses whether to enter or not; if it enters the entrant incurs fixed cost, K_e. In the third stage, nature draws values for the firms' costs and the firms only observe their own costs. However, if the firms have the same technology, then they can infer each other's costs from observation of their own. In the fourth stage, if the entrant enters, the firms play a quantity-setting game; otherwise the incumbent remains a monopoly.

With regards to our assumptions on fixed setup cost we acknowledge that introducing a new technological system for an AT&T would not be a trivial exercise. While presumably it would be more costly for AT&T to switch to the new technology, we assume the fixed costs are the same between two firms, i.e., $K_e = K_i = K$. This assumption is imposed to prevent AT&T from choosing the old technology for reasons other than the one considered here (i.e., because the fixed costs of the new technology is too great), but can be easily relaxed.[5]

What is important is that, if the incumbent chooses the old technology and the entrant enters, then the firms face the same cost ex post. On the other hand, if the incumbent chooses the

[5] Of course, as with all first mover models, the move (e.g., choosing capacity as in Dixit 1979) needs an irreversible aspect to it; ALCOA must have been unable to undo its capacity if rivals entered. Furthermore, at least in the case of AT&T, making the changes to introduce the new technology was a slow process, so even if the potential entrant entered, it would take time before AT&T would be able to switch.

new technology and the entrant enters with the old technology their cost shocks will be less correlated. Furthermore, they cannot infer each other's cost realization from observing their own, given independence of distributions *O* and *N*.

3. Analysis

3.A. The fourth-stage game

We solve the model backward, starting with the fourth stage. Consider first the subgame in which the incumbent chooses the old technology and the entrant enters (and by default is using the old technology). Nature has drawn the cost $\tilde{c}_O$ from distribution *O*, which is common for both firms. Since they can infer each other's cost by observing their own, the firms play a game of complete information with identical costs. The equilibrium quantity and operational profit (i.e., ignoring fixed costs) for firm $j = i, e$ are therefore

$$q_j^O = [1 - \tilde{c}_O]/3, \text{ and}$$

(1) $$\pi_j^O(c_j, c_k) = \pi_j^O(\tilde{c}_O, \tilde{c}_O) = [1 - \tilde{c}_O]^2/9, \; j \neq k,$$

where the superscript *O* indicates that the incumbent has chosen the old technology.

If instead the incumbent chooses the new technology and the entrant enters, then nature draws a cost realization $\tilde{c}_N$ from distribution *N* for the incumbent and $\tilde{c}_O$ from distribution *O* for the entrant. Given independence between *O* and *N*, the firms cannot infer each other's cost realization. Thus, the game is one of incomplete information, and we look for a Bayesian-Nash equilibrium. Firm *j* maximizes expected profit

$$E[(1 - q_j - q_k - \tilde{c}_j)q_j].$$

The first-order condition can be arranged to yield firm *j*'s best response

$$q_j = [1 - \tilde{c}_j - E(q_k)]/2.$$

It is a routine exercise to show that the equilibrium outputs are

$$q_i^N = [1 - 2\tilde{c}_N + \bar{c}_O]/3 + [\tilde{c}_N - \bar{c}_N]/6$$

$$q_e^N = [1 - 2\tilde{c}_O + \bar{c}_N]/3 + [\tilde{c}_O - \bar{c}_O]/6$$

where the superscript N denotes the incumbent choosing the new technology. Firm *j*, after setting its output, has fourth-stage operational profits of

(2) $$\pi_j^N(\tilde{c}_j, \tilde{c}_k) = \{[2 + 3\tilde{c}_j + 3\tilde{c}_k - \bar{c}_O - \bar{c}_N]/6\}\, q_j^N .$$

Finally, if there is no entry, the incumbent's *monopoly* operational profits are $\pi_M^O = (1 - \tilde{c}_O)^2/4$ if it chooses the old technology and $\pi_M^N = (1 - \tilde{c}_N)^2/4$ with new technology, where the *M* subscript indicates the monopoly. Note that if there were no potential entrant, then the incumbent would select the new technology because its expected profits would be greater.

3.B. Entry Deterrence

In stage three Nature moves, revealing the technology-specific cost information to the firms only if they chose that technology. We now turn to the second stage, in which the potential entrant makes its entry decision.

Suppose that the incumbent chose the old technology in the first stage. Then the expected operational profit to the potential entrant is obtained by taking expectations of (1), so the total expected profit is

(3) $$E[\Pi_e^N] = E[\pi_e^O] - K = \pi_e^O(\bar{c}_O, \bar{c}_O) + \sigma^2/9 - K$$

where

$$\pi_e^O(\bar{c}_O, \bar{c}_N) \equiv (1 - \bar{c}_O)^2/9$$

is the mean operating profit (i.e., the operating profit if variance equals zero).

If the incumbent chose instead the new technology in the first stage, the firms do not learn each other's cost, and hence neither firm reacts to the rival's cost realizations. It follows that the competitor's cost cannot introduce variance into the firm's profit.[6] Taking expectations of (2) yields the entrant's expected profit

(4) $$E[\Pi_e^N] = E[\pi_e^N] - K = \pi_e^N(\bar{c}_O, \bar{c}_N) + \sigma^2/4 - K$$

where

$$\pi_e^N(\bar{c}_O, \bar{c}_N) \equiv [1 - 2\bar{c}_O + \bar{c}_N]^2/9$$

is the "mean" operation profit, and the variance term corresponds to shocks to the old technology..

Comparing the two expected profits for the entrant in (3) and (4), the variance term is smaller when the incumbent chooses the old technology. Therefore, if the expected marginal costs are identical across technologies, the entrant's expected profit is smaller when the incumbent chooses the old technology. This result stems from two effects entailed by the incumbent choosing the same technology that is available to the entrant.

First, the exposure to the common cost shocks results in a correlation of the firms' strategies. To understand this effect intuitively, note first that profits are convex in costs. Now, suppose that the entrant has a lower-than-average cost shock and expands its output. If it chose the new technology, being uninformed, the incumbent would not react to the entrant having drawn a low cost, given that cost shocks are uncorrelated across technologies. With the old

[6] This is because the rival's cost enters the firm's profit function linearly.

technology, however, the incumbent draws the same cost realization that the entrant does. Hence, the incumbent also faces the low cost and expands its output as well. With the incumbent also expanding output, the entrant's profit does not increase as much as it does with separate technologies. Similar observations obtain when the entrant draws a higher-than-average cost. As the incumbent also draws a higher cost and contracts output, the entrant's profit does not fall as much as when the incumbent had chosen the new technology. Thus, the incumbent, by choosing the same technology as available to the entrant, makes the entrant's profits less convex and the entrant worse off relative to the choice of the new technology.

Second, without correlations in the cost shocks, the entrant would rather the incumbent choose the old, less efficient technology; i.e., $\bar{c}_N < \bar{c}_O$. However, as we will show below, this preference ranking can be reversed with cost correlations and sufficiently high variance. That is, a potential entrant could prefer the new technology even if that gives the incumbent strictly lower expected marginal cost.

Comparing the entrant's expected operational profits in (3) and (4) leads to

$$E[\pi_e^N] > E[\pi_e^O] \Leftrightarrow$$

(5) $$\sigma^2 > (4/5)(\bar{c}_O - \bar{c}_N)(2 - 3\bar{c}_O + \bar{c}_N)$$

In particular, if $\bar{c}_N = \bar{c}_O$, the right-hand side of (5) is zero and so the above inequality holds. However, even if $\bar{c}_N < \bar{c}_O$, the above inequality holds if $\bar{c}_N$ is sufficiently close to $\bar{c}_O$ or if σ^2 is sufficiently large.

When (5) holds, we have

(6) $$E[\pi_e^N] - K > E[\pi_e^O] - K.$$

Define $\underline{K}^{B} \equiv E[\pi_e^N]$ and $\overline{K}^{E} \equiv E[\pi_e^O]$. If $K \in (\overline{K}^{E}, \underline{K}^{B})$, then we have

$$E[\pi_e^N] - K > 0 > E[\pi_e^O] - K.$$

For such values of K, entry is deterred only if the incumbent firm chooses the old technology. For this reason, call $(\overline{K}^{E}, \underline{K}^{B})$ the entry-deterrence set.

On the other hand, if $K > \underline{K}^{B}$, both sides of (6) are negative, indicating that there will be no entry regardless of the incumbent's technology choice. This case is known as blockaded entry. If $K < \overline{K}^{E}$, both sides of (6) are positive, so there will be entry regardless of the incumbent's technology choice. For both these cases (either $K > \underline{K}^{B}$ or $K < \overline{K}^{E}$), the incumbent's technology choice has no effect on the potential entrant's entry decision, and hence the incumbent clearly will choose the new technology.

We now determine the incumbent's decision. To determine when the incumbent would choose the less efficient old technology to deter entry we must determine the incumbent's profit with the old technology and compare it with its profit with the new technology. Given that K is in the entry deterrence set, if the incumbent chooses the old technology then it is a monopoly (since entry would be deterred) and its operational profit would be

$$E[\pi_M^O] = (1 - \bar{c}_O)^2/4 + \sigma^2/4$$

On the other hand, choosing the new technology would result in expected operating profit of

$$E[\pi_i^N] = E[q_i^N]^2 = \pi_i^N(\bar{c}_N, \bar{c}_O) + \sigma^2/4$$

where

$$\pi_i^N(\bar{c}_N, \bar{c}_O) \equiv [1 - 2\bar{c}_N + \bar{c}_O]^2/9.$$

Thus,

$$E[\pi_M^O] \geq E[\pi_i^N] \Leftrightarrow$$

(7) $$0 \geq (5 - \bar{c}_O - 4\bar{c}_N)[4(\bar{c}_O - \bar{c}_N) - (1 - \bar{c}_O)]/9.$$

From (7) it is clear that if the two technologies have identical marginal cost, then the incumbent selects the old technology. Moreover, even if the new technology is strictly superior, the incumbent still chooses the old technology so long as $\bar{c}_N \in \left(\bar{c}_O - \frac{(1-\bar{c}_O)}{4}, \bar{c}_O\right)$. Finally, if introducing a new technology requires a greater fixed cost than keeping the old technology, the incumbent will choose the old technology.

The next proposition summarizes what we found in this section.

Proposition 1: Suppose that firms compete in quantities and that the new technology is superior to the old technology in that the marginal cost is distributed with a lower expected value $\bar{c}_N \in \left(\bar{c}_O - \frac{(1-\bar{c}_O)}{4}, \bar{c}_O\right)$**.**

A. If there is no potential entrant, then the incumbent chooses the new technology.

B. If there is an entrant and its fixed (entry) cost K satisfies (6), then the incumbent chooses the old technology and deters entry.

We emphasize that what drives the result is not risk aversion; after all, we have assumed that both firms are risk neutral. Rather, our results are driven by the fact that different technologies have different cost distributions, combined with the fact that the firms compete strategically. As a consequence, the incumbent could choose the less efficient, older technology regardless of whether the older technology is riskier than the new technology. To emphasize this point we have assumed that the two technologies are equally risky (that is, have the same variance since higher order moments do not play a role).

This is not to argue that changes in variance (or risk) cannot have effects. Consider what happens if all technologies have an identical increase in variance. To begin with, as an inspection can readily confirm, an increase in variance raises E[π_e^N], expanding the upper bound of the entry deterrence set, $\underline{K}^{B}$. As a result, the entry deterrence set now contains some higher values of K that did not initially belong there. For those values of K now included in the set, if $\bar{c}_N \in \left(\bar{c}_O - \frac{(1-\bar{c}_O)}{4}, \bar{c}_O\right)$, the incumbent now prefers the old technology while when variance was smaller it preferred the new technology. That is, an increase in variance changes the incumbent's technology choice, not because of risk aversion but because it wants to deter entry.

An increase in variance also increases E[π_e^O], thereby raising the lower bound of the entry deterrence set, $\overline{K}^{E}$. Therefore, some low values of K drop out of the set. For those values of K now outside the deterrence set, if $\bar{c}_N \in \left(\bar{c}_O - \frac{(1-\bar{c}_O)}{4}, \bar{c}_O\right)$, then the incumbent will change the technology choice from the old technology (deterring entry) to the new technology (accommodating entry). However, a further inspection reveals that an increase in variance increases E[π_e^N] more than E[π_e^O] so that the entry deterrence set expands. That is, as variance is increased, the incumbent is more likely to use the old technology and deter entry.

3.C Publicly observed cost shocks

We have so far assumed that the cost shocks are privately observed. Consider now what occurs if the cost shocks were publicly observed. This does not affect the game when both use the old technology, but now the firms play a game of complete information when using different technologies. Then it is a straightforward calculation to show that both the incumbent's and the entrant's expected profits are greater with publicly observed costs when using different technologies. (This is a well-known result in the information sharing literature; see, e.g., Gal-Or 1986 or Vives 1990).

While it does not change our result qualitatively, the case of publicly observed cost shocks yields two interesting results. First, E[π_e^N] increases while E[π_e^O] remains unchanged. That is, $\underline{K}^B$ rises but $\overline{K}^E$ remains intact, indicating that the entry deterrence set has expanded upward. Therefore the incumbent is more likely to use the old technology to deter entry when costs are publicly observed.

Second, while in quantity competition a firm is normally made better off when its cost shocks are publicly observed, in the model here the incumbent could be made worse off when its cost shocks are publicly observed.[7] To see how the firm could be harmed, recall that $\underline{K}^B$, the upper bound of the entry deterrence set, is increased when the cost shocks become publicly observed. That is, the entry deterrence set now contains some values of K that were not in the set when shocks were publicly unobservable. For those values of K, with publicly observed costs, the incumbent must use the old technology to deter entry, and would use the old technology if $\overline{c}_N \in \left(\overline{c}_O - \frac{(1-\overline{c}_O)}{4}, \overline{c}_O\right)$. In contrast, if instead those costs were not publicly observable, then for those same values of K the incumbent would be able to keep its monopoly position with the choice of the new technology, i.e., entry would be blockaded.

4. Price competition

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[7] See, e.g., Gal-Or (1986) or Vives (1990).

Often in strategic competition the results hinges critically on the type of strategic competition. In this section we examine whether our findings from quantity competition hold when firms compete in prices. To that end, we consider the Hotelling model.[8]

Let there be a linear city of unit length with the incumbent located at 0 and the potential entrant, if it enters, is located at 1. Consumers have identical value for the product, *v*, and linear transportation costs *t*, which are normalize to one. Assuming the market is "covered," $v > \tilde{c}_i + 3t/2$, it is straightforward to derive demand (see, e.g., Tirole 1988):

$$q_i = (1 - p_j + p_k)/2.$$

Operational profits for firm *j* are

$$\pi_j = (p_j - c_j)(1 - p_j + p_k)/2$$

with its first order condition

$$(8) \qquad 1 - 2p_j + p_k + c_j = 0.$$

Otherwise, the assumptions (specifically, regarding the cost distributions) are as before. The remainder of the analysis closely follows the steps from the previous section and so we only sketch the main points.

4.A The fourth stage

Again using backward-induction we start with the fourth stage. In the subgame in which the incumbent chooses the old technology and the entrant entered with the old technology, each firm has observed the common marginal cost $\tilde{c}_O$ and so the fourth stage is a game of complete

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[8] The standard duopoly model of price competition, which specifies ad-hoc demand functions such as $q_i = 1 - p_j + \delta p_k$, $\delta \in (0,1)$ has the unattractive implication that profits are greater in a duopoly than in a monopoly. Therefore the model is not suited for having a meaningful comparison of the monopoly and the duopoly outcome.

information. Using (8), the equilibrium prices and operational profit for firm $j = i$, e are

$$p_j^O = 1 + \tilde{c}_O \text{, and}$$

(9) $$\pi_j^O(c_j, c_k) = \pi_j^O(\tilde{c}_O, \tilde{c}_O) = 1/2.$$ [9]

If instead the incumbent chooses the new technology and the entrant enters, then nature draws a cost realization $\tilde{c}_N$ from distribution N for the incumbent and $\tilde{c}_O$ from distribution O for the entrant. This fourth stage is a game of incomplete information, and following the outline of the previous section, the Bayesian-Nash equilibrium prices are

$$p_i^N = (3 + 2\tilde{c}_N + \overline{c}_O)/3 + (\overline{c}_N - \tilde{c}_N)/6$$

$$p_e^N = (3 + 2\tilde{c}_O + \overline{c}_N)/3 + (\overline{c}_O - \tilde{c}_O)/6$$

In this case it is convenient to use firm j's expected fourth stage profits given its cost $\tilde{c}_j$ (since the rival's cost enters firm j's profit linearly):

(9) $$E[\pi_j^N | \tilde{c}_j] = (p_j^N - \tilde{c}_j)^2/2 = (6 - 3\tilde{c}_j + \overline{c}_j - \tilde{c}_i)^2/72.$$

Finally, if there is no entry, the incumbent's *monopoly* profits are as before: $\pi_M^O = (v - \tilde{c}_O)^2/4$ if it chooses the old technology and $\pi_M^N = (v - \tilde{c}_N)^2/4$ with new technology.

4.B. Entry Deterrence

Turning to the second stage, the potential entrant's expected profits from entering given that the incumbent chose the old technology is

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[9] While with the Hotelling model costs do not enter into the profit expression when the same technology is used, the qualitative aspect of technology choice (an incumbent by choosing the old technology would lower the rival's profit) would also hold with an *ad hoc* model such as $q_i = 1 - p_j + \delta p_k$, $\delta \in (0,1)$. However, the latter ad hoc model has the unattractive implication that profits are greater in a duopoly than a monopoly.

(10) $$E[\pi_e^O(\tilde{c}_O, \tilde{c}_O)] = \pi_e^O(\bar{c}_O, \bar{c}_O) = 1/2.$$

If the incumbent chooses instead the new technology in the first stage, the firms do not learn each other's cost, and hence neither firm reacts to the rival's cost realizations. Taking expectations of (9) yields the entrant's expected profit

(11) $$E[\pi_e^N] = \pi_e^N(\bar{c}_O, \bar{c}_N) + \sigma^2/8$$

where

$$\pi_e^N(\bar{c}_O, \bar{c}_N) \equiv (3 - 2\bar{c}_O + 2\bar{c}_N)^2/18$$

is the "mean profit" and the variance term corresponds to the old technology cost term.

As with quantity competition, the variance term is smaller when the incumbent chooses the old technology and so again, if the expected marginal costs are identical across technologies, the entrant's expected profit is smaller when the incumbent chooses the old technology. The intuition for this follows as with quantity competition. As a result, the entrant is worse off when the incumbent chose the old technology both in price and quantity competition. This is unusual since generally these interactions depend on the type of competition.

Comparing the entrant's expected profits in (9) and (11) leads to

$$E[\pi_e^N] > E[\pi_e^O] \Leftrightarrow$$

(12) $$\sigma^2 > 4(\bar{c}_O - \bar{c}_N)(6 - \bar{c}_O + \bar{c}_N)/9.$$[10]

As with quantity competition, if $\bar{c}_N = \bar{c}_O$, the right-hand side of (12) is zero and so the above inequality holds. Even if $\bar{c}_N < \bar{c}_O$, (12) holds when $\bar{c}_N$ is sufficiently close to $\bar{c}_O$. When (12) holds, there is again a K such that:

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[10] The condition is $\sigma^2 > 4(\bar{c}_O - \bar{c}_N)[2(2+\delta) - 2\bar{c}_O(2-\delta^2) + \delta(\bar{c}_O + \bar{c}_N)]/(2+\delta)^2(4-3\delta)$ in the *ad hoc* model where demand is specified as $q_i = 1 - p_j + \delta p_k$, $\delta \in (0,1)$.

(13) $\qquad E[\pi_e^N] - K > 0 > E[\pi_e^O] - K,$

that is, for K satisfying the above condition, the entrant does not enter if the incumbent firm chooses the old technology, but does enter if the new technology is chosen.

Turning to the incumbent, if (13) holds, then when it chooses the old technology the incumbent earns the monopoly profit:

$$E[\pi_M^O] = (v - \overline{c}_O)^2/4 + \sigma^2/4,$$

while choosing the new technology would result in expected duopoly profit

$$[\pi_i^N] = \pi_i^N(\overline{c}_N, \overline{c}_O) + \sigma^2/8$$

where

$$\pi_i^N(\overline{c}_N, \overline{c}_O) \equiv (3 - 2\overline{c}_N + 2\overline{c}_O)^2/18.$$

To begin with, if $\overline{c}_N = \overline{c}_O$, then $E[\pi_M^O] \geq E[\pi_i^N]$ and the incumbent chooses the old technology. However, with Hotelling competition, the variance term is greater with the monopoly profits (old technology) than with duopoly profits, which makes the old technology even more attractive. To abstract from this effect, let $\sigma^2 = 0$. In that case, if v is sufficiently large relative to $\overline{c}_O$, that is $v \geq \sqrt{2}\,(1 + \overline{c}_O(2+3\sqrt{2})/6)$, then even without the variance effect a monopoly with the old technology is more profitable than a duopoly with the new technology no matter how efficient is the new technology. However, if v is sufficient small (and the market remains covered), then the old technology is still more profitable if $\overline{c}_N \in \left(3\dfrac{v\sqrt{2}-2}{2+3\sqrt{2}}, \overline{c}_O\right)$ no matter how small σ is.

Proposition 2: In a Hotelling model, suppose that the new technology is superior to the old

technology in that marginal cost is distributed with a lower expected value $\bar{c}_N \in \left(3\frac{v\sqrt{2}-2}{2+3\sqrt{2}}, \bar{c}_O\right)$.

A. If there is no potential entrants, then the incumbent chooses the new technology.

B. If there is an entrant and its fixed (entry) cost K satisfies (13), then the incumbent chooses the old technology and deters entry.

Note that, given our discussion preceding the proposition, as σ increases, the lower bound on $\bar{c}_N$ decreases. That is, the condition $\bar{c}_N \in \left(3\frac{v\sqrt{2}-2}{2+3\sqrt{2}}, \bar{c}_O\right)$ is sufficient but not necessary for the incumbent to choose the old technology to deter entry.

Another similarity with quantity competition is the effect that a uniform increase in variance has on the entry deterrence set. By an analogous logic it can be shown that an increase in variance increases the entry deterrence set. However, with price competition there is a new effect: the incumbent's profits are differently affected depending on its technology choice. Specifically, an increase in variance increases the incumbent's monopoly profits due to deterred entry more than it does its duopoly profits due to accommodated entry. As a result, entry deterrence is more attractive to a monopolist and so more likely to occur. Thus, both effects go in the same direction: an increase in variance makes entry deterrence more likely.

5. Concluding remarks

While holding a monopoly position during the 20th century AT&T was known for both funding a world class research lab and supposedly delaying beyond reason deployment of useful innovations from the lab. In this paper we present a new explanation as to why AT&T and other incumbent monopolists, when faced by potential entry, may want to suppress a new and more efficient technology they have developed. Our analysis shows that the suppression of new technology can occur when it is sufficiently distinct from the old technology such that, should the incumbent adopt it and the entrant enter with the old technology, the two firms will be exposed to uncorrelated cost or production shocks. That is, when the incumbent chooses the new technology, the entrant would be shielded from the cost shocks affecting the incumbent. As a result, the entrant finds entry more appealing than when the incumbent keeps the old technology.

One question that may remain would be: why then did AT&T, IBM and others spend resources on the developing the technologies? The answer, of course, is that, although they would not implement them so long as the old technology could work to deter entry, the environments could change in the future. In particular, when the demand grows sufficiently strong, the entrants would choose to enter despite the incumbent's choice of the old technology, at which time the incumbent would introduce the new technology. And indeed, once the competitors made enough inroads, the incumbents such as IBM and GE introduced the new technologies.

References

Choi, J.P., and S.-S. Yi, 2000, Vertical foreclosure with the choice of input pecifications,*RAND Journal of Economics* 31,717-743.

Dasgupta, P. and E. Masking, 1987, The simple economics of research portfolios,*Economic Journal*97, 581-595.

Dixit, A., 1979, A model of duopoly suggesting a theory of entry barriers, *Bell Journal of Economics*, 10, 20-32.

Dunford, R., 1987, The suppression of technology as a strategy for controlling resource dependence," *Administrative Science Quarterly*, 32, 512-525.

Ellison, G. and S. Ellison, 2007, Strategic entry deterrence and the behavior of pharmaceutical incumbents prior to patent expiration, working paper.

Farrell, J., and G. Saloner, 1986, Installed base and compatibility: innovation, product preannouncements, and predation, *American Economic Review* 76, 940-955.

Galambos, L., 1992, Theodore N. Vail and the role of innovation in the modern Bell system, *Business History Review* 66, 95-126

Gal-Or, E. 1986, Information transmission – Cournot and Bertrand equilibrium, *Review of Economic Studies* 53, 85-92.

Gilbert, R., and Newbery, D., 1982, Preemptive patenting and the persistence of monopoly, *American Economic Review* 72, 514-526.

Harrington, J., 1987, Oligopolistic entry deterrence under incomplete information, *Rand Journal of Economics*, 211-231

Hochfelder, D., 2002, Constructing an industrial divide: Western Union, AT&T, and the Federal Government, 1876-1971, *Business History Review* 76, 705-32

Katz, M.L. and C. Shapiro, 1992, Product introduction with network externalities, *Journal of Industrial Economics* 40, 55-83.

King, J.L. and J. West, 2002, Ma Bell's orphan: US cellular telephony, 1947–1996, *Telecommunications Policy* 26, 189-203.

Maskin E.S., 1999, Uncertainty and entry deterrence, *Economic Theory* 14, 429-437.

Nix, J. and D. Gabel, 1993, AT&T's strategic response to competition: why not preempt entry? *Journal of Economic History* 53, 377-387

Reinganum, J., 1983, Uncertain innovation and the persistence of monopoly, *American Economic Review* 73, 7341-748

Riordan, M., 2005, The end of AT&T: Ma Bell may be gone, but its innovations are everywhere, *Spectrum, IEEE* 42, 46-51

Salop, S., and Scheffman, D., 1983, Raising rivals' cost, *American Economic Review* 73, 267-271.

Salop, S., and Scheffman, D.. 1987, Cost raising strategies, *Journal of Industrial Economics* 36, 19-34.

Salop, .S 1979, Strategic entry deterrence, *American Economic Review* 69.335-338.

Scherer, F.M., *forthcoming*, Technological innovation and monopolization, in W. D. Collins, ed., *Issues in Competition Law and Policy* (American Bar Association).

Tirole, J., 1988, *The Theory of Industrial Organization*, MIT Press: Cambridge, Massachusetts.

Vives, X. 1990, Trade association disclosure rules, incentives to disclose information and welfare. *Rand Journal of Economics* 21(3): 409-430.

Waldman, M., 1987, Noncooperative entry deterrence, uncertainty, and the free rider problem, *Review of Economic Studies*54, 301-10