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OPTIMISM INVITES DECEPTION*

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I. INTRODUCTION

Recent literature has focused on reputation as a mechanism for (partially) correcting information asymmetries that can exist in markets. Where sellers produce an output whose quality is not easily observed by buyers prior to sale, then sellers' reputation, based on past observations, can be used by consumers to prejudge quality. Consumers may pay a premium price for such firms, for whom a reputation is a valuable asset. In choosing quality anew each period, the prospect of future profits from this premium price may dissuade the firm from cheating on quality. This theory is developed in Klein and Leffler [1981], Shapiro [1982, 1983], Dybvig and Spatt [1983], Rogerson [1983], and Allen [1984].

This literature has presumed that the quality of firms' chosen inputs is perfectly correlated with the quality of their outputs; there is no noise in the production process. Indeed, adding noise to a reputation model would seem to be a trivial generalization; at first blush, we would expect the product of a firm that delivered high quality only 90 percent of the time to be worth roughly 90 percent of the value of the product of a firm that had perfect quality control.

In this paper we investigate the pure-strategy equilibria of a rational expectations model that incorporates quality noise. We find that the market for high quality may not be sustainable in the presence of such noise (ruling out mixed strategies). Since consumers cannot observe the quality of a firm's inputs (assumed fixed and sunk), they must infer this quality from observed outputs. In equilibrium consumers' initial beliefs about the quality of the firm's inputs are determined by what they (correctly) predict to be the firm's strategy; observations of the output lead them to revise these beliefs in accordance with Bayes' law.

If consumers are sure that a firm will purchase good inputs, then it pays the firm to "cheat," and purchase bad inputs, since

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consumers do not learn. Consumers know that such optimistic beliefs invite deception, so that in this simple model there is no equilibrium in which the firm purchases good inputs.¹ This rather stark result suggests that a richer model may yield more economically meaningful conclusions. We extend the model to include uncertainty about the firm's ability to select inputs. If this uncertainty is sufficiently large, but not too large, consumers become sufficiently skeptical so that the firm's first-period performance affects consumers' willingness to pay in subsequent periods, and a good input equilibrium can be supported. If this uncertainty about the firm is small, consumers are not sufficiently skeptical, their optimism would invite deception, and a good input equilibrium cannot be supported. Further, if this uncertainty is too large, then the cost to the firm of building a reputation is too great, and again a good input equilibrium cannot be supported.

In order to clarify the exposition, we present a model in which a monopoly firm purchases an input (a machine, an education) with one of two quality levels (good or bad); a good machine costs more than a bad machine. The input is sunk for two periods, and in each period will produce either high- or low-quality output, with high-quality output more valued by consumers than low-quality output. Good machines produce high-quality output with higher probability than bad machines.² Section II outlines this basic model. In Section III it is extended to include the firm imperfectly choosing inputs, either because the choice process is subject to error or because of quality noise in the upstream production of machines. Section IV contains concluding remarks.

II. THE MODEL

We consider a monopoly firm that purchases a machine which will produce output (normalized to one unit) in each of two subsequent periods, at zero marginal cost. The firm can choose either a good machine at a cost c_G or a bad machine at a cost of $c_B <$

1. This result contrasts with the literature on infinitely repeated games with one-sided moral hazard, in which the first-best allocation is achieved even with noise if players are sufficiently patient. See Radner [1981], Rubinstein and Yaari [1981], and Fudenberg and Maskin [1986].

2. While the analysis presented in the paper is limited to a monopoly market, with two input quality levels, two output quality levels, and two periods, it is important to note that all the results obtain in models with a competitive market, a continuum of input quality levels, a continuum of output quality levels, and an infinite time horizon. The generalizations are straightforward (though lengthy) and are omitted from the paper.

c_G . Both good and bad machines can produce high-quality output, but good machines yield high quality with probability π_G , and bad machines yield high quality with probability $\pi_B < \pi_G$. The firm is risk neutral and maximizes expected profits, discounting second-period receipts by the factor δ .

Consumers are (homogeneous) price-takers and expected utility maximizers; they value high-quality output at $v > 0$, and low-quality output at zero. They know π_G and π_B , so they are willing to pay

$$(1) \quad w_i = \pi_i v, \quad \text{for } i = G, B,$$

for the output of a machine they know to be of type i .

To simplify the analysis, we assume that the net value of a good machine is greater than the value of a bad machine, and greater than zero:

$$(2) \quad (1 + \delta)w_G - c_G > (1 + \delta)w_B - c_B \geq 0.$$

We shall assume throughout that these inequalities are satisfied.

If consumers can observe the monopoly firm's machine type, then they are willing to pay w_G for the output of a good machine in each period, and w_B for the output of a bad machine. If the monopolist installs a type i machine, it can set its price at w_i to extract all surplus. The monopolist installs a good machine, since from (2) this is more profitable than a bad machine. If the firm's machine type is observable, then the first-best outcome is always achieved.

Previous studies have focused on the case in which inputs are not observable, but output quality is a perfectly informative signal of input quality. In our model this corresponds to $\pi_G = 1$ and $\pi_B = 0$. In this case, consumers are willing to pay $w_G = v$ in the second period if they observe high-quality output in the first period, and $w_B = 0$ if they observe low quality. Of course, first-period price cannot depend upon as-yet-unobserved quality. Therefore, the firm's profits can depend on machine type only to the extent that their choice affects consumers' second-period willingness to pay, and thus the price they can charge. The firm will install a good machine rather than a bad one if and only if the difference in discounted second-period revenues minus the difference in cost is nonnegative; that is,

$$(3) \quad \Delta = \delta v - (c_G - c_B) \geq 0,$$

(assuming, as we do throughout, that if the firm is indifferent, it chooses a good machine). If this incentive compatibility condition obtains, the first-best outcome is achieved as an equilibrium.³ However, if it is not met, then the firm will not install a good machine. Consumers know that (3) is not satisfied, and that the only machine the firm would install is a bad one. Therefore, they would not be willing to pay more than zero in the first period for a machine they know must be bad. Consequently, if (3) is not satisfied, the firm does not produce at all (unless $c_B = 0$, in which case the firm will buy a bad machine, produce at zero cost, and sell at a price of zero). The result here is similar to Allen [1984], where consumers can deduce *ex ante* the firm's decision about quality, without the necessity of its investing in a reputation, in contrast to Shapiro [1983], where costly investment in reputation is always required by high-quality firms.

When both information asymmetry and quality noise are present, we have $0 < \pi_B < \pi_G < 1$, and consumers learn the firm's machine type only imperfectly from observing output quality. Consumers have a prior probability r_0 that the firm's machine is good; using Bayes' rule, we can express the consumers' posterior probability that the machine is good, having observed a high- or low-quality output, respectively, as

$$(4a) \quad r_H(r_0) = \frac{r_0\pi_G}{r_0\pi_G + (1 - r_0)\pi_B}$$

$$(4b) \quad r_L(r_0) = \frac{r_0(1 - \pi_G)}{r_0(1 - \pi_G) + (1 - r_0)(1 - \pi_B)}.$$

Note that (4) cannot be used in the previous case in which $\pi_G = 1$ and $\pi_B = 0$; if (3) obtains ($\Delta \geq 0$), then consumers would expect a good machine with probability $r_0 = 1$, and (4b) is undefined at $\pi_G = 1$ and $r_0 = 1$. If $\Delta < 0$, then consumers expect a bad machine ($r_0 = 0$), and (4a) is undefined at $\pi_B = 0$ and $r_0 = 0$.

The firm's first-period performance affects consumers' willingness to pay (equal to price) in the second period through this posterior. Conditional upon the firm's performance (high or low quality), second period prices are

$$(5) \quad p_j(r_0) = r_j(r_0)\pi_G v + [1 - r_j(r_0)]\pi_B v, \quad j = H, L.$$

3. There can also be a bad-machine equilibrium. If consumers' initial beliefs are that the firm's machine is bad for certain, then consumers' expectations after the first period are not determined by Bayes' rule if output turns out to be good (an out-of-equilibrium event); if they are sufficiently pessimistic in this situation, the firm will not choose a good machine.

As before, the firm's profits can depend on its choice of machine type only to the extent that their choice affects these second-period prices. Without consumer observability of machine type, the firm cannot affect consumers' priors, and so it takes r_0 as independent of its machine choice. As in (3), the firm installs a good machine if the difference in expected discounted second-period revenues minus the difference in cost is nonnegative:

$$(6) \quad \Delta(r_0) = \delta v(\pi_G - \pi_B)^2[r_H(r_0) - r_L(r_0)] - (c_G - c_B) \geq 0.$$

Both consumers as well as the firm will know whether or not (6) obtains: either a good machine is profitable, or it is not. If it were, then the firm would install a good machine for sure. The only consumer prior consistent with this strategy for the firm would be $r_0 = 1$. But then from (4), we have $r_H(1) = r_L(1) = 1$, and $\Delta(1) = -(c_G - c_B)$ is negative. If consumers have the optimistic prior $r_0 = 1$, no learning takes place, and it is more profitable for the firm to install a bad machine; "optimism invites deception."

If a good machine were less profitable than a bad one, then the firm would install a bad machine, and the only consumer prior consistent with this strategy for the firm is $r_0 = 0$. From (4) we have that $r_H(0) = r_L(0) = 0$, and $\Delta(0) = -(c_G - c_B)$ is negative. Hence, $r_0 = 0$ is the unique pure-strategy⁴ equilibrium. Consumers expect the firm to install a bad machine, and the firm finds it optimal to do so. We have thus shown the following.

PROPOSITION 1. If $0 < \pi_B < \pi_G < 1$, then in the unique pure-strategy equilibrium, the firm installs a bad machine.

Consumers' ability to deduce the firm's optimal behavior from the model leads them to have extreme priors, which in turn leads them to ignore experience. No track record could be so poor as to discourage the optimistic consumer, and no track record could be so outstanding as to impress the jaded skeptic. Consumers know, as does the firm, that optimism invites deception; they thus choose the skeptic's role, and the firm finds it optimal to fulfill their expectations.

While Proposition 1 clearly suggests that the introduction of quality noise may present problems, the result cannot be defended as particularly economically meaningful. The starkness of the

4. This proposition depends upon our "tie-breaker" assumption that when indifferent between a good and bad machine, the firm always chooses good. Under an alternative "tie-breaker" assumption, a mixed-strategy equilibrium can exist. Suppose that when indifferent between buying a good machine and a bad machine, the firm chooses a good machine with probability α . If $\Delta(\alpha) = 0$, then $r_0 = \alpha$ is fulfilled in a mixed-strategy equilibrium.

“optimism invites deception” result follows from the absence of experience-based learning. More meaningful conclusions require that consumers make use of their experience. In Section III we develop a richer model of this type.

III. IMPERFECT INPUT SELECTION

The analysis of the previous section assumed that the firm is able to choose which type of machine to install. Once installed, the machines are subject to quality noise, but the firm makes its input choice faultlessly. Clearly, this assumption is neither realistic nor in keeping with the spirit of this paper. In this section we introduce noise into the input selection process, and analyze the resulting effects on the equilibrium outcome.⁵ We assume that the firm which intends to buy, and does pay for, a good machine will actually end up with a good one with probability λ , $0 < \lambda < 1$. A firm that intends to buy a bad machine is always successful. Both the firm and consumers know λ . We assume that it is Pareto efficient to intend to install a good machine rather than a bad machine, analogously to (2).

As before, the monopoly firm's choice of which machine it intends to buy depends only upon the relative prospects for higher revenues in the second period, and the difference in costs. For a given r_0 , consumers' learning is as described in (4), and the second-period prices conditional on first-period quality are as in (5). In this model, however, the firm must consider the possibility of error in its input decision, and consumers are aware of this possibility as well.

It is easy to show that the firm will attempt to install a good machine if and only if

$$(7) \quad \Delta_\lambda(r_0) = \lambda \delta v (\pi_G - \pi_B)^2 [r_H(r_0) - r_L(r_0)] - (c_G - c_B) \geq 0,$$

a condition identical to that of (6), except for the presence of λ .

Since consumers as well as the firm know λ , the only consumer priors that could be fulfilled in equilibrium are $r_0 = 0$ (if consumers believe the firm will choose a bad machine) and $r_0 = \lambda$ (if consumers believe that the firm will try to install a good machine, and will be successful with probability λ). Since for any λ , $\Delta_\lambda(0) = -(c_G - c_B)$ is negative, there always exists an equilibrium in which the firm

5. There are several possible sources of input selection noise. (1) There may be quality noise in the upstream production of machines; even if the firm buys its machine from a reputable machine firm, it may still get a “lemon.” If quality noise π_G^* in the upstream production process caused this selection error, then $\lambda = \pi_G^*$. (2) The internal process by which the firm chooses machines may be inherently noisy.

installs a bad machine, and consumers expect a bad machine. If $\Delta_\lambda(\lambda)$ is also negative, no other pure-strategy equilibrium exists.⁶ However, if $\Delta_\lambda(\lambda)$ is nonnegative, then λ is a consistent prior. In this equilibrium the firm intends to install a good machine and is successful with probability λ , and this is what consumers expect. This good-machine equilibrium Pareto dominates the bad-machine equilibrium, since (i) the firm earns higher profits in the good-machine equilibrium and (ii) consumers are indifferent since they obtain zero surplus in either equilibrium. These results can be summarized as follows.

PROPOSITION 2. If $0 < \pi_B < \pi_G < 1$, and if the firm intending to install a good machine is successful with probability $\lambda < 1$, then

1. an equilibrium always exists in which the firm installs a bad machine;
2. an equilibrium exists in which the firm intends to install a good machine, if and only if $\Delta_\lambda(\lambda) \geq 0$. This equilibrium Pareto dominates the bad-machine equilibrium.

Comparing Propositions 1 and 2 reveals that accounting for noise in the input selection process allows the possibility of a high-quality equilibrium, even with quality noise in the production process. Introducing an additional source of noise has reestablished the good-machine equilibrium. However, Proposition 2 has the paradoxical feature that only if bad machines are possible will a high-quality equilibrium be sustainable in the presence of quality noise. Only the likelihood of a bad machine will ensure that the firm will try to install a good machine!

The intuition behind this result comes from the nature of the “optimism invites deception” principle: if consumers are too optimistic ($r_0 = 1$), they know that the firm will take advantage of their optimism and install a bad machine. However, if consumers know that a well-intentioned firm may err, then they are sufficiently skeptical so they do not fall into the “optimism invites deception” trap. The consumers’ prior is not so strong that they ignore the data, and thus they reward high quality in the first period with higher prices in the second period. It is this rational skepticism that permits high quality to be sustained.

How much input selection noise is “enough”? In Figure I the function $\Delta_\lambda(\lambda)$ is plotted against λ for a particular example. For both

6. As with the model of Section II, modifying the “tie-breaker” rule as described in note 4 admits the possibility of mixed-strategy equilibria.

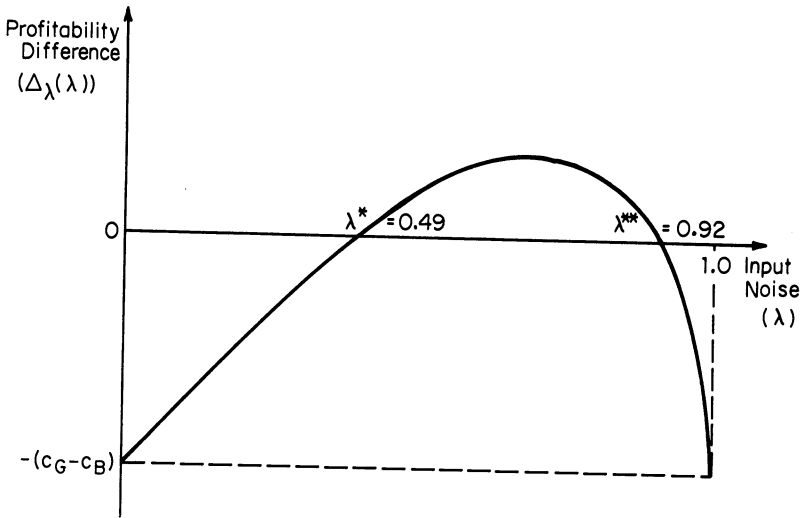


FIGURE I

The Firm's Choice of Input

$$\delta = 1, \nu = 4, \pi_G = 0.9, \pi_B = 0.1, c_G = 1, c_B = 0$$

$\lambda = 0$ and $\lambda = 1$, the function is negative. In Figure I only the set $[\lambda^*, \lambda^{**}]$ will sustain good machine equilibria. The function $\Delta_\lambda(\lambda)$ can be shown to be concave in general, so that it has at most two (real) roots. If it has two roots, then the set of λ 's that sustain good-machine equilibria form an interval. If the function has one root, this set is but a single point; it may have no roots, in which case this set is empty, and no good-machine equilibria exist for any λ . Note that for λ between λ^{**} and 1, the good-machine equilibrium cannot be sustained; consumers are too optimistic for experience to punish inferior performance sufficiently to induce the firm to try a good machine. For λ less than λ^* , consumers are too skeptical for experience to reward superior performance sufficiently. In order for a good-machine equilibrium to be sustained, there must be enough noise, but not too much.

Figure II shows how the set of λ 's that sustain a good-machine equilibrium depends upon the quality noise parameters π_G and π_B . It can be seen that decreasing π_G shrinks this set, and increasing π_B shrinks it as well, eventually to the null set. The intuition for this is that if good and bad machines are more similar in performance, consumers learn more slowly, and the good machine is a relatively

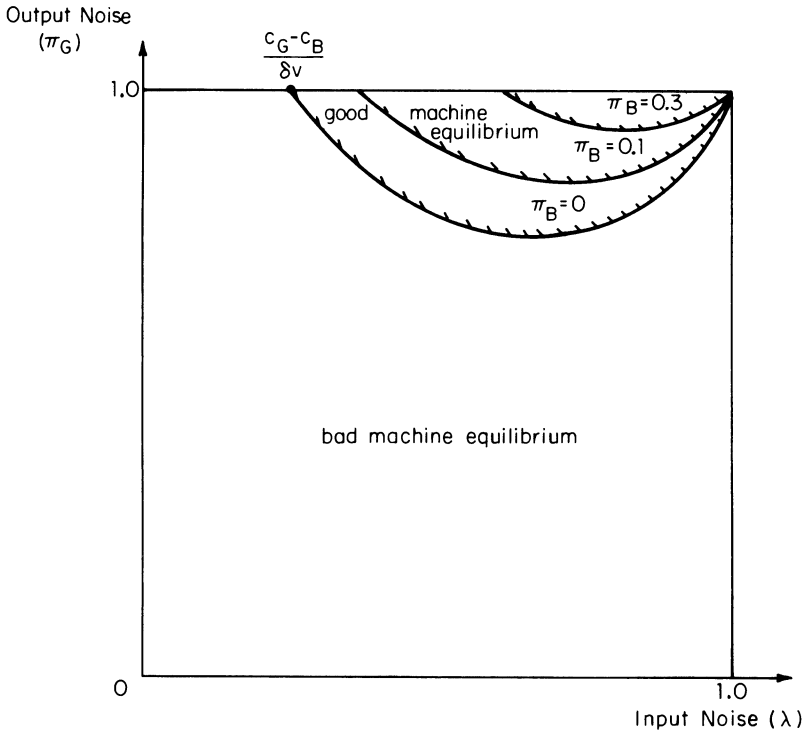


FIGURE II
 Input Noise, Output Noise, and the Nature of Equilibrium
 $\delta = 1, \nu = 4, c_G = 1, c_B = 0$

less attractive investment for the firm. These results are summarized in the following.

PROPOSITION 3. If $0 < \pi_B < \pi_G < 1$, there exists a (possibly empty) set $[\lambda^*, \lambda^{**}]$ that sustains good-machine equilibria. As π_G decreases or π_B increases, this set shrinks, eventually to the null set.

The relationship of the model in Section II to that of this section is brought out in Figure II. First, the set of λ 's that support good-machine equilibria, $[\lambda^*, \lambda^{**}]$, is always contained within the set $[(c_G - c_B)/\delta\nu, 1]$. Should condition (3) not be satisfied (that is, if $\delta\nu < (c_G - c_B)$), then there are no good-machine equilibria. Second, the simpler model of Section II corresponds to the ray $\lambda = 1$ in this figure. It is this restriction that leads to the starkness of Proposition

1, in which no good-machine equilibria exist for $\pi_G < 1$. In the richer model, this starkness disappears, and the set of pure-strategy equilibria is well-behaved. Nevertheless, it can be seen that the "optimism invites deception" problem still constrains the conditions under which good machines will be installed.

IV. CONCLUDING REMARKS

The results of this paper suggest that in rational expectations models with learning, the nature of equilibrium depends critically on the balance between what agents can deduce from the model *ex ante*, what they observe from experience *ex post*, and how they weight these two sources of information.

In previous models with no quality noise, experience is perfectly informative, and consumers base their second-period actions only on their observations of first-period results, without regard to prior beliefs. In the model of Section II, with quality noise, experience is only partially informative, and Bayes' rule tells us consumers will temper their observations with their prior deductions. If these prior deductions are extreme enough, experience is discounted. Since high quality is unrewarded, it will not be sustained in equilibrium.

Only if consumers have sufficient prior skepticism (in the model of Section III, from input selection error) will they abandon extreme priors and allow experience to weight their second-period actions enough that the firm sees high quality as profitable. With output noise but no input noise, consumers weight their prior deductions more than their observations; with enough, but not too much, input noise, consumers have less extreme initial conjectures, more weight is placed on experience, and a good equilibrium can be sustained. Skepticism, it seems, is most valuable in moderation: not too little, not too much, but just enough!

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